

**APPLICATION FOR INCIDENTAL
HARASSMENT AUTHORIZATION**

**for
Apache Alaska Corporation
3D Seismic Program
Cook Inlet, Alaska**

July 2011

Prepared for
Apache Alaska Corporation
2000 Post Oak Boulevard
Suite 100
Houston, TX 77056-4400

Prepared by
Northern Exploration Services, LLC
9525 King Street
Anchorage Alaska

**JUNE 15, 2011
REVISED JULY 19, 2011**

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APPENDICES

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ACRONYMS AND ABBREVIATIONS

3D	three dimensional
ADF&G	Alaska Department of Fish and Game
AMAR	Advanced Multichannel Acoustic Recorder
APACHE	Apache Alaska Corporation
CFR	Code of Federal Regulations
CIMMC	Cook Inlet Marine Mammal Council
cui	cubic inches
dB re 1 μ Pa	decibel referenced to one microPascal
DGPS/RTK	differential global positioning system/roving units
ESA	Endangered Species Act
ft	feet
FR	Federal Register
Hz	Hertz
IHA	Incidental Harassment Authorization
INS	Integrated Navigation System
JASCO	JASCO Applied Sciences
KABATA	Knik Arm Bridge and Toll Authority
kHz	kilohertz
km	kilometer
km ²	square kilometer
LOA	Letters of Authorization
m	meter
MMPA	Marine Mammal Protection Act
NMFS	National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NOAA	National Oceanic and Atmospheric Administration
OBH	ocean bottom hydrophone
OBRL	Ocean Bottom Receiver Location
OSP	Optimum Sustainable Population
PAM	Passive Acoustic Monitoring
PSO	Protected Species Observer
PTS	permanent threshold shift
rms	root-mean-squared
SEL	sound energy level
SPL	sound pressure level
SSV	Sound source verification
TS	threshold shift
TTS	temporary threshold shift
USBL	Ultra-Short BaseLine
USC	United States Code

INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) regulations governing the issuance of Incidental Harassment Authorizations (IHAs) and Letters of Authorization (LOAs) permitting the incidental, but not intentional, take of marine mammals under certain circumstances are codified in 50 Code of Federal Regulations (CFR) Part 216, Subpart I (Sections 216.101-216.108). The Marine Mammal Protection Act (MMPA) defines take to mean “to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal” (16 United States Code [USC] Chapter 31, Section 1362 (13)). Section 216.104 sets out 14 specific items that must be addressed in requests for rulemaking and renewal of regulations pursuant to Section 101(a)(5) of the MMPA. The 14 items are addressed in Sections 1 through 14 of this application.

Apache Alaska Corporation (APACHE) plans to acquire three-dimensional (3D) seismic surveys throughout the Cook Inlet, Alaska over the course of the next three to five years starting in the fall of 2011. This application for harassment of marine mammals incidental to the seismic operations is for the first year of seismic activities, planned to begin in October 2011. APACHE proposes to conduct offshore/transition zone operations in approximately 8 to 9 months of the first year of the program (during windows of opportunity). APACHE anticipates a supplemental application for rulemaking for LOAs will be submitted during the first year of activities in order to operate in subsequent years.

1.0 DESCRIPTION OF ACTIVITIES

A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals.

1.1 PROJECT PURPOSE

APACHE acquired over 300,000 acres of oil and gas leases in Cook Inlet in 2010 with the primary objective to explore for and develop oil fields in Cook Inlet. In the spring of 2011, APACHE conducted a seismic test program to evaluate the feasibility of using new nodal (no cables) technology seismic recording equipment for operations in the Cook Inlet environment and to test various seismic acquisition parameters in order to finalize the design for a 3D seismic program in the Cook Inlet. The test program occurred in late March 2011 and results showed that the nodal technology was feasible in the Cook Inlet environment. Therefore, APACHE now proposes to conduct a phased 3D seismic survey program throughout Cook Inlet over the course of the next three to five years. The first area (Area 1) proposed to be surveyed over the course of the next year, beginning in fall 2011, is located along the western coast of upper Cook Inlet (Figure 1). The proposed Area 1 program area is approximately 2,719 square kilometers (km², 1,050 square miles [mi²]) and is along the west coast from McArthur River up and to the south of Beluga River. As detailed further below, the program consists of an onshore, transition zone, and offshore component (Figure 2).



Figure 1. Location of Area 1 Seismic Survey Program.

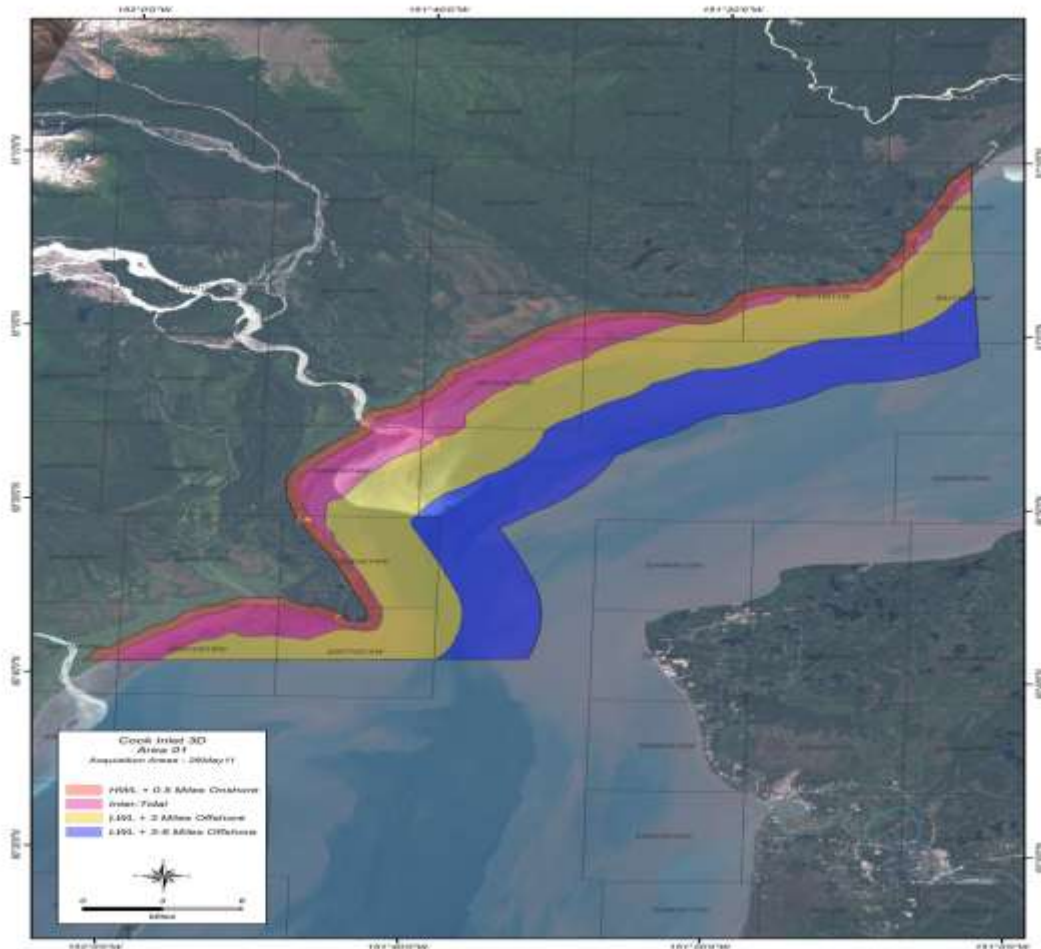


Figure 2: Map of Area 1 Showing Offshore and Transition Components.

Each phase of the program within an area will have an onshore component, a transition zone component, and an offshore component. Transition zone and offshore acquisition will include areas below the high water mark as depicted in Figure 2. The seismic operation will be active 24 hours per day. In-water air gun activity will average 10-12 hours per day and will generally occur around the slack tide or low current periods. Vessels will lay and retrieve the nodal sensors on the sea floor bottom in periods of low current or, in the case of the intertidal area, during high tide. The offshore and transition zone source effort will include the use of input/output sleeve air guns in two different configurations of arrays: a 440 and 2400 cubic inches [cui]). The seismic source vessels currently planned for use are the *M/V Peregrine Falcon* and *M/V Arctic Wolf*, or similar vessel. Cable/Nodal deployment and retrieval operations will be supported by three shallow draft vessels (*M/V Miss Diane I*, *MV Miss Diane II*, and *M/V Maxime*), or similar vessels. The mitigation/chase vessel, which will also house the Protected Species Observers (PSO) will be the *M/V Dreamcatcher*, or similar vessel. Two smaller jet boats will be used for personnel transport and node support in the extremely shallow water in the intertidal area. Water depths for the program will range 0 to 128 meters (m, 0 to 420 feet [ft]).

1.2 PROPOSED PROGRAM OVERVIEW – GENERAL

Each phase of the Apache program encounters land, inter-tidal transition zone, and marine environments. The following provides a general overview of the methodology that will be employed during the acquisition of the seismic survey.

1.2.1 Recording System

The recording system that will be employed is an autonomous system “nodal” (i.e., no cables), which is expected to be made up of at least two types of nodes; one for the land and one for the intertidal and marine environment. For the land environment, this would be a single-component sensor land node (Figure 3); for the inter-tidal and marine zone, this would be a submersible multi-component system made up of three velocity sensors and a hydrophone (Figure 4). These systems have the ability to record continuous data. Inline receiver intervals for the node systems will be 50 m (165 ft).



Figure 3. Onshore Nodal Recording System.



Figure 4. Offshore Nodal Recording System.

The geometry methodology that APACHE will employ to gather the data is called *patch shooting*. This type of seismic surveying requires the use of multiple vessels for cable layout/pickup, recording, and sourcing. Operations begin by laying nodes off the back of the layout vessels on the seafloor parallel to each other with a node line spacing of a 402 m (1,320 ft). APACHE’s patch will have 6–8 node lines (receivers) laid in parallel to each other. The lines are generally run perpendicular to the shoreline. The

node lines will be separated by either 402 or 503 m (1,320 or 1,650 ft). Inline spacing between nodes will be 50 m (165 ft). The node vessels will lay the entire patch on the seafloor prior to the air gun activity. Individual vessels are capable of carrying up to 400 nodes. With three node vessels operating simultaneously, a patch can be laid down in a single 24 hour period, weather permitting. A sample patch is depicted in Figure 5.



Figure 5. A Single Intertidal Patch, Six Lines of Nodes (Blue), 16 Source Lines (Red).

As the patches are acquired, the node lines will be moved either side to side or inline to the next patch's location. Figure 6 depicts multiple side to side patches that are acquired individually but when seamed together at the processing phase, create continuous coverage along the coastline.

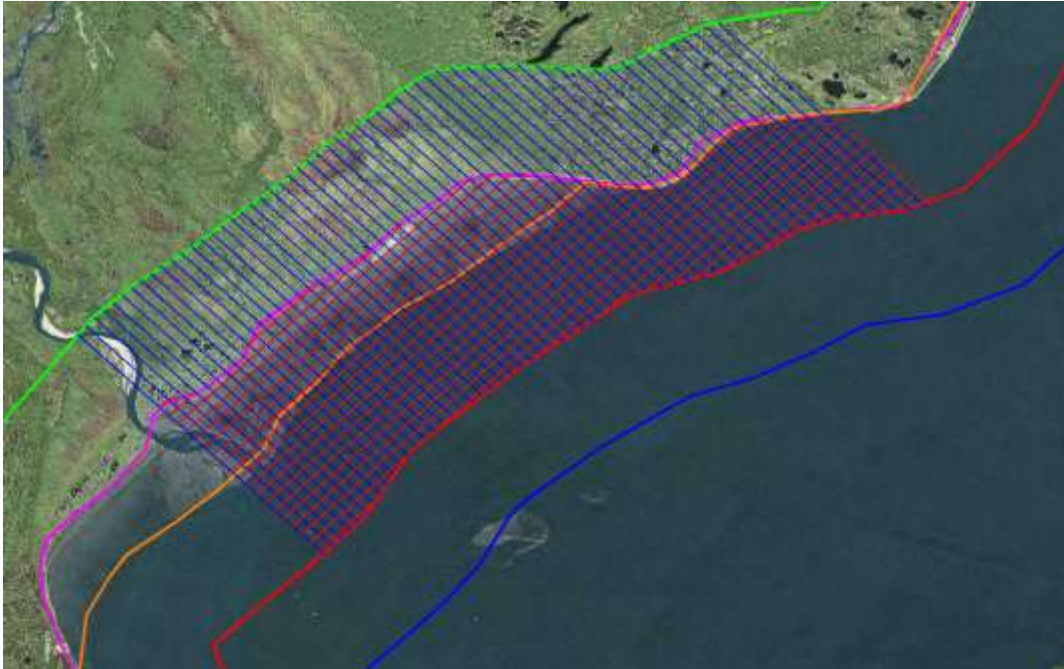


Figure 6. Multiple Intertidal Patches.

1.2.2 Sensor Positioning

1.2.2.1 Transition Zone/Offshore Components

Once the nodes are in place on the seafloor, the exact position of each nodes is required. There are several techniques used to locate the nodes on the seafloor, depending on the depth of the water. In very shallow water, the nodes position is either surveyed by a land surveyor when the tide is low, or the position is accepted based on the position at which the navigator has laid the unit.

In deeper water, there are two recognized techniques. The first is to use a hull or pole mounted pinger to send a signal to transponder which is attached to each node. The transponders are coded and the crew knows which transponder goes with which node prior to the layout. The transponders response (once pinged) is added together with several other responses to create a suite of ranged and bearing between the pinger boat and the node. Those data are then calculated to precisely position the node. In good conditions, the nodes can be interrogated as they are laid out. It is also common for the nodes to be pinged after they have been laid out. The pinger that will be used is a Sonardyne Shallow Water Cable Positioning system. The two instruments used are a Scout Ultra-Short BaseLine (USBL) Transceiver that operates at a frequency of 33-55 kiloHertz (kHz) at a max source level of 188 decibels referenced to one microPascal (dB re 1 μ Pa) at 1 m; and a LR USBL Transponder that operates at a frequency of 35-50 kHz at a source level of 185 dB re 1 μ Pa at 1 m.

The second technique for the deeper water is called Ocean Bottom Receiver Location (OBRL). This technique uses a small volume (10 cui) air gun firing parallel to the node line. The air gun is fired along each side of the line, the data are then gathered from the node and combined with the known position of the air gun to give a precise location of each node. Figure 7 shows a typical pinger or OBRL geometry that is used to position the nodes. Once the patch of nodes is on the sea floor and positioning information has been gathered, the source activity begins.

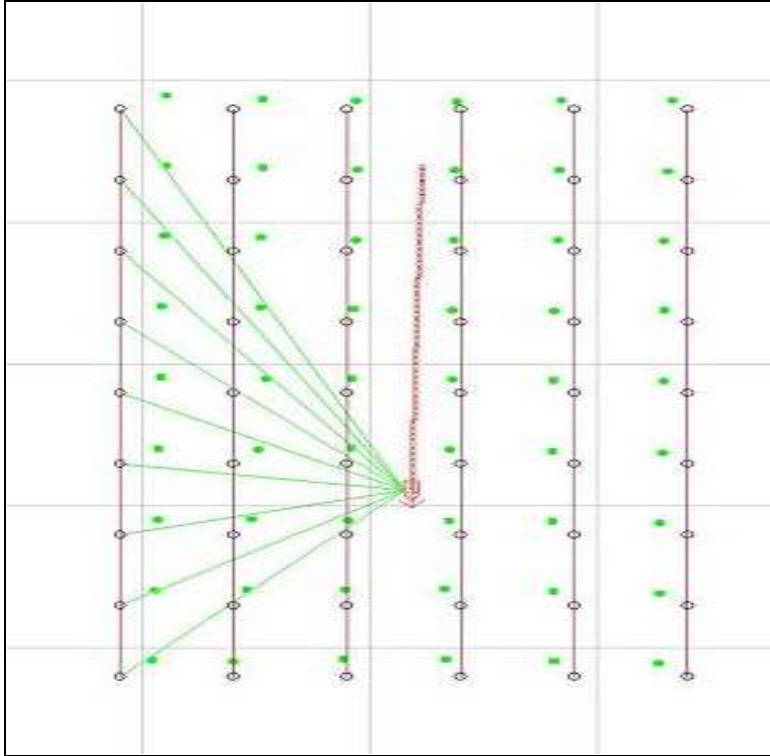


Figure 7. Pinger or OBRL Vessel Interrogating a Patch Of 6 Lines.

1.2.2.2 Onshore/Intertidal Components

Onshore and intertidal locating of source and receivers will be accomplished with Differential Global Positioning System/roving units (DGPS/RTK) roving units equipped with telemetry radios which will be linked to a base station established on the *M/V Arctic Wolf*. Survey crews will have both helicopter and light tracked vehicle support. Offshore source and receivers will be positioned with an integrated navigation system (INS) utilizing DGPS/RTK link to the land located base stations. The integrated navigation system will be capable of many features that are critical to efficient safe operations. The system will include a hazard display system that can be loaded with known obstructions, or exclusion zones. Typically the vessel displays are also loaded with the day-to-day operational hazards, buoys, etc. This display gives a quick reference when a potential question regarding positioning or tracking arises. In the case of inclement weather, the hazard display can and has been used to vector vessels to safety.

1.2.3 Seismic Source

1.2.3.1 Transition Zone/Offshore Components

APACHE's methodology will employ the use of two source vessels synchronized in time. The source vessels *M/V Peregrine Falcon* and the *M/V Arctic Wolf* (or similar vessels) will be equipped with compressors and 2400 cui air gun arrays. In addition the *M/V Peregrine Falcon* will be equipped with a 440 cui shallow water source which it can deploy at high tide in the intertidal area in less than 1.8 m (6 ft) of water. Source lines are orientated perpendicular to the node lines and parallel to the beach (see red lines on Figure 5). The two source vessel will traverse source lines of the same patch using a shooting technique called *ping/pong*. The ping/pong methodology will have the first source boat commence the source effort. As the first air gun pop is initiated, the second gun boat is sent a command and begins a countdown to pop its guns 12 seconds later than the first vessel. The first source boat would then take its

second pop 12 seconds after the second vessel has popped and so on. The vessels try to manage their speed so that they cover approximately 50 m (165 ft) between pops. The objective is to generate source positions for each of the two arrays close to a 50 m (165 ft) interval along each of the source lines in a patch. Vessel speeds will range from 2-4 knots. The source effort will average 10-12 hours per day.

Each source line is approximately 12.9 km (8 mi) long. A single vessel is capable of acquiring a source line in approximately 1 hour. With two source vessels operating simultaneously, a patch of approximately 3900 source points can be acquired in a single day assuming a 10-12 hour source effort.

In addition to the marine mammal monitoring radii outlined in this document, there will be 1.6 km (1 mi) setback of source points from the mouths of any anadromous streams to comply with Alaska Department of Fish and Game (ADF&G) restrictions.

When the data from the patch of nodes have been acquired, the node vessels pick up the patch and roll it to the next location. The pickup effort will take 3/4 of a day

1.2.3.2 Onshore/Intertidal Components

The onshore source effort will be shot holes. These holes are drilled every 50 m (165 ft) along source lines which are orientated perpendicular to the receiver lines and parallel to the coast. To access the onshore drill sites, APACHE would use a combination of helicopter portable and tracked vehicle drills. At each source location, APACHE will drill to the prescribed hole depth of approximately 10 m (35 ft) and load it with 4 kilograms (kg) of explosive (likely Orica OSX Pentolite Explosive). The hole will be capped with a “smart cap” that will make it impossible to detonate the explosive without the proper blaster.

1.2.4 Vessels

The *M/V Peregrine Falcon*, *M/V Miss Diane I* and *II*, *M/V Arctic Wolf*, *M/V Maxime*, and *M/V Dreamcatcher* will serve as the primary offshore acquisition platforms (or similar vessels). Details of the vessels likely to be used are as follows:

M/V Arctic Wolf (Source Vessel / Mother Ship)

Size: 41 m X 9 m (135 ft X 30 ft)
Documentation: #687450
Gross Tonnage: 251

M/V Peregrine Falcon (Source Vessel)

Size: 26 m X 6 m (85 ft X 24 ft)
Documentation: #950245
Call sign: WCZ6285
Gross tonnage: 131

M/V Miss Diane I (Node Vessel)

Size: 26 m X 6 m (85 ft X 20 ft)
Documentation: #1210779
Call sign: WAV0779
Gross tonnage: 53

M/V Miss Diane II (Node Vessel)

Size: 26 m X 6.7 m (85 ft X 22 ft)
Documentation: Being constructed
Call sign: TBD
Gross tonnage: TBD

M/V Maxime (Node Vessel)

Size: 21 m X 4.9 m (70 ft X 16 ft)
Documentation: #1196716
Call sign: WAV6716
Gross tonnage: 48

M/V Dreamcatcher (Mitigation /chase boat)

Size: 26 m X 7.1 m (85 ft X 23 ft)
Documentation: #963070
Call sign: WBN5411
Gross tonnage: 100

1.2.5 Crew Accommodations

The onshore crew will be housed in commercial facilities local near the project site. Offshore staff will be housed on the vessels, which are several and certified for housing 24 hour crews. The offshore capability for berthing are as follows:

M/V Arctic Wolf: 22 berths

M/V Peregrine Falcon: 10 Berths

M/V Miss Diane I: 6 Berths

M/V Miss Diane II: 10 Berths

M/V Maxime: 4 Berths

M/V Dreamcatcher: 22 berths

1.2.6 Fuel Storage

Any fuel storage required within the program site will be positioned away from waterways and lakes and located in modern containment enclosures. The capacity of the containment will be 125% of the total volume of the fuel stored in the bermed enclosures. All storage fuel sites will be equipped with additional absorbent material and spill clean-up tools. Any transfer or bunkering of fuel for offshore activities will either occur dock side or comply with U.S. Coast Guard (USCG) bunkering at sea regulations.

2.0 DATES, DURATION, AND GEOGRAPHICAL REGION OF ACTIVITIES

The dates and duration of such activity and the specific geographical region where it will occur.

2.1 DATES AND DURATIONS OF ACTIVITIES

APACHE proposes to conduct offshore/transition zone operations in approximately 8 to 9 months of the first year of the program (during windows of opportunity). Transition zone activities near intertidal areas adjacent to ADF&G refuges are estimated to be acquired during the months October – December 2011 and March 2012. Nearshore areas adjacent to uplands and offshore areas will be acquired in open water periods from April through September 2012. For the proposed Area 1 in the upper Cook Inlet, anticipated windows of opportunity will be defined by regulatory thresholds with respect to agency coordination, subsistence, and appropriate weather conditions.

APACHE anticipates completing approximately 829 km² (320 mi²) of seismic acquisition in Area 1 in the first year of operations in Cook Inlet. During each 24 hour period, seismic operations will be active throughout the entire period. However, in-water air guns will only be active for approximately 2.5 hours during each of the slack tide periods. There are approximately 4 slack tide periods in a 24-hour period; therefore, air gun operations will be active during approximately 10-12 hours per day, if weather conditions allow. APACHE anticipates that a crew can acquire approximately 5.2 km² (2 mi²) per day, assuming an efficient crew can work 10-12 hours per day. Thus, the actual survey duration to acquire the approximately ~829 km² (320 mi²) will take approximately 160 days over the course of the 8-9 months.

Mobilization of operations for Area One will occur in September out of Homer and Anchorage, Alaska, and the survey is proposed to begin in early October depending on weather conditions and permit stipulations.

3.0 TYPE AND ABUNDANCE OF MARINE MAMMALS IN PROJECT AREA

The species and numbers of marine mammals likely to be found within the activity area.

3.1 SPECIES AND NUMBER IN THE PROJECT AREA

Of the 15 species of marine mammals with documented occurrences in Cook Inlet, only five species are documented in the upper inlet: Cook Inlet beluga whale (*Delphinapterus leucas*), harbor seal (*Phoca vitulina*), killer whale (*Orcinus orca*), harbor porpoise (*Phocoena phocoena*), and Steller sea lion (*Eumatopia jubatus*) (Shelden et al. 2003). Table 1 provides a summary of the abundance and status of the species likely to occur in the project area. While killer whales and Steller sea lions have been sighted in upper Cook Inlet, their occurrence is considered rare. Cook Inlet beluga whales, harbor porpoises, and harbor seals are the species most likely to be sighted during the seismic program. Recent passive acoustic monitoring research has indicated that harbor porpoises occur more frequently in the project area more than expected based solely on previous visual observations (National Marine Mammal Laboratory [NMML] 2011, personal communication). A more detailed description of these five species is provided in Section 4.

Table 1. Marine Mammal Species in Cook Inlet

Species	Abundance	Comments
Beluga whale (<i>Delphinapterus leucas</i>)	355 ²	Occurs in the project area. Listed as Depleted under the MMPA, endangered under ESA, critical habitat in project area.
Harbor seal (<i>Phoca vitulina richardsi</i>)	29,175 ¹	Occurs in the project area. No special status or ESA listing.
Killer whale (<i>Orcinus orca</i>)	1,123 Resident 314 Transient ³	Occurs rarely in the project area. No special status or ESA listing.
Harbor porpoise (<i>Phocoena phocoena</i>)	31,046 ⁴	Occurs in the project area. No special status or ESA listing.
Steller sea lion (<i>Eumatopia jubatus</i>)	41,197 ⁵	Occurs infrequently in the project area. Listed as Depleted under the MMPA, endangered under ESA.

Notes: MMPA = Marine Mammal Protection Act, ESA = Endangered Species Act

¹ Abundance estimate for the Gulf of Alaska stock (Allen and Angliss 2010)

² Abundance estimate for Cook Inlet stock (Allen and Angliss 2010)

³ Resident estimate from Alaska resident stock; transient estimate from Gulf of Alaska, Aleutian Islands, and Bering Sea transient stock (Allen and Angliss 2010)

⁴ Abundance estimate for the Gulf of Alaska stock (Allen and Angliss 2010)

⁵ Abundance estimate for the western stock (Allen and Angliss 2010)

4.0 DESCRIPTION OF MARINE MAMMALS IN PROJECT AREA

A description of the status, distribution, and seasonal distribution of the affected species or stocks of marine mammals likely to be affected by such activities.

4.1 HARBOR SEAL

Harbor seals range from Baja California north along the west coasts of the Washington, Oregon, and California, British Columbia, and Southeast Alaska; west through the Gulf of Alaska, Prince William Sound, and the Aleutian Islands; and north in the Bering Sea to Cape Newenham and the Pribilof Islands. There are three stocks in Alaska: Southeast Alaska stock, Gulf of Alaska stock (including Cook Inlet), and Bering Sea stock. The Gulf of Alaska stock is estimated to have 29,175 individuals (Allen and Angliss 2010). Harbor seals are taken incidentally during commercial fishery operations at an estimated annual mortality of 24 individuals (Allen and Angliss 2010).

Harbor seals inhabit the coastal and estuarine waters of Cook Inlet. A relatively small but unknown proportion of the population occurs in Cook Inlet. Harbor seals are more abundant in lower Cook Inlet than in upper Cook Inlet, but they occur in the upper inlet throughout most of the year (Rugh et al. 2005a,b). Harbor seals haul out on rocks, reefs, beaches, and drifting glacial ice, and feed on capelin, eulachon, cod, pollock, flatfish, shrimp, octopus, and squid in marine, estuarine, and occasionally fresh waters. Harbor seals are non-migratory; their local movements are associated with tides, weather, season, food availability, and reproduction.

The major haulout sites for harbor seals are located in lower Cook Inlet. The presence of harbor seals in upper Cook Inlet is seasonal. Harbor seals are commonly observed along the Susitna River and other tributaries within upper Cook Inlet during eulachon and salmon migrations (NMFS 2003). During aerial surveys of upper Cook Inlet in 2001, 2002, and 2003, harbor seals were observed 24 to 96 km (15 to 60 mi) south-southwest of Anchorage at the Chickaloon, Little Susitna, Susitna, Ivan, McArthur, and Beluga Rivers (Rugh et al. 2005a). The closest traditional haulout side to the project area is located on Kalgin Island, which is about 22 km (14 mi) away from the McArthur River.

Harbor seals respond to underwater sounds from approximately 1 to 80 kHz with the functional high frequency limit around 60 kHz and peak sensitivity at about 32 kHz (Kastak and Schusterman 1995). Hearing ability in the air is greatly reduced (by 25 to 30 dB); harbor seals respond to sounds from 1 to 22.5 kHz, with a peak sensitivity of 12 kHz (Kastak and Schusterman 1995). Figure 8 is an in-air audiogram and Figure 9 is an in-water audiogram for the harbor seal (taken from Nedwell et al. 2004). An audiogram shows the lowest level of sounds that the animal can hear (hearing threshold) at different frequencies (pitch). The y-axis of the audiogram is sound levels expressed in dB (either in-air or in-water) and the x-axis is the frequency of the sound expressed in kHz.

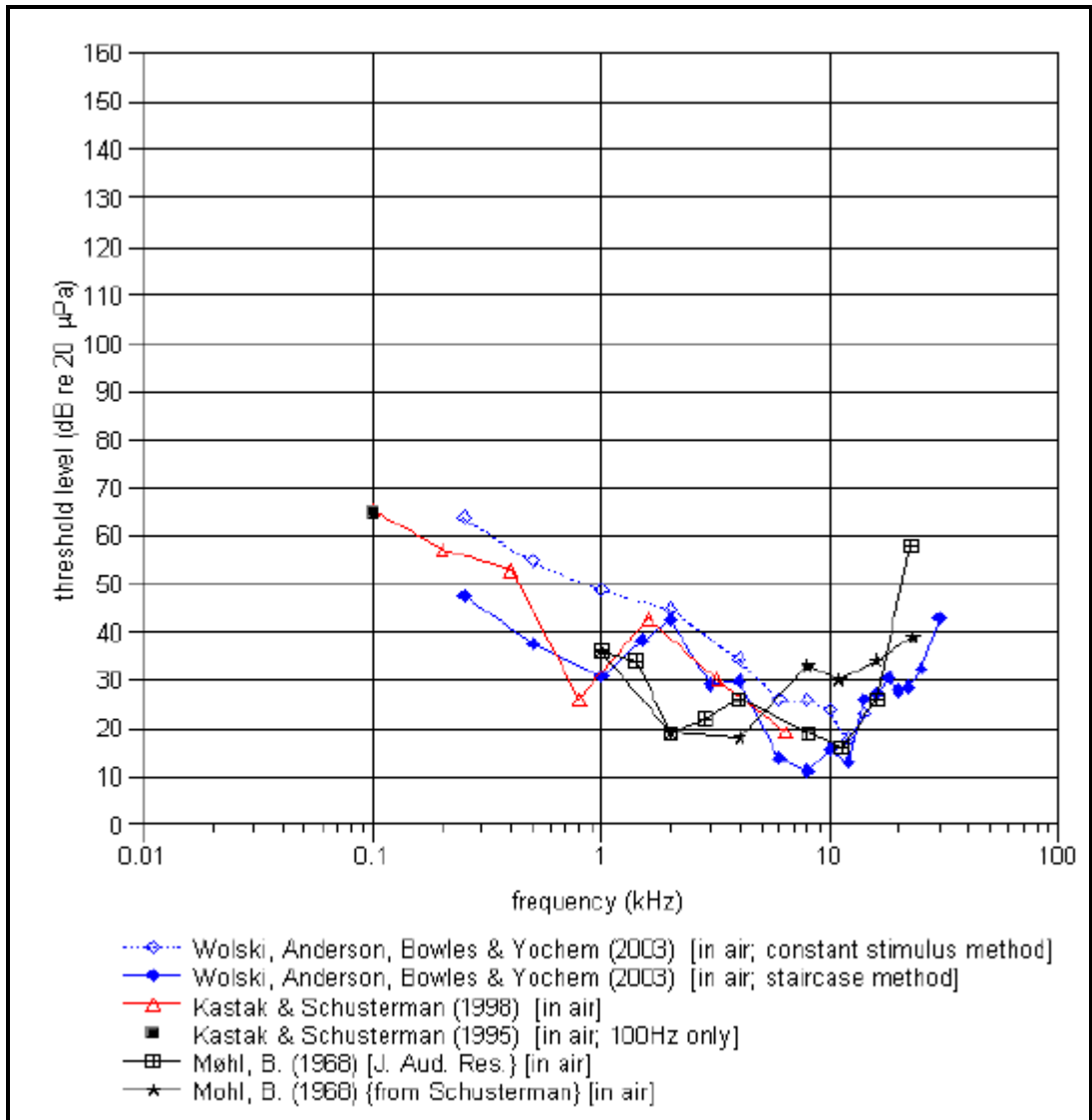


Figure 8. Harbor Seal In-air Audiogram (taken from Nedwell et al. 2004).

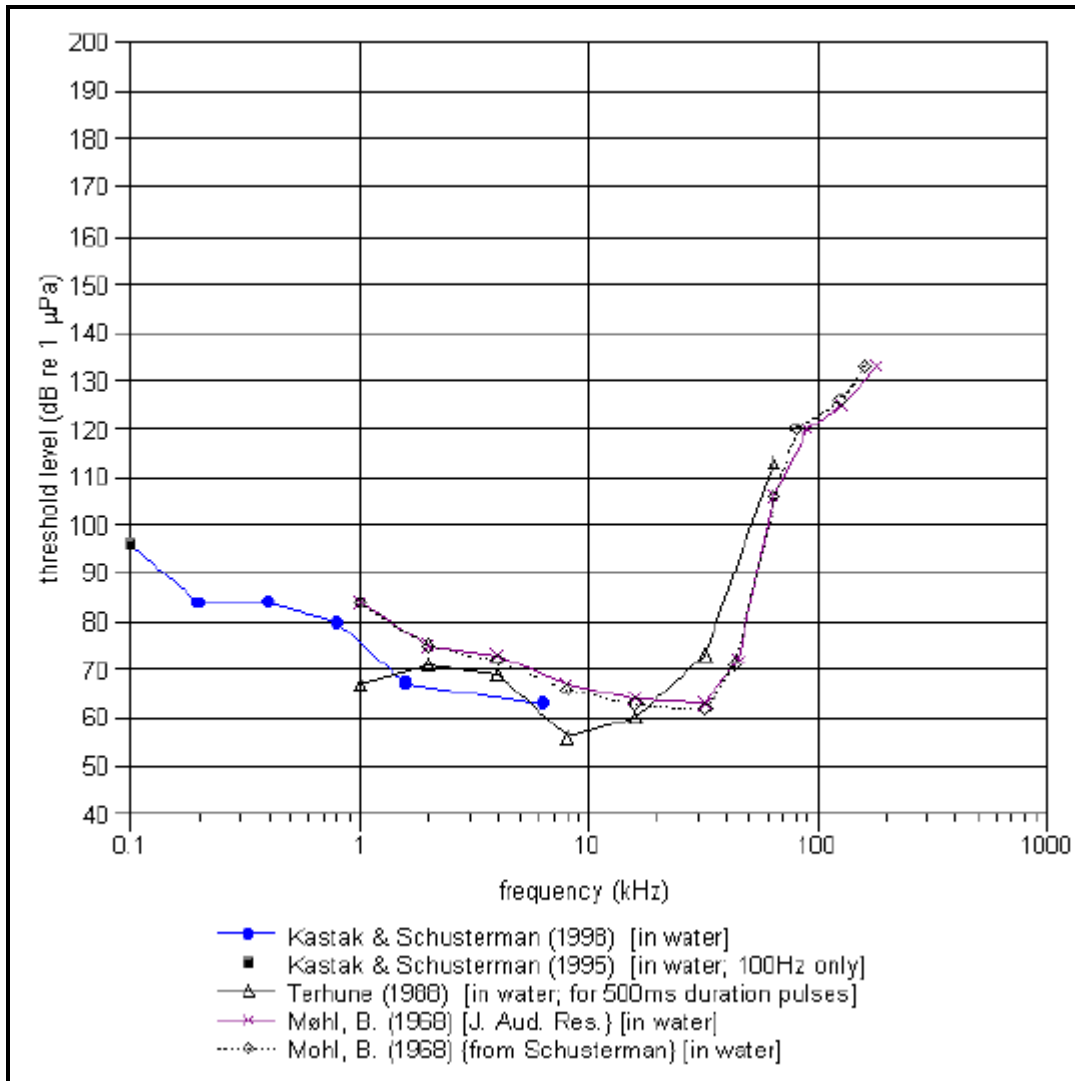


Figure 9: Harbor Seal In-water Audiogram (taken from Nedwell et al. 2004).

4.2 KILLER WHALE

The population of the North Pacific stock of killer whales contains an estimated 1,123 animals in the resident group and 314 animals in the transient group (Allen and Angliss 2010). Numbers of killer whales in Cook Inlet are small compared to the overall population and most are recorded in the lower Cook Inlet. Killer whales are rare in upper Cook Inlet, where transient killer whales are known to feed on beluga whales, and resident killer whales are known to feed on anadromous fish (Shelden et al. 2003). The availability of these prey species largely determines the likeliest times for killer whales to be in the area. Twenty-three sightings of killer whales were reported in the lower Cook Inlet between 1993 and 2004 in aerial surveys by Rugh et al. (2005a). Surveys over 20 years by Shelden et al. (2003) reported 11 sightings in upper Cook Inlet between Turnagain Arm, Susitna Flats, and Knik Arm. No killer whales were spotted during recent surveys by Funk et al. (2005), Ireland et al. (2005), Brueggeman et al. (2007a, 2007b, 2008), or Prevel Ramos et al. (2006, 2008). Eleven killer whale strandings have been reported in

Turnagain Arm, six in May 1991, and five in August 1993. Very few killer whales, if any, are expected to approach or be in the vicinity of the Project area.

The hearing of killer whales is well developed. Szymanski et al. (1999) found that they responded to tones between 1 and 120 kHz, with the most sensitive range between 18 and 42 kHz. Their greatest sensitivity was at 20 kHz, which is lower than many other odontocetes, but it matches peak spectral energy reported for killer whale echolocation clicks. Figure 10 is an audiogram for the killer whale (taken from Nedwell et al. 2004).

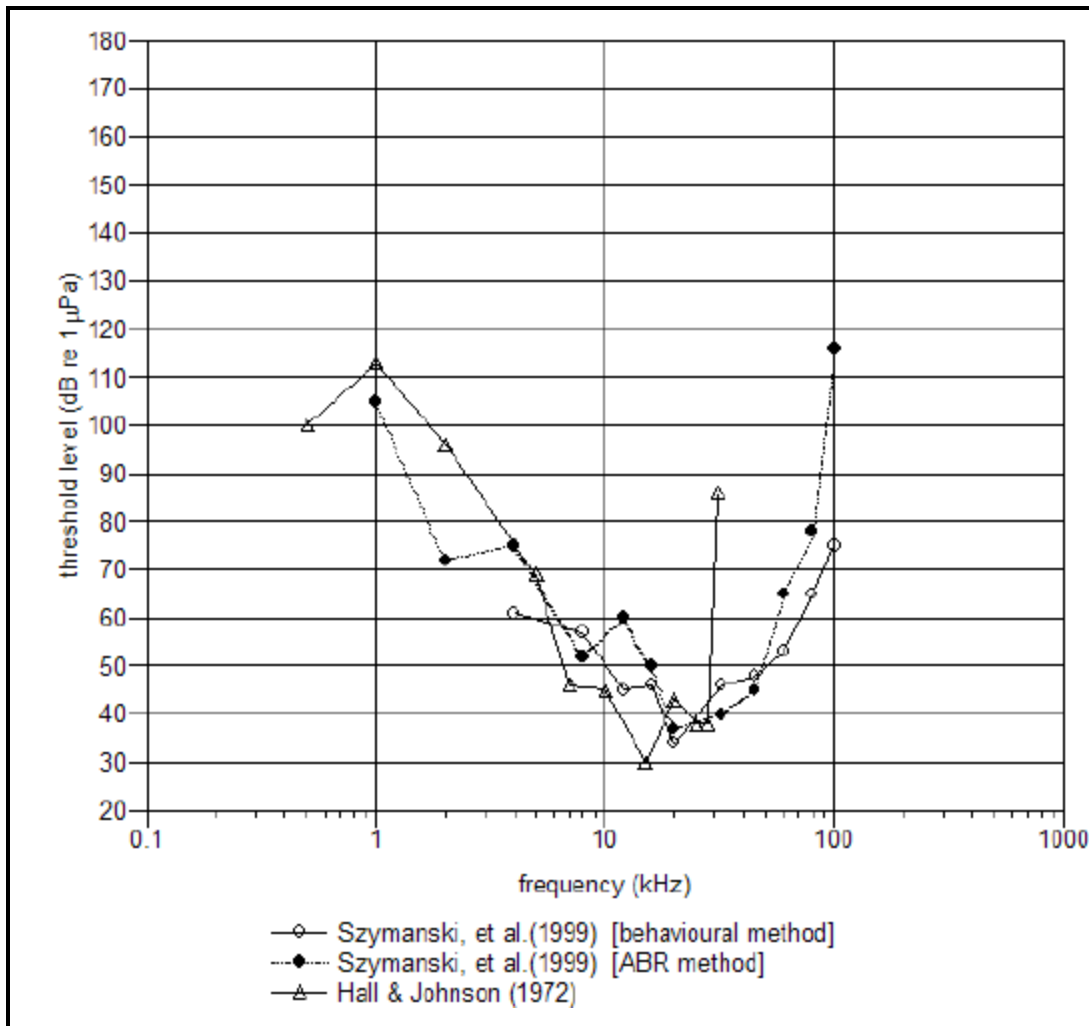


Figure 10. Killer Whale In-water Audiogram (taken from Nedwell et al. 2004).

4.3 HARBOR PORPOISE

Harbor porpoise stocks in Alaska are divided into three stocks: the Bering Sea stock, the Southeast Alaska stock, and the Gulf of Alaska stock. The Gulf of Alaska stock is currently estimated at 41,854 individuals (Allen and Angliss 2010). The most recent estimated density of animals in Cook Inlet is 7.2 per 1,000 km² (386 mi²) (Dahlheim et al. 2000) indicating that only a small number use Cook Inlet. Harbor porpoise have been reported in lower Cook Inlet from Cape Douglas to the West Foreland, Kachemak Bay, and offshore (Rugh et al. 2005a). Small numbers of harbor porpoises have been consistently reported in the

upper Cook Inlet between April and October, except for a recent survey that recorded higher numbers than typical. Highest monthly counts include 17 harbor porpoises reported for spring through fall 2006 by Prevel Ramos et al. (2008), 14 for spring of 2007 by Brueggeman et al. (2007a), 12 for fall of 2007 by Brueggeman et al. (2008), and 129 for spring through fall in 2007 by Prevel Ramos et al. (2008) between Granite Point and the Susitna River during 2006 and 2007; the reason for the recent spike in numbers (129) of harbor porpoises in the upper Cook Inlet is unclear and quite disparate with results of past surveys, suggesting it may be an anomaly. The spike occurred in July, which was followed by sightings of 79 harbor porpoise in August, 78 in September, and 59 in October in 2007. The number of porpoises counted more than once was unknown indicating that the actual numbers are likely smaller than reported.

Recent passive acoustic research in Cook Inlet by ADF&G and NMML have indicated that harbor porpoises occur more frequently than expected, particularly in the West Foreland area in the spring (NMFS 2011, personal communication), although overall numbers are still unknown at this time.

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 re 1 μ Pa) 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). Figure 11 is an audiogram for the harbor porpoise (taken from Nedwell et al. 2004).

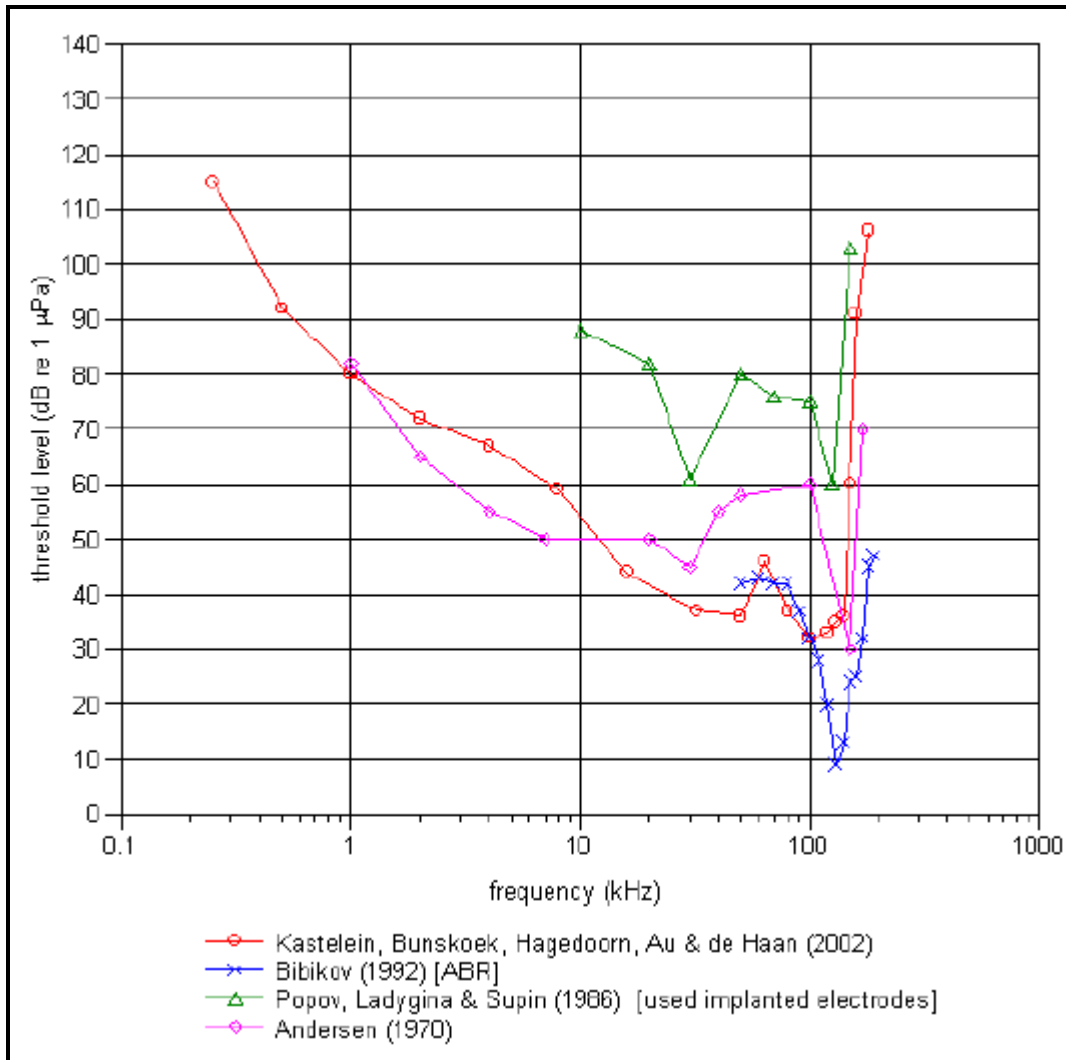


Figure 11: Harbor Porpoise In-water Audiogram (taken from Nedwell et al. 2004).

4.4 BELUGA WHALE

Beluga whales appear seasonally throughout much of Alaska, except in the Southeast region and the Aleutian Islands. Five stocks are recognized in Alaska: Beaufort Sea stock, eastern Chukchi Sea stock, eastern Bering Sea stock, Bristol Bay stock, and Cook Inlet stock (Allen and Angliss 2010). The Cook Inlet stock is the most isolated of the five stocks, as it is separated from the others by the Alaska Peninsula and resides year round in Cook Inlet (Laidre et al. 2000). Only the Cook Inlet stock inhabits the Project area.

4.4.1 Population

Cook Inlet beluga whales may have numbered fewer than several thousand animals but there were no systematic population estimates prior to 1994. Although ADF&G conducted a survey in August 1979, it did not include all of upper Cook Inlet, the area where almost all beluga whales are currently found during summer. However, it is the most complete survey of Cook Inlet prior to 1994 and incorporated a correction factor for beluga whales missed during the survey. Therefore, the ADF&G summary (Calkins 1989) provides the best available estimate for the historical beluga whale abundance in Cook Inlet. For

management purposes, NMFS has adopted 1,300 beluga whales as the numerical value for the carrying capacity to be used in Cook Inlet. (65 Federal Register [FR] 34590)

NMFS began comprehensive, systematic aerial surveys on beluga whales in Cook Inlet in 1994. Unlike previous efforts, these surveys included the upper, middle, and lower inlet. These surveys documented a decline in abundance of nearly 50 percent between 1994 and 1998, from an estimate of 653 to 347 whales (Rugh et al. 2000). In response to this decline, NMFS initiated a status review on the Cook Inlet beluga whale stock pursuant to the MMPA and the ESA in 1998 (63 FR 64228). The annual abundance surveys conducted each June since 1999 provide the following abundance estimates: 367 beluga whales in 1999, 435 beluga whales in 2000, 386 beluga whales in 2001, 313 beluga whales in 2002, 357 beluga whales in 2003, 366 beluga whales in 2004, 278 beluga whales in 2005, 302 beluga whales in 2006, 375 beluga whales in 2007; 321 beluga whales in 2009; and 340 beluga whales in 2010 (Hobbs et al. 2000; Rugh et al. 2003, 2004a, 2004b, 2005a, 2005b, 2005c, 2006, 2007, 2009; NMFS 2010 [<http://www.alaskafisheries.noaa.gov/newsreleases/2010/belugapopulation.htm>]).

These results show the population is not growing and is exhibiting a decline(<http://www.alaskafisheries.noaa.gov/newsreleases/2010/belugapopulation.htm>). The Cook Inlet beluga whale population has been designated as depleted under the MMPA (65 FR 34590). This designation is because the current population estimate (321) places it at about 41 percent of the Optimum Sustainable Population (OSP) of 780 whales (60 percent of the estimated carrying capacity of 1,300 whales). The estimate has remained below half of the OSP, which is the threshold NMFS is required to use to designate the population as depleted under the MMPA (Angliss and Outlaw 2008).

In 1999, NMFS received petitions to list the Cook Inlet beluga whale stock as an endangered species under the ESA (64 FR 17347). However, NMFS determined that the population decline was due to over harvest by Alaska Native subsistence hunters and, because the Native harvest was regulated in 1999, listing this stock under the ESA was not warranted at the time (65 FR 38778). This decision was upheld in court. NMFS announced initiation of another Cook Inlet beluga whale status review under the ESA (71 FR 14836) and received another petition to list the Cook Inlet beluga whale under the ESA (71 FR 44614). In 2006, NMFS issued a decision on the status review on April 20, 2007 concluding that the Cook Inlet beluga whale is a distinct population segment that is in danger of extinction throughout its range; NMFS issued a proposed rule to list the Cook Inlet beluga whale as an endangered species (72 FR 19821). Public hearings were conducted in July 2007, and the comment period extended to August 3, 2007. On April 22, 2008, NMFS announced that it would delay the decision on the proposed rule until after it had assessed the population status in the summer of 2008, moving the deadline for the decision to October 20, 2008 (73 FR 21578). On October 17, 2008, NMFS announced that the population is listed as endangered under ESA (73 FR 62919). On April 11, 2011, NMFS announced the two areas of critical habitat (76 FR 20180) comprising 7,800 km² (3,013 mi²) of marine habitat (Figure 12). NMFS also released the Final Conservation Plan (NMFS 2008b).

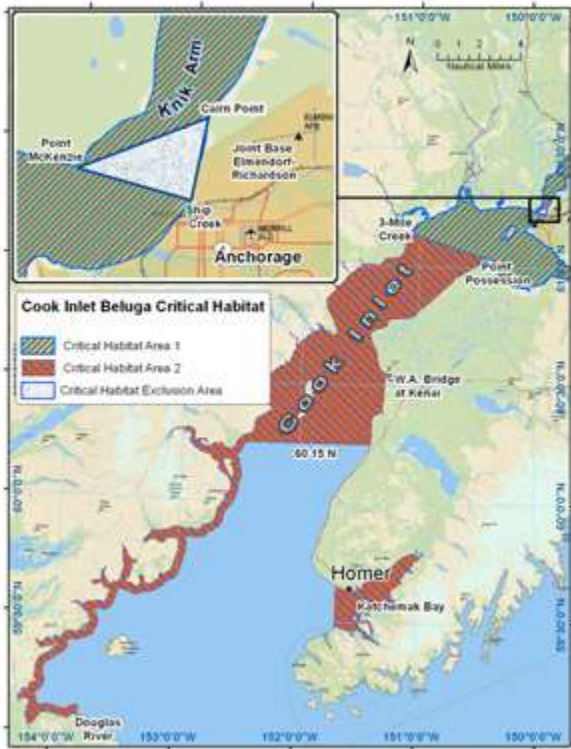


Figure 12. Final critical habitat of Cook Inlet beluga whales (76 FR 20180, April 11, 2011).

4.4.2 Hearing Abilities

In terms of hearing abilities, beluga whales are one of the most studied odontocetes because they are a common marine mammal in public aquariums around the world. Although they are known to hear a wide range of frequencies, their greatest sensitivity is around 10 to 100 kHz (Richardson et al. 1995), well above sounds produced by most industrial activities (<100 Hz or 0.1 kHz) recorded in Cook Inlet. Average hearing thresholds for captive beluga whales have been measured at 65 and 120.6 dB re 1 μ Pa at frequencies of 8 kHz and 125 Hz, respectively (Awbrey et al. 1988). Masked hearing thresholds were measured at approximately 120 dB re 1 μ Pa for a captive beluga whale at three frequencies between 1.2 and 2.4 kHz (Finneran et al. 2002). Beluga whales do have some limited hearing ability down to ~35 Hz, where their hearing threshold is about 140 dB re 1 μ Pa (Richardson et al. 1995). Thresholds for pulsed sounds will be higher, depending on the specific durations and other characteristics of the pulses (Johnson 1991). An audiogram for beluga whales from Nedwell et al. (2004) is provided in Figure 13.

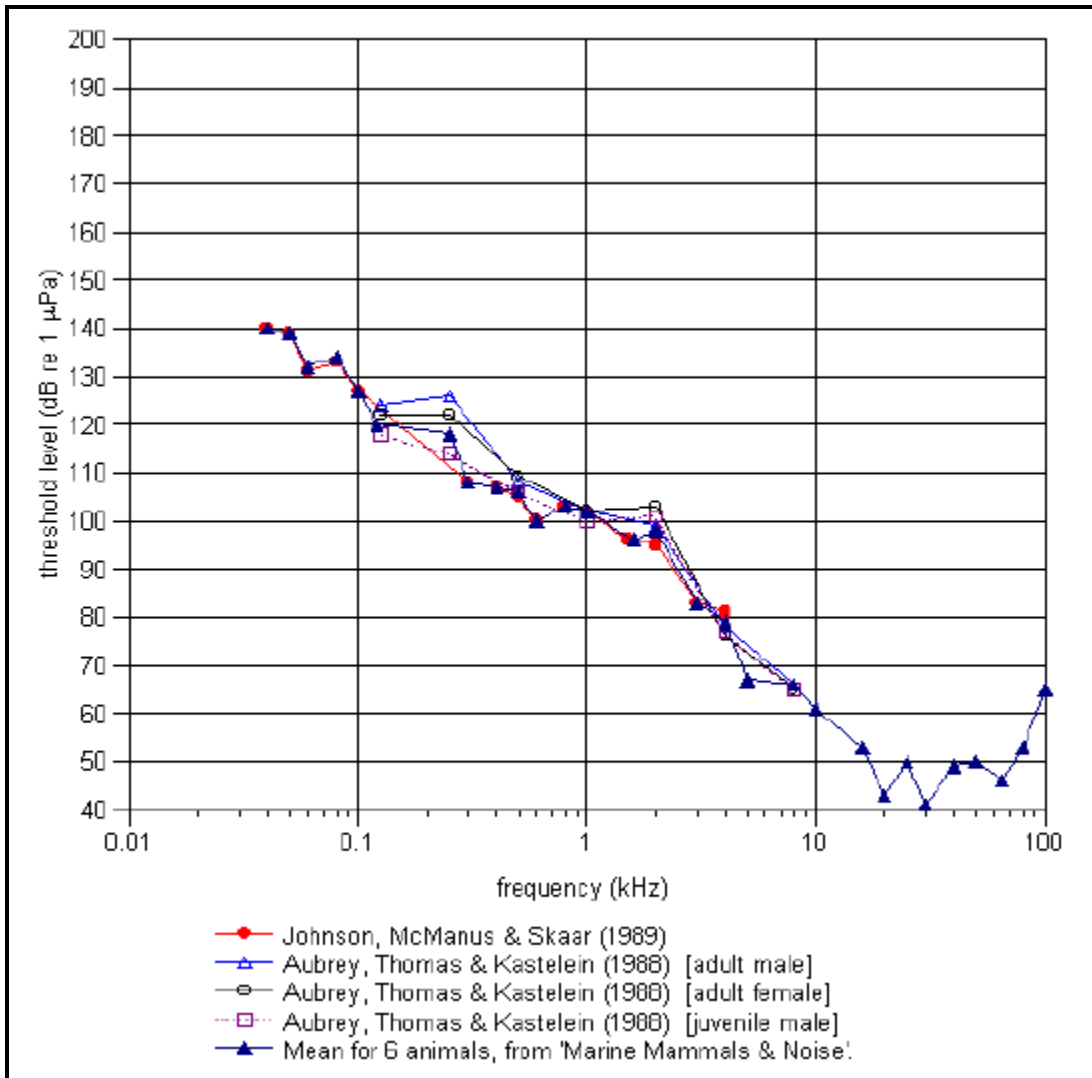


Figure 13: Beluga Whale In-water Audiogram (taken from Nedwell et al. 2004).

4.4.3 Distribution

The following discussion of the distribution of beluga whales in upper Cook Inlet is based upon NMML data including NMFS aerial surveys (Figure 14); NMFS data from satellite-tagged belugas, and opportunistic sightings (NMML 2004); baseline studies of beluga whale occurrence in Knik Arm conducted for Knik Arm Bridge and Toll Authority (KABATA, Funk et al. 2005); baseline studies of beluga whale occurrence in Turnagain Arm conducted in preparation for Seward Highway improvements (Markowitz et al. 2007); marine mammal surveys conducted at Ladd Landing to assess a coal shipping project (Prevel Ramos et al. 2008); and marine mammal surveys off Granite Point, the Beluga River, and further down the inlet at North Ninilchik (Brueggeman et al. 2007a, 2007b, 2008).

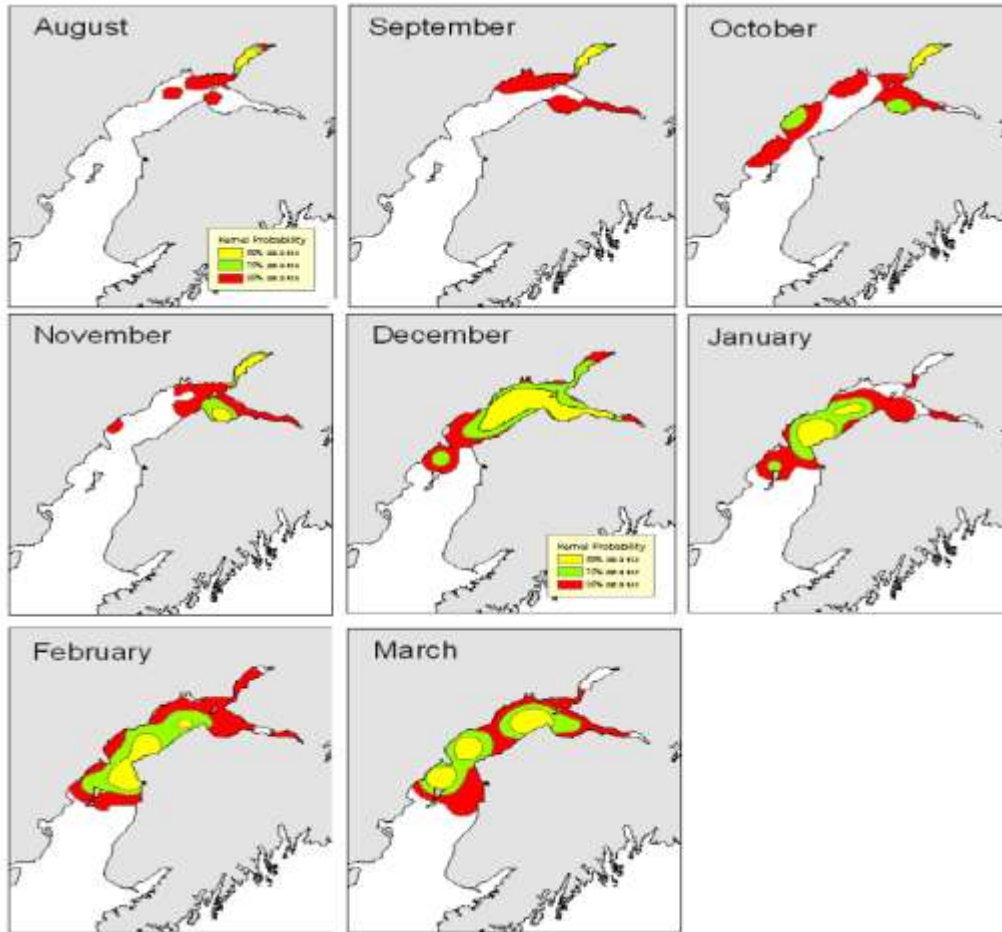


Figure 14. Predicted beluga distribution by month based upon known locations of 14 satellite tagged belugas (predictions derived via kernel probability estimates; Hobbs et al. 2005). Note the large increase in total area use and offshore locations beginning in December and continuing through March. The red area (95 percent probability) encompasses the green (75 percent) and yellow (50 percent) regions. From NMFS 2008.

4.4.3.1 NMFS Aerial Surveys

Since 1993, NMFS has conducted annual aerial surveys in June or July to document the distribution and abundance of beluga whales in Cook Inlet. In addition, to help establish beluga whale distribution in Cook Inlet throughout the year, aerial surveys were conducted every one to two months between June 2001 and June 2002 (Rugh et al. 2004a). These annual aerial surveys for beluga whales in Cook Inlet have provided systematic coverage of 13 to 33 percent of the entire inlet each June or July since 1994 including a 3 to km (1.9 mi) wide strip along the shore and approximately 1,000 km (621 mi) of offshore transects (Rugh et al. 2000, 2005a, 2005b, 2006, 2007). Surveys designed to coincide with known seasonal feeding aggregations (Table 1.3 in Rugh et al. 2000) were generally conducted on two to four days per year in June or July at or near low tide in order to reduce the search area (Rugh et al. 2000). However from June 2001 to June 2002, surveys were conducted during most months in an effort to assess seasonal variability in beluga whale distribution in Cook Inlet (Rugh et al. 2005a).

The collective survey results show that beluga whales have been consistently found near or in river mouths along the northern shores of upper Cook Inlet (i.e., north of East and West Foreland). In particular, beluga whale groups are seen in the Susitna River Delta, Knik Arm, and along the shores of Chickaloon Bay. Small groups had also been recorded seen farther south in Kachemak Bay, Redoubt Bay (Big River), and Trading Bay (McArthur River) prior to 1996, but very rarely thereafter. Since the mid-1990s, most (96 to 100 percent) beluga whales in upper Cook Inlet have been concentrated in shallow areas near river mouths, no longer occurring in the central or southern portions of Cook Inlet (Hobbs et al. 2008). Based on these aerial surveys, the concentration of beluga whales in the northernmost portion of Cook Inlet appears to be fairly consistent from June to October (Rugh et al. 2000, 2004a, 2005a, 2006, 2007; Sheldon et al. 2008, 2009, 2010).

4.4.3.2 NMFS Satellite Tag Data

In 1999, one beluga whale was tagged with a satellite transmitter, and its movements were recorded from June through September of that year. Since 1999, 18 beluga whales in upper Cook Inlet have been captured and fitted with satellite tags to provide information on their movements during late summer, fall, winter, and spring. Hobbs et al. (2005) described: 1) the recorded movements of two beluga whales (tagged in 2000) from September 2000 through January 2001; 2) the recorded movements of seven beluga whales (tagged in 2001) from August 2001 through March 2002; and 3) the recorded movements of eight beluga whales (tagged in 2002) from August 2002 through May 2003.

The concentration of beluga whales in the upper Cook Inlet appears to be fairly consistent from June to October based on aerial surveys (Rugh et al. 2000, 2004a, 2005a). Studies for KABATA in 2004 and 2005 confirmed the use of Knik Arm by beluga whales from July to October (Funk et al. 2005). Data from tagged whales (14 tags between July and March 2000 through 2003) show beluga whales use upper Cook Inlet intensively between summer and late autumn (Hobbs et al. 2005). As late as October, beluga whales tagged with satellite transmitters continued to use Knik Arm and Turnagain Arm and Chickaloon Bay, but some ranged into lower Cook Inlet south to Chinitna Bay, Tuxedni Bay, and Trading Bay (McArthur River) in the fall (Hobbs et al. 2005). In November, beluga whales moved between Knik Arm, Turnagain Arm, and Chickaloon Bay, similar to patterns observed in September (Hobbs et al. 2005). By December, beluga whales were distributed throughout the upper to mid-inlet. From January into March, they moved as far south as Kalgin Island and slightly beyond in central offshore waters. Beluga whales also made occasional excursions into Knik Arm and Turnagain Arm in February and March in spite of ice cover greater than 90 percent (Hobbs et al. 2005). While they moved widely around Cook Inlet there was no indication from the tagged whales (Hobbs et al. 2005) that beluga whales had a seasonal migration in and out of Cook Inlet.

4.4.3.3 Opportunistic Sightings

Opportunistic sightings of beluga whales in Cook Inlet have been reported to the NMFS since 1977. Beluga whale sighting reports are maintained in a database by NMML. Their high visibility and distinctive nature make them well-suited for opportunistic sightings along public access areas (e.g., the Seward Highway along Turnagain Arm, the public boat ramp at Ship Creek). Opportunistic sighting reports come from a variety of sources including: NMFS personnel conducting research in Cook Inlet, ADF&G, commercial fishermen, pilots, and the general public. Location data range from precise locations (e.g., GPS-determined latitude and longitude) to approximate distances from major landmarks. In addition to location data, most reports include date, time, approximate number of whales, and notable whale behavior (Rugh et al. 2000, 2004a, 2005a). Since opportunistic data are collected any time, and

often multiple times a week, these data often provide an approximation of beluga whale locations and movements in those areas frequented by natural resource agency personnel, fishermen, and others.

Depending upon the season, beluga whales can occur in both offshore and coastal waters. Although they remain in the general Cook Inlet area during the winter, they disperse throughout the upper and mid-inlet areas. Data from NMFS aerial surveys, opportunistic sighting reports, and satellite-tagged beluga whales confirm they are more widely dispersed throughout Cook Inlet during the winter months (November-April), with animals found between Kalgin Island and Point. Based upon monthly surveys (e.g., Rugh et al. 2000), opportunistic sightings, and satellite-tag data, there are generally fewer observations of these whales in the Anchorage and Knik Arm area from November through April (NMML 2004; Rugh et al. 2004a).

During the spring and summer, beluga whales are generally concentrated near the warmer waters of river mouths where prey availability is high and predator occurrence is low (Moore et al. 2000). Most beluga whale calving in Cook Inlet occurs from mid-May to mid-July in the vicinity of the river mouths, although Native hunters have described calving as early as April and as late as August (Huntington 2000).

Beluga whale concentrations in upper Cook Inlet during April and May correspond with eulachon migrations to rivers and streams in the northern portion of upper Cook Inlet (NMFS 2003; Angliss and Outlaw 2005). Data from NMFS aerial surveys, opportunistic sightings, and satellite-tagged beluga whales confirm that they are concentrated along the rivers and nearshore areas of upper Cook Inlet (Susitna River Delta, Knik Arm, and Turnagain Arm) from May through October (NMML 2004; Rugh et al. 2004a). Beluga whales are commonly seen from early July to early October at the mouth of Ship Creek where they feed on salmon and other fish, and also in the vicinity of the Port (e.g., alongside docked ships and within 300 ft of the docks) (Blackwell and Greene 2002; NMML 2004). Beluga whales have also been observed feeding immediately offshore of the tidelands north of the Port and south of Cairn Point (NMFS 2004).

4.4.3.4 Knik Arm Bridge and Toll Authority (KABATA) 2004-2005 Baseline Study

To assist in the evaluation of the potential impact of a proposed bridge crossing of Knik Arm north of Cairn Point, KABATA initiated a study to collect baseline environmental data on beluga whale activity and the ecology of Knik Arm. Boat and land-based observations were conducted in Knik Arm from July 2004 through July 2005. Land-based observations were conducted from nine stations along the shore of Knik Arm. The three primary stations were located at Cairn Point, Point Woronzof, and Birchwood. The majority of the beluga whales were observed north of Cairn Point. Temporal use of Knik Arm by beluga whales was related to tide height. During the study period, most beluga whales using Knik Arm stayed in the upper portion of Knik Arm north of Cairn Point. Approximately 90 percent of observations occurred during the months of August through November, and only during this time were whales consistently sighted in Knik Arm. The relatively low number of sightings in Knik Arm throughout the rest of the year suggested the whales were using other portions of Cook Inlet. In addition, relatively few beluga whales were sighted in the spring and early to mid-summer months. Beluga whales predominantly frequented Eagle Bay (mouth of Eagle River), Eklutna, and the stretch of coastline in between, particularly when they were present in greater numbers (Funk et al. 2005).

4.4.3.5 Seward Highway Study along Turnagain Arm

Markowitz et al. (2007) documented habitat use and behavior of beluga whales along the Seward Highway in Turnagain Arm from May through November 2006. This study was focused around the high tides when whales regularly traverse the near-shore channels to the mouths of rivers and streams, where

they feed on fish. Most of the observations of whales occurred between the end of August and the end of October. No beluga whales were sighted in the study area in May, June, or July. The age composition of all whales observed was 58 percent adults, 17 percent subadults, 8 percent calves, and 17 percent unknown. Most beluga whale observations were in the upper Turnagain Arm, east of Bird Creek. The observation station closest to the Port was at Potter Creek but few beluga whales were sighted in the lower Turnagain Arm section of the Project area. About 80 percent of all beluga whale sightings were within 1,100 m off shore. About a third of all sightings in September were less than 50 m from shore while two-thirds of all sightings in October were within 50 m off shore. Most beluga whale movements were with the tide: eastward into the upper Turnagain Arm on the rising tide and westward out of Turnagain Arm on the falling tide. The few observations of beluga whales in the lower Turnagain Arm were close to the mid-tide, indicating that beluga whales may use these areas closer to the low tide rather than the high tide pattern observed in the upper Turnagain Arm.

4.4.3.6 Marine Mammal Surveys at Ladd Landing

Prevel Ramos et al. (2008) conducted surveys near Ladd Landing on the north side of upper Cook Inlet between Tyonek and the Beluga River from April through October in 2006 and July through October 2007. The results from 2006 indicated that July through October had the least amount of beluga whale activity in the Project area. Relatively few beluga whales were observed during the 2007 surveys near Ladd Landing, with three groups of one or two whales observed in July, two groups of three whales in September, and two groups averaging seven whales in October. Two groups of 20 whales were observed near the Susitna Flats in August. Some of these whales may have been recorded more than once. Most of the whales sighted were close to shore. Of the whales seen in 2006 and 2007, 60 to 75 percent were white, 16 to 18 percent were gray, and the color of 10 to 22 percent was unknown.

4.4.3.7 Marine Mammal Surveys at Granite Point, Beluga River, and North Ninilchik

Brueggeman et al. (2007a, 2007b, 2008) conducted vessel and aerial surveys in 2007 near the Beluga River between April 1 and May 15, Granite Point between September 29 and October 21, and North Ninilchik between October 25 and November 7. They recorded 148 to 162 belugas near the Beluga River with most observed during early May, 35 belugas near Granite Point with most observed in early to mid-October, and no belugas recorded off North Ninilchik. Most of the whales were observed near the shore. In addition, the movements indicated they were transiting through the areas to the head of the upper inlet. Small percentages of calves and yearlings were recorded with adults during the spring and early fall surveys. No belugas were observed at North Ninilchik which is considered marginal habitat because of a lack of habitat structure (bays, inlets, etc.) combined with easy public access, typical of the eastern shore of the inlet.

4.4.4 Feeding

Hobbs et al. (2008) presents the most current analysis of stomach contents derived from stranded or harvested belugas in Cook Inlet. This analysis is continuing and provides information on prey availability and prey preferences of Cook Inlet belugas which is summarized below.

Cook Inlet belugas feed on a wide variety of prey species particularly those that are seasonally abundant. In spring, the preferred prey species are eulachon and cod. Other fish species found in the stomachs of belugas may be from secondary ingestion by cods that feed on polychaetes, shrimp, amphipods, mysids, as well as other fish (e.g., walleye pollock and flatfish), and invertebrates.

From late spring and throughout summer most beluga stomachs sampled contained Pacific salmon corresponding to the timing of fish runs in the area. Anadromous smolt and adult fish concentrate at river

mouths and adjacent intertidal mudflats (Calkins 1989). Five Pacific salmon species: Chinook, pink, coho, sockeye, and chum spawn in rivers throughout Cook Inlet (Moulton 1997; Moore et al. 2000). Calkins (1989) recovered 13 salmon tags in the stomach of an adult beluga found dead in Turnagain Arm. Beluga hunters in Cook Inlet reported one whale having 19 adult Chinook salmon in its stomach (Huntington 2000). Salmon, overall, represent the highest percent frequency of occurrence of the prey species in Cook Inlet beluga stomachs. This suggests that their spring feeding in upper Cook Inlet, principally on fat-rich fish such as salmon and eulachon, is very important to the energetics of these animals.

In the fall, as anadromous fish runs begin to decline, belugas return to consume fish species (cod and bottom fish) found in nearshore bays and estuaries. Bottom fish include Pacific staghorn sculpin, starry flounder, and yellowfin sole. Stomach samples from Cook Inlet belugas are not available for winter months (December through March), although dive data from belugas tagged with satellite transmitters suggest whales feed in deeper waters during winter (Hobbs et al. 2005), possibly on such prey species as flatfish, cod, sculpin, and pollock.

4.5 STELLER SEA LION

Steller sea lions' habitat extends around the North Pacific Ocean rim from northern Japan, the Kuril Islands and Okhotsk Sea, through the Aleutian Islands and Bering Sea, along Alaska's southern coast, and south to California (NMFS 2008c). NMFS reclassified Steller sea lions as two distinct population segments under the ESA based on genetic studies and phylogeographical analyses from across the sea lion's range (62 FR 24345). The eastern DPS includes sea lions born on rookeries from California north through Southeast Alaska; the western DPS includes those animals born on rookeries from Prince William Sound westward (NMFS 2008c). Steller sea lions occur in Cook Inlet but south of Anchor Point around the offshore islands and along the west coast of the upper inlet in the bays (Chinitna Bay, Iniskin Bay, etc.) (Rugh et al. 2005a). Portions of the southern reaches of the lower inlet are designated as critical habitat, including a 20-nautical mile buffer around all major haul out sites and rookeries. Rookeries and haulout sites in lower Cook Inlet include those near the mouth of the inlet, which are far south of the project area. It is unlikely that any Steller sea would be in the project area during operations.

4.5.1 Hearing Abilities

Steller sea lions have similar hearing thresholds in-air and underwater to other otariids. In-air hearing range from 0.250–30 kHz, with a region of best hearing sensitivity from 5–14.1 kHz (Muslow and Reichmuth 2010). The underwater audiogram shows the typical mammalian U-shape. The range of best hearing was from 1 to 16 kHz. Higher hearing thresholds, indicating poorer sensitivity, were observed for signals below 16 kHz and above 25 kHz (Kastelein et al. 2005).

5.0 REQUESTED TYPE OF INCIDENTAL TAKING AUTHORIZATION

The type of incidental taking authorization that is being requested and the method of incidental taking.

APACHE requests an IHA from NMFS for the incidental take by harassment (Level B as defined in 50 CFR 216.3) of a small number of marine mammals during its planned first year of 3D seismic survey operations in Cook Inlet beginning in fall 2011. The operations outlined in Sections 1 and 2 have the potential to result in takes by harassment of marine mammals by acoustic disturbance during seismic operations. The effects will depend on the species and the distance and received level of the sound (Section 7). Temporary disturbance or localized displacement reactions are most likely to occur. With implementation of the mitigation and monitoring measures described in Sections 11 and 13, no takes by injury or mortality (Level A) are anticipated and takes by disturbance (Level B) are expected to be minimized.

6.0 NUMBER OF INCIDENTAL TAKES BY ACTIVITIES

By age, sex, and reproductive condition, the number of marine mammals [by species] that may be taken by each type of taking, and the number of times such takings by each type of taking are likely to occur.

The proposed seismic survey operations outlined in Sections 1 and 2 have the potential to temporarily disturb or displace small numbers of marine mammals in Cook Inlet. These potential effects, as summarized in Section 7, will not exceed MMPA Level B harassment, as defined by 30 CFR 213.6. The mitigation measures to be implemented during the survey are based on Level B harassment criteria using the 160 dB re 1 μ Pa rms threshold defined below. No take by injury or death is anticipated with implementation of the mitigation and monitoring measures. The following text provides text on the applicable noise criteria and a description of the methods used to calculate numbers of marine mammals that may be potentially encountered during the seismic program.

6.1 APPLICABLE NOISE CRITERIA

Under the MMPA, NMFS has defined levels of harassment for marine mammals. Level A harassment is defined as "...any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild." Level B harassment is defined as "...any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

Since 1997, NMFS has been using generic sound exposure thresholds to determine when an activity in the ocean that produces sound might result in impacts to a marine mammal such that a take by harassment might occur (70 FR 1871). NMFS is developing new science-based thresholds to improve and replace the current generic exposure level thresholds, but the criteria have not been finalized (Southall et al. 2007). The current Level A (injury) threshold for impulse noise is 180 dB re 1 μ Pa rms for cetaceans (whales, dolphins, and porpoises) and 190 dB re 1 μ Pa rms for pinnipeds (seals, sea lions). The current Level B (disturbance) threshold for impulse noise is 160 dB re 1 μ Pa rms for cetaceans and pinnipeds.

6.2 CALCULATION OF 24-HOUR ACOUSTIC FOOTPRINTS

A computer modeling study was performed to predict 24-hour acoustic footprints of airgun arrays for Apache's planned Cook Inlet seismic surveys. The modeling study report is attached as Appendix A. The study considered seismic survey activities at nearshore locations at the sides of Cook Inlet having sloping bottoms and in the Inlet's main channel where depth is relatively constant. The nearshore locations were sub-divided into three depth intervals of 5-21 m (16-69 ft), 21-38 m (69-125 ft), and 38-54 m (125-177 ft). The channel scenario had constant water depth 80 m (262 ft) to correspond approximately with the mean channel depth over the region of Cook Inlet that Apache plans to survey. The nearshore survey depth interval subdivisions are based on the zones that can be surveyed in 24 hour periods based on anticipated nominal survey line length: 16.1 km (10 mi), and survey line spacing: 503 m (1,650 ft). Adjacent lines will be surveyed sequentially. Apache estimates that it can complete 12-14 survey lines per day based on normal survey vessel speed. The depth intervals listed above each correspond with 14 adjacent parallel lines based on the rate of depth increase with distance from shore. The different depth intervals were considered separately because the size of the air gun array sound footprint varies with water depth.

The largest possible airgun array configuration of 2400 cui was considered by the modeling study to provide conservative estimates of noise footprints; smaller arrays may be used and those would produce smaller footprints.

The nearshore modeling scenarios were examined by placing the source at three distances offshore corresponding with water depths: 5, 25, and 45 m (16, 82, 148 ft). For each source position, the model predicted distances to the 160 dB re 1 μ Pa rms threshold in multiple directions. These distances were subsequently interpolated to predict threshold distances for survey source positions at all depths between 5 m (16 ft) and 54 m (177 ft) depth. The deep channel survey scenario, with constant water depth of 80 m (262 ft), was modeled to predict the distances in the endfire and broadside directions relative to the array that sound levels attenuated to 160 dB re 1 μ Pa rms.

Twenty four-hour composite acoustic footprints were calculated from the footprints of the individual survey lines. Each survey line footprint was estimated using a rectangle that encompassed the 160 dB broadside (inshore and offshore directions) and endfire (along-shore) extents for all air gun pulses on that line. The union of the 14 survey line footprints created the 24-hour composite acoustic footprint. The union of the single line footprints is smaller than their sum because of overlap.

6.2.1 Nearshore Survey Results

The distances to the 160, 180, and 190 dB re 1 μ Pa rms sound level thresholds for the nearshore survey locations are given in Table 1. Distances correspond to the three transects modeled at each site in the onshore, offshore, and parallel to shore directions. The 160 dB re 1 μ Pa footprints for one day of nearshore surveying in shallow, mid-depth, and deep water are shown in Figure 15; the corresponding areas of the footprints are listed in Table 3.

Table 1: Distances to Sound Level Thresholds for the Nearshore Surveys

Sound Level Threshold (dB re 1 μ Pa)	Water Depth at Source Location (m)	Distance in the Onshore Direction (km)	Distance in the Offshore Direction (km)	Distance in the Parallel to Shore Direction (km)
160	5	0.85	3.91	1.48
	25	4.70	6.41	6.34
	45	5.57	4.91	6.10
180	5	0.46	0.60	0.54
	25	1.06	1.07	1.42
	45	0.70	0.83	0.89
190	5	0.28	0.33	0.33
	25	0.35	0.36	0.44
	45	0.10	0.10	0.51

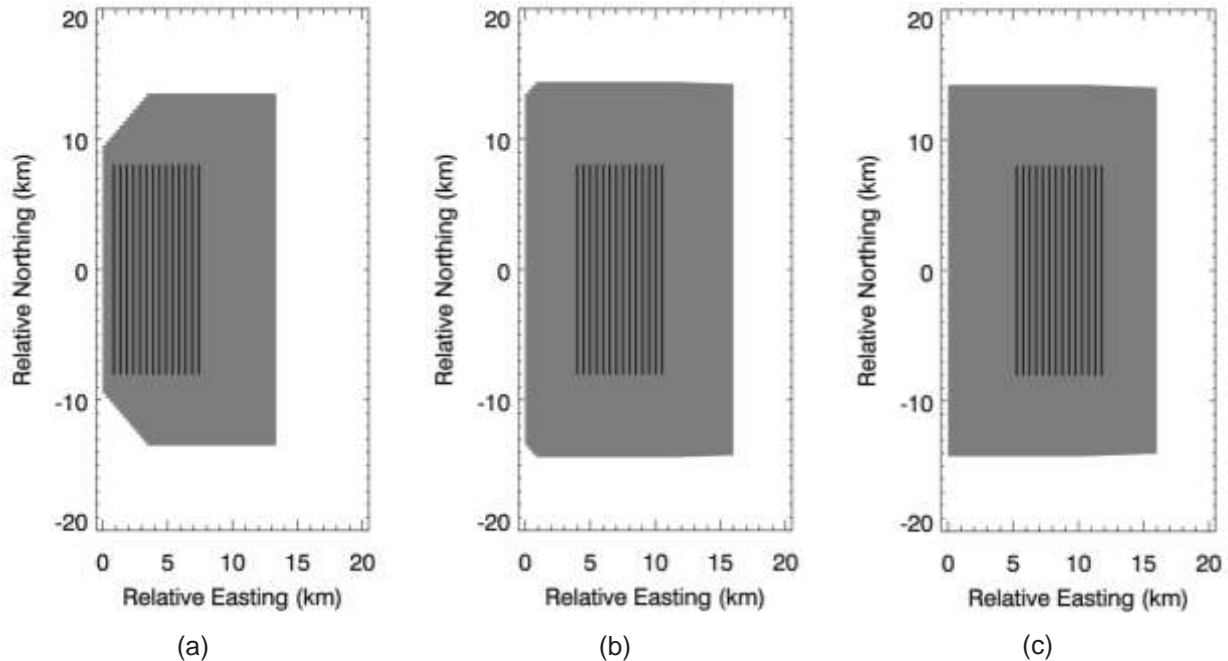


Figure 15: Daily footprints for (a) shallow, (b) mid-depth, and (c) deep water nearshore surveys. The ensonified areas are shown in gray and survey lines are shown in black.

Table 2: Areas Ensonified to 160 dB re 1 μ Pa for Nearshore Surveys in 24 Hours

Nearshore Survey Depth Classification	Depth Range (m)	Area Ensonified to 160 dB re 1 μ Pa (km ²)
Shallow	5-21	346
Mid-depth	21-38	458
Deep	38-54	455

6.2.2 Channel Survey Results

The distances to the 160, 180, and 190 dB re 1 μ Pa rms sound level thresholds for the channel surveys are shown below in Table 4. Distances correspond to the broadside and endfire directions. The 160 dB re 1 μ Pa rms footprint for 24 hours of seismic survey in the inlet channel is shown in Figure 16; the corresponding area of the footprint is 389 km².

Table 4: Distances To Sound Level Thresholds For The Channel Surveys

Sound Level Threshold (dB re 1 μ Pa)	Water Depth at Source Location (m)	Distance in the Broadside Direction (km)	Distance in the Endfire Direction (km)
160	80	4.24	4.89
180	80	0.91	0.98
190	80	0.15	0.18

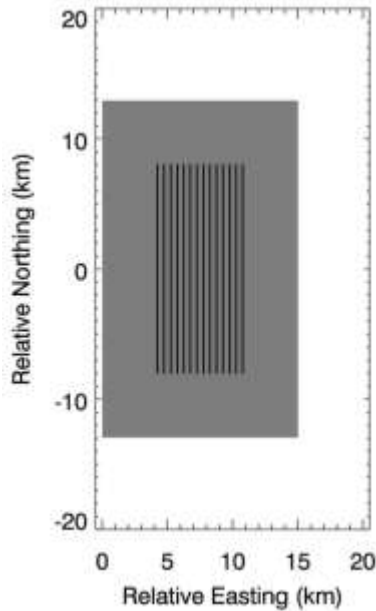


Figure 16: Daily footprint for channel surveys. The ensonified area is shown in gray and the survey lines are shown in black. Its area is 389 km².

6.2.3 Positioning pinger

As described in Section 1.2.5, the maximum source level of the pinger is 188 dB re μPa at 1 m rms (at 33-55 kHz). Assuming a simple spreading loss of $20 \log R$ (where R is radius) with a source level of 188 dB, the distance to the 190, 180, and 160 dB isopleths would be 1, 3, and 25 m (3.28, 9.8, and 82 ft). This spreading loss is appropriate for high-frequency pulsed systems. The reason is that the multipaths (direct path, surface reflection, bottom reflection, etc.) of short duration pulses arrive at the receivers spaced in time. The rms level therefore should be computed for the strength of the strongest multipath, which will be the direct path. The use of $20 \log R$ is fully appropriate because this path does not interact with surface or bottom (otherwise it would have an even higher coefficient than 20).

6.3 ESTIMATES OF MARINE MAMMAL DENSITY

Estimated densities of marine mammals in the proposed project area were estimated from the annual aerial surveys conducted by NMFS for Cook Inlet beluga whale between 2000 and 2010 in June (Rugh et al. 2000, 2001, 2002, 2003, 2004b, 2005b, 2006, 2007; Sheldon et al. 2008, 2009, 2010). These surveys are flown in June to collect abundance data of beluga whales, but sightings of other marine mammals are also reported. Although these data are only collected in one month each year, these surveys provide the best available relatively long term data set for sighting information in the proposed Project Area. The general trend in marine mammal sighting is that beluga whales and harbor seals are seen most frequently in upper Cook Inlet, with higher concentrations of harbor seals near haul out sites on Kalgin Island and of beluga whales near river mouths, particularly the Susitna River. The other marine mammals of interest for this IHA (killer whales, harbor porpoises, Steller sea lions) are observed infrequently in upper Cook Inlet and more commonly in lower Cook Inlet. In addition, these densities are calculated based on a relatively large area that was surveyed, much larger than Area 1, the proposed semisic area in the first year. Furthermore, these annual surveys are conducted only in June (numbers from August surveys were not used because the area surveyed was not provided), so it does not account for seasonal variations in distribution or habitat use of each species. Therefore, the use of these data to estimate density is extremely

conservative and provides a worst-case estimate of the probability of observing these animals in the Project Area, which is located in upper Cook Inlet.

Table 5 provides a summary of the results of each annual survey conducted from between 2000 and 2010 in June. The total number of individuals sighted for each survey by year is reported, as well as total hours for the entire survey and total area surveyed. To estimate density of marine mammals, the total number of animals observed for the entire survey by year (surveys usually last several days) was divided by the total number of hours for each aerial survey by the approximate total area surveyed for each year (density = individuals/hr/km²). As noted previously, the total number of animals observed for the entire survey includes both lower and upper Cook Inlet, so the total number reported and used to calculate density is higher than the number of marine mammals anticipated to be observed in Area 1. In particular, the total number of harbor seals observed on several surveys is very high due to several large haul outs in lower and middle Cook Inlet.

As discussed in Section 4.4.3.1 and shown in Table 5, beluga whales are observed in higher concentrations in river mouths, particularly Susitna River, due to feeding. Therefore, to account for the higher concentration near river mouths, the highest number of beluga whales observed for each year (which was always in the Susitna River delta) was used to provide a density for river mouths. To account for the lower concentration away from river mouths, the average number of beluga whales observed for each year was used to provide density away from river mouths. The maximum and average of the total years (2000-2010) is provided in Table 6. A maximum and average density are provided to account for the inherent level of uncertainty in using aerial surveys conducted a few days once a year to estimate density for the entire year. These densities will be used to estimate the number of Level B takes in the following section.

Table 5. Density of Marine Mammals from NMFS Annual Aerial Surveys

Location	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Beluga whales											
Turnagain Arm (north and east of Chickaloon Bay)	0	34	0	0	50	21	0	76	0	0	4
Chickaloon Bay to Pt. Possession	28	0	11	64.5	65	66	60	50	33	40	131
Mid-Inlet east of Trading Bay	0	0	0	0	0	0	15	0	0	0	9
East Foreland to Homer	0	0	0	0	0	0	0	0	0	0	0
Susitna Delta (N. Foreland to Pt. Mackenzie)	114	175	93	109.8	41	155	126	152	103	290	160
Knik Arm	42	0	88	0	0	43	9	23	0	0	0
Fire Island	0	0	0	0	0	16	0	2	0	0	9
Harbor seals (total observed)	1800	672	1481	974	975	633	887	393	1219	387	543
Harbor porpoise (total observed)	29	0	0	0	100	2	0	4	6	32	9
Killer whales (total observed)	0	15	0	0	0	0	0	0	0	0	33
Steller sea lions (total observed)	10	0	54	76	1	104	3	0	75	39	1
Number of hours surveyed (hrs)	43	55	45	61	45	54	58.4	47.2	47.7	39.4	48.4
Total area surveyed (km ²)	6500	5200	5244	5100	6000	5500	6723	5255	7172	5766	6120
Density (number of animals / number of hrs / area surveyed)											
Belugas (avg number observed)	0.00006	0.00007	0.00007	0.00005	0.00005	0.00009	0.00005	0.00011	0.00004	0.00015	0.00010
Belugas (max number observed - rivers)	0.00041	0.00061	0.00039	0.00035	0.00024	0.00052	0.00032	0.00061	0.00030	0.00128	0.00054
Harbor seals (total number observed)	0.00644	0.00235	0.00628	0.00313	0.00361	0.00213	0.00226	0.00158	0.00356	0.00170	0.00183
Harbor porpoise (total number observed)	0.00010	0.00000	0.00000	0.00000	0.00037	0.00001	0.00000	0.00002	0.00002	0.00014	0.00003
Killer whales (total number observed)	0.00000	0.00005	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00011
Steller sea lions (total number observed)	0.00004	0.00000	0.00023	0.00024	0.00000	0.00035	0.00001	0.00000	0.00022	0.00017	0.00000

Table 6. Summary of Density of Marine Mammals

Species	Density (number/km ²)	
	max	avg
Beluga whale (avg number observed)	0.00103	0.00026
Beluga whale (max number observed - rivers)	0.00770	0.00154
Harbor seal (total number observed)	0.00776	0.00290
Harbor porpoise (total number observed)	0.00037	0.00004
Killer whale (total number observed)	0.00011	0.00001
Steller sea lion (total number observed)	0.00035	0.00007

6.4 CALCULATION OF TAKES

The estimated number of marine mammals that may be potentially harassed during the seismic surveys was calculated by multiplying the expectation densities discussed in the previous section (in individuals/hr/km²) by the anticipated area ensounded by levels ≥ 160 dB re μ Pa rms by the number of expected days that will be surveyed seismically in Area 1. As discussed in Section 2, APACHE anticipates that a crew will collect seismic data 10-12 hours per day over approximately 160 days over the course of 8 to 9 months. It was assumed that over the course of this 160 days, 100 days would be working in the offshore region and 60 days in the shallow, intermediate, and deep nearshore region. Of those 60 days in the nearshore region, 20 days would be in each depth. Because operations would occur over 12 hours per day, the total number of days for each region was divided by two (or half a day) for purposes of calculating takes. It is important to note that environmental conditions (such as ice, wind, fog) will play a significant role in the actual operating days; therefore, these estimates are conservative in order to provide a basis for probability of encountering these marine mammal species in the project area. The number of estimated takes by harassment was calculated using the following assumptions:

- The number of nearshore and shallow water survey days is 10 (20 days/12 hours) and daily acoustic footprint is 356 km².
- The number of nearshore and intermediate water depth survey days is 10 (20 days/12 hours) and daily acoustic footprint is 468 km².
- The number of nearshore and deep water depth survey days is 10 (20 days/12 hours) and daily acoustic footprint is 455 km².
- The number of offshore survey days is 50 (100 days/12 hours) and daily footprint is 389 km².

Table 7 shows the estimated maximum and average takes by species for the first year of the program in Area 1 with the methods and assumptions outlined above. As noted previously, the use of the NMML aerial survey data has inherent weaknesses that need to be discussed further. The estimated number of takes by harassment of harbor seals is higher than what is anticipated in the first year of the proposed program, as there are no reported large haul out sites in the Area 1. Seals in some numbers are expected to be observed in the Susitna River delta, but not in the large numbers that are observed in the lower Cook Inlet. These density estimates are skewed by the numbers observed in large haul outs on the aerial surveys; seals on land would not be exposed to in-water sounds during that time. Seals in the water usually travel in small groups or as singles. Therefore, although Table 7 indicates an average of 102 and maximum of 207 seals to be harassed, it is highly unlikely that those numbers of seals would be taken by harassment during seismic operations.

For many of the same reasons discussed above for harbor seals, the number of actual takes by harassment of Steller sea lions are expected to be much lower than the average of 4 and maximum of 11. In all of the NMFS aerial surveys, no Steller sea lions were observed in upper Cook Inlet. Less than five Steller sea lions have been observed by the Port of Anchorage monitoring program, and those observed have been single, juvenile animals (likely male). APACHE anticipates less than five Steller sea lions in the project area in the first year.

The average and maximum take estimates for the harbor porpoise and killer whales shown in Table 7 appear to be reasonable based on the NMFS aerial surveys, although the actual number of animals observed is expected to be low.

The average and maximum estimated number of takes by harassment for beluga whales away from river mouths in the first year of the program is 2 and 5, respectively. Given that belugas are usually transiting from one feeding area to another in lower concentrations, these estimates appear to be reasonable in assessing probability of beluga whales potentially observed. However, it is important to note that a combination of visual and acoustic monitoring will be used extensively throughout this project, particularly for sighting beluga whales approaching the operations, so the actual number of takes is expected to be lower than these estimates for beluga whales away from river mouths.

The average and maximum estimated number of takes by harassment for beluga whales near river mouths is at 16 and 41 whales, respectively. It is very important to note that APACHE will implement a rigorous monitoring program when conducting seismic operations near river mouths during periods of high potential for encountering beluga whales, consisting of both vessel and aerial visual and acoustic monitoring. APACHE commits to shutting down air guns when beluga whales are observed to be approaching the 160 dB threshold to minimize and avoid takes of beluga whales to the greatest extent possible. Furthermore, the total number of days actually surveying near river mouths is much lower than the 160 days used to estimate takes in these different water depths, so this take estimate is extremely conservative. Therefore, due to actual number of days and hours likely to be operating air guns near river mouths and the strict monitoring and mitigation measures to be used when operating near rivers, the actual number of takes by harassment estimated for beluga whales is expected to be extremely low, much lower than the numbers in Table 7.

Table 7. Estimated Takes per Species for First Year

Species	shallow		mid-depth		deep		offshore		Total	
	max	avg	max	avg	max	avg	max	avg	max	avg
Beluga whales – away from river mouths	0.5	0.3	0.7	0.3	0.7	0.3	2.8	1.5	4.7	2.4
Beluga whales – near river mouths	4.5	1.8	5.8	2.3	5.8	2.3	24.8	9.9	41.0	16.3
Harbor seals	22.9	11.3	29.5	14.5	29.3	14.4	125.3	61.7	207.0	101.9
Harbor porpoises	1.3	0.2	1.7	0.3	1.7	0.3	7.2	1.2	11.9	2.0
Killer whales	0.4	0.1	0.5	0.1	0.5	0.1	2.2	0.3	3.6	0.5
Steller sea lions	1.2	0.4	1.6	0.5	1.6	0.5	6.8	2.2	11.3	3.7

Notes:
 Shallow water (5-21 m): area ≥ 160 dB re 1 μPa rms = 356 km², number of days = 10
 Intermediate water (21-38 m): area ≥ 160 dB re 1 μPa rms = 458 km², number of days = 10
 Deep water (38-54 m): area ≥ 160 dB re 1 μPa rms = 455 km², number of days = 10
 Offshore: area ≥ 160 dB re 1 μPa rms = 389 km², number of days = 50

Takes estimated by multiplying density (# animals/hour/km²) from NMFS June surveys 2000-2010 by area ensounded ≥ 160 dB re 1 μPa rms from JASCO by number of days estimated to be seismically surveyed.

6.5 SUMMARY OF REQUESTED TAKES

Based on the discussion and estimates above, APACHE requests the following number of takes by harassment by species for the first year of the program in Area 1 (Table 8). The abundance of the population, as summarized in Section 3.0, is also provided with the calculated percent of the population that will be temporarily behaviorally disturbed during seismic operations. As shown in the table, the percent of all species requested to be taken by harassment is less than 10% of the population. Therefore, APACHE anticipates there will be no more than a negligible impact on small numbers of marine mammals during the seismic operations.

Table 8. Requested Number of Takes

Species	Number of Requested Takes	Population Abundance	Percent of Population
Beluga whales	30	355	8.45%
Harbor seals	50	29,175	0.17%
Harbor porpoises	20	31,406	0.06%
Killer whales	10	1,123	0.89%
Steller sea lions	20	41,197	0.12%

Note: population abundance summarized in Section 3

7.0 DESCRIPTION OF IMPACT ON MARINE MAMMALS

The anticipated impact of the activity upon the species or stock.

7.1 GENERAL EFFECTS OF NOISE ON MARINE MAMMALS

Marine mammals use hearing and sound transmission to perform vital life functions. Introducing sound into their environment could be disrupting to those behaviors. Sound (hearing and vocalization/echolocation) serves four primary functions for marine mammals, including: 1) providing information about their environment, 2) communication, 3) prey detection, and 4) predator detection. The distances to which air gun noise associated with the test program are audible depend upon source levels, frequency, ambient noise levels, the propagation characteristics of the environment, and sensitivity of the receptor (Richardson et al. 1995).

The effects of sounds from air guns on marine mammals might include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and temporary or permanent hearing impairment, or non-auditory physical effects (Richardson et al. 1995). In assessing potential effects of noise, Richardson et al. (1995) has suggested four criteria for defining zones of influence. These zones are described below from greatest influence to least:

Zone of hearing loss, discomfort, or injury – the area within which the received sound level is potentially high enough to cause discomfort or tissue damage to auditory or other systems. This includes temporary threshold shifts (TTS, temporary loss in hearing) or permanent threshold shifts (PTS, loss in hearing at specific frequencies or deafness). Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage.

Zone of masking – the area within which the noise may interfere with detection of other sounds, including communication calls, prey sounds, or other environmental sounds.

Zone of responsiveness – the area within which the animal reacts behaviorally or physiologically. The behavioral responses of marine mammals to sound is dependent upon a number of factors, including: 1) acoustic characteristics the noise source of interest; 2) physical and behavioral state of animals at time of exposure; 3) ambient acoustic and ecological characteristics of the environment; and 4) context of the sound (e.g., whether it sounds similar to a predator) (Richardson et al. 1995; Southall et al. 2007). However, temporary behavioral effects are often simply evidence that an animal has heard a sound and may not indicate lasting consequence for exposed individuals (Southall et al. 2007).

Zone of audibility – the area within which the marine mammal might hear the noise. Marine mammals as a group have functional hearing ranges of 10 Hz to 180 kHz, with best thresholds near 40 dB (Ketten 1998; Kastak et al. 2005; Southall et al. 2007). These data show reasonably consistent patterns of hearing sensitivity within each of three groups: small odontocetes (such as the harbor porpoise), medium-sized odontocetes (such as the beluga and killer whales), and pinnipeds (such as the harbor seal). Hearing capabilities of the species included in this Application are discussed in Section 4.0. There are no applicable criteria for the zone of audibility due to difficulties in human ability to determine the audibility of a particular noise for a particular species.

7.1.1 Potential Effects of Air Gun Sounds

The following text describes the potential impacts on marine mammals due to seismic activities. Due to the mitigation measures discussed in Sections 11 and 14, it is unlikely there would be any temporary or

especially permanent hearing impairment, or non-auditory physical effects on marine mammals. In addition, most of nearshore area of Cook Inlet is a poor acoustic environment because of its shallow depth, soft bottom, and high background noise from currents and glacial silt which greatly reduces the distance sound travels (Blackwell and Greene 2002).

7.1.1.1 Tolerance

Studies have shown that pulsed sounds from air guns are often readily detectable in the water at distances of many kilometers, but they don't necessarily cause behavioral disturbances. Numerous studies have shown that marine mammals at distances over a few kilometers from operating seismic vessels often show no apparent response. That is often true even when pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to temporarily react behaviorally to air gun pulses under some conditions, at other times they have shown no overt reactions. In general, pinnipeds and small odontocetes are more tolerant of exposure to air gun pulses than baleen whales.

7.1.1.2 Masking

Masking of marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data of relevance. Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999; Nieukirk et al. 2004). Masking effects of seismic pulses are expected to be negligible in the case of the odontocete cetaceans, given the intermittent nature of seismic pulses. Also, the sounds important to small odontocetes are predominantly at much higher frequencies than are air gun sounds. Therefore, the potential problem of auditory masking for beluga whales is diminished by the small amount of overlap between frequencies produced by seismic and other industrial noise (<1 kHz) and frequencies which beluga whales call (0.26-20 kHz) and echolocate (40-60 kHz and 100-120 kHz) (Blackwell and Greene 2002).

7.1.1.3 Disturbance Reactions

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, environmental conditions, and many other factors (Richardson et al. 1995). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a short distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, which is not anticipated in the proposed seismic program, impacts on the animals could be significant. Given the many uncertainties in predicting the quantity and types of impacts of sound on marine mammals, it is common practice to estimate how many mammals were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound to assess behavioral disturbance. However, this procedure likely overestimates the numbers of marine mammals that are affected in some biologically important manner.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically important but unknown degree by a seismic program are based on behavioral observations during studies of several species. However, information is largely lacking for many species including those species likely to occur in the project areas. Detailed studies have been done on other species found elsewhere in Alaska waters including gray whales, bowhead whales, and ringed seals. The criteria established for these marine mammals, which are applied to others are conservative and have not been demonstrated to

significantly affect individuals or populations of marine mammals in Alaska waters. Therefore, the effect of the test seismic program on the behavior of marine mammals should be no more than negligible for reasons stated earlier, and since the immediate project area is not an important feeding or breeding area, and it appears to be primarily a transition area during the fall that marine mammals pass through while going between the mid or upper inlet to the lower inlet and Gulf of Alaska to winter.

Toothed Whales. Little systematic information is available about reactions of beluga whales, killer whales, and harbor porpoise to noise pulses. Beluga whales exhibit changes in behavior when exposed to strong, pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002). However, the animals tolerated high received levels of sound (peak–peak level >200 dB re 1 μ Pa) before exhibiting aversive behaviors (Richardson et al. 1995). Some belugas summering in the Eastern Beaufort Sea may have avoided the specific area of seismic operations (2 arrays with 24 air guns per array), which used a much larger array than the proposed program (2 arrays of 3 air guns per array), by 10 to 20 km, although belugas occurred as close as 1,540 m to the line of seismic operations (Miller et al 2005). Observers stationed on seismic vessels operating off the United Kingdom from 1997–2000 have provided data on the occurrence and behavior of various toothed whales exposed to seismic pulses (Stone 2003; Gordon et al. 2004). Killer whales were found to be significantly farther from large air gun arrays during periods of shooting compared with periods of no shooting. The displacement of the median distance from the array was ~0.5 km (0.3 miles) or more. Killer whales also appear to be more tolerant of seismic shooting in deeper water. Killer whales are rare to uncommon in the inlet, therefore, the planned seismic program should have no more than a negligible impact on killer whales and no effect on the population. Harbor porpoises are rarely sighted, but have been detected acoustically throughout the inlet. However, based on the relatively few animals observed, the planned should have no more than a negligible impact and no effect on the population.

Pinnipeds. While there are no published data on seismic effect on sea lions or harbor seals, anecdotal data and data on arctic seals indicate that sea lions and other pinnipeds generally tolerate strong noise pulses (Richardson et al 1995). Monitoring studies in the Alaskan and Canadian Beaufort Sea during 1996–2002 provided considerable information regarding behavior of arctic seals exposed to seismic pulses (Miller et al. 2005; Harris et al. 2001; Moulton and Lawson 2002). These seismic projects usually involved arrays of 6 to 16 with as many as 24 air guns with total volumes 560 to 1500 cui. The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings tended to be farther away from the seismic vessel when the air guns were operating than when they were not (Moulton and Lawson 2002). However, these avoidance movements were relatively small, on the order of 100 m (328 ft) to (at most) a few hundred meters, and many seals remained within 100 to 200 m (328 to 656 ft) of the trackline as the operating air gun array passed by them. Seal sighting rates at the water surface were lower during air gun array operations than during no-air gun periods in each survey year except 1997. Miller et al. (2005) also reported higher sighting rates during non-seismic than during line seismic operations, but there was no difference for mean sighting distances during the two conditions nor was there evidence ringed or bearded seals were displaced from the area by the operations. The operation of the air gun array had minor and variable effects on the behavior of seals visible at the surface within a few hundred meters of the array. The behavioral data from these studies indicated that some seals were more likely to swim away from the source vessel during periods of air gun operations and more likely to swim towards or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to air gun noise and proportions of seals engaged in other recognizable behaviors, e.g. “looked” and “dove”. Such a relationship might have

occurred if seals seek to reduce exposure to strong seismic pulses, given the reduced air gun noise levels close to the surface where “looking” occurs (Miller et al. 2005; Moulton and Lawson 2002).

Consequently, by using the responses of bearded, ringed, and spotted seals (least amount of data on reaction to seismic operations) to seismic operations as surrogates for harbor seals and sea lions, it is reasonable to conclude that the relatively small numbers relative to the population size (see Table 8) of harbor seals and the even smaller numbers of Steller sea lions possibly occurring in the project area during seismic operations are not likely to show a strong avoidance reaction to the proposed air gun sources. Pinnipeds frequently do not avoid the area within a few hundred meters of operating air gun arrays, even for air gun arrays much larger than that planned for the proposed project (e.g., Harris et al. 2001). Reactions are expected to be very localized and confined to relatively small distances and durations, with no long-term effects on individuals or populations.

7.1.1.4 Strandings and Mortality

There is no evidence in the literature that air gun pulses can cause serious injury, death, or stranding of marine mammals even in the case of much larger air gun arrays than planned for the proposed program. While strandings have been associated with military mid-frequency sonar pulses, APACHE does not plan to use such sonar systems during the seismic test program. Seismic pulses and military mid-frequency sonar pulses are quite different. Sounds produced by air gun arrays are broadband with most of the energy below 1 kHz.

7.1.1.5 Noise Induced Threshold Shift

Animals exposed to intense sound may experience reduced hearing sensitivity for some period of time following exposure. This increased hearing threshold is known as noise induced threshold shift (TS). The amount of TS incurred in the animal is influenced a number of noise exposure characteristics, such as amplitude, duration, frequency content, temporal pattern, and energy distribution (Kryter 1985; Richardson et al. 1995; Southall et al. 2007). It is also influenced by characteristics of the animal, such as behavior, age, history of noise exposure and health. The magnitude of TS generally decreases over time after noise exposure and if it eventually returns to zero, it is known as ‘temporary threshold shift’ (TTS). If TS does not return to zero after some time (generally on the order of weeks), it is known as ‘permanent threshold shift’ (PTS). Temporary threshold shift is not considered to be auditory injury and does not constitute ‘Level A Harassment’ as defined by the MMPA. Sound levels associated with TTS onset are generally considered to be below the levels that will cause PTS, which is considered to be auditory injury.

Temporary threshold shift has been studied in captive odontocetes and pinnipeds (reviewed in Southall et al. 2007). Data are available for three cetacean species (bottlenose dolphin, *Tursiops truncatus*; beluga whale, and harbor porpoise) and three pinniped species (harbor seal, California sea lion, *Zalophus californianus*; Northern elephant seal, *Mirounga angustirostris*). However, these data have all been collected from captive animals and no documentation exists of TTS or PTS in free ranging marine mammals exposed to air gun pulses.

The current NMFS policy regarding exposure of marine mammals to impulsive sound is that cetaceans should not be exposed to impulsive sounds >180 dB re 1 μ Pa rms and that pinnipeds should not be exposed to impulsive sounds >190 dB re 1 μ Pa rms (NMFS 2000). These criteria were established before information was available about minimum received levels of sound that would cause auditory injury in marine mammals. They are likely lower than necessary and are intended to be precautionary estimates below which no physical injury will occur (Southall et al. 2007). Many marine mammal species avoid ships and/or seismic operations. This behavior in and of itself should be sufficient to avoid TTS onset. In

addition, monitoring and mitigation measures often implemented during seismic surveys are designed to detect marine mammals near the air gun array and avoid exposing them to sound pulses that may cause hearing impairment. For example, it is standard protocol for many seismic operators to ramp up air gun arrays, which should allow animals near the air guns at startup time to move away from the source and thus avoid TTS. If animals do incur TTS, it is a temporary and reversible phenomenon unless exposure exceeds the TTS-onset threshold by an amount sufficient to cause PTS. The following subsections summarize the available data on noise-induced hearing impairment in marine mammals.

Sound Exposure Level (SEL)

Sound exposure level is a measure of sound energy, calculated as 10 times the logarithm of the integral (with respect to duration) of the mean-square sound pressure, referenced to $1 \mu\text{Pa}^2\text{s}$ (Kastak et al. 2005, Southall et al. 2007). It is useful for assessing the cumulative level of exposure to multiple sounds because it allows sounds with different durations and involving multiple exposures to be compared in terms of total energy. This type of comparison assumes that sounds with equivalent total energy will have similar effects on exposed subjects, even if the sounds differ in SPL, duration and/or temporal exposure patterns. Sound exposure level likely over estimates TTS and PTS arising from complex noise exposures because it does not take varying levels and temporal patterns of exposure and recovery into account (Southall et al. 2007). Some support for the use of SEL to evaluate TTS and PTS has been shown for marine mammals (e.g., Finneran et al 2002, 2005), and this measure will be referred to in the following sections of this document.

Temporary Threshold Shift (TTS)

Temporary threshold shift is the mildest form of hearing impairment that can occur during exposure to loud sound (Kryter 1985). It is not considered to represent physical injury, as hearing sensitivity recovers relatively quickly after the sound ends. It is, however, an indicator that physical injury is possible if the animal is exposed to higher levels of sound. The onset of TTS is defined as a temporary elevation of the hearing threshold by at least 6 dB (Schlundt et al. 2000). Several physiological mechanisms are thought to be involved with inducing TTS. These include reduced sensitivity of sensory hair cells in the inner ear, changes in the chemical environment in the sensory cells, residual middle-ear muscular activity, displacement of inner ear membranes, increased blood flow, and post-stimulatory reduction in efferent and sensory neural output (Kryter 1994; Ward 1997).

Very few data are available regarding the sound levels and durations that are necessary to cause TTS in marine mammals. Data are available for only three species of cetaceans and three species of pinnipeds. No data are available for mysticete species. No data are available for any free ranging marine mammals or for exposure to multiple pulses of sound during seismic surveys.

TTS in Odontocetes

Most studies of TTS in odontocetes have focused on non-impulsive sound, and all have been carried out on captive animals. A detailed review of all TTS data available for marine mammals can be found in Southall et al. (2007). The following is a summary of key results.

Finneran et al. (2005) measured TTS in bottlenose dolphins exposed to 3 kHz tones with various durations and SPL levels in a quiet pool. The amount of TTS was positively correlated with the SEL, and statistically significant amounts of TTS were observed for SELs $> 195 \text{ dB re } 1\mu\text{Pa}^2\text{s}$. These data agree with those reported by Schlundt et al. (2000) and Nachtigall et al. (2004) and support the use of $195 \text{ dB re } 1\mu\text{Pa}^2\text{s}$ as a threshold for TTS onset in dolphins and belugas exposed to mid-frequency sounds. Finneran et al. (2005) also found that each additional dB of SEL produced an additional 0.4 dB of TTS and that for

TTS of 3-4 dB, recovery was nearly complete within 10 minutes post-exposure. For larger TTS, longer recovery times were required. The authors caution, however, that interpretation of TTS growth and recovery curves is hampered by the very small amounts of TTS measured relative to the variability of the measurements. They also note that not all exposures above a certain TTS threshold will cause TTS. For example, only 18% of exposures to an SEL of 195 dB re 1 μ Pa²s resulted in measurable TTS.

Mooney et al. (2009a) measured TTS in a bottlenose dolphin exposed to octave-band non-impulse noise ranging from 4 to 8 kHz at SPLs of 130-178 dB re 1 μ Pa for 1.88 to 30 min. The results of this study showed a strong positive relationship between SEL and the amount of TTS, however the relationship was not a simple equal energy relationship. When SEL was kept constant and exposure duration decreased, TTS did not stay constant, as expected by the equal energy rule. The amount and occurrence of TTS decreased as the duration of sound exposure decreased, so relative to longer duration exposures, shorter duration exposures required greater SELs to induce TTS. Recovery time also varied with both SPL and duration of sound exposure and followed a logarithmic function according to the amount of TTS. Similar results were reported by Mooney et al (2009b). The results of this work illustrate the importance of reporting both SPL and duration of sound exposure when evaluating TTS in odontocetes.

The TTS threshold for odontocetes exposed to a single impulse from a watergun appears to be lower than that for exposure to non-impulse sound (Finneran et al. 2002). An exposure SEL of 186 dB re 1 μ Pa²s resulted in mild TTS in a beluga whale. However, these measurements were made in the presence of band-limited white noise (masking noise), which may have resulted in a lower TTS than would have been observed in the absence of masking noise. Data from terrestrial mammals also show that broadband pulsed sounds with rapid rise times have a greater auditory effect than do non-impulse sounds (Southall et al. 2007). The rms level of an airgun pulse is typically 10-15 dB higher than the SEL for the same pulse when received within a few km of the airguns. A single airgun pulse might therefore need to have a received level of approx 196-201 dB re 1 μ Pa rms to produce brief, mild TTS. Exposure to several strong seismic pulses, each with a flat-weighted received level near 190 dB rms (175-180 dB SEL) could result in cumulative exposure of approximately 186 dB SEL and thus slight TTS in a small odontocete.

While the majority of TTS research has been conducted on bottlenose dolphins and beluga whales, one study involved another odontocete species, the harbor porpoise (Lucke et al. 2009). The TTS threshold for this harbor porpoise was lower than that measured for the larger odontocetes. TTS occurred in the harbor porpoise upon exposure to one airgun pulse with a received level of approximately 200 dB re 1 μ Pa pk-pk or an SEL of 164.3 dB re 1 μ Pa²s.

When estimating the amount of sound energy required for the onset of TTS, it is generally assumed that the effect of a given cumulative SEL from a series of pulses is the same as if that amount of sound energy were received as a single strong sound (Southall et al. 2007). However, some recovery may occur between pulses and it is not currently known how this may affect TTS threshold. In addition, more data are needed in order to determine the received levels at which odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of air gun sound with variable received levels. For example, the total energy received by an animal will be a function of received levels of air gun pulses as an air gun array approaches, passes at various distances and moves away (e.g., Erbe and King 2009). Finally, as TTS threshold was lower for the harbor porpoise than for bottlenose dolphins or beluga whales, more data are needed regarding TTS thresholds in other odontocete species.

TTS in Pinnipeds

Temporary threshold shift has been measured for only three pinniped species: harbor seals, California sea lions, and northern elephant seals, and only one study has examined TTS in response to exposure to

underwater pulses (Finneran et al. 2003). Of the three species for which data are available, the harbor seal exhibits TTS onset at the lowest exposure levels to non-pulsed sounds. A 25 minute exposure to a 2.5 kHz sound elicited TTS in a harbor seal at an SPL of 152 dB re 1 μ Pa (SEL 183 dB re 1 μ Pa²s), as compared to 174 dB re 1 μ Pa (SEL 206 dB re 1 μ Pa²s) for the California sea lion and 172 dB re 1 μ Pa (SEL 204 dB re 1 μ Pa²s) for the elephant seal (Kastak et al 2005).

The auditory response of pinnipeds to underwater pulsed sounds has been examined in only one study. Finneran et al. (2003) measured TTS onset in two captive California sea lions exposed to single underwater pulses produced by an arc-gap transducer. No measurable TTS was observed following exposures up to a maximum level of 183 dB re 1 μ Papeak-to-peak (SEL 163 dB re 1 μ Pa²s). Finneran et al. (2003) suggest that the equal energy rule may apply to pinnipeds, however Kastak et al. (2005) found that for harbor seals, California sea lions and elephant seals exposed to prolonged non-impulse noise, higher SELs were required to elicit a given TTS if exposure duration was short than if it was longer. For example, for a non-impulse sound, doubling the exposure duration from 25 to 50 min (a 3 dB increase in SEL) had a greater effect on TTS than an increase of 15 dB (95 vs 80 dB) in exposure level. These results are similar to those reported by Mooney et al (2009a, b) for bottlenose dolphins and emphasize the need for taking both SPL and duration into account when evaluating the effect of sound exposure on marine mammal auditory systems.

Permanent Threshold Shift (PTS)

Permanent threshold shift is defined as ‘irreversible elevation of the hearing threshold at a specific frequency’ (Yost 2000). It involves physical damage to the sound receptors in the ear and can be either total or partial deafness or impaired ability to hear sounds in specific frequency ranges (Kryter 1985). Some causes of PTS are severe extensions of effects underlying TTS (e.g. irreparable damage to sensory hair cells). Others involve different mechanisms, for example exceeding the elastic limits of certain tissues and membranes in the middle and inner ears and resultant changes in the chemical composition of inner ear fluids (Ward 1997; Yost 2000). The onset of PTS is determined by pulse duration, peak amplitude, rise time, number of pulses, inter-pulse interval, location, species and health of the receivers ear (Ketten 1994).

The relationships between TTS and PTS thresholds have not been studied in marine mammals and there is currently no evidence that exposure to air gun pulses can cause PTS in any marine mammal, however there has been speculation about that possibility (e.g. Richardson et al. 1995; Gedamke et al. 2008). In terrestrial mammals, prolonged exposure to sounds loud enough to elicit TTS can cause PTS. Similarly, shorter term exposure to sound levels well above the TTS threshold can also cause PTS (Kryter 1985). Terrestrial mammal PTS thresholds for impulse sounds are thought to be at least 6 dB higher than TTS thresholds on a peak-pressure basis (Southall et al. 2007). Also, pulses with rapid rise times can result in PTS even when peak levels are only a few dB higher than the level causing slight TTS.

Southall et al. (2007) used available marine mammal TTS data and precautionary extrapolation procedures based on terrestrial mammal data to estimate exposures that may be associated with PTS onset. For terrestrial mammals, TTS exceeding 40 dB generally requires a longer recovery time than smaller TTS, which suggests a higher probability of irreversible damage (Ward 1970) and possibly different underlying mechanisms (Kryter 1994; Nordman et al. 2000). Based on this, and the similarities in morphology and functional dynamics among mammalian cochleae, Southall et al. (2007) assumed that PTS would be likely if the hearing threshold was increased by more than 40 dB and assumed an increase of 2.3 dB in TTS with each additional dB of sound exposure. This translates to an injury criterion for pulses that is 15 dB above the SEL of exposures causing TTS onset. Finneran et al. (2002) found TTS

onset in belugas exposed to a single pulse of sound at an SEL of 183 dB re $1\mu\text{Pa}^2\text{s}$. Therefore, according to the assumptions above, the PTS threshold would be approximately 198 dB re $1\mu\text{Pa}^2\text{s}$ for a single pulse.

There are no data on the sound level of pulses that would cause TTS onset in pinnipeds. Southall et al. (2007) therefore assumed that known pinniped-to-cetacean differences in TTS-onset for non-pulsed sounds also apply to pulse sounds. Harbor seals experience TTS onset at received levels that are 12 dB lower than those required to elicit TTS in beluga whales (Kastak et al. 2005, Finneran 2002). Therefore, TTS onset in pinnipeds exposed to a single underwater pulse was estimated to occur at an SEL of 171 dB re $1\mu\text{Pa}^2\text{s}$. Adding 15 dB results in a PTS onset of 186 dB re $1\mu\text{Pa}^2\text{s}$ for pinnipeds exposed to a single pulse. This is likely to be a precautionary estimate as the harbor seal is the most sensitive pinniped species studied to date and these results are based on measurements taken from a single individual (Kastak et al. 1999, 2005).

It is unlikely that a marine mammal would remain close enough to a large airgun array long enough to incur PTS. Some concern arises for bowriding dolphins, however the auditory effects of seismic pulses are reduced by Lloyd's mirror and surface release effects. In addition, the presence of the ship between the bowriding animals and the airgun array may also reduce received levels (e.g. Gabriele and Kipple 2009). As discussed in the TTS section, the levels of successive pulses received by a marine mammal will increase and then decrease gradually as the seismic vessel approaches, passes and moves away, with periodic decreases also caused when the animal goes to the surface to breath, reducing the probability of the animal being exposed to sound levels large enough to elicit PTS.

8.0 DESCRIPTION OF IMPACT ON SUBSISTENCE USES

The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses.

The Cook Inlet beluga whale has traditionally been hunted by Alaska Natives for subsistence purposes. For several decades prior to the 1980s, the Native Village of Tyonek residents were the primary subsistence hunters of Cook Inlet beluga whales. During the 1980s and 1990s, Alaska Natives from villages in the western, northwestern, and North Slope regions of Alaska either moved to or visited the south central region and participated in the yearly subsistence harvest (Stanek 1994). From 1994 to 1998, NMFS estimated 65 whales per year (range 21-123) were taken in this harvest, including those successfully taken for food, and those struck and lost. NMFS has concluded that this number is high enough to account for the estimated 14 percent annual decline in population during this time (Hobbs et al. 2008). Actual mortality may have been higher, given the difficulty of estimating the number of whales struck and lost during the hunts. In 1999, a moratorium was enacted (Public Law 106-31) prohibiting the subsistence take of Cook Inlet beluga whales except through a cooperative agreement between NMFS and the affected Alaska Native organizations. Since the Cook Inlet beluga whale harvest was regulated in 1999 requiring cooperative agreements, five beluga whales have been struck and harvested. Those beluga whales were harvested in 2001 (one animal), 2002 (one animal), 2003 (one animal), and 2005 (two animals). The Native Village of Tyonek agreed not to hunt or request a hunt in 2007, when no co-management agreement was to be signed (NMFS 2008a).

The 2008 Cook Inlet Beluga Whale Subsistence Harvest SEIS (NMFS 2008a) authorizes how many beluga whales can be taken during a five-year interval based on the five-year population estimates and ten-year measure of the population growth rate. Based on the current five-year abundance estimate, no hunt will occur between 2008 and 2012 (NMFS 2008a). The Cook Inlet beluga whale population and possible subsistence harvest will be reexamined by NMFS for the 2013-2017 five-year interval, using the previous five-year abundance estimates.

Residents of the Native Village of Tyonek are the primary subsistence users in Knik Arm area. The project should have any effect because no beluga harvest will take place in 2011 or 2012 and the area is not an important native subsistence site for other subsistence species of marine mammals.

Data on the harvest of other marine mammals in Cook Inlet are lacking. The only data available for subsistence harvest of harbor seals, harbor porpoises, and killer whales in Alaska are in the marine mammal stock assessments. However, these numbers are for the Gulf of Alaska including Cook Inlet, and they are not indicative of the harvest in Cook Inlet. Because the relatively small proportion of marine mammals utilizing Cook Inlet, the number harvested is expected to be extremely low. Therefore, because the proposed program would result in only temporary disturbances, the seismic program would not impact the availability of these other species for subsistence uses.

9.0 DESCRIPTION OF IMPACT ON MARINE MAMMAL HABITAT

The anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat.

Fish are the primary prey species for marine mammals in upper Cook Inlet. Beluga whales feed on a variety of fish, shrimp, squid, and octopus (Burns and Seaman 1986). Common prey species in Knik Arm include salmon, eulachon and cod. Harbor seals feed on fish such as pollock, cod, capelin, eulachon, Pacific herring, and salmon as well as a variety of benthic species, including crabs, shrimp, and cephalopods. Harbor seals are also opportunistic feeders with their diet varying with season and location. The preferred diet of the harbor seal in the Gulf of Alaska consists of pollock, octopus, capelin, eulachon, and Pacific herring (Calkins 1989). Other prey species include cod, flat fishes, shrimp, salmon, and squid (Hoover 1988). Harbor porpoises feed primarily on Pacific herring, cod, whiting (hake), pollock, squid, and octopus (Leatherwood et al. 1982). In the upper Cook Inlet area, harbor porpoise feed on squid and a variety of small schooling fish, which would likely include Pacific herring and eulachon (Bowen and Siniff 1999; NMFS unpublished data). Killer whales feed on either fish or other marine mammals depending on genetic type (resident versus transient respectively). Killer whales in Knik Arm are typically the transient type (Shelden et al. 2003) and feed on beluga whales and other marine mammals, such as harbor seal and harbor porpoise.

While there may be few definitive studies on the use of the near shore shallow coastal areas in the upper inlet, use of this type of habitat elsewhere by salmon and other species in Cook Inlet will be supported in literature (NMFS 2008b). In general, fish perceive underwater sounds in the frequency range of 50 to 2,000 Hz, with peak sensitivities below 800 Hz (Popper and Carlson 1998; Department of the Navy 2001). However, fish are sensitive to underwater impulsive sounds due to swimbladder resonance. As the pressure wave passes through a fish, the swimbladder is rapidly squeezed as the high pressure wave, and then under pressure component of the wave, passes through the fish. The swimbladder may repeatedly expand and contract at the high sound pressure levels (SPL), creating pressure on the internal organs surrounding the swimbladder.

Permanent injury to fish from acoustic emissions has been shown for high-intensity sounds of several hours long. In a review on the effects of low-frequency noise to fish, a threshold of 180 dB peak sound level was used to define the potential injury to fish. Sound pressure levels greater than an average of 150 dB rms are expected to cause temporary behavioral changes such as a startle response or behaviors associated with stress. Although these SPLs are not expected to cause direct injury to a fish, they may decrease the ability of a fish to avoid predators.

Carlson (1994), in a review of 40 years of studies concerning the use of underwater sound to deter salmonids from hazardous areas at hydroelectric dams and other facilities, concluded that salmonids were able to respond to low-frequency sound and to react to sound sources within a few feet of the source. He speculated that the reason that underwater sound had no effect on salmonids at distances greater than a few feet is because they react to water particle motion/acceleration, not sound pressures. Detectable particle motion is produced within very short distances of a sound source, although sound pressure waves travel farther.

Hastings and Popper (2005) reviewed all pertinent peer-reviewed and unpublished papers on noise exposure of fish through early 2005. They proposed the use of sound exposure level (SEL) to replace peak SPL in pile driving criteria. This report identified interim thresholds based on SEL or sound energy.

The interim thresholds for injury were based on exposure to a single pile driving pulse. The report also indicates that there was insufficient evidence to make any findings regarding behavioral effects associated with these types of sounds. Interim thresholds were identified for pile driving consisting of a single-strike peak sound pressure and a single strike SEL for onset of physical injury. A peak pressure criterion was retained to function in concert with the SEL value for protecting fishes from potentially damaging aspects of acoustic impact stimuli. The available scientific evidence suggested that a single-strike peak pressure of 208 dB and a single strike SEL of 187 dB were appropriate thresholds for the onset of physical injury to fishes.

Following the Hasting and Popper (2005) paper, NMFS developed their version of the dual criteria that included the single strike peak pressure threshold of 208 dB, but addressed the accumulation of multiple strikes through accumulation of sound energy by setting a criterion of 187 dB SEL. The accumulated SEL is calculated using an equal energy hypothesis that combines the SEL of a single strike to 10 times the 10-based logarithm of the number of pile strikes.

Only a small fraction of the potentially available habitat in Cook Inlet would be impacted by noise from the test program at any given time during the seismic survey. Furthermore, the constant movement of the seismic vessel and the short duration of actual seismic testing would result in short-term, temporary, and very localized acoustic impacts on fish and other prey species. Thus, the seismic program is not expected to have any effects on habitat or prey that could cause permanent or long-term consequences for marine mammals.

10.0 DESCRIPTION OF IMPACT FROM LOSS OR MODIFICATION TO HABITAT

The anticipated impact of the loss or modification of habitat on the marine mammal populations involved.

The proposed seismic program will not result in any permanent impact on habitats used by marine mammals, or to the food sources they utilize. Direct impacts are physical destruction or alteration of habitat, which will not occur from the seismic program. Indirect impacts are primarily caused by ensonification of habitat from noise, which will be very localized and short term, because the proposed test program will be of short duration and confined to one location. Ensonification from seismic operations should have no more than a negligible effect on marine mammal habitat because:

- No studies have demonstrated that seismic noise affects the life stages, condition, or amount of food resources (fish, invertebrates, eggs) comprising habitats used by marine mammals, except when exposed to sound levels within a few meters of the seismic source or in a few very isolated cases. Where fish or invertebrates did respond to seismic noise, the affects were of temporary and of short duration. Consequently, disturbance to fish species would be short-term and fish would return to their pre-disturbance behavior once the seismic activity ceases. Thus, the proposed survey would have little, if any, impact on marine mammals to feed in the area where seismic work is planned.
- The seismic area covers a small percentage of the potentially available habitat used by marine mammals in Cook Inlet allowing beluga and other marine mammal to move away from any seismic program sounds to feed, rest, migrate or conduct other elements of their life history.

Thus, the proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, since operations will be limited in duration, location, timing, and intensity.

11.0 MEASURES TO REDUCE IMPACTS TO MARINE MAMMALS

The availability and feasibility [economic and technological] of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance.

The primary marine mammal species potentially exposed to seismic sounds during the seismic program will be beluga whales, harbor seals, and harbor porpoises. There are no known rookeries, mating grounds, or areas of similar significance in the project area. The following text describes the proposed measures to minimize takes by harassment. The monitoring plan is discussed in more detail in Section 13.

11.1 VESSEL-BASED MONITORING

Vessel-based observers will monitor marine mammals at the seismic program during all daytime air gun operations. These observations will provide the real-time data needed to implement some of the key mitigation measures. When marine mammals are observed within, or about to enter, designated shut-down safety zones (see below) where there is a possibility of significant effects on hearing or other physical effects, air gun operations will be powered down (or shut down if necessary) immediately. Mitigation measures will be communicated by the PSO on the source vessel to the air gun operators and vessel captain/crew.

During daytime operations, vessel-based observers will watch for marine mammals at the project location during all periods of seismic operations and for a minimum of 30 minutes prior to the planned start of air gun operations after an extended shut down. PSOs will also observe opportunistically during daylight hours when no seismic activity is taking place.

APACHE proposes to conduct both daytime and nighttime operations. Nighttime operations can be initiated only if a mitigation gun has been continuously operational from the time that the PSO monitoring ended. Seismic activity will not ramp up from an extended shutdown during nighttime operations. PSOs will not monitor during seismic operations at night. Vessel captain and crew will watch for marine mammals (insofar as practical at night) and will call for the air gun(s) to be shut down if marine mammals are observed in or about to enter the safety radii. After a shut down during night operations, seismic activity will be suspended until the following day and the full safety zone is visible.

11.2 PROPOSED SAFETY RADII

In order to avoid any takes by injury (Level A), APACHE proposes to shut down air guns or positioning pingers in the event a marine mammal approaches the 180 or 190 dB injury sound level zone and monitor the 160 dB harassment sound level zone to shut down if large groups of animals approach. APACHE proposes to shut down if a group of more than five beluga whales is sighted within the 160 dB harassment sound level zone. APACHE also proposes to shut down if a beluga whale calf is sighted approaching or within the 160 dB harassment zone.

As discussed in detail in Appendix A, received sound levels for determining safety zones were obtained for the 2010 APACHE test program. Distances to the 190, 180, and 160 dB with the 440 and 2400 cui air gun configurations and pinger were estimated. The methods for estimating distances to the 160 dB harassment zone for the sensor positioning systems (air guns and pingers) are discussed in Section 6.2. These estimates are provided in Table 9.

Table 9. Summary of Distance to NMFS Sound Level Thresholds

Source	190 dB	180 dB	160 dB
Pinger	1 m	3 m	25 m
10 cui air gun	10 m	33 m	330 m
2400 cui air gun (nearshore)	0.51 km	1.42 km	6.41 m
2400 cui air gun (offshore)	1.18 km	0.98 km	4.89 km

APACHE proposes to monitor these zones for marine mammals before, during, and after the operation of the offshore air guns and pingers. Monitoring will be conducted using qualified PSOs on three vessels and a boat-based and fixed real-time passive acoustic monitoring (PAM), as discussed in Section 13.

11.3 POWER DOWN PROCEDURE

A power down procedure involves reducing the number of air guns in use such that the radius of the 180 dB (or 190 dB) zone is decreased to the extent that marine mammals are not in the safety zone. In contrast, a shut down procedure occurs when all air gun activity is suspended. During a power down, a mitigation air gun, typically the 10 cui, is operated. Operation of the mitigation gun allows the safety radii to decrease to 10 m, 33 m, and 330 m for the 190 dB, 180 dB, and 160 dB zones, respectively. If a marine mammal is detected outside the safety radius (either injury or harassment) but is likely to enter that zone, the air guns may be powered down before the animal is within the safety radius, as an alternative to a complete shut down. Likewise, if a marine mammal is already within the harassment safety zone when first detected, the air guns will be powered down immediately if this is a reasonable alternative to a complete shut down. If a marine mammal is already detected within the injury safety zone when first detected, the air guns will be shut down immediately.

Following a power down, air gun activity will not resume until the marine mammal has cleared the safety zone. The animal will be considered to have cleared the safety zone if it:

- Is visually observed to have left the safety zone, or
- Has not been seen within the zone for 15 min in the case of pinnipeds and harbor porpoise, or
- Has not been seen within the zone for 30 min in the case of cetaceans.

11.4 SHUT-DOWN PROCEDURE

As noted previously, a shut-down occurs when all air gun activity is suspended. The operating air gun (s) and/or pinger will be shut down completely if a marine mammal approaches the applicable injury safety zone. The shutdown procedure will be accomplished within several seconds (of a “one shot” period) of the determination that a marine mammal is either in or about to enter the safety zone.

Air gun activity will not resume until the marine mammal has cleared the safety radius. Following a shut-down, air gun activity will not resume until the marine mammal has cleared the safety zone. The animal will be considered to have cleared the safety zone if it:

- Is visually observed to have left the safety zone;

- Has not been seen within the zone for 15 min in the case of pinnipeds or harbor porpoise;
- Has not been seen within the zone for 30 min in the case of cetaceans.

11.5 RAMP-UP PROCEDURE

A “ramp up” procedure gradually increases air gun volume at a specified rate. Ramp up is used at the start of air gun operations, including a power down, shut down, and after any period greater than 10 minutes in duration without air gun operations. The air gun array begins operating after a specified-duration period without air gun operations. NMFS normally requires that the rate of ramp up be no more than 6 dB per 5 minute period. Ramp up will begin with the smallest gun in the array that is being used for all air gun array configurations. During the ramp up, the safety zone for the full air gun array will be maintained.

If the complete safety radius has not been visible for at least 30 minutes prior to the start of operations, ramp up will not commence unless the mitigation gun has been operating during the interruption of seismic survey operations. This means that it will not be permissible to ramp up the 24-gun source from a complete shut-down in thick fog or at other times when the outer part of the safety zone is not visible. Ramp up of the air guns will not be initiated if a marine mammal is sighted within or near the applicable safety radii at any time.

11.6 SPEED OR COURSE ALTERATION

If a marine mammal is detected outside the safety radius and, based on its position and the relative motion, is likely to enter the safety radius, the vessel's speed and/or direct course may, when practical and safe, be changed that also minimizes the effect on the seismic program. This can be used in coordination with a power down procedure. The marine mammal activities and movements relative to the seismic and support vessels will be closely monitored to ensure that the marine mammal does not approach within the safety radius. If the mammal appears likely to enter the safety radius, further mitigative actions will be taken, i.e., either further course alterations, power down, or shut down of the air gun(s).

12.0 MEASURES TO REDUCE IMPACTS TO SUBSISTENCE USERS

Where the proposed activity would take place in or near a Traditional Arctic Subsistence Hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses.

APACHE met with the Cook Inlet Marine Mammal Council (CIMMC) to describe the Project activities and discuss subsistence concerns on March 29, 2011. The meeting provided information on the time, location, and features of the proposed 3D program, opportunities for involvement by local people, potential impacts to marine mammals, and mitigation measures to avoid impacts.

In addition, APACHE met with the Tyonek Native Corporation on November 9, 2010 and the Salamatof Native Corporation on November 22, 2010. No concerns were raised regarding potential conflict with subsistence harvest.

The features of the test should prevent any adverse effects on the availability of marine mammals for subsistence.

- In-water seismic activities will follow mitigation procedures to minimize effects on the behavior of marine mammals and; therefore, opportunities for harvest by Alaska Native communities.
- Regional subsistence representatives may support recording marine mammal observations along with marine mammal biologists during the monitoring program and be provided annual reports.
- The size of the affected area, mitigation measures, and input from the CIMMC should result in the test program having no effect on the availability of marine mammals for subsistence uses.

13.0 MONITORING AND REPORTING

The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding. Guidelines for developing a site-specific monitoring plan may be obtained by writing to the Director, Office of Protected Resources.

13.1 MONITORING

APACHE's proposed Monitoring Plan is described below. APACHE understands that this Monitoring Plan will be subject to review by NMFS and others, and that refinements may be required.

13.1.1 Visual Boat-Based Monitoring

Three vessels will employ PSOs to identify marine mammals during all daytime hours of air gun operations: the two source vessels (*M/V Peregrine Falcon* and *M/V Arctic Wolf*) and one support vessel (*M/V Dreamcatcher*). Two PSOs will be on the source vessels and two PSOs on the support vessel in order to better observe the safety, power down, and shut down areas. When marine mammals are about to enter or are sighted within designated safety zones, air gun or pinger operations will be powered down (when applicable) or shut down immediately. The vessel-based observers will watch for marine mammals at the seismic operation during all periods of source effort and for a minimum of 30 minutes prior to the planned start of air gun or pinger operations after an extended shut down. APACHE personnel will also watch for marine mammals (insofar as practical) and alert the observers in the event of a sighting. APACHE personnel will be responsible for the implementation of mitigation measures only when a PSO is not on duty (e.g., nighttime operations).

Seismic operations will not be initiated or continue when adequate observation of the designated safety zone is not possible due to environmental conditions such as high sea state, fog, ice and low light. Termination of seismic operations will be at the discretion of the lead PSO based on continual observation of environmental conditions and communication with other PSOs.

With NMFS consultation, PSOs will be hired by APACHE. APACHE will provide the curriculum vitae and references for all PSOs. PSOs will follow a schedule so observers will monitor marine mammals near the seismic vessel during all ongoing operations and air-gun ramp ups. PSOs will normally be on duty in shifts no longer than 4 hours with 2 hour minimum breaks to avoid observation fatigue. The vessel crew will also be instructed to assist in detecting marine mammals and implementing mitigation requirements (if practical). Before the start of the seismic survey the crew will be given additional instruction on how to do so.

The source and support vessels are suitable platform for marine mammal observations. When stationed on the flying bridge, the observer will have an unobstructed view around the entire vessel. If surveying from the bridge, the observer's eye level will be about 6 m (20 ft) above sea level. During operations, the PSO(s) will scan the area around the vessel systematically with reticle binoculars (e.g., 7 × 50 or equivalent) and with the naked eye. Laser range finders (Leica LRF 1200 laser rangefinder or equivalent) will be available to assist with distance estimation. They are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to animals directly.

All observations mitigation measures will be recorded in a standardized format. Data will be entered into a custom database using a notebook computer. The accuracy of the data entry will be verified by computerized validity data checks as the data are entered and by subsequent manual checking of the database. These procedures will allow initial summaries of data to be prepared during and shortly after the field program, and will facilitate transfer of the data to statistical, graphical, or other programs for further processing and archiving.

Results from the vessel-based visual observations will provide:

- The basis for real-time mitigation (air gun shut down, power down, and ramp up).
- Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study is conducted.
- Information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity.
- Data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity.

13.1.2 Visual Shore-Based Monitoring

In addition to the vessel-based PSOs, APACHE proposes to utilize a shore-based station when possible. The shore-based station will follow all safety procedures, including bear safety. The shore-based location will need to have sufficient height to observe marine mammals; the PSO would be outfitted on scaffolding with big-eye binoculars. The PSO would scan the area prior to, during, and after the air gun operations. The PSO would be in contact with the other PSOs on the vessels, as well as the source vessel operator via radio to be able to communicate the sighting of a marine mammal approaching or sighted within the project area.

13.1.3 Aerial-Based Monitoring

When practicable, APACHE proposes to utilize the crew helicopter to conduct aerial surveys near river mouths prior to the commencement of operations in order to identify locations of congregations of beluga whales. The helicopter will not be used every day, but will be used when operating near a river mouth. The types of helicopters currently planned to be used by APACHE include a Bell 407, Bell UH1B, and ASB3. Aerial surveys will fly at an altitude of 305 m (1,000 ft) when practical and weather conditions permit. In the event of a marine mammal sighting, aircraft will attempt to maintain a radial distance of 457 m (1,500 ft) from the marine mammal(s). Aircraft will avoid approaching marine mammals from head-on, flying over or passing the shadow of the aircraft over the marine mammals. Using these operational requirements, sound levels underwater are not expected to reach NMFS harassment thresholds (Richardson et al. 1995; Blackwell et al. 2002).

Results from the aerial and shore-based observations will provide:

- The basis for real-time mitigation (air gun power down, shut down, and ramp up).
- Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study is conducted.
- Information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity.

- Data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity. When practicable, APACHE proposes to utilize the crew helicopter to conduct aerial surveys of areas near river mouths prior to the commencement of operations. These surveys will assist in the identification of congregations of beluga whales.

13.1.4 Acoustic Monitoring

In order to further enhance detection of cetaceans, APACHE proposes to utilize passive acoustic monitoring (PAM). The actual PAM system has not yet been identified, but APACHE anticipates utilizing the same system as used in the 2D test program in March, 2011 in Cook Inlet.

13.1.4.1 Fixed PAM Stations

The fixed system will include two JASCO Advanced Multichannel Acoustic Recorders (AMAR) systems deployed in surface buoys on anchored moorings. The AMARs will send real-time acoustic data via digital UHF radio-broadcast systems to the PAM operators aboard the *M/V Dreamcatcher* (one on each vessel). The PAM operators will use specialized real-time detection software and audio playback to detect marine mammal sounds. If the PAM operators detect marine mammals, APACHE will initiate a temporary shut-down of air gun systems to avoid takes. Restarting of the air gun systems would occur as defined in Section 11.2.

Proposed Locations

Based on results of the test program, these buoys are not deployable when there is ice present. However, the buoys were operational when anchored on the crew boat (*M/V Dreamcatcher*) and signals of beluga whales were detectable up to 8 km. Therefore, if ice conditions allow, the PAM systems will be located inside the exclusion zone boundary in both the up-inlet and down-inlet directions. The boundaries are predicted to occur at between 4400 m and 5700 m from the sources, depending on air gun array configuration. Detection ranges for beluga whales are nominally a maximum of 2 km for whistles and 500 m for clicks, although much greater ranges for whistle detections have been achieved with AMARs (>8 km in the Cook Inlet in the spring test program). We propose to locate the PAM moorings in the middle of the inlet at 1 km inside the exclusion zone boundaries both east and west of the survey sites. This approach will be able to detect whistles from animals just entering the exclusion zone and well into the zone. It has the added benefit of providing coverage closer to the air gun sources to identify animals that may have eluded visual observers near the boundary. Prior to the start of the test program, APACHE and JASCO will work to identify the best location for the fixed PAMs to allow for monitoring of the safety zone.

If there is ice present, the PAM system will be deployed from the *M/V Dreamcatcher*.

Acoustic Systems and Frequencies

We will deploy JASCO's AMAR-G2 digital acoustic recording/streaming systems (Figure 17). The AMARs will be set to digitally sample at 100 kHz (depending on quality of radio link at the site) with 24-bit samples, in order to capture both whistles and clicks. These sample rates capture acoustic frequencies up to 16 and 32 kHz respectively. Killer whale calls occur primarily between 400 Hz and 15 kHz. Beluga whistles occur primarily between 3 kHz and 11 kHz. Clicks for both species occur primarily in the 10 kHz to 50 kHz band. Both sample rates will effectively capture the full range of call and whistle frequencies but the higher 64 kHz sample rate is required to capture the significant bandwidth of clicks. Calls and whistles are detectable to larger ranges so are the more important signal of interest here.

However, only clicks may be present while the animals are feeding. Belugas may not vocalize when killer whales are present to avoid detection.

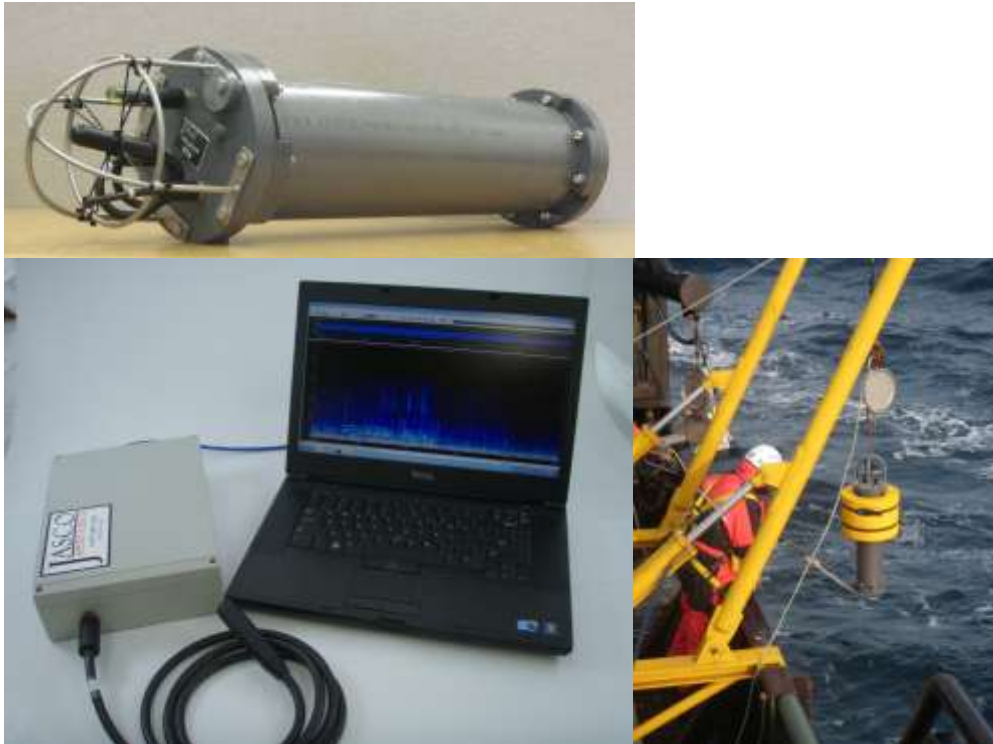


Figure 17: AMAR Recorders. In pressure case (top and right) and in deck box (left-bottom)

Radio Telemetry Acoustic Buoys

The AMAR deck box units (Figure 17, bottom left) with batteries will be mounted in surface-buoys that also support the radio telemetry systems. The buoys have 12-ft masts on which the telemetry antennas are mounted. These buoys are highly visible so will reduce the risk of collision by support vessels working nearby.

The radio telemetry system provides high-bandwidth TCP-IP connectivity direct to the AMAR recorder from a base station located on nearby vessels. The AMAR has built in ability to stream data through the radio's TCP-IP channels. The buoy's radio system will be a 5 GHz 1000 mW 802.11b/g/N extended range outdoor TCP/IP link. The radio telemetry system includes LS5 transmitting radios (Figure 18, left) with whip-style antennas on the buoys. AirMax base stations (Figure 18, right) will be mounted on the work boats where the PAM operators will work. The LS5 radio is designed for multi-kilometer marine telemetry links. The present application will use shorter distances so very good performance is expected even in poor weather conditions.

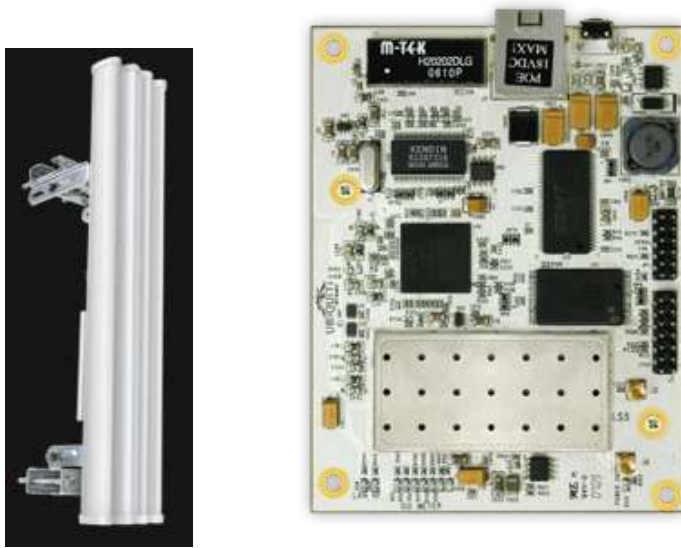


Figure 18: Radio system base station (built into antenna at left) and buoy radio transmitter at right. A co-linear array whip antenna will be mounted on a standard seismic streamer tail-buoy and connected to the transmitter which will be housed in a small pressure case at the buoy.

Real-Time Data Display and Logging

Acoustic data received at the buoys will be streamed back to the work boats over the radio links described in Section 11.1.6.3. These data will be directly displayed in a scrolling spectrogram format and audio played out to a speaker and headphone system using JASCO's standard SpectroPlotter software (Figure 19). The software also logs data to acoustic files in PCM WAV format. We will log all recorded data for possible post-processing (not included in this application).

SpectroPlotter will run on ruggedized field laptop computers connected directly to the radio-link system. The PAM operators will utilize the displays to assist in detections of beluga and killer whale sounds.

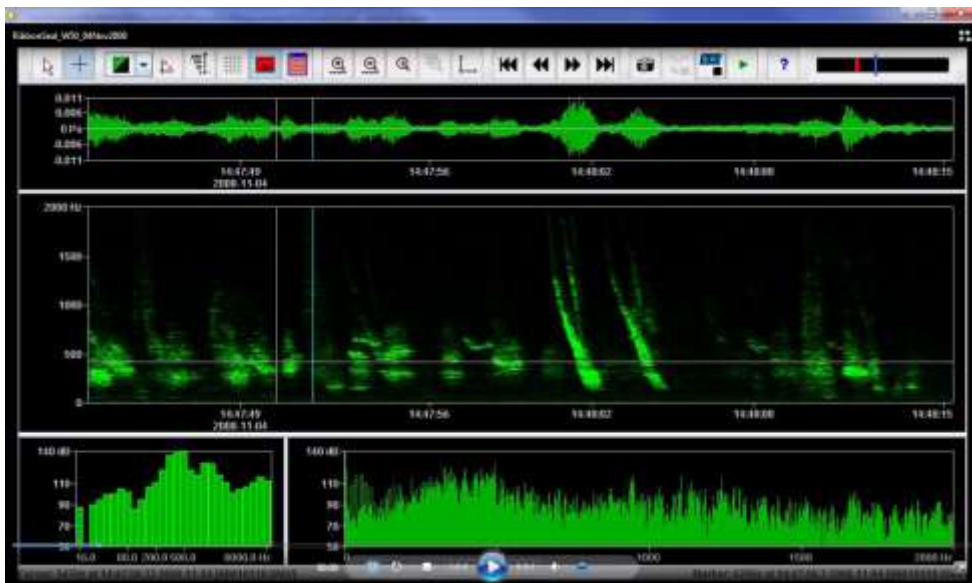


Figure 19: SpectroPlotter display window. Spectrogram scrolls as sound is received and played back through audio system. This software also logs data to files for possible post-processing.

Data Analysis

Only real-time analysis is proposed here, but all data will be recorded for possible post-processing. Post processing is not included in this proposal but can be discussed as an add-on. The real-time analysis will consist of:

- a. Audio playback of real-time acoustic data on the work boats.
- b. Real-time display of spectrogram and current sound levels.
- c. PAM operator to log anthropogenic (man-made) noise events other than seismic survey sounds.
- d. PAM operator to log start and stop times for air gun activity (only start and stop times for shot sequences).
- e. PAM operator to log all marine mammal sound detections. All detections occurring during seismic shooting will be red-flagged and immediate notifications sent to the survey operators to initiate shut-downs.
- f. Logging acoustic data to files containing 30 minutes of data.

Limitations

Acoustic monitoring for detecting marine mammals has limitations. First, it requires that the animals produce sounds, and second it requires those sounds to be of sufficient amplitude to be detected at the monitoring location. Sounds produced by marine mammals will decrease in amplitude with distance from the animal. Detection of sounds at the monitoring stations requires that the received levels of the biological sounds exceed background noise and other measurement noise. Background noise originates from waves, rain and from other vessels operating in the inlet. Measurement noise will include water flow noise at the hydrophone and low level electronic noise. Flow noise could be significant for this study due to high tidal currents in Cook Inlet. Flow noise is a significant issue for masking low frequency sounds from mysticetes. It will be less of a problem for detecting beluga and killer whale calls that occur at higher frequencies (most above 1 kHz). We also understand that seismic survey activity will be limited to times close to tide changes, when currents are small. Still flow noise likely will be the dominant measurement noise source. We estimate that the maximum detection range for belugas and killer whales will be 2-3 km for this study.

13.2 REPORTING

A report will be submitted to NMFS within 90 days after the end of the project. The report will describe the operations that were conducted and the marine mammals that were observed. The report will be submitted to NMFS, providing full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report will summarize the dates and locations of seismic operations, and all marine mammal sightings (dates, times, locations, activities, associated seismic survey activities, marine mammal behavior and any observed behavioral changes).

14.0 RESEARCH COORDINATION

Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.

Open-water seismic operations have been conducted in Alaska waters for over 25 years and, during this time, there have been no noticeable adverse impacts from them on the marine mammal populations or their availability for subsistence uses. This includes seismic operations involving air gun arrays far more powerful and extensive than that proposed for the test program. Over the time period these larger air gun arrays have been used in the Chukchi and Beaufort seas, bowheads, gray whales, and other species have increased to where they are approaching or at carrying capacity of the habitat. Furthermore, the subsistence harvest of bowhead whales has been very consistent over the last ten years among the whaling villages suggesting no decrease in their availability for harvest (Suydam and George 2004). While studies of seismic surveys on marine mammals have not been conducted in Cook Inlet, those referred above for the Alaska Arctic suggest the nearshore location, site characteristic, short time frame, and limited number and length of time of active seismic operations each day of the proposed test program should have no impact on the marine mammal populations.

However, to further ensure that there will be no adverse effects resulting from the planned seismic operations, APACHE will continue to cooperate with the NMFS, BOEM, other appropriate federal agencies, the State of Alaska, CIMMC, Tyonek Village Council, the affected communities, and other monitoring programs to coordinate research opportunities and assess all measures that can be taken to eliminate or minimize any impacts from these activities.

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APPENDIX A



Hydroacoustic Modeling of Airgun Noise for Apache's Cook Inlet Seismic Program

24-Hour Harassment Area Calculations

Submitted to:
NES-LLC

Authors:
Graham Warner
Jennifer Wladichuk
David Hannay

2011 June 15

P001134-004
Version 1.0

JASCO Applied Sciences
Suite 2101, 4464 Markham St.
Victoria, BC, V8Z 7X8, Canada
Phone: +1.250.483.3300
Fax: +1.250.483.3301
www.jasco.com



Suggested citation:

Warner, G., J. Wladichuk and D.E. Hannay. *Hydroacoustic Modeling of Airgun Noise for Apache's Cook Inlet Seismic Program: 24-Hour Harassment Area Calculations* Version 1.0. Technical report for NES-LLC by JASCO Applied Sciences. June 3, 2011.

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1. Introduction

This acoustic modeling study has been performed to estimate underwater sound levels produced by airgun array systems of Apache's planned Cook Inlet seismic surveys. Sound from airgun arrays has the potential to harass nearby marine mammals. The National Marine Fisheries Service (NMFS) presently considers exposures of marine mammals to impulsive airgun sound levels above 160 dB re 1 μ Pa (rms) to cause harassment. Exposures above this threshold are considered level-B takes by NMFS (in contrast to level-A takes which refer to injury). Level-B takes generally need to be permitted under Incidental Harassment Authorizations (IHA). Apache will apply for an IHA for their seismic programs and consequently needs to estimate the number of takes for several species. The number of acoustic takes for each species is calculated by multiplying the area ensonified above 160 dB re 1 μ Pa (rms), by the spatial density of that species. The modeling work performed here estimates the areas needed to calculate the take numbers to be requested in the IHA application.

This report describes the methods and computer models used to predict noise levels. It provides distances to several SPL thresholds and reports the areas ensonified above 160 dB re 1 μ Pa per 24-hour period of surveying in Cook Inlet for several depth environments. The predictions will be used to estimate the number of takes over the duration of Apache's seismic program.

2. Acoustic Metrics

2.1. Impulsive Noise Metrics

Impulsive or transient noise is characterized by brief acoustic events characterized by rapid pressure change at the onset of the event followed by pressure decay back to pre-existing levels within a few seconds or less. Impulsive sound levels are commonly characterized using three acoustic metrics: peak pressure, rms pressure or sound pressure level (SPL), and sound exposure level (SEL). The peak pressure (symbol L_{pk}) is the maximum instantaneous absolute sound pressure level measured over the impulse duration:

$$L_{pk} = 20 \log_{10} \left(\max |p(t)| / P_{ref} \right) \quad (1)$$

In this formula, $p(t)$ is the instantaneous sound pressure as a function of time t , measured over the impulse duration $0 \leq t \leq T$. This metric is very commonly quoted for impulsive sounds but does not take into account the duration or bandwidth of the noise.

The rms sound pressure level may be measured over the impulse duration according to the following equation:

$$L_p = 10 \log_{10} \left(\frac{1}{T} \int_T p(t)^2 dt / P_{ref}^2 \right) \quad (2)$$

In practice the beginning and end times of an impulse can be difficult to identify precisely. In studies of underwater impulsive noise, T is often taken to be the interval over which the cumulative per-pulse SEL (see following discussion) rises from 5% to 95% of the total pulse SEL. This interval, (T_{90}), contains 90% of the total SEL and the SPL computed over this interval

is therefore referred to as the 90% rms SPL (L_{P90}). Figure 1 shows an example of an impulsive noise pressure waveform, with the corresponding peak pressure, rms pressure, and 90% time interval.

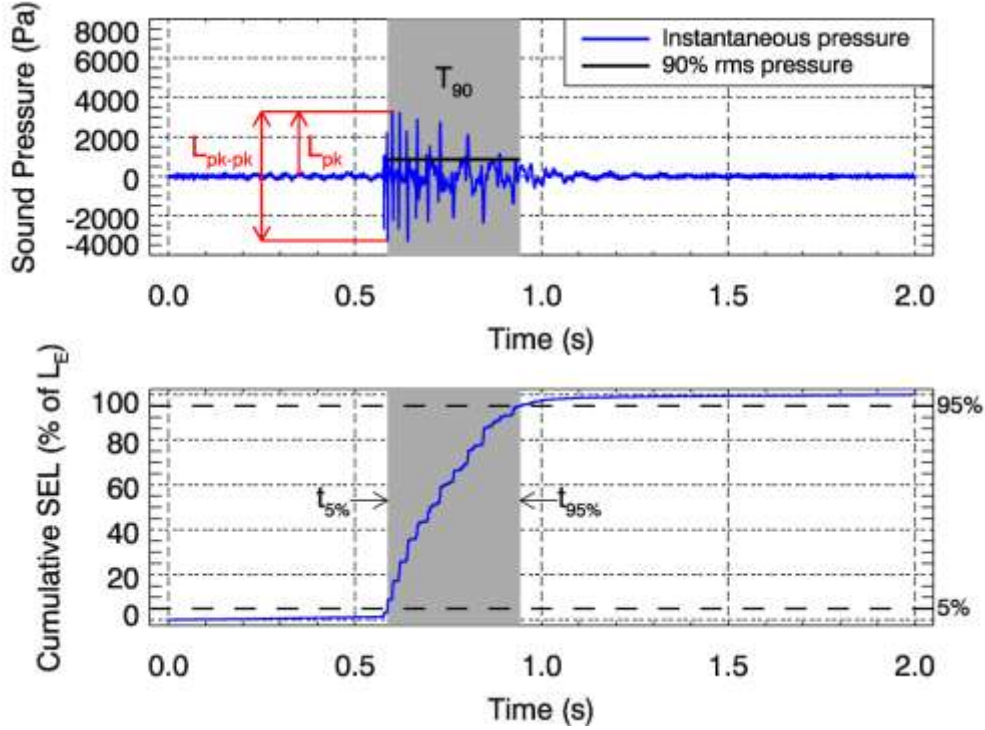


Figure 1. Example waveform (top) and cumulative SEL (bottom) for an impulsive noise measurement. The peak and peak-to-peak levels are annotated on the waveform plot and the 90% rms SPL is indicated with a black line. The gray area indicates the 90% time interval (T_{90}) over which the rms pressure is computed.

The sound exposure level or SEL (symbol L_E) is a measure related to the sound energy flux density of one or more impulses, but it does not account for impedance of the propagating medium and it is not measured in energy density units. The SEL for a single impulse is computed from the time-integral of the squared pressure over the impulse duration:

$$L_E = 10 \log_{10} \left(\int_{T_{100}} p(t)^2 dt / P_{ref}^2 \right) \quad (3)$$

Sound exposure levels for impulsive noise sources (i.e. airgun impulses) presented in this report refer to single pulse SELs.

Because the 90% rms SPL and SEL for a single impulse are both computed from the integral of square pressure, these metrics are related by a simple expression that depends only on the duration of the 90% time window T_{90} :

$$L_E = L_{P90} + 10 \log_{10}(T_{90}) + 0.458 \quad (4)$$

In this formula, the 0.458 dB factor accounts for the remaining 10% of the impulse SEL that is excluded from the 90% time window. In the following sections of this report, all references to rms levels refer to the 90% rms SPL metric.

Finally, the SPL and SEL metrics are sometimes calculated from a pressure signal that has been first passed through frequency filters. The filters are designed to account for frequency-dependent hearing sensitivity of the species exposed to the sound. If filtering is applied then the SPL and SEL levels are described as frequency-weighted. Several standard filters are used, including filters designed for marine mammal hearing, but these are not currently considered by NMFS for Cook Inlet effects assessment. A good discussion of filtering approaches for marine mammals is given in a recent report that describes methods for noise effects assessments based on frequency-weighted SEL (Southall *et. al.*, 2007).

3. Methods

3.1. Sound Propagation Model

The acoustic propagation model used for this study was JASCO's Marine Operations Noise Model. MONM computes the received sound pressure level from noise sources such as airguns and vessels. MONM treats sound propagation in range-varying acoustic environments through a wide-angled parabolic equation (PE) solution to the acoustic wave equation. The PE code used by MONM is based on a version of the Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for shear wave losses due to reflections from elastic seabeds. The PE method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins, 1993).

MONM accounts for depth and/or range dependence of several environmental parameters including bathymetry and sound speed profiles in the water column and the sea floor. It also accounts for the additional reflection loss that is due to partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces. It includes wave attenuations in all layers. The acoustic environment is sampled at a fixed range step along traverses.

Full waveform pressure-time series predictions were computed using MONM in full wave mode. In this mode, MONM computes pressure waveforms via Fourier synthesis of the modeled acoustic transfer function in closely spaced frequency bands between 10 and 2048 Hz. This frequency range includes the important bandwidth of noise emissions for the airgun array considered here. Range-dependent impulse-response functions were modeled between these frequencies in 1 Hz steps and convolved with the far-field source signature of the airgun array to generate synthetic pressure waveforms along each transect. These waveforms were then analyzed to determine the rms SPL as a function of range from the source. MONM's sound level predictions have been validated against other models and experimental data (Hannay & Racca, 2005).

3.2. Acoustic Source Levels of the Airgun Array

The acoustic source level of the 2400 in³ airgun array was predicted using JASCO's airgun array source model (AASM). AASM simulates the expansion and oscillation of the air bubbles generated by each airgun within a seismic array, taking into account pressure interaction effects between bubbles from different airguns. It includes effects from surface-reflected pressure waves, heat transfer from the bubbles to the surrounding water, and the movements of bubbles due to their buoyancy. The model outputs high-resolution airgun pressure signatures for each airgun. These signatures are superimposed with the appropriate time delays to yield the overall array source signature in any direction.

The array geometry is shown in Figure 2. The array consists of 16 individual guns with individual volumes of 150 in³ arranged in clustered pairs. The overall layout is comprised of two sub-arrays of 8 guns each. Only 12 airguns are shown in the figure below because each sub-array contains a pair of airguns suspended below the middle pairs (and hence not visible in this plan view).

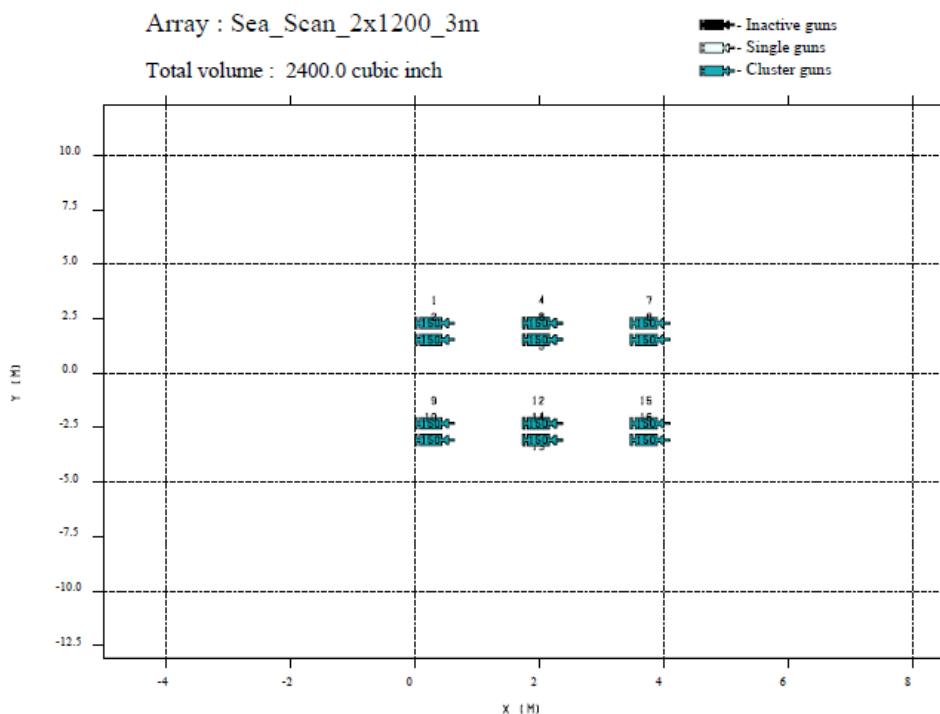


Figure 2: Geometry layout of 2400 in³ array. Tow direction is to the right; tow depth is 3.0 m; the volume of each airgun is indicated in cubic inches.

The airgun array is expected to be operated at a constant depth of 3 m during the course of the survey. The modeling of the airgun array signature was carried out for a towing depth of 3 meters with a firing pressure of 2000 psi.

AASM was used to characterize the spectral and directional attributes of the array's composite pressure signature in all directions as described above. The overpressure signatures and the power spectra for the broadside (perpendicular to tow) and forward endfire (parallel to tow) directions are shown in Figure 3.

The general trend is for spectral levels to decrease with increasing frequency, and most of the airgun energy is contained in frequencies below 500 Hz. To calculate the source directivity, the far-field array signature was filtered into 1/3-octave pass bands. Source directivity is insignificant below 100 Hz but it becomes prominent at higher frequencies. The horizontal directivity of the array as a function of frequency is presented in Figure 4. In these plots, the arrow indicates the tow direction of the array and the solid black curves indicate sound exposure level in dB re $1 \mu\text{Pa}^2\text{s}$ at 1 m as a function of angle in the horizontal plane. These levels are not directly used by MONM in full waveform mode; they are included here only to illustrate the horizontal directivity pattern of the array. MONM inherently treats vertical and horizontal directivity in full-wave mode.

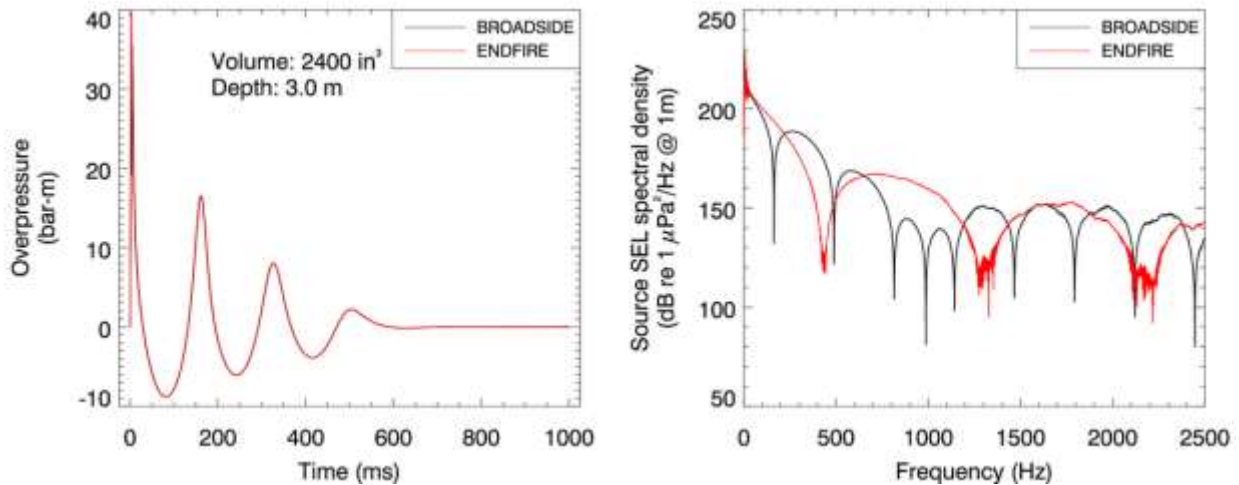


Figure 3: Overpressure signature and power spectrum for the 2400 in³ array in the broadside and endfire directions. Surface ghosts are not included in these signatures.

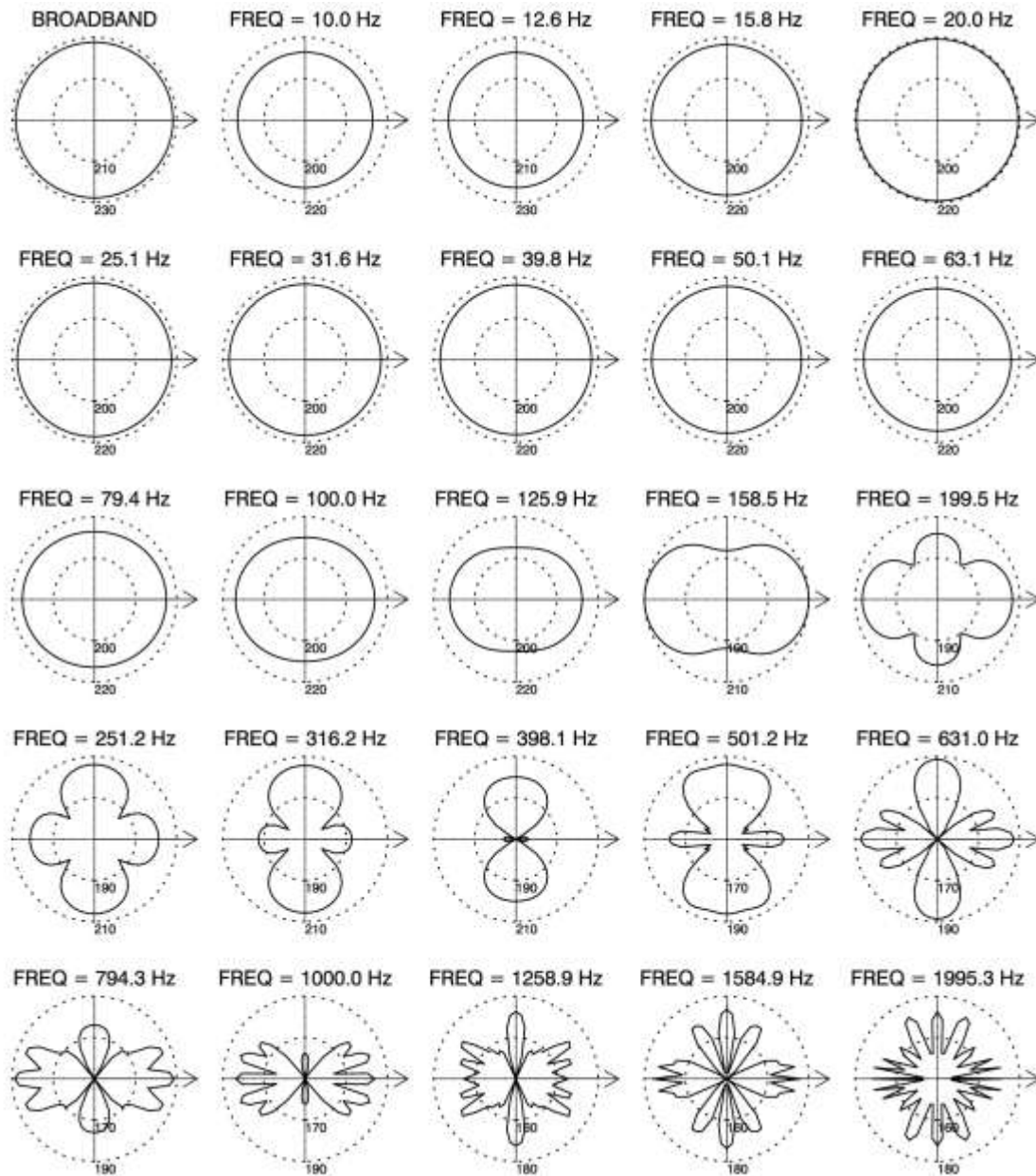


Figure 4: Azimuthal directivity patterns of the seismic array source levels (dB re 1 μPa^2 s at 1 m) for the 2400 in³ array towed at 3 m depth, in 1/3-octave bands, by center frequency.

3.3. Acoustic Environment

3.3.1. Bathymetry

The acoustic models use high-resolution grids of bathymetry to define water depths inside a region of interest. Apache plans to survey many prospects in Cook Inlet over the duration of their surveys and the precise locations and sequence of prospects to be surveyed are presently unknown. However, the general bathymetry along the inlet is relatively uniform and consequently representative environments can be defined that are relevant for multiple survey locations.

Two general survey environment scenarios were considered for this modeling study: a nearshore survey scenario (from shore out to 18 km offshore) and a channel survey scenario (more than 18 km from each shore). The nearshore scenario was further divided into 3 distance intervals of 6 km each from shore, with this interval defined by the zone that can be surveyed in a 24 hour period based on an anticipated survey line length and line spacings that are discussed later.

Water depths for the nearshore scenario increase by 25 m per 10 km distance away from shore. The depth of the channel scenario has constant depth of 80 m, which is the approximate median depth along the center of the Cook Inlet's channel.

3.3.2. Underwater sound speed

The sound velocity profile (SVP) used in the acoustic model was derived from conductivity-temperature-depth (CTD) surveys conducted within the project test area in Cook Inlet between 25 March and 1 April 2011. The CTD data reveal a fairly uniform sound speed with depth for all fourteen casts conducted (typically < 2 m/s variation) (see Figure 5), with a mean value of 1436 m/s across all depths.

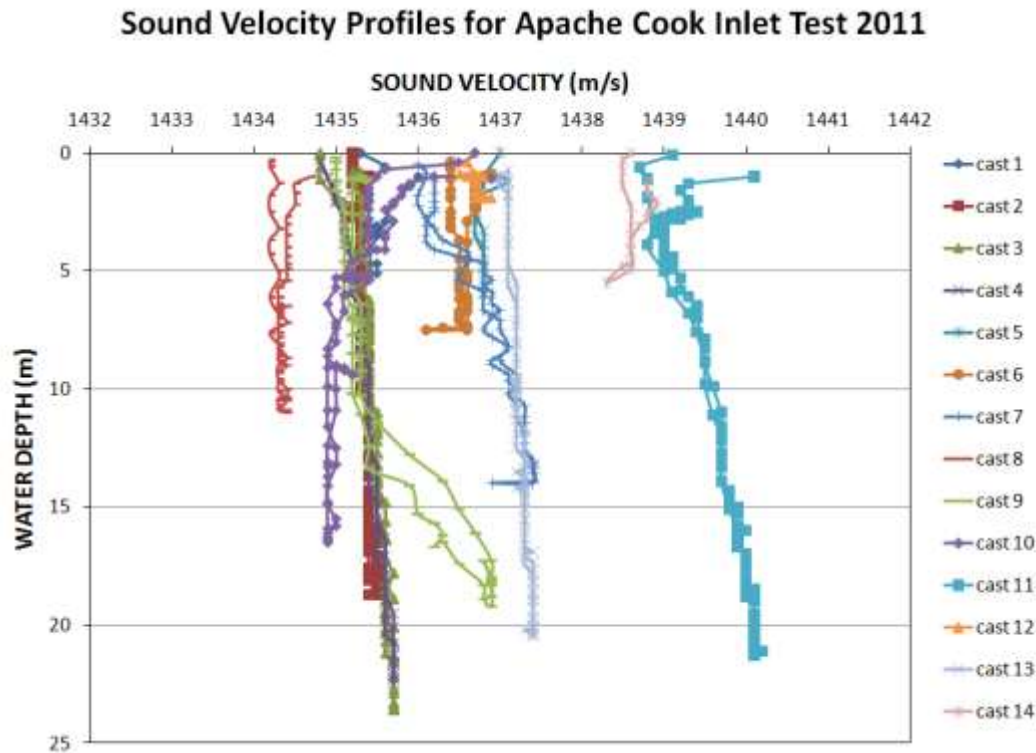


Figure 5: Sound velocity profiles as derived from CTD cast measurements obtained between 25 March and 1 April 2011 in Cook Inlet, Alaska.

Variability in sound velocity profile shape can exist with time of year due to seasonal temperature and salinity cycles. Therefore, a review of two other sources of SVP data for Cook Inlet was done to confirm the validity of this observed iso-velocity SVP shape and mean value.

Sound velocity profiles were examined for each month of the year using the US Naval Oceanographic Office's Generalized Digital Environmental Model (Teague *et al.* 1990) database

for a location in the middle of Cook Inlet. The other source of SVP is from field work conducted in April 2007 (JASCO). The data from these two sources concurs with the SVP from the 2011 measurements, and thus a constant sound velocity of 1436 m/s was used in the acoustic model.

3.3.3. Seabed geoacoustics

The geoacoustic profile for Cook Inlet, describing the elasto-acoustic properties of the seabed sediments, was first estimated from a geological profile at the Port of Anchorage (Hashash, 2008). The engineered fill and Bootlegger Cove formation layers were disregarded as they would not be present in the majority of Cook Inlet. The resulting profile consisted of a surface layer of sand, silt, and clay, overlaying glacial-fluvial sands, gravels, and glacial till. Descriptions of soil composition for these layers were used to estimate geoacoustic properties, using the methods described by Hamilton (1980).

The five geoacoustic layer properties considered by the sound propagation model for sub-bottom sediments are as follows:

1. Relative density: The density of the bottom materials relative to the density of water.
2. Compressional-wave sound speed: The phase speed of longitudinal body waves (P-waves) in the bottom materials (units of m/s).
3. Compressional attenuation: The rate of attenuation (units of dB per wavelength) of longitudinal body waves in the bottom materials.
4. Shear-wave sound speed: The phase speed of transverse body waves (S-waves) in the bottom materials (units of m/s).
5. Shear attenuation: The rate of attenuation (units of dB per wavelength) of transverse body waves in the bottom materials.

MONM accepts profiles of density, compressional-wave speed, and compressional attenuation defined to arbitrary depth in the bottom. Reflection losses at the seabed, caused by partial conversion of compressional waves to shear waves at each layer interface, are accounted for in MONM using a complex-density approximation.

In order to ensure that the derived geoacoustic parameters were appropriate for Cook Inlet, MONM was run to model sound levels from the 880 in³ array used in the ConocoPhillips 2007 survey (JASCO, 2007). The modeled peak, rms, and SEL values were compared to measured data and the compressional sound speed at the seabed was adjusted until an optimal fit between the modeled and measured levels was obtained. The resulting geoacoustic profile, intended to represent mean sediment properties over Cook Inlet, is presented in the table below.

Table 1: Seabed geoacoustic profile for Cook Inlet. Geoacoustic parameters are based on the soils containing a mixture of sands, silts, and clays transitioning to glacial-fluvial sands, gravels, and glacial till with depth.

Depth (mbsf)	Density (g/cm ³)	Compressional Sound Speed (m/s)	Compressional Attenuation (dB/λ)	Shear Sound Speed (m/s)	Shear Attenuation (dB/λ)
0	1.58	1480	0.17	110	2.0
108	2.18	1844	0.50	-	-

3.4. Area of Harassment Calculation

The area ensonified to above 160 dB re 1 μ Pa over 24 hours of seismic surveying is dependent on the seismic survey line geometry because the zones from multiple survey lines often overlap. Apache plans to survey 12 to 14, 16.1 km long lines each day. The survey lines will be parallel to shore, separated nominally by 503 m, and immediately-adjacent lines will be surveyed sequentially. Based on this survey description, MONM was used to model sounds from the array in the two characteristic environments described in Section 3.3.1.

For the nearshore surveys, the source was modeled at three positions on the slope with water depths 5, 25, and 45 m. At each source position, three transects were modeled corresponding to the onshore, offshore, and parallel-to-shore directions. Since the airgun array will be towed parallel to shore, these directions correspond with the onshore-broadside, offshore-broadside, and endfire directions relative to the array. For the channel surveys, the source was modeled in 80 m deep water in the broadside and endfire directions.

The received levels vary with distance from the array and with receiver depth (that can be anywhere in the water column). The distances to 160 dB re 1 μ Pa were calculated in each direction by considering the maximum level over all possible receiver depths. We interpolated and extrapolated from the distance values modeled for the 3 different source location water depths of the nearshore scenario to obtain the 160 dB re 1 μ Pa distances for all source location water depths between 5 and 54 m.

The acoustic footprint for each survey line was calculated by defining encompassing rectangles formed by the distance of the 160 dB re 1 μ Pa threshold from the survey line, accounting for the differences in these distances for the different directions (Figure 6). The total area ensonified over the period of 24 hours was calculated from the union of 14 single survey line rectangles. Figure 7 illustrates the process for the union of just two survey line rectangles; this process was extended to all 14 lines of one day's anticipated survey production.

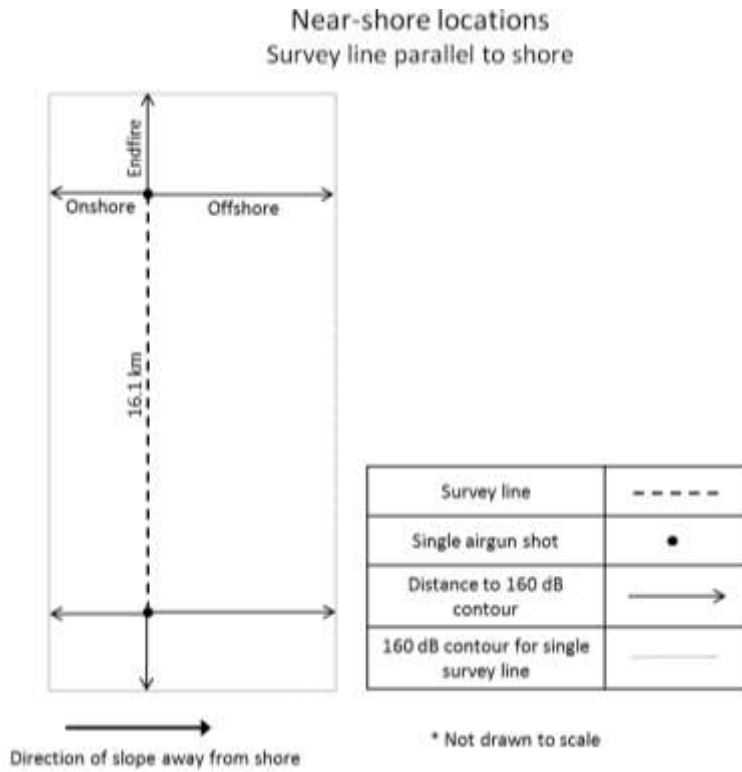


Figure 6: Diagram showing the creation of the 160 dB rectangular contour for a single survey line. In practice the corners are rounded but this has only a small reducing influence on the total areas.

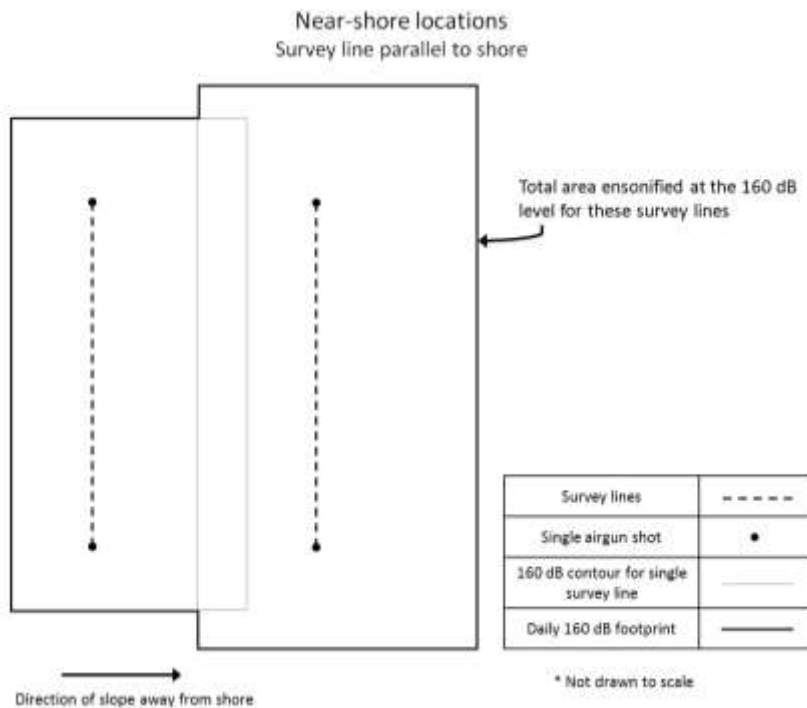


Figure 7: Diagram showing the union of two 160 dB rectangles (light grey lines) from two survey lines to get the combined 160 dB footprint (bold black line). The more offshore survey line (right) is in deeper water which supports better sound propagation. It consequently has a larger individual footprint size, hence its larger rectangle.

The daily area ensonified to 160 dB for nearshore surveys depends on the water depths of the lines surveyed. A daily survey of 14 parallel lines with 500 m spacing would span 6.5 km, corresponding to a water depth variation of about 16 m. Because the total daily footprint for nearshore surveying varies with depth, we divided the nearshore scenarios into three depth intervals, each of which could be surveyed in a single day: shallow (5-21 m), intermediate (21-38 m), and deep (38-54 m). The 24-hour ensonified areas were computed separately for each of the three nearshore survey depth intervals.

4. Model Scenarios and Results

4.1. Overview of Model Scenarios

The distances to 190, 180 and 160 dB re 1 μ Pa threshold for various source depths and in different directions from the source, and relative to shore, were calculated by the acoustic model. The 160 dB re 1 μ Pa threshold distances were calculated for the three nearshore survey depth intervals and single depth channel survey also in different directions from the source. The daily areas ensonified above the 160 dB re 1 μ Pa threshold were then calculated for each of the four survey depth intervals. The distance and area results are presented below.

4.2. Nearshore Survey Results

The distances to the 160, 180, and 190 dB re 1 μ Pa sound level thresholds for the nearshore survey locations are given in Table 2. Distances correspond to the three transects modeled at each site in the onshore, offshore, and parallel to shore directions.

Table 2: Distances to sound level thresholds for the nearshore surveys.

Sound Level Threshold (dB re 1 μ Pa)	Water Depth at Source Location (m)	Distance in the Onshore Direction (km)	Distance in the Offshore Direction (km)	Distance in the Parallel to Shore Direction (km)
160	5	0.85	3.91	1.48
	25	4.70	6.41	6.34
	45	5.57	4.91	6.10
180	5	0.46	0.60	0.54
	25	1.06	1.07	1.42
	45	0.70	0.83	0.89
190	5	0.28	0.33	0.33
	25	0.35	0.36	0.44
	45	0.10	0.10	0.51

The 160 dB re 1 μ Pa footprints for one day of nearshore surveying in shallow, mid-depth, and deep water are shown in Figure 8; the corresponding areas of the footprints are listed in Table 3.

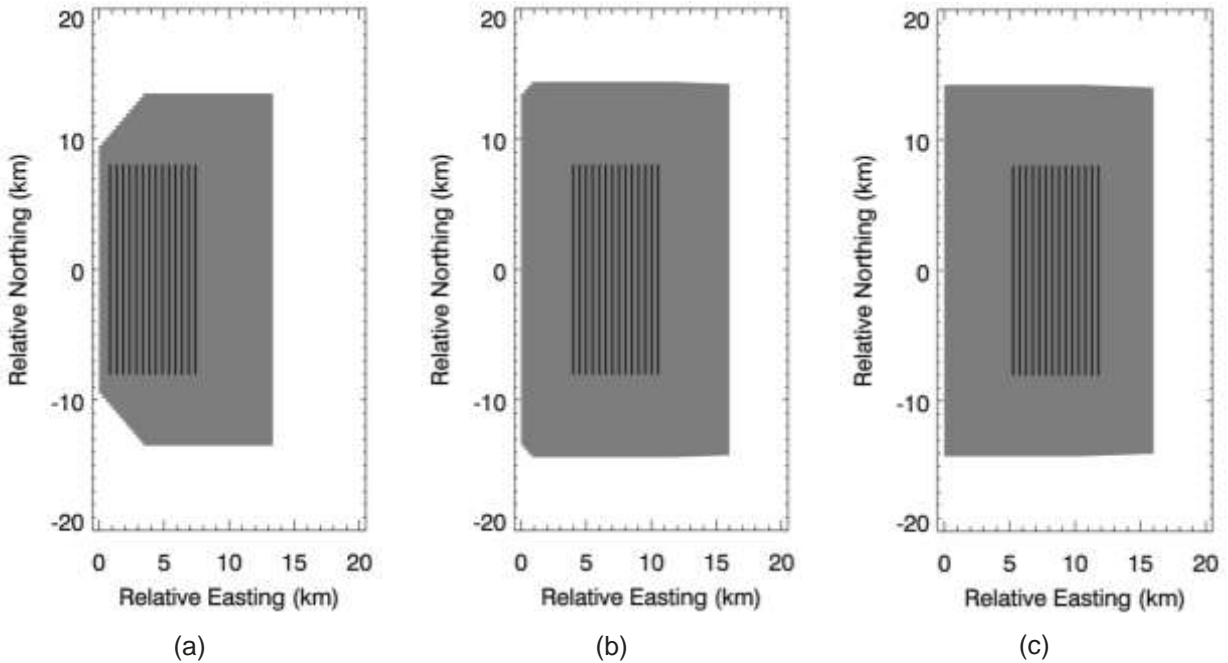


Figure 8: Daily footprints for (a) shallow, (b) mid-depth, and (c) deep water nearshore surveys. The ensonified areas are shown in gray and survey lines are shown in black.

Table 3: Areas ensonified to 160 dB re 1 μ Pa for nearshore surveys in 24 hours.

Nearshore Survey Depth Classification	Depth Range (m)	Area Ensonified to 160 dB re 1 μ Pa (km ²)
Shallow	5-21	346
Mid-depth	21-38	458
Deep	38-54	455

4.3. Channel Survey Results

The distances to the 160, 180, and 190 dB re 1 μ Pa sound level thresholds for the channel surveys are shown below in Table 4. Distances correspond to the broadside and endfire directions.

Table 4: Distances to sound level thresholds for the channel surveys.

Sound Level Threshold (dB re 1 μ Pa)	Water Depth at Source Location (m)	Distance in the Broadside Direction (km)	Distance in the Endfire Direction (km)
160	80	4.24	4.89
180	80	0.91	0.98
190	80	0.15	0.18

The 160 dB re 1 μ Pa footprint for 24 hours of seismic survey in the inlet channel is shown in Figure 9; the corresponding area of the footprint is 389 km².

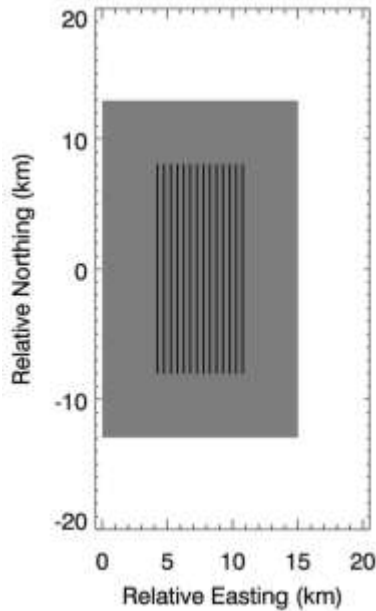


Figure 9: Daily footprint for channel surveys. The ensonified area is shown in gray and the survey lines are shown in black. Its area is 389 km².

5. Summary and Conclusion

This report presents results from a noise modeling study of Apache's planned seismic survey operations in Cook Inlet. The study characterized the acoustic environment in the Cook Inlet area by defining a generic nearshore sloped environment and a flat (constant depth) channel environment. Underwater noise was modeled from a 2400 in³ airgun array and the distances that sound levels reached thresholds 160, 180, and 190 dB re 1 μ Pa (90% rms SPL) were computed. The areas ensonified above 160 dB re 1 μ Pa were calculated for 24 hour surveying periods in shallow, mid-depth, and deep water for the nearshore environment, and for 24 hours of surveying in the channel environment.

The signature of the 2400 in³ airgun array was modeled using an airgun array source model (AASM) and was input to a range-dependent acoustic model in full waveform mode (MONM). Bathymetry has substantial influence on the distances that sound travels in the environments considered. Seismic sounds are predicted to propagate most strongly in the 21-55 m depth range, with greater attenuation (reduction of sound levels) for smaller and greater depths.

The maximum predicted distances for 90% rms SPL values to reach thresholds of 160, 180 and 190 dB re 1 μ Pa over all depths and azimuths modeled were 6.41 km, 1.42 km, 0.51 km, respectively. The areas ensonified above 160 dB re 1 μ Pa during 24 hours of surveying for the different environments considered is summarized in Table 5. These values can be used to estimate the number of takes expected over the course of a multi-day survey by simply multiplying by the corresponding animal spatial densities.

Table 5: Summary of ensonified areas to 160 dB re 1 μ Pa for one day of surveying.

Survey Classification	Depth Range (m)	Area Ensonified to 160 dB re 1 μ Pa (km ²)
Nearshore - Shallow	5-21	346
Nearshore - Mid-depth	21-38	458
Nearshore - Deep	38-54	455
Channel	80	389

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