# Application for Incidental Harassment Authorization for the Non-Lethal Taking of Whales and Seals in Conjunction with a Proposed Open Water Marine Surveys Program in the Chukchi Sea, Alaska, During 2013

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# Executive Summary

As described herein, during the open water season in 2013, Shell plans to conduct geophysical surveys (aka Open Water Marine surveys) designed to gather additional data relative to site clearance and shallow hazards and ice gouge in select areas of the Chukchi Sea, as identified herein. In addition, Shell plans to conduct equipment recovery and maintenance activity at the Burger A well site in the Chukchi Sea. These geophysical surveys are continuations of similar data acquisition programs conducted by Shell in the Beaufort Sea beginning in 2006, and in the Chukchi Sea in 2008, with the addition of the equipment removal and maintenance activity. These surveys and the equipment recovery and maintenance constitute all of the work proposed within Shell's open water marine surveys program of 2013.

Site clearance and shallow hazards surveys will evaluate the seafloor, and shallow sub seafloor at prospective exploration drilling locations, focusing on the depth to seafloor, topography, the potential for shallow faults or gas zones, and the presence of archaeological features. Offshore ice gouge surveys investigate the depth width, orientation, frequency, and distribution of ice gouges. Both of these surveys are focused on limited areas in order to characterize the seafloor at prospective drilling locations and along potential pipeline routes. The geophysical surveys planned by Shell are industry-standard, scientific surveys that have been routinely conducted in the Beaufort and Chukchi Seas since the early 1980s. The equipment used by Shell to complete these surveys typically employ low-level, very-high to low frequency acoustic impulse sound sources or low-level, low frequency continuous sound sources during discrete time periods over very limited areas of the ocean bottom and intervening water column. Since the early 1990s, the National Marine Fisheries Service has issued incidental harassment authorizations to industry for the non-lethal taking of small numbers of marine mammals related to these low level energy source surveys. Equipment recovery and maintenance activity will involve a vessel operating in dynamic-positioning (DP) mode at the location of Burger A.

In support of the required written application for incidental take authorizations, and in keeping with the best available understanding of marine mammal densities and presence in the Beaufort and Chukchi Seas, Shell has calculated an estimated incidental, non-lethal take of small numbers of marine mammals from the low-level acoustic sources to be employed during these surveys and from a vessel operating on DP while conducting the equipment recovery and maintenance. None of the incidental, non-lethal takes resulting from Shell's marine surveys will result in impacts that are of biological significance to marine mammal populations in the Chukchi Sea.

The organization of this request for an Incidental Harassment Authorization (IHA) follows the organization of Chapter 50 Code of Federal Regulations (CFR) 216.104 (a). The remainder of this document is organized as to follow 50CFR§216.104 (a) (1)-(14).

Shell Gulf of Mexico Inc., the lessee for OCS leases in the Chukchi Sea, collectively known as Shell, used the following guidance to prepare its request for IHA, or IHA application (IHAA).

*50 CFR 216.104 "Submission of Requests"*

In order for the National Marine Fisheries Service (NMFS) to consider authorizing the taking by U.S. citizens of small numbers of marine mammals incidental to a specified activity (other than commercial fishing), or to make a finding that incidental take is unlikely to occur, a written request must be submitted to the Assistant Administrator. All requests must include the following information for their activity.

**Information required by 50 CFR§216.104 (a):**

# 1. 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 Overview of Program

Shell plans to complete geophysical surveys (aka Open Water Marine surveys), during the 2013 open water season in the Chukchi Sea from a single vessel. Equipment recovery and maintenance activity at Burger A will be conducted from a separate vessel, while a third vessel may be used to provide logistical support to either and/or both operations. Aircraft may be utilized for vessel support. Shell's surveys and other work are discussed separately in this IHAA as:

- Chukchi Sea Offshore Ice Gouge Surveys;
- Chukchi Sea Offshore Site Clearance and Shallow Hazards Survey; and
- Equipment Recovery and Maintenance

Location maps that show areas proposed for geophysical surveys are included as Figures 1-1 and 1-2 of this IHAA. Figure 1-3 cites the location of the equipment recovery and maintenance in the Chukchi Sea.

The vessels and aircraft described herein as platforms from which equipment will be deployed, surveys conducted, or support provided are not currently under contract to Shell. In this IHAA, Shell describes the tasks for which the support of vessels and aircraft are anticipated. The proposed vessel and aircraft types are discussed in Section 1.6 of this IHAA.

Ice and weather conditions will influence when and where the open water marine surveys will be conducted. For initial planning purposes, Shell anticipates that the offshore geophysical surveys and equipment recovery and maintenance will be conducted within the time frame of July through October 2013. More specific, estimated timeframes for the surveys and equipment recovery and maintenance work are discussed in Section 2 of this IHAA. Not all of the activities described are expected to result in incidental taking of marine mammals (*e.g.*, ice gouge, equipment recovery), but all activities are discussed herein, since vessel and aircraft operations in the area of requested incidental take authorization will adhere to general vessel and aircraft mitigation measures (*e.g.*, cetacean avoidance distances; see section 12).

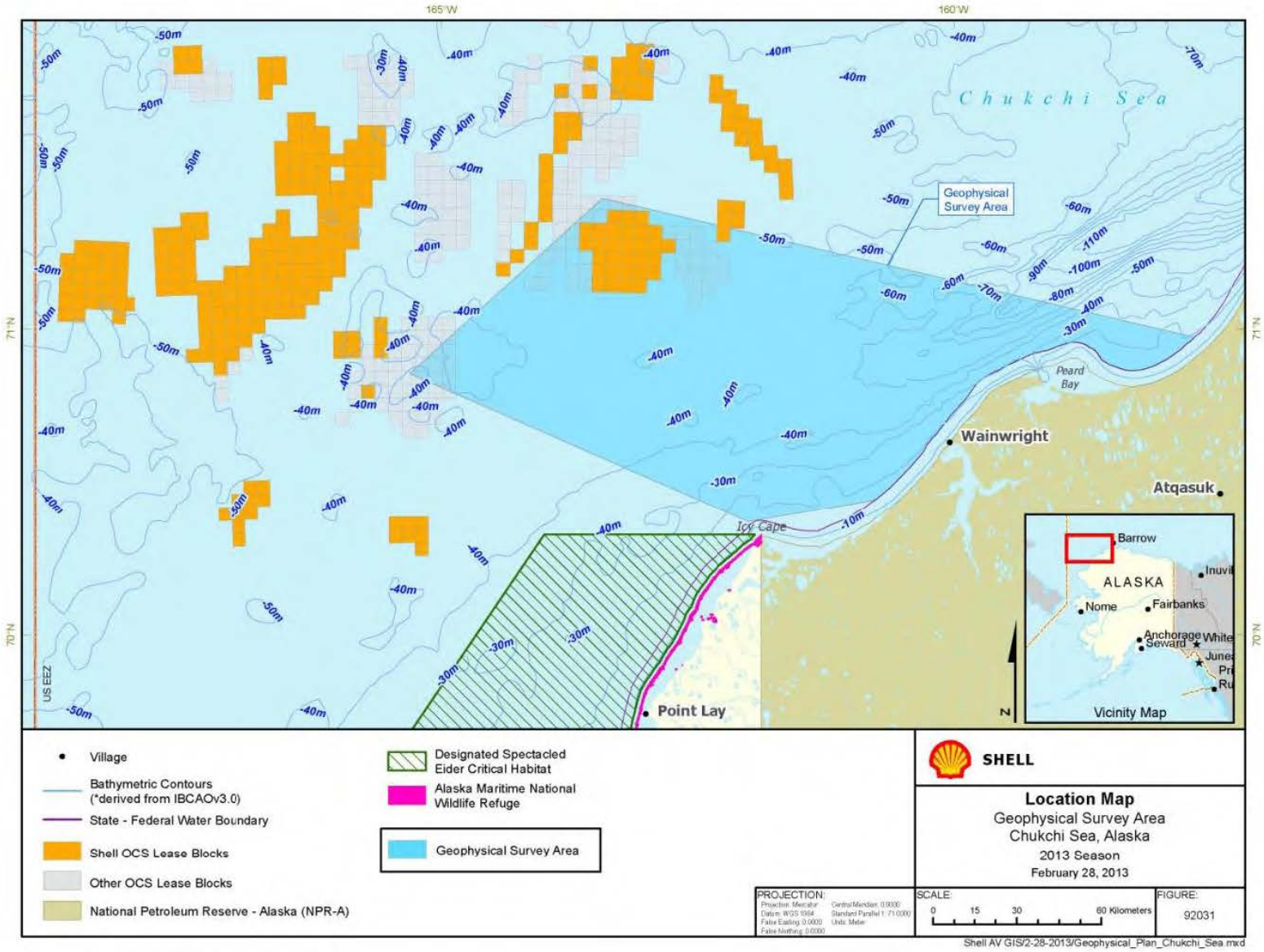


**Figure 1-1 Location Map for Chukchi Sea Offshore Ice GougeSurveys**

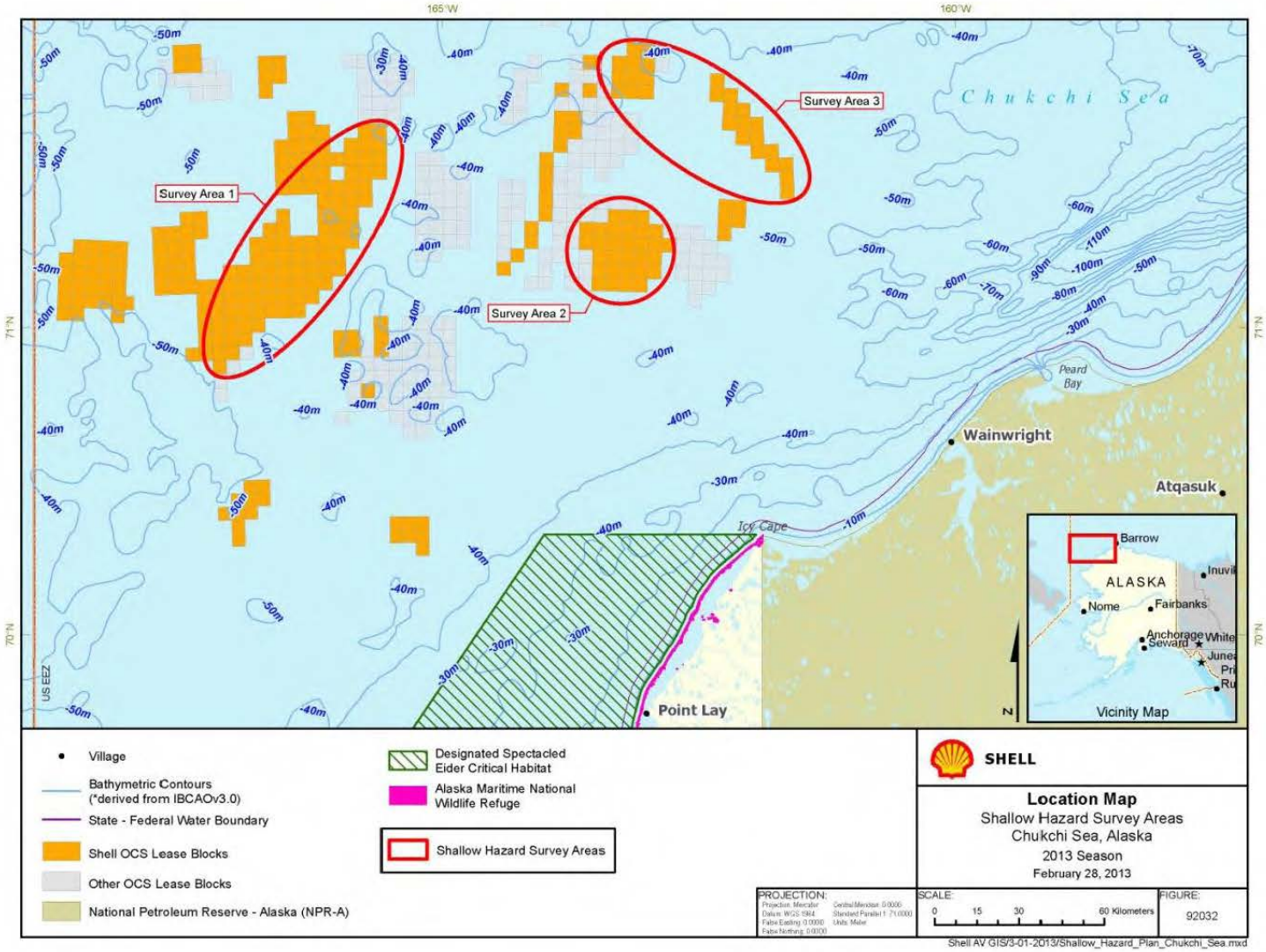


**Figure 1-2 Location Map for Chukchi Sea Site Clearance and Shallow Hazards Surveys (Survey Area 1: Crackerjack; Survey Area 2: Burger; Survey Area 3: Northeast of Burger)**

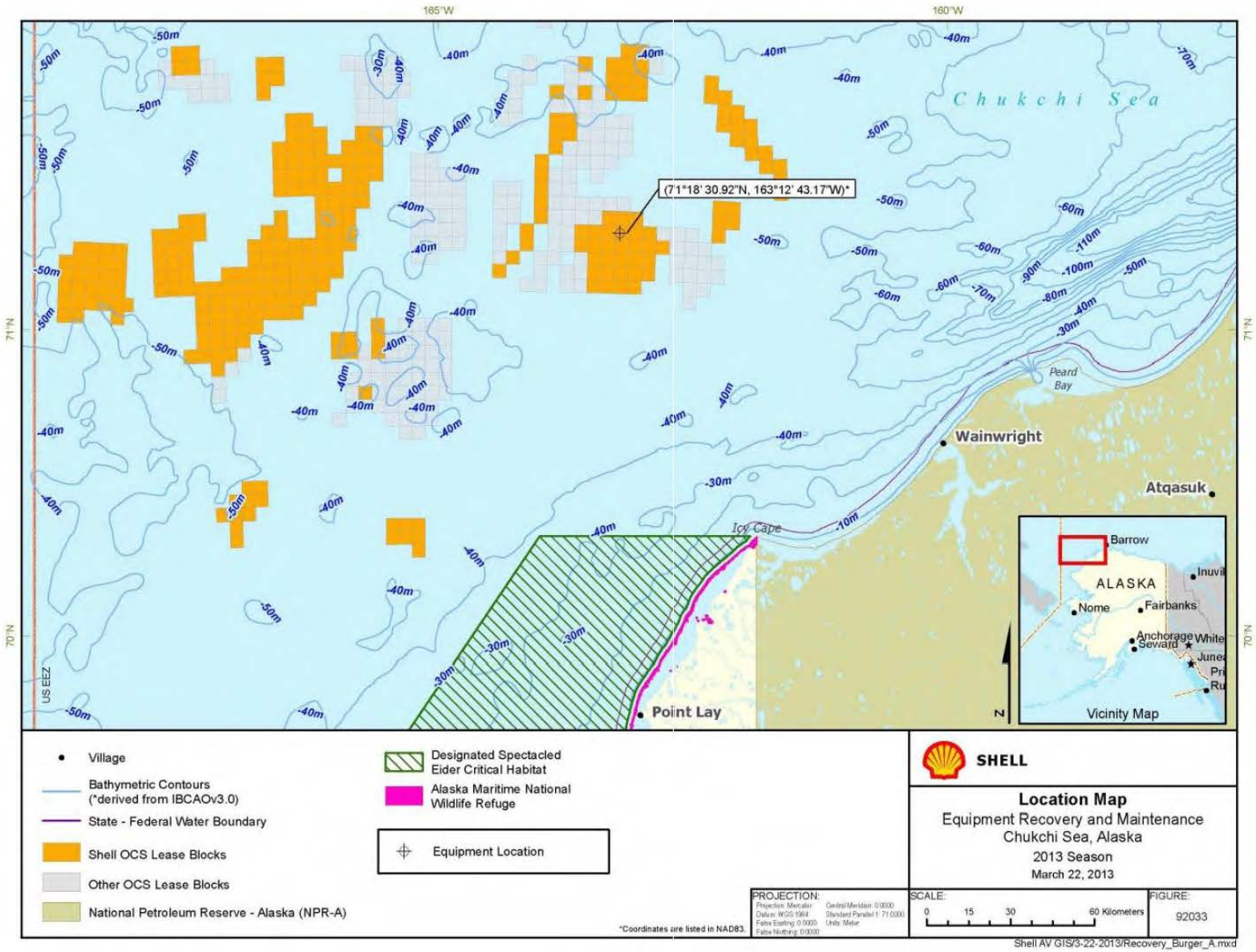


**Figure 1-3 Location Map for Chukchi Sea Equipment Recovery and Maintenance**

## 1.2 Overview of Equipment

The types of acoustic equipment intended for use during each of the geophysical surveys are indicated in Table 1-1. Brief descriptions of the types of data acquired by equipment type are provided below.

**TABLE 1-1 PROPOSED EQUIPMENT FOR 2013 GEOPHYSICAL SURVEYS**

| Equipment Type[1] | Offshore Ice Gouge | Site Clearance and Shallow Hazard |
|---|---|---|
| Dual-frequency, side-scan sonar (100/500kHz) | ● | ● |
| Single-beam, bathymetric sonar (8-20kHz) | ● | ● |
| Multi-beam, bathymetric sonar (200-300 kHz), or similar | ● | ● |
| Shallow sub-bottom profiler (2-24kHz) | ● | ● |
| Deep Penetration Profiler 4 x 10 cubic inches ($in^3$) airgun array with 48-channel streamer, or similar | -- | ● |
| Medium Penetration Profiler, 4 x 10 cubic inches ($in^3$) airgun array with 24-channel streamer, or similar | -- | ● |
| Navigation Instrumentation | ● | ● |
| Magnetometer | ● | ● |

Note:
[1] Equipment types may vary slightly from that proposed, thus all equipment types are qualified with, "or similar".
Key:
● – Proposed for use in 2013.
-- – Not intended for this survey.
kHz - kilohertz

### Dual-frequency Side Scan Sonar

Side scan sonar data provide a two-dimensional view (map or plan view) of seafloor topography and of objects on the seafloor. Generally, side scan sonar systems do not provide depth information. The sonar images provide a swath display or record covering an area on the seafloor on both sides of the survey trackline. The side scan sonar transmits very high frequency acoustic signals (100 to 500 kHz) and records the energy signal reflected from the seafloor. Side scan sonar is useful for mapping areas of boulders, rock outcrops, and other areas of rough seafloor, and for determining the location and trends of seafloor scarps and ice gouges.

**Single-beam Bathymetric Sonar**

The single-beam bathymetric sonar is used as a navigation tool for maritime operations and may also compliment the multi-beam bathymetric sonar data. The system transmits acoustic signals (8 to 20 kHz).

**Multi-beam Bathymetric Sonar**

The multi-beam sonar transducer is mounted either on the hull of the survey vessel (or can be pole-mounted over the side of the vessel). The system transmits acoustic signals (in the 200-300 kHz range) from multiple projectors propagating to either side of the vessel at angles that vary from vertical to near horizontal. The locations of the soundings cover a swath whose width may be equal to many times the water depth. The time it takes to receive the signals as well as signal intensity, position, and other characteristics for echoes received across the swath are used to calculate depth of each individual beam transmitted.

Water column sound velocity for input into the multi-beam sonar may either be obtained using a conductivity, temperature, and depth (pressure) meter (CTD) or by using a direct velocity measurement instrument capable of recording in the maximum water depths expected within the survey area. The water column velocity is used to adjust or correct the depth measured by the multi-beam system.

**Shallow Sub-Bottom Profiler**

Sub-bottom profile systems are used to map the subsurface structure of sediment and rock formations beneath the seabed. They employ a technique known as Reflection Seismology that uses reflected seismic waves to produce an image of the subsurface profile. These systems emit sound energy which travels down to the seafloor and penetrates the layers beneath.

The energy reflects off the differing layers with different intensities depending on the density of the soil, and these reflected energy waves travel up through the sea and are received by one or more surface hydrophones. Once received, the reflected energy waves can be recorded and processed to create an image of the seabed geology. The sub-bottom profiler type to be used during the surveys operates in the 2-24 kHz range. Shell would notionally choose to operate a chirp type system with a typical 3.5 kHz operating frequency.

**High-Resolution Profiling**

In this method, reflected sound energy produces graphic images of seafloor and sub-seafloor features. These systems transmit the acoustic energy from towed sources. Part of this energy is reflected from the seafloor and from geologic strata below the seafloor. This reflected energy is received by the hydrophone or streamer (300 to 600 meters (m) (984 to 1969 feet [ft]) long and towed near the surface. High-resolution profiles often resemble geologic cross-sections along the course traveled by the survey vessel.

Several high-resolution profiling systems may be operated to obtain detailed records of seafloor and sub-seafloor conditions. A typical survey will include data acquisition using a shallow penetration sub-bottom profiler as described above, and a 4 x 10 cubic inches (in3) airgun array with 24 channel and 48 channel hydrophone streamers, not to be confused with the deep seismic used for hydrocarbon exploration.

**Magnetometer**

A magnetometer is a non acoustic measuring instrument used to measure the strength and, in some cases, the direction of magnetic fields. Magnetometers are widely used for measuring the Earth's magnetic fields and in geophysical surveys to detect magnetic anomalies of various types Magnetometers can be used as metal detectors: they can detect only magnetic (ferrous) metals, but can detect such metals at a much larger depth than conventional metal detectors; they are capable of detecting large objects, such as cars, at tens of meters, while a metal detector's range is rarely more than 2 meters. This system is most useful in conjunction with the side scan sonar to identity an object.

## 1.3 Chukchi Sea Offshore Ice Gouge Surveys

Shell plans to conduct ice gouge surveys as part of its overall feasibility study to identify and evaluate seabed conditions in its Alaska prospects. Ice gouge information is required for the design of potential pipelines and pipeline trenching and installation equipment. Ice gouges are created by ice keels that project from the bottom of ice, and gouge the seafloor sediment as the ice moves with the wind or currents. Ice gouge features can be mapped and surveyed, and by surveying the same locations from year to year, new gouges can be identified and the rate of ice gouging can be estimated. The resulting ice gouge information will assist Shell in predicting the probability, frequency, orientation, and depth of future ice gouges.

Shell plans to conduct ice gouge surveys in Federal waters of the Chukchi Sea OCS (offshore ice gouge survey) as described below. The objectives of these surveys are to: (a) accumulate multi-year statistical data on ice gouge feature along selected previously surveyed tracklines, (b) provide data to delineate favorable areas for man-made seabed structures within Shell's Chukchi Sea prospects, (c) provide data to delineate favorable corridors for buried pipelines within these prospects, and (d) provide data to delineate favorable corridors for buried export pipelines between these prospects and shore.

**Offshore Ice Gouge Survey Design and Methods**

Shell plans to conduct ice gouge surveys along approximately 621 mi (1,000 km) of tracklines in the Chukchi Sea in 2013, within the area denoted in Figure 1-1. These surveys will: (a) resurvey selected previously surveyed tracklines for ice gouge features to determine the rate or frequency of new ice gouges; and (b) map seafloor topography and characterize the upper 34 ft (10 m) of the seabed (seafloor and sub-seafloor) using acoustic methods. The ice gouge surveys will be conducted using the conventional survey method where the acoustic instrumentation will be towed behind the survey vessel (Figure 1-4).

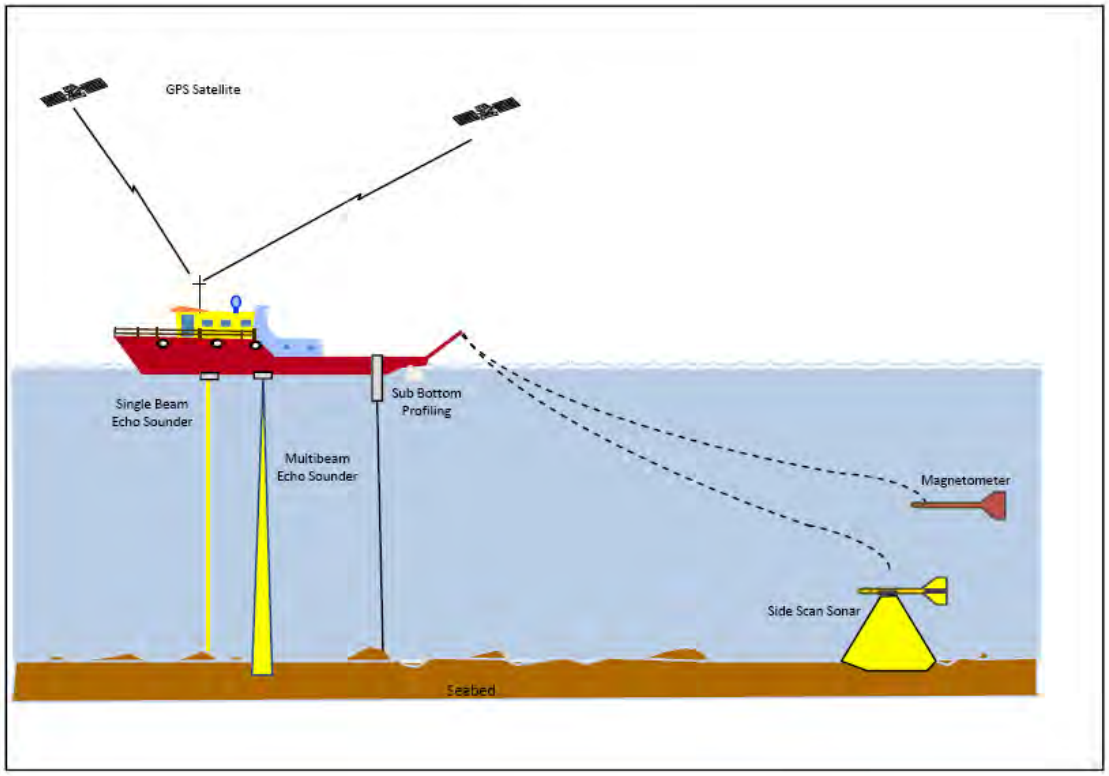


**Figure 1-4 Schematic of Offshore Ice Gouge Survey Acquisition**

## 1.4 Chukchi Sea Site Clearance and Shallow Hazards Surveys

Shell plans to conduct site clearance and shallow hazards surveys of potential exploratory drilling locations in the Chukchi Sea. These surveys gather data on: (1) bathymetry, (2) seabed topography and other seabed characteristics (*e.g.*, ice gouges), (3) potential shallow geohazards (*e.g.*, shallow faults and shallow gas zones), and (4) the presence of any possible archeological features (prehistoric or historic, *e.g.*, middens, shipwrecks). Marine surveys for site clearance and shallow hazard surveys can be accomplished by one vessel with acoustic sources.

### Site Clearance and Shallow Hazards Survey Design and Methods

Shell plans to conduct site clearance and shallow hazards surveys along approximately 3,200 kilometers [km] of tracklines in the Chukchi Sea in 2013, within the three survey areas denoted in Figure 1-2. These surveys will to characterize the upper 1,000 meters (m) (3,128 feet [ft]) of the seabed and sub seafloor topography and measure water depths of potential exploratory drilling locations using acoustic methods. The site clearance and shallow hazard surveys will be conducted using the conventional survey method where the acoustic instrumentation will be towed behind the survey vessel (Figure 1-5).

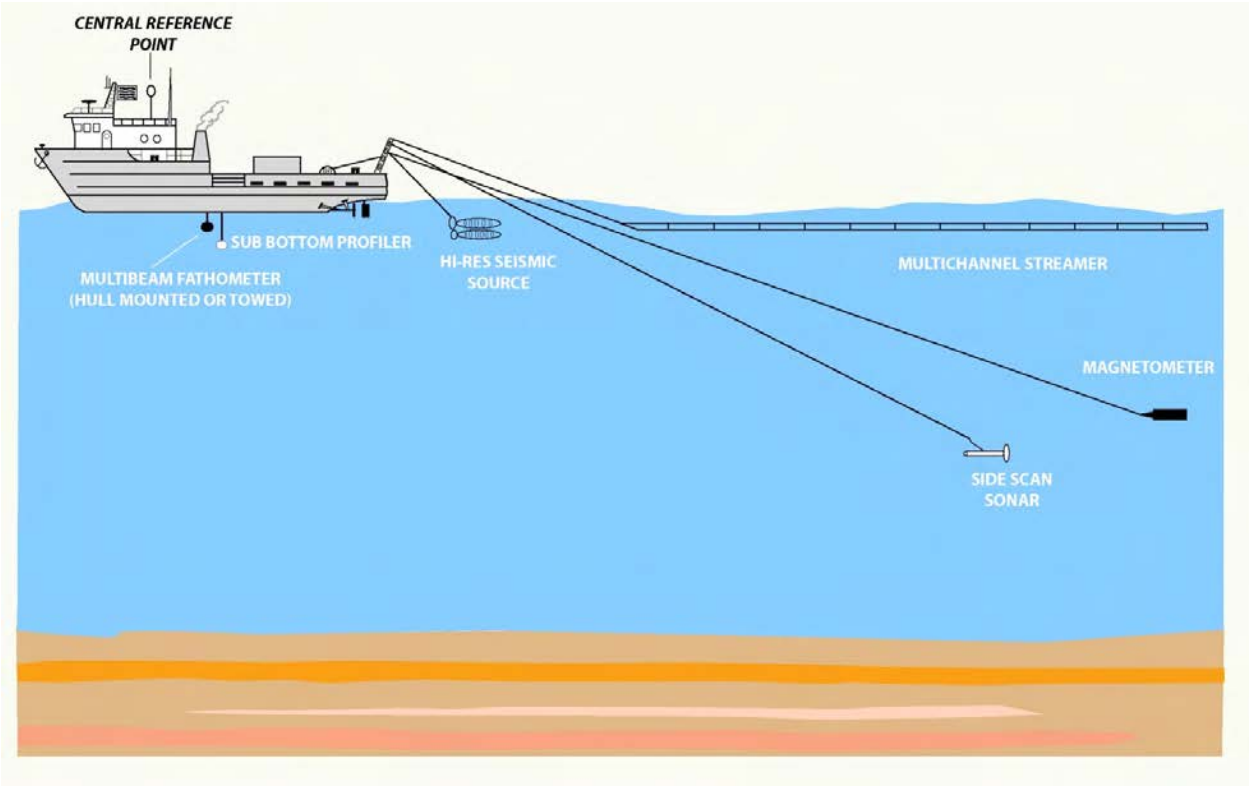


**Figure 1-5 Schematic of Site Clearance and Shallow Hazards Acquisition**

## 1.5 Equipment Recovery and Maintenance

Shell plans to conduct equipment recovery and maintenance activity at the Burger A well site in the Chukchi Sea. The equipment recovery and maintenance activity can be accomplished by one vessel operating in DP mode for extended period over the drilling site. The vessel may be resupplied during the activity by vessel or aircraft.

**Equipment Recovery and Maintenance**

Work will be conducted subsea within the mudline cellar (MLC; ~ 20 ft wide by 40 ft. deep excavation dug for the Burger A wellhead during 2012 drilling at this well site) with a suite of Remotely Operated Vehicles and divers that will recover equipment left sub-mudline on the well head during the 2012 open water drilling season. The survey vessel would be dynamically positioned at the well site for up to ~28 days while subsurface equipment recovery and maintenance occurs, however Shell anticipates this work being accomplished in less than 28 days. During this planned work scope the state and integrity of the well will not be changed since no form of entry will be made into the well.

## 1.6 Proposed Vessel and Aircraft Support to Conduct Open Water Marine Surveys

Shell plans to conduct the geophysical surveys from a single vessel, the equipment recovery and site maintenance from a second, with a possible third vessel providing logistical support. Shell plans to conduct crew change and resupply at a coastal port(s) during the season, but has allowed

for the option of using a helicopter to support the vessels. If a helicopter is used, any such helicopter flights would be infrequent.

## Vessels

Neither the vessels nor the aircraft have been selected or contracted. General descriptions of the marine vessels and aircraft proposed to be used in the geophysical surveys, equipment recovery and maintenance, are presented below. Specifications of the types of vessels that might be contracted are summarized below in Table 1-2.

Shell will contract a marine survey vessel to conduct the offshore ice gouge and site clearance and shallow hazards surveys in the Chukchi Sea in 2013. The surveys will be conducted on a 24 hr / day schedule. Specifications for the marine survey vessel are provided in Table 1-2.

Shell will contract one marine survey vessel to conduct the equipment recovery and maintenance activities in the Chukchi Sea in 2013. The activities will be conducted on a 24 hr / day schedule. Specifications for the equipment recovery and maintenance vessel are provided in Table 1-2.

**TABLE 1-2 SPECIFICATIONS OF VESSELS THAT COULD BE USED FOR THE GEOPHYSICAL SURVEYS AND EQUIPMENT RECOVERY AND MAINTENANCE**

| Specification | Offshore Ice Gouge, Site Clearance and Shallow Hazards Survey Vessel | Equipment Recovery and Maintenance Vessel |
|---|---|---|
| Length | 380.5 ft (116 m) | 380.5 ft (116 m) |
| Width | 85 ft (26 m) | 85 ft (26 m) |
| Draft | 27.5 ft (8.4 m) | 27.5 ft (8.4 m) |
| Accommodations | 82 berths | 82 berths |

## Aircraft

Though not planned for this program, a helicopter might be operated out of an onshore support base location at Barrow. The helicopter has not yet been contracted. The helicopter may be used to transport crew and haul small amounts of food, materials, equipment, and waste between the vessel and the shorebase. Shell may have a second helicopter for Search and Rescue (SAR). This aircraft would stay grounded at the shorebase location except during training drills, emergencies, and other non-routine events.

# 2. THE DATES AND DURATION OF SUCH ACTIVITY AND THE SPECIFIC GEOGRAPHIC REGION WHERE IT WILL OCCUR

**Duration of time that this application is proposed to cover**

This request for IHAA is for the period of planned operations for the 2013 open water season described below.

Shell expects that the vessels that will be used for the 2013 geophysical surveys and equipment recovery and maintenance activity will mobilize into the Chukchi Sea and will exit via the Bering Strait at or before the end of the season. In accordance with 33 CFR 151, Subpart D, any vessel coming from another Captain of the Port Zone will undergo one or more complete mid-ocean ballast water exchanges before entering U.S. waters or the Alaska Captain of the Port Zone (COTPZ) from another zone to prevent the unintentional introduction of non-native species into the Chukchi Sea.

The schedule for the activities in the Chukchi Sea will depend on ice conditions and other factors. The vessels will sail from south of the Chukchi Sea and transit through the Bering Strait into the Chukchi Sea on or after 1 July or later depending on ice conditions. The 1 July date for entry into the Chukchi Sea is in accordance with requirements in US Fish & Wildlife Service (USFWS) incidental take regulations for the Chukchi Sea. The July entry is also responsive to concerns voiced by the local communities of Wainwright and Point Lay; these communities have requested that entry into the Chukchi Sea be delayed until after the walrus and beluga whale hunts.

**TABLE 2-1 TENTATIVE SCHEDULE FOR THE 2013 GEOPHYSICAL SURVEYS EQUIPMENT RECOVERY AND MAINTENANCE IN THE CHUKCHI SEA**

| Activities | Schedule |
|---|---|
| Offshore Ice Gouge | Marine vessel surveys mid July – mid October |
| Site Clearance and Shallow Hazards | Marine vessel surveys mid July – mid October |
| Equipment Recovery and Maintenance | Marine vessel activity mid July – mid October |

Given that access to the proposed areas where Shell plans to conduct activities is dependent on ice, weather, and coordinated avoidance of potential impacts to subsistence activities, Shell has estimated a broader range of time to conduct these activities than if the activities were not constrained. For example, without any of the above constraints to conducting the proposed activities, the duration of time necessary to complete offshore ice gouge surveys could be as few as 13 days in the Chukchi Sea. Likewise, the duration of time necessary to complete site clearance and shallow hazard surveys in the Chukchi Sea could be on the order of 50+ days. However, these time estimates do not include transit between survey locations, potential stand-by time due to ice and/or weather, or crew changes and re-supply. Therefore, Shell proposes those timeframes for the respective surveys shown in Table 2-1.

# 3. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

Marine mammals that occur in the area of the planned marine survey activities belong to three taxonomic groups: odontocetes (toothed cetaceans, such as beluga whale and narwhal), mysticetes (baleen whales), and carnivora (pinnipeds and polar bears). Cetaceans and pinnipeds (except Pacific walrus) are the subject of this IHA application to NMFS. The Pacific walrus and polar bear are managed by the U.S. Fish & Wildlife Service (USFWS) are not discussed further in this application.

Marine mammal species under the jurisdiction of NMFS that are known to or may occur in the area of the planned marine survey activities include nine cetacean species and four species of pinnipeds. Three of these species, the bowhead, humpback and fin whales, are listed as "endangered" under the Endangered Species Act (ESA). The bowhead whale is more common in the area than the other two species. The fin whale is unlikely to be encountered near the planned activities, but a few sightings in the Chukchi Sea have been reported in recent years. Similarly, humpback whales are not known to regularly occur in the Chukchi Sea; however, several humpback sightings were recorded during vessel-based surveys in the Chukchi Sea in 2007 (Reiser et al. 2009a). Two species of seal (ringed seal and bearded seal) have been listed as "threatened" species under the ESA (NMFS 2012a,b). Both species are common and abundant in the Chukchi and Beaufort seas.

To avoid redundancy, we have included the required information about the species that are known to or may be present and, insofar as they are known, numbers of these species in Section 4, below.

# 4. STATUS, DISTRIBUTION AND SEASONAL DISTRIBUTION OF AFFECTED SPECIES OR STOCKS OF MARINE MAMMALS

Sections 3 and 4 are integrated here to minimize repetition.

Marine mammal species under NMFS jurisdiction most likely to occur in the area of the planned activities in the Chukchi Sea include four cetacean species (beluga, bowhead and gray whales, and harbor porpoise), and three pinniped species (ringed, bearded, and spotted seals). Densities of marine mammals in the area of operations are likely to be higher if the ice edge occurs nearby. The marine mammal species that is likely to be encountered most widely (in space and time) throughout the period of the marine surveys is ringed seal. Encounters with bowhead and gray whales are expected to be limited to particular seasons, as discussed below.

Five additional cetacean species—the narwhal, killer whale, minke whale, humpback whale, and fin whale—could occur, but each of these species is uncommon or rare in the project area and relatively few encounters with these species are expected during the planned activities. The narwhal occurs in Canadian waters and occasionally occurs in the Alaskan Beaufort Sea and the Chukchi Sea, but is considered extralimital in U.S. waters and is not expected to be encountered.

**TABLE 4-1 THE HABITAT, ABUNDANCE, AND CONSERVATION STATUS OF MARINE MAMMALS INHABITING THE AREA**

| Species | Habitat | Abundance | ESA[1] | IUCN[2] | CITES[3] |
|---|---|---|---|---|---|
| ***Odontocetes***<br>Beluga whale<br>*(Delphinapterus leucas*)<br>(Eastern Chukchi Sea Stock) | Offshore,<br>Coastal, Ice edges | 3,710[4] | Not listed | NT | – |
| **Beluga Whale**<br>*(Beaufort Sea Stock)* | Offshore,<br>Coastal, Ice edges | 39,258[5] | Not listed | NT | – |
| **Harbor Porpoise**<br>*(Phocoena phocoena)*<br>(Bering Sea Stock) | Coastal, inland waters, shallow offshore waters | 48,215[4]<br>Common (Chukchi)[6] | Not listed | LR-lc | – |
| **Killer whale**<br>*(Orcinus orca)* | Widely distributed | Uncommon | Not listed | DD | – |
| **Narwhal**<br>*(Monodon monoceros)* | Offshore, Ice edge | Rare[7] | Not listed | NT | – |
| ***Mysticetes***<br>Bowhead whale<br>*(Balaena mysticetus)* | Pack ice &<br>coastal | 10,545[8]<br>12,631[9] | Endangered | LR-lc | I |
| **Gray whale**<br>*(Eschrichtius robustus)*<br>(Eastern Pacific population) | Coastal, lagoons, shallow offshore waters | 17,500[10] | Not listed | LR-lc | I |
| **Minke whale**<br>*(Balaenoptera acutorostrata)* | Shelf, coastal | Rare | Not listed | LR-lc | I |
| **Fin whale**<br>*(Balaenoptera physalus)* | Slope, mostly pelagic | Rare | Endangered | EN | I |
| **Humpback whale**<br>*(Megaptera novaeangliae)* | Shelf, coastal | Rare | Endangered | LR-lc | I |
| **Pinnipeds**<br>Bearded seal<br>*(Erignathus barbatus)* | Pack ice, shallow offshore waters | 250,000-300,000[11]<br>155,000[12] | Threatened | LR-lc | – |
| **Spotted seal**<br>*(Phoca largha)* | Pack ice, coastal haulouts, offshore | ~141,497[13] | Arctic pop. segments not listed | DD | – |
| **Ringed seal**<br>*(Pusa hispida)* | Landfast &<br>pack ice, offshore | (Chukchi)<br>~208,000-252,000[14] | Threatened | LR-lc | – |
| **Ribbon seal**<br>*(Histriophoca fasciata)* | pack ice, offshore | 90-100,000[15] | Not Listed | DD | – |

[1] U.S. Endangered Species Act.
[2] Red List of Threatened Species (IUCN 2010), Codes for IUCN classifications: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LR = Lower Risk (nt = Near Threatened; lc = Least Concern); DD = Data Deficient
[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2004)
[4] Minimum population estimate (Allen and Angliss 2012)
[5] Beaufort Sea population (IWC 2000, Allen and Angliss 2012)
[6] Vessel-based observations from Industry activities in 2006–2010 (Hartin et al. 2011)
[7] Population in Baffin Bay and the Canadian arctic archipelago is ~60,000 (DFO 2004); very few enter the Beaufort Sea
[8] 2001 B-C-B Bowhead population estimate (Zeh and Punt 2005)
[9] 2004 B-C-B Bowhead population estimate (Koski et al. 2010)
[10] North Pacific gray whale population (Rugh 2003 *in* Keller and Gerber 2004) ; see also Rugh et al. (2005)
[11] Alaska population (MMS 1996)
[12] Beringia Distinct Population Segment (NMFS 2010a)
[13] Central and Eastern Bering Sea stock based on aerial surveys in 2007 (Allen and Angliss 2012)
[14] Eastern Chukchi Sea population (Bengtson et al. 2005)
[15] Bering Sea, (Burns 1981a)

## 4.1 Odontocetes

### (a) Beluga (Delphinapterus leucas)

The beluga whale is an arctic and subarctic species that includes several populations in Alaska and northern European waters. It has a circumpolar distribution in the Northern Hemisphere and occurs between 50º and 80ºN latitude (Reeves et al. 2002). It is distributed in seasonally ice-covered seas and migrates to warmer coastal estuaries, bays, and rivers in summer for molting (Finley 1982).

Pod structure in beluga groups appears to be along matrilineal lines, with males forming separate aggregations. Small groups are often observed traveling or resting together. Belugas often migrate in groups of 100 to 600 animals (Braham and Krogman 1977), although smaller groups are also commonly seen. The relationships between whales within groups are not known, although hunters have reported that belugas form family groups with whales of different ages traveling together (Huntington 2000).

In Alaska, beluga whales comprise five distinct stocks: Beaufort Sea, eastern Chukchi Sea, eastern Bering Sea, Bristol Bay, and Cook Inlet (O'Corry-Crowe et al. 1997). For the planned project, only the Beaufort Sea and eastern Chukchi Sea stocks may be encountered.

The most recent estimate of the ***eastern Chukchi Sea population*** is 3,710 animals (Allen and Angliss 2012). This estimate was based on surveys conducted in 1989–1991. Survey effort was concentrated on the 106 mi (171 km) long Kasegaluk Lagoon where belugas are found during the open-water season. The actual number of beluga whales recorded during the surveys was much lower. Correction factors to account for animals that were underwater and for the proportion of newborns and yearlings that were not observed due to their small size and dark coloration were used to calculate the estimate. The calculation was considered to be a minimum population estimate for the eastern Chukchi Sea stock because the surveys on which it was based did not include offshore areas where belugas are also likely to occur. This population is considered to be stable. It is assumed that beluga whales from the eastern Chukchi stock winter in the Bering Sea (Allen and Angliss 2012).

Although beluga whales are known to congregate in Kasegaluk Lagoon during summer, evidence from a small number of satellite-tagged animals suggests that some of these whales may subsequently range into the Arctic Ocean north of the Beaufort Sea. Suydam et al. (2005) put satellite tags on 23 beluga whales captured in Kasegaluk Lagoon in late June and early July 1998–2002. Five of these whales moved far into the Arctic Ocean and into the pack ice to 79–80°N latitude. These and other whales moved to areas as far as 685 mi (1,102 km) offshore between Barrow and the Mackenzie River Delta spending time in water with 90 percent ice coverage.

During aerial surveys in nearshore areas (within ~23 mi (~37 km) of the coast) in the Chukchi Sea in 2006-2010, peak beluga sighting rates were recorded in July. Lowest monthly sighting rates were recorded in September (Thomas et al. 2011). When data from the three years were pooled, beluga whale sighting rates and number of individuals were highest in the band 16-19 mi (25-30 km) offshore. However the largest single groups were sighted at locations near shore in the band within 3 mi (5 km) of the shoreline.

Beluga whales from the eastern Chukchi Sea stock are an important subsistence resource for residents of the village of Point Lay, adjacent to Kasegaluk Lagoon, and other villages in northwest Alaska. Each year, hunters from Point Lay drive belugas into the lagoon to a traditional hunting location. The belugas have been predictably sighted near the lagoon from late-June through mid- to late-July (Suydam et al. 2001). In 2007, approximately 70 belugas were also harvested at Kivalina located southeast of Point Hope.

Belugas of the eastern Chukchi Sea population could occur in the vicinity of the planned marine surveys throughout the summer months. Based on the results of satellite telemetry data at least some of this stock may also pass the project area during fall migration.

The ***Beaufort Sea population*** was estimated to contain 39,258 individuals as of 1992 (DeMaster 1995; Allen and Angliss 2012). This estimate was based on the application of a sightability correction factor of 2× to the 1992 uncorrected census of 19,629 individuals made by Harwood et al. (1996). This estimate was obtained from a partial survey of the known range of the Beaufort Sea population and may be an underestimate of the true population size. This population is not considered by NMFS to be a strategic stock although the current population trend is unknown (Allen and Angliss 2012).

Beluga whales of the Beaufort Sea stock winter in the Bering Sea, summer in the eastern Beaufort Sea, and migrate through offshore waters of western and northern Alaska (Allen and Angliss 2012). The majority of belugas in the Beaufort Sea stock migrate into the Beaufort Sea in April or May, although some whales may pass Point Barrow as early as late March and as late as July (Braham et al. 1984; Ljungblad et al. 1984; Richardson et al. 1995b). During late summer and autumn, most belugas migrate westward far offshore near the pack ice or shelf break (Frost et al. 1988; Hazard 1988; Clarke et al. 1993; Miller et al. 1999, Moore et al. 2000, Clarke et al. 2012). Beluga whales associated with the Beaufort Sea population would be most likely to occur near the planned activities during fall migration through the Chukchi Sea in October.

## (b) Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise is a small odontocete that inhabits shallow, coastal waters—temperate, subarctic, and arctic—in the Northern Hemisphere (Read 1999). Harbor porpoises occur mainly in shelf areas where they can dive to depths of at least 722 ft (220 m) and stay submerged for more than 5 minutes (Harwood and Wilson 2001) feeding on small schooling fish (Read 1999). Harbor porpoises typically occur in small groups of only a few individuals and tend to avoid vessels (Richardson et al. 1995a).

The subspecies *Phocoena phocoena vomerina* ranges from the Chukchi Sea, Pribilof Islands, Unimak Island, and the southeastern shore of Bristol Bay south to San Luis Obispo, California. Point Barrow, Alaska, is the approximate northeastern extent of their regular range (Suydam and George 1992), though there are extralimital records east to the mouth of the Mackenzie River in the Northwest Territories, Canada and recent sightings in the Beaufort Sea in the vicinity of Prudhoe Bay during surveys in 2007 and 2008 (Lyons et al. 2009).

Although separate harbor porpoise stocks for Alaska have not been identified, Alaskan harbor porpoises have been divided into three groups for management purposes. These groups include animals from southeast Alaska, Gulf of Alaska, and Bering Sea populations. Harbor porpoises present in the Chukchi Sea belong to the Bering Sea group, which includes animals from Unimak

Pass northward. Based on aerial surveys in 1999, the Bering Sea population was estimated at 66,078 animals, although this estimate is likely conservative as the surveyed area did not include known harbor porpoise range near the Pribilof Islands or waters north of Cape Newenhan (~55°N latitude; Allen and Angliss 2012). Suydam and George (1992) suggested that harbor porpoises occasionally occur in the Chukchi Sea and reported nine records of harbor porpoise in the Barrow area in 1985–1991. More recent vessel-based surveys in the Chukchi Sea found that the harbor porpoise was commonly encountered during summer and fall from 2006–2010 (Hartin et al. 2011).

Based on observations during recent industry activities, the harbor porpoise may be frequently encountered throughout the Chukchi Sea and is likely to occur in the vicinity of the planned activities.

## (c) Killer Whale (*Orcinus orca*)

Killer whales are cosmopolitan and globally fairly abundant. The killer whale is very common in temperate waters, but it also frequents the tropics and waters at high latitudes. Killer whales appear to prefer coastal areas, but are also found in deep water (Dahlheim and Heyning 1999). The greatest abundance is thought to be within 497 mi (800 km) of major continents (Mitchell 1975) and the highest densities occur in areas with abundant prey. Both resident and transient stocks have been described. These are believed to differ in several aspects of morphology, ecology, and behavior including dorsal fin shape, saddle patch shape, pod size, home range size, diet, travel routes, dive duration, and social integrity of pods (Allen and Angliss 2012).

Killer whales are known to inhabit almost all coastal waters of Alaska, extending from southeast Alaska through the Aleutian Islands to the Bering and Chukchi seas (Allen and Angliss 2012). Killer whales probably do not occur regularly in the Beaufort Sea although sightings have been reported (Lowry et al. 1987, George and Suydam 1998). George et al. (1994) reported that they and local hunters see a few killer whales at Point Barrow each year. Killer whales are more common southwest of Barrow in the southern Chukchi Sea and the Bering Sea. Based on photographic techniques, ~100 animals have been identified in the Bering Sea (ADFG 1994). Killer whales from either the North Pacific resident or transient stock could occur in the Chukchi Sea during the summer or fall. The number of killer whales likely to occur in the Chukchi Sea during the planned activity is unknown. MMOs onboard industry vessels in the Chukchi Sea recorded two killer whale sightings in 2006 and 2008 and one killer whale sighting in 2007 and 2010 (Hartin et al. 2011).

## (d) Narwhal (Monodon monoceros)

Narwhals have a discontinuous Arctic distribution (Hay and Mansfield 1989; Reeves et al. 2002). A large population inhabits Baffin Bay, West Greenland, and the eastern part of the Canadian Arctic archipelago, while much smaller numbers inhabit the Northeast Atlantic/East Greenland area. The IUCN-World Conservation Union lists the species as “near threatened” (IUCN 2010). Aerial surveys of four hunting grounds off the coast of Greenland in 2006 yielded abundance estimates between 6,024 and 8,368 individuals in each area (Heide-Jørgensen et al. 2010). Innes et al. (2002) estimated a population size of 45,358 narwhals in the Canadian Arctic although little of the area was surveyed. More recent surveys of portions of Baffin Bay in the Canadian High Arctic resulted in a total population estimate of >60,000 individuals (Richard et

al. 2010). The Alaskan Beaufort Sea is not defined as a portion of a narwhal population's range and it is considered extralimital in this region (Reeves et al. 2002). However, there are scattered records of narwhal in Alaskan waters. Thus, it is possible, but very unlikely, that individuals could be encountered in the area of the planned marine surveys in the Chukchi Sea.

## 4.2 Mysticetes

### (a) Bowhead Whale (Balaena mysticetus)

Bowhead whales only occur at high latitudes in the northern hemisphere and have a disjunct circumpolar distribution (Reeves 1980). The bowhead is one of only three whale species that spend their entire lives in the Arctic. Bowhead whales are found in four areas: the western Arctic (Bering, Chukchi, and Beaufort seas) of northeastern Russia, Alaska and northwestern Canada; the Canadian High Arctic and West Greenland (Nunavut, Baffin Bay, Davis Strait, and Hudson Bay); the Okhotsk Sea (eastern Russia); and the Northeast Atlantic from Spitzbergen westward to eastern Greenland. Those four stocks are recognized for management purposes. The largest is the Western Arctic or Bering–Chukchi–Beaufort (BCB) stock, which includes whales that winter in the Bering Sea, and migrate through the Bering Strait, Chukchi Sea, and Alaskan Beaufort Sea to the Canadian Beaufort Sea, where they feed during the summer. These whales migrate west through the Alaskan Beaufort Sea in the fall as they return to wintering areas in the Bering Sea. Satellite tracking data reported by the Alaska Department of Fish and Game (ADF&G) indicate that most bowhead whales continue migrating west past Barrow and through the northern Chukchi Sea to Russian waters before turning south toward the Bering Sea. Visual and satellite tracking data show that many bowhead whales continue migrating west past Barrow and through the northern Chukchi Sea to Russian waters before turning southeast toward the Bering Sea (Moore et al. 1995; Mate et al. 2000; Quakenbush et al. 2010). Some bowheads reach ~75ºN latitude during the westward fall migration (Quakenbush et al. 2010).

The pre-exploitation population of bowhead whales in the Bering, Chukchi, and Beaufort seas is estimated to have been 10,400-23,000 whales. Commercial whaling activities in the late-1800s and early-1900s may have reduced this population to as few as 3,000 animals (Woodby and Botkin 1993). Up to the early 1990s, the population size was believed to be increasing at a rate of about 3.2 percent per year (Zeh et al. 1996) despite annual subsistence harvests of 14–74 bowheads from 1973 to 1997 (Suydam et al. 1995). A census in 2001 yielded an estimated annual population growth rate of 3.4 percent (95 percent confidence interval, 1.7–5 percent) from 1978 to 2001 and a population size (in 2001) of ~10,470 animals (George et al. 2004, revised to 10,545 by Zeh and Punt (2005). A photo identification population estimate from data collected in 2004 estimated the population (in 2004) to be 12,631 (Koski et al. 2010), which further supports the estimated 3.4 percent population growth rate. Assuming a continuing annual population growth of 3.4 percent, the 2013 bowhead population may number around 15,750 animals. The large increases in population estimates that occurred from the late 1970s to the early 1990s were partly a result of actual population growth, but were also partly attributable to improved census techniques (Zeh et al. 1993). Although apparently recovering well, the BCB bowhead population is currently listed as endangered under the ESA and is classified as a strategic stock by NMFS and depleted under the MMPA (Allen and Angliss 2012).

The BCB stock of bowhead whales winters in the central and western Bering Sea and many of these whales summer in the Canadian Beaufort Sea (Moore and Reeves 1993). Spring migration

through the Chukchi Sea occurs through offshore ice leads, generally from March through mid-June (Braham et al. 1984; Moore and Reeves 1993), well before the onset of the planned marine survey activities.

Some bowheads arrive in coastal areas of the eastern Canadian Beaufort Sea and Amundsen Gulf in late May and June, but most may remain among the offshore pack ice of the Beaufort Sea until mid- summer. After feeding primarily in the Canadian Beaufort Sea and Amundsen Gulf, bowheads migrate westward from late August through mid- or late-October. Fall migration into Alaskan waters is primarily during September and October. However, small numbers of bowheads have been seen or heard offshore from the Prudhoe Bay region during the later half of August (Treacy 1993; LGL and Greeneridge 1996; Greene 1997; Greene et al. 1999; Blackwell et al. 2004, 2009a; Greene et al. 2007). Satellite tracking of bowheads has also shown that some whales move to the Chukchi Sea prior to September (Quakenbush 2010).

Bowheads commonly interrupt their migration to feed along the Alaskan Beaufort Sea coast (Ljungblad et al. 1986; Lowry 1993; Landino et al. 1994; Würsig et al. 2002; Lowry et al. 2004) and their stopovers vary in duration from a few hours to a few weeks (Koski et al. 2002). The nearest of these known feeding areas to the proposed marine surveys in the Chukchi Sea is just east of Pt. Barrow, which is approximately 250 km from the Burger prospect.

Westbound bowheads typically reach the Barrow area in mid-September, and remain there until late October (*e.g.*, Brower 1996). However, over the years, local residents report having seen a small number of bowhead whales feeding off Barrow or in the pack ice off Barrow during the summer. Bowhead whales that are thought to be part of the Western Arctic stock may also occur in small numbers in the Bering and Chukchi seas during the summer (Rugh et al. 2003). Thomas et al. (2009) also reported bowhead sightings in 2006 and 2007 during summer aerial surveys in the Chukchi Sea. All sightings were recorded in the northern portion of the study area, north of 70ºN latitude. Autumn bowhead whaling near Barrow normally begins in mid-September to early October, but may begin as early as August if whales are observed and ice conditions are favorable (USDI/BLM 2005). Whaling near Barrow can continue into October, depending on the quota and conditions.

Most spring-migrating bowhead whales would likely pass through the Chukchi Sea prior to the start of the planned marine survey activities. However, a few whales that may remain in the Chukchi Sea during the summer could be encountered during the marine survey activities or by transiting vessels. More encounters with bowhead whales would be likely to occur during the westward fall migration in late September through October. An ongoing GPS tagging study (Quakenbush et al. 2010) has provided information on fall bowhead movements across the Chukchi Sea. Most bowheads migrating in September and October appear to transit across the northern portion of the Chukchi Sea to the Chukotka coast before heading south toward the Bering Sea (Quakenbush et al. 2009). Some of these whales have traveled well north of the planned operations, but others have passed near to, or through, the proposed project area. In addition to other planned mitigation, Shell will operate in consultation with stakeholders to avoid disturbance to subsistence bowhead whaling activities in the Chukchi Sea, should such a subsistence bowhead hunt occur during the period of Shell's planned activities.

## (b) Gray Whale (Eschrichtius robustus)

Gray whales originally inhabited both the North Atlantic and North Pacific oceans. The Atlantic populations are believed to have become extinct by the early 1700s. There are two populations in the North Pacific. A relic population, which survives in the Western Pacific, summers near Sakhalin Island far from the area of the planned marine survey activities. The larger eastern Pacific or California gray whale population recovered significantly from commercial whaling during its protection under the MMPA (and ESA until 1994) and numbered about 29,758 ±3,122 in 1997 (Rugh et al. 2005). However, abundance estimates since 1997 indicate a consistent decline followed by the population stabilizing or gradually recovering. Rugh et al. (2005) estimated the population to be 18,178 ±1,780 in winter 2001-2002 and Rugh et al. (2008) estimated the population in winter 2006-2007 to have been 20,110 ±1,766. The eastern Pacific stock is not considered by NMFS to be endangered or to be a strategic stock.

Eastern Pacific gray whales calve in the protected waters along the west coast of Baja California and the east coast of the Gulf of California from January to April (Swartz and Jones 1981; Jones and Swartz 1984). At the end of the calving season, most of these gray whales migrate about 5,000 mi (8,000 km), generally along the west coast of North America, to the main summer feeding grounds in the northern Bering and Chukchi seas (Tomilin 1957, Rice and Wolman 1971, Nerini 1984, Moore et al. 2003, Bluhm et al. 2007). Most gray whales begin the southward migration in November with breeding and conception occurring in early December (Rice and Wolman 1971).

Most summering gray whales have historically congregated in the northern Bering Sea, particularly off St. Lawrence Island in the Chirikov Basin (Moore et al. 2000), and in the southern Chukchi Sea. More recently, Moore et al. (2003) suggested that gray whale use of Chirikov Basin has decreased, likely as a result of the combined effects of changing currents resulting in altered secondary productivity dominated by lower-quality food. Coyle et al. (2007) noted that amplescid amphipod production in the Chirikov Basin had declined by 50 percent from the 1980s to 2002-2003 and that as little as 3-6 percent of the current gray whale population could consume 10-20 percent of the amplescid amphipod annual production. These data support the hypotheses that changes in gray whale distribution may be caused by changes in food production and that gray whales may be approaching or have surpassed the carrying capacity of their summer feeding areas. Bluhm et al. (2007) noted high gray whale densities along ocean fronts and suggested that ocean fronts may play an important role in influencing prey densities in eastern North Pacific gray whale foraging areas. The northeastern-most of the recurring feeding areas is in the northeastern Chukchi Sea southwest of Barrow (Clarke et al. 1989).

Gray whales routinely feed in the Chukchi Sea during the summer. Moore et al. (2000) reported that during the summer, gray whales in the Chukchi Sea were clustered along the shore primarily between Cape Lisburne and Point Barrow and were associated with shallow, coastal shoal habitat. In autumn, gray whales were clustered near shore at Point Hope and between Icy Cape and Point Barrow, as well as in offshore waters southwest of Point Barrow at Hanna Shoal and northwest of Point Hope. The distribution of grays was different during aerial surveys in the Chukchi Sea in 2006 than in and 2007-2008 and 2010 (Thomas et al. 2011). In 2006, gray whales were most abundant along the coast south of Wainwright and offshore of Wainwright (Thomas et al. 2011). In the following years, gray whales were most abundant in nearshore areas from Wainwright to Barrow (Thomas et al. 2011). Gray whales occur fairly often near Point

Barrow, however historically only a small number of gray whales have been sighted in the Beaufort Sea east of Point Barrow.

Although they are most common in portions of the Chukchi Sea close to shore, gray whales may also occur in offshore areas of the Chukchi Sea, particularly over offshore shoals. Gray whales are likely to be in the vicinity of the planned activities in the Chukchi Sea and are likely to be one of the most commonly encountered cetacean species, along with the harbor porpoise (Hartin et al. 2011).

## (c) Minke Whale (Balaenoptera acutorostrata)

Minke whales have a cosmopolitan distribution at ice-free latitudes (Stewart and Leatherwood 1985), and also occur in some marginal ice areas. Allen and Angliss (2012) recognize two minke whale stocks in U.S. waters: (1) the Alaska stock, and (2) the California/Oregon/ Washington stock. There is no abundance estimate for the Alaska stock. Provisional estimates of minke whale abundance based on surveys in 1999 and 2000 are 810 and 1003 whales in the central-eastern and south-eastern Bering Sea, respectively. These estimates have not been corrected for animals that may have been submerged or otherwise missed during the surveys, and only a portion of the range of the Alaskan stock was surveyed. Minke whales range into the Chukchi Sea, but the level of minke whale use of the Chukchi Sea is unknown. Minke whales have been observed from vessels during previous industry activities in the Chukchi Sea (Hartin et al. 2011) and during aerial surveys conducted by the NMML (COMIDA 2011).

## (d) Fin Whale (Balaenoptera physalus)

Fin whales are widely distributed in all the world's oceans (Gambell 1985), but typically occur in temperate and polar regions. Fin whales feed in northern latitudes during the summer where their prey include plankton, as well as shoaling pelagic fish, such as capelin *Mallotus villosus* (Jonsgård 1966a,b). The North Pacific population's summering grounds span from the Chukchi Sea to California (Gambell 1985). Three fin whale sightings were made in 2008 from industry vessels and NMFS/National Marine Mammal Laboratory (NMML) survey aircraft in the northern Chukchi Sea off of Ledyard Bay indicating that the range of fin whales may be expanding. Population estimates for the entire North Pacific region range from 14,620 to 18,630, however, reliable estimates are not available (Allen and Angliss 2012). Provisional estimates of fin whale abundance in the central-eastern and southeastern Bering Sea are 3,368 and 683, respectively. No estimates for fin whale abundance during the summer in the Chukchi Sea are available. Reiser et al. (2009a) reported a fin whale sighting during vessel-based surveys in the southern Chukchi Sea in 2006, and Hartin et al (2011) reported three sightings in 2008. Fin whale is listed as "endangered" under the ESA and by the IUCN (2010), and in the North Pacific is classified as a strategic stock by NMFS. Fin whales could be encountered in very low numbers during the marine survey activities in the Chukchi Sea.

## (e) Humpback Whale (Megaptera novaeangliae)

Humpback whales are distributed in major oceans worldwide but are apparently absent from Arctic waters of the North Pacific (Allen and Angliss 2012). In general, humpback whales spend

the winter in tropical and sub-tropical waters where breeding and calving occur, and migrate to higher latitudes for feeding during the summer.

Humpback whales were hunted extensively during the 20th century and worldwide populations may have been reduced to ~10 percent of their original numbers. The International Whaling Commission banned commercial hunting of humpback whales in the Pacific Ocean in 1965 and humpbacks were listed as "endangered" under the ESA and depleted under the MMPA in 1973. Most humpback whale populations appear to be recovering well.

Humpbacks feed on euphausiids, copepods, and small schooling fish, notably herring, capelin, and sandlance (Reeves et al. 2002). As with other baleen whales, the food is trapped or filtered when large amounts of water are taken into the mouth and forced out through the baleen plates. Individual humpback whales can often be identified by distinctive patterns on the tail flukes. They are frequently observed breaching or engaged in other surface activities.

Allen and Angliss (2012) reported that at least three humpback whale populations have been identified in the North Pacific. Two of these stocks may be relevant to the planned marine survey activities in the Chukchi Sea. The Central North Pacific stock winters in waters near Hawaii and migrates to British Columbia, Southeast Alaska, and Prince William Sound to Unimak Pass to feed during the summer. The Western North Pacific stock winters off the coast of Japan and probably migrates to the Bering Sea to feed during the summer. There may be some overlap between the Central and Western North Pacific stocks.

Humpback whale sightings in the Bering Sea have been recorded southwest of St. Lawrence Island, the southeastern Bering Sea, and north of the central Aleutian Islands (Moore et al. 2002, Allen and Angliss 2012). Recently there have been sightings of humpback whales in the Chukchi Sea and a single sighting in the Beaufort Sea (Green et al. 2007). Hartin et al. (2011) reported four humpback whales during vessel-based surveys in the Chukchi Sea in 2007, 2 in 2008, and one in 2010. Green et al. (2007) reported and photographed a humpback whale cow/calf pair east of Barrow near Smith Bay in 2007. Small numbers of humpback whales could occur within or near the marine survey activities in the Chukchi Sea or Beaufort Sea.

## 4.3 Pinnipeds

### (a) Bearded Seal (*Erignathus barbatus*)

Bearded seals are associated with sea ice and have a circumpolar distribution (Burns 1981b). In Alaskan waters, bearded seals occur over the continental shelves of the Bering, Chukchi, and Beaufort Seas (Burns 1981b). No reliable estimate of bearded seal abundance is available for the Chukchi Sea (Allen and Angliss 2012); although the Alaska stock of bearded seals is estimated to be about 155,000 (Beringia DPS, Cameron et al. 2010). The Alaska stock of bearded seals, part of the Beringia distinct population segment, has been listed by NMFS as threatened under the ESA (NMFS 2012a).

Bearded seals are primarily benthic feeders, preferring a variety of infaunal and epifaunal invertebrates as well as occasional demersal fishes (Bluhm and Gradinger 2008). They apparently also feed on ice-associated organisms when they are present, and this allows a few bearded seals to live in areas where water depth is considerably greater than 656 ft (200 m)

(Cameron et al. 2009). During the summer period, bearded seals occur mainly in relatively shallow areas because they are predominantly benthic feeders (Burns 1981b).

Seasonal movements of bearded seals are directly related to the advance and retreat of sea ice and to water depth (Kelly 1988). During winter, most bearded seals in Alaskan waters are found in the Bering Sea. In the Chukchi and Beaufort seas, favorable conditions are more limited, and consequently, bearded seals are less abundant there during winter; although they have occasionally been reported to maintain breathing holes in sea ice and broken areas within the pack ice, particularly if the water depth is <200 m [<656 ft] (*e.g.*, Harwood et al. 2005). From mid-April to June as the ice recedes, some of the bearded seals that overwintered in the Bering Sea migrate northward through the Bering Strait. During the summer they are found near the widely fragmented margin of sea ice covering the continental shelf of the Chukchi Sea and in nearshore areas of the central and western Beaufort Sea.

Bengtson et al. (2005) reported bearded seal densities in the Chukchi Sea ranging from 0.18 to 0.36 seals/square miles ($mi^2$) (0.07 to 0.14 seals/square kilometers [$km^2$]) in 1999 and 2000, respectively. No population estimates could be calculated since these densities were not adjusted for haulout behavior. Bearded seals are common in offshore pack ice, but there have been high bearded seal numbers observed near the shore south of the project area near Kivalina. Hartin et al. (2011) reported bearded seal densities ranging from 0.03 to 0.23 seals/$mi^2$ (0.01 to 0.09 seals/$km^2$) in the summer and fall, respectively, during vessel-based surveys in the Chukchi Sea. These densities were lower than those reported by Bengtson et al. (2005) but are not directly comparable since the latter densities were based on aerial surveys of seals on sea ice in late May and early June. Bearded seals are likely to be encountered during planned activities, and greater numbers of bearded seals are likely to be encountered if the ice edge occurs nearby.

## (b) Spotted Seal (*Phoca largha*)

Spotted seals (also known as largha seals) occur in the Beaufort, Chukchi, Bering, and Okhotsk Seas, and south to the northern Yellow Sea and western Sea of Japan (Shaughnessy and Fay 1977). They migrate south from the Chukchi Sea and through the Bering Sea in October (Lowry et al. 1998). Spotted seals overwinter in the Bering Sea and inhabit the southern margin of the ice during spring (Shaughnessy and Fay 1977).

An early estimate of the size of the world population of spotted seals was 370,000–420,000, and the size of the Bering Sea population, including animals in Russian waters, was estimated to be 200,000–250,000 animals (Bigg 1981). During the summer, spotted seals are found in Alaska from Bristol Bay through western Alaska to the Chukchi and Beaufort seas. The total number of spotted seals in Alaskan waters is not known (Allen and Angliss 2012), but based on aerial surveys conducted in 2007, Allen and Angliss (2012) estimate the Alaskan population at 141,479 animals. The Alaska stock of spotted seals is not classified as endangered, threatened, or as a strategic stock by NMFS (Allen and Angliss 2012), although the southern distinct population segment of spotted seals was recently listed as a threatened species, it occurs entirely outside of U.S. waters.

During spring when pupping, breeding, and molting occur, spotted seals are found along the southern edge of the sea ice in the Okhotsk and Bering seas (Quakenbush 1988; Rugh et al. 1997). In late April and early May, adult spotted seals are often seen on the ice in female-pup or male-female pairs, or in male-female-pup triads. Subadults may be seen in larger groups of up to

200 animals. During the summer, spotted seals are found primarily in the Bering and Chukchi seas, but some range into the Beaufort Sea (Rugh et al. 1997; Lowry et al. 1998) from July until September. At this time of year, spotted seals haul out on land part of the time, but also spend extended periods at sea. Spotted seals are commonly seen in bays, lagoons and estuaries, but also range far offshore as far north as 69–72ºN latitude. In summer, they are rarely seen on the pack ice, except when the ice is very near shore. As the ice cover thickens with the onset of winter, spotted seals leave the northern portions of their range and move into the Bering Sea (Lowry et al. 1998).

In the Chukchi Sea, Kasegaluk Lagoon and Icy Cape are important areas for spotted seals. Spotted seals haul out in this region from mid-July until freeze-up in late October or November. Lowry et al. (1998) reported a maximum count of about 2,200 spotted seals in the lagoon during aerial surveys. No spotted seals were recorded along the shore south of Pt. Lay. Based on satellite tracking data, Lowry et al. (1994) reported that spotted seals tagged at Kasegaluk Lagoon spent 94 percent of the time at sea. Extrapolating the count of hauled-out seals to account for seals at sea would suggest a Chukchi Sea population of about 36,000 animals. Few spotted seals are expected to occur near the planned activities in the Chukchi Sea.

## (c) Ringed Seal (*Phoca hispida*)

Ringed seals have a circumpolar distribution and occur in all seas of the Arctic Ocean (King 1983). They are closely associated with ice and, in the summer, they often occur along the receding ice edges or farther north in the pack ice. In the North Pacific, they occur in the southern Bering Sea and range south to the seas of Okhotsk and Japan. They are found throughout the Beaufort, Chukchi, and Bering seas (Allen and Angliss 2012). The Alaska stock, part of the Arctic subspecies of ringed seal, has been listed as threatened under the ESA (NMFS 2012b).

Ringed seals are year-round residents in the Chukchi and Beaufort seas and the ringed seal is the most frequently encountered seal species in the area. During winter, ringed seals occupy landfast ice and offshore pack ice of the Bering, Chukchi and Beaufort seas. In winter and spring, the highest densities of ringed seals are found on stable shorefast ice. However, in some areas where there is limited fast ice but wide expanses of pack ice, including the Beaufort Sea, Chukchi Sea and Baffin Bay, total numbers of ringed seals on pack ice may exceed those on shorefast ice (Burns 1970, Stirling et al. 1982, Finley et al. 1983). Ringed seals maintain breathing holes in the ice and occupy lairs in accumulated snow (Smith and Stirling 1975). They give birth in lairs from mid-March through April, nurse their pups in the lairs for 5–8 weeks, and mate in late April and May (Smith 1973, Hammill et al. 1991, Lydersen and Hammill 1993).

No estimate for the size of the Alaska ringed seal stock is currently available (Allen and Angliss 2012). In the past, ringed seal population estimates in the Bering-Chukchi-Beaufort area ranged from 1–1.5 million (Frost 1985) to 3.3–3.6 million (Frost et al. 1988). During aerial surveys in 1999, Bengtson et al. (2005) reported ringed seal densities offshore from Shishmaref to Barrow ranging from 1.0 to 9.6 seals/mi$^2$ (0.4 to 3.7 seals/km$^2$) and estimated the total Chukchi Sea population at 245,048 animals in 1999. Densities were higher in nearshore than offshore locations. During vessel-based observations from industry activities in the Chukchi Sea, Hartin et al. (2011) reported seal densities (assumed to be primarily ringed seals) from 0.125 to 2.1

seals/mi$^2$ (0.048 to 0.807 seals/km$^2$). Ringed seal will likely be the most abundant marine mammal species encountered in the Chukchi Sea during the planned activities.

### (d) Ribbon Seal (Histriophoca fasciata)

Ribbon seals are found along the pack-ice margin in the southern Bering Sea during late winter and early spring and they move north as the pack ice recedes during late spring to early summer (Burns 1970, Burns et al. 1981a). Little is known about their summer and fall distribution, but Kelly (1988) suggested that they move into the southern Chukchi Sea, based on a review of sightings during the summer. However, ribbon seals appeared to be relatively rare in the northern Chukchi Sea. During recent vessel-based surveys in 2006-2010 there were only seven ribbon seal sightings in the Chukchi Sea among the total of 4,063 seal sightings identified to species (Hartin et al. 2011). Ribbon seals are expected to be rare in the planned project areas.

## 5. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

Shell requests an IHA pursuant to Section 101(a)(5)(D) of the MMPA for incidental take by harassment of small numbers of cetaceans and pinnipeds during its planned open-water marine survey activities in the Chukchi sea during July–October, 2013.

The operations outlined in sections 1 and 2 have the potential to take marine mammals by "Level B" harassment as a result of sound energy introduced to the marine environment. Sounds that may "harass" marine mammals may include pulsed sounds from the site clearance and shallow hazards survey airgun cluster and possibly continuous sounds generated by vessels using dynamic positioning thrusters while conducting equipment recovery and maintenance at the Burger A well site. The effects will depend on the species of cetacean or pinniped, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see section 7). Disturbance reactions are likely to vary among some of the marine mammals in the general vicinity of the sound source. No "take" by serious injury is reasonably expected or reasonably likely, given the nature of the specified activities and the mitigation measures that are planned (see Section 11). No lethal takes are expected.

## 6. NUMBERS OF MARINE MAMMALS THAT MAY BE TAKEN

Shell seeks authorization for potential "taking" of small numbers of marine mammals under the jurisdiction of the NMFS in the planned areas of activity. Species most likely to be encountered include bowhead and gray whales, beluga, harbor porpoise, and ringed, spotted, and bearded seals. Exposure estimates and requests for takes of ribbon seal, fin whale, humpback whale, killer whale, minke whale, and narwhal are also included, but are minimal because sightings of these species in the Chukchi Sea are rare.

The only anticipated impacts to marine mammals are associated with underwater sound propagation from the site clearance and shallow hazards survey airguns and dynamic positioning thrusters on the vessels conducting equipment recovery and maintenance at the Burger A well site. Impacts may consist of temporary displacement of marine mammals from within ensonified zones produced by the airguns or vessel thrusters.

The activities in the Chukchi Sea planned by Shell are not expected to "take" more than small numbers of marine mammals, or have more than a negligible effect on their populations. Discussions of estimated "takes by harassment" are presented below.

All anticipated takes would be "takes by harassment" involving temporary changes in behavior. In the sections below, we describe the methods used to estimate "take by harassment" and present estimates of the numbers of marine mammals that might be affected during the planned marine survey program in the Chukchi Sea. The estimates are based on data obtained during marine mammal surveys in or near the planned survey areas and on estimates of the sizes of the areas where effects could potentially occur. Adjustments to reported population or density estimates were made to account for seasonal distributions and population increases or declines insofar as possible.

The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection. There is some uncertainty about the representativeness of those data and the assumptions used below to estimate the potential "take by harassment". However, the approach used here is the best available at this time.

## Basis for Estimating "Take by Harassment"

"Take by Harassment" is calculated in this section by multiplying the expected densities of marine mammals that may occur near the planned activities by the area of water likely to be exposed to pulsed sound levels of ≥160 dB re 1 μPa (rms) and continuous sound levels ≥120 dB re 1 μPa (rms).

Marine mammal occurrence near the operation is likely to vary by season and habitat, mostly related to the presence or absence of sea ice. This section provides descriptions of the estimated densities of marine mammals and areas of water exposed to pulsed sounds ≥160 dB and non-pulse sounds ≥120 dB over the course of the planned operations. There is no evidence that avoidance at these received sound levels would have significant biological effects on individual animals or that the subtle changes in behavior or movements would "rise to the level of taking" according to guidance by the NMFS (NMFS 2001). Any changes in behavior caused by sounds at or near the specified received levels would likely fall within the normal variation in such activities that would occur in the absence of the planned operations.

## Marine Mammal Density Estimates

Marine mammal density estimates in the Chukchi Sea have been derived for two time periods, the summer period covering July and August, and the fall period including September and October. Animal densities encountered in the Chukchi Sea during both of these time periods will further depend on the habitat zone within which the operations are occurring: open water or ice margin. Vessel and equipment limitations will result in very little activity occurring in or near sea ice; however, if ice is present near the areas of activity some sounds produced by the activities may remain above disturbance threshold levels in ice margin habitats. Therefore, open water densities have been used to estimate potential "take by harassment" in 90 percent of the area expected to be ensonified above disturbance thresholds while ice margin densities have been used in the remaining 10 percent of the ensonified area.

As noted above, there is some uncertainty about the representativeness of the data and assumptions used in the calculations. To provide some allowance for the uncertainties,

"maximum estimates" as well as "average estimates" of the numbers of marine mammals potentially affected have been derived. For a few marine mammal species, several density estimates were available. In those cases, the mean and maximum estimates were determined from the reported densities or survey data. In other cases, no applicable estimate (or perhaps a single estimate) was available, so correction factors were used to arrive at "average" and "maximum" estimates. These are described in detail in the following sections.

Detectability bias, quantified in part by *f*(0), is associated with diminishing sightability with increasing lateral distance from the survey trackline. Availability bias, *g*(0), refers to the fact that there is <100 percent probability of sighting an animal that is present along the survey trackline. Some sources below included these correction factors in the reported densities (*e.g.*, ringed seals in Bengtson et al. 2005) and the best available correction factors were applied to reported results when they had not already been included (*e.g.*, Clarke and Ferguson *in prep*).

## Cetaceans

Nine species of cetaceans are known to occur in the planned project area in the Chukchi Sea. Only four of these (bowhead and gray whales, beluga, and harbor porpoise) are expected to be encountered during the planned activities. Three of the nine species (bowhead, fin, and humpback whales) are listed as "endangered" under the ESA.

Summer densities of ***belugas*** in offshore waters are expected to be low, with somewhat higher densities in ice-margin and nearshore areas. Aerial surveys have recorded few belugas in the offshore Chukchi Sea during the summer months (Moore et al. 2000). Aerial surveys of the Chukchi Sea in 2008-2009 flown by the NMML as part of the Chukchi Offshore Monitoring in Drilling Area (COMIDA) project have only reported 5 beluga sightings during >8,700 mi (>14,000 km) of on-transect effort, only 2 of which were offshore (COMIDA 2009). One of the three nearshore sightings was of a large group (~275 individuals on July 12, 2009) of migrating belugas along the coastline just north of Peard Bay. Additionally, only one beluga sighting was recorded during >49,710 mi (>80,000 km) of visual effort during good visibility conditions from industry vessels operating in the Chukchi Sea in September-October of 2006-2010 (Hartin et al. 2011). If belugas are present during the summer, they are more likely to occur in or near the ice edge or close to shore during their northward migration. Expected densities have previously been calculated from data in Moore et al. (2000). However, more recent data from COMIDA aerial surveys during 2008-2010 are now available (Clarke and Ferguson *in prep.*). Effort and sightings reported by Clarke and Ferguson (*in prep.*) were used to calculate the average open-water density estimate. Clarke and Ferguson (*in prep*) reported two on-transect beluga sightings (5 individuals) during 11,985 km of on-transect effort in waters 36-50 m deep in the Chukchi Sea during July and August. The mean group size of these two sightings is 2.5. A *f(0)* value of 2.841 and *g(0)* value of 0.58 from Harwood et al. (1996) were also used in the density calculation. The CV associated with group size was used to select an inflation factor of 2 to estimate the maximum density that may occur in both open-water and ice-margin habitats. Specific data on the relative abundance of beluga in open-water versus ice-margin habitat during the summer in the Chukchi Sea is not available. However, belugas are commonly associated with ice, so an inflation factor of 4 was used to estimate the average ice-margin density from the open-water density. Very low densities observed from vessels operating in the Chukchi Sea during non-seismic periods and locations in July-August of 2006-2010 (0.0-0.0003/mi$^2$, 0.0-

0.0001/km$^2$; Hartin et al. 2011), also suggest the number of beluga whales likely to be present near the planned activities will not be large.

In the fall, beluga whale densities offshore in the Chukchi Sea are expected to be somewhat higher than in the summer because individuals of the eastern Chukchi Sea stock and the Beaufort Sea stock will be migrating south to their wintering grounds in the Bering Sea (Allen and Angliss 2012). Densities derived from survey results in the northern Chukchi Sea in Clarke and Ferguson (*in prep*) were used as the average density for open-water fall season estimates (see Table 6-2). Clarke and Ferguson (*in prep*) reported 3 beluga sightings (6 individuals) during 10,036 km of on-transect effort in water depths 36–50 m. The mean group size of those three sightings is 2. A *f(0)* value of 2.841 and *g(0)* value of 0.58 from Harwood et al. (1996) were used in the calculation. The same inflation factor of 2 used for summer densities was used to estimate the maximum density that may occur in both open-water and ice-margin habitats in the fall. Moore et al. (2000) reported lower than expected beluga sighting rates in open-water during fall surveys in the Beaufort and Chukchi seas, so an inflation value of 4 was used to estimate the average ice-margin density from the open-water density. Based on the few beluga sightings from vessels operating in the Chukchi Sea during non-seismic periods and locations in September-November of 2006-2010 (Hartin et al. 2011), the relatively low densities shown in Table 6-2 are consistent with what is likely to be observed form vessels during the planned operations.

By July, most ***bowhead whales*** are northeast of the Chukchi Sea, within or migrating toward their summer feeding grounds in the eastern Beaufort Sea. No bowheads were reported during 6,640 mi (10,686 km) of on-transect effort in the Chukchi Sea by Moore et al. (2000). Aerial surveys in 2008-2010 by the NMML as part of the COMIDA project reported only 6 sightings during >16,020 mi (>25,781 km) of on-transect effort (Clarke and Ferguson *in prep*). Two of the six sightings were in waters ≤35 m deep and the remaining four sightings were in waters 51-200 m deep. Bowhead whales were also rarely sighted in July-August of 2006-2010 during aerial surveys of the Chukchi Sea coast (Thomas et al. 2011). This is consistent with movements of tagged whales (see ADFG 2010), all of which moved through the Chukchi Sea by early May 2009, and tended to travel relatively close to shore, especially in the northern Chukchi Sea. The estimate of bowhead whale density in the Chukchi Sea was calculated by assuming there was one bowhead sighting during the 7,447 mi (11,985 km) of survey effort in waters 36-50 m deep in the Chukchi Sea during July-August reported in Clarke and Ferguson (*in prep*), although no bowheads were actually observed during those surveys. The mean group size from September–October sightings reported in Clarke and Ferguson (*in prep*) is 1.1, and this was also used in the calculation of summer densities. The group size value, along with a *f(0)* value of 2 and a *g(0)* value of 0.07, both from Thomas et al. (2002) were used to estimate a summer density of bowhead whales (Table 6-1). The CV of group size and standard errors reported in Thomas et al (2002) for *f(0)* and *g(0)* correction factors suggest that an inflation factor of 2 is appropriate for estimating the maximum density from the average density. Bowheads are not expected to be encountered in higher densities near ice in the summer (Moore et al. 2000), so the same density estimates are used for open-water and ice-margin habitats. Densities from vessel based surveys in the Chukchi Sea during non-seismic periods and locations in July-August of 2006-2010 (Hartin et al. 2011) ranged from 0.0005-0.0021/mi$^2$ (0.0002-0.0008/km$^2$) with a maximum 95 percent confidence interval (CI) of 0.0221/mi$^2$ (0.0085/km$^2$). This suggests the densities used in the calculations and shown in Table 6-1 are similar to what are likely to be observed from vessels near the areas of planned operations.

During the fall, bowhead whales that summered in the Beaufort Sea and Amundsen Gulf migrate west and south to their wintering grounds in the Bering Sea making it more likely that bowheads will be encountered in the Chukchi Sea at this time of year. Moore et al. (2000; Table 8) reported 34 bowhead sightings during 27,560 mi (44,354 km) of on-transect survey effort in the Chukchi Sea during September-October. Thomas et al. (2011) also reported increased sightings on coastal surveys of the Chukchi Sea during October and November of 2006-2010. GPS tagging of bowheads appear to show that migration routes through Chukchi Sea are more variable than through the Beaufort Sea (Quakenbush et al. 2010). Some of the routes taken by bowheads remain well north of the planned marine survey activities while others have passed near to or through the area. Kernel densities estimated from GPS locations of whales suggest that bowheads do not spend much time (*e.g.,* feeding or resting) in the north-central Chukchi Sea near the area of planned activities (Quakenbush et al. 2010). Clarke and Ferguson (*in prep*) reported 14 sightings (15 individuals) during 10,036 km of on transect aerial survey effort in 2008-2010. The mean group size of those sightings is 1.1. The same *f(0)* and *g(0)* values that were used for the summer estimates above were used for the fall estimates (Table 6-2). As with the summer estimates, an inflation factor of 2 was used to estimate the maximum density from the average density in both habitat types. Moore et al. (2000) found that bowheads were detected more often than expected in association with ice in the Chukchi Sea in September-October, so a density of twice the average open-water density was used as the average ice-margin density. Densities from vessel based surveys in the Chukchi Sea during non-seismic periods and locations in September-November of 2006-2010 (Hartin et al. 2011) ranged from 0.0008 to 0.0135/mi$^2$ (0.0003-0.0052/km$^2$) with a maximum 95 percent confidence interval (CI) of 0.133/mi$^2$ (0.051/km$^2$). This suggests the densities used in the calculations and shown in Table 6-2 are somewhat higher than are likely to be observed from vessels near the areas of planned operations.

**TABLE 6-1 EXPECTED DENSITIES OF CETACEANS AND SEALS IN AREAS OF THE CHUKCHI SEA, ALASKA, FOR THE PLANNED SUMMER (JULY–AUGUST) PERIOD. SPECIES LISTED UNDER THE U.S. ESA AS ENDANGERED ARE IN ITALICS.**

| | Open Water | | Ice Margin | |
|---|---|---|---|---|
| **Species** | **Average Density (# / km$^2$)** | **Maximum Density (# / km$^2$)** | **Average Density (# / km$^2$)** | **Maximum Density (# / km$^2$)** |
| **Odontocetes** | | | | |
| ***Monodontidae*** | | | | |
| Beluga | 0.0010 | 0.0020 | 0.0040 | 0.0080 |
| Narwhal | 0.0000 | 0.0000 | 0.0000 | 0.0001 |
| ***Delphinidae*** | | | | |
| Killer whale | 0.0001 | 0.0004 | 0.0001 | 0.0004 |
| ***Phocoenidae*** | | | | |
| Harbor porpoise | 0.0022 | 0.0029 | 0.0022 | 0.0029 |
| **Mysticetes** | | | | |
| *Bowhead whale* | 0.0013 | 0.0026 | 0.0013 | 0.0026 |
| *Fin whale* | 0.0001 | 0.0004 | 0.0001 | 0.0004 |
| Gray whale | 0.0258 | 0.0516 | 0.0258 | 0.0516 |
| *Humpback whale* | 0.0001 | 0.0004 | 0.0001 | 0.0004 |
| Minke whale | 0.0001 | 0.0004 | 0.0001 | 0.0004 |
| **Pinnipeds** | | | | |
| Bearded seal | 0.0107 | 0.0203 | 0.0142 | 0.0270 |
| Ribbon seal | 0.0007 | 0.0028 | 0.0007 | 0.0028 |
| Ringed seal | 0.3668 | 0.6075 | 0.4891 | 0.8100 |
| Spotted seal | 0.0073 | 0.0122 | 0.0098 | 0.0162 |

***Gray whale*** densities are expected to be much higher in the summer months than during the fall. Moore et al. (2000) found the distribution of gray whales in the planned operational area was scattered and limited to nearshore areas where most whales were observed in water less than 114 ft (35 m) deep. Thomas et al. (2011) also reported substantial declines in the sighting rates of gray whales in the fall. The average open-water summer density (Table 6-1) was calculated from 2008–2010 aerial survey effort and sightings in Clarke and Ferguson (*in prep*) for water depths 118-164 ft (36-50 m) including 54 sightings (73 individuals) during 7,447 mi (11,985 km) of on-transect effort. The average group size of those sightings is 1.35. Correction factors $f(0)$ = 2.49 (Forney and Barlow 1998) and $g(0)$ = 0.30 (Forney and Barlow 1998, Mallonee 1991) were also used in the density calculation. Similar to beluga and bowhead whales, an inflation factor of 2 was used to estimate the maximum densities from average densities in both habitat types and seasons. Gray whales are not commonly associated with sea ice, but may be present near it, so the same densities were used for ice-margin habitat as were derived for open-water habitat during both seasons. Densities from vessel based surveys in the Chukchi Sea during non-seismic periods and locations in July-August of 2006-2010 (Hartin et al. 2011) ranged from 0.0021/mi$^2$ to 0.0221/mi$^2$ (0.0008/km$^2$ to 0.0085/km$^2$) with a maximum 95 percent CI of 0.0918 mi$^2$ (0.0353 km$^2$).

In the fall, gray whales may be dispersed more widely through the northern Chukchi Sea (Moore et al. 2000), but overall densities are likely to be decreasing as the whales begin migrating south. A density calculated from effort and sightings (15 sightings [19 individuals] during 6,236 mi (10,036 km) of on-transect effort) in water 118-164 ft (36-50 m) deep during September–October reported by Clarke and Ferguson (*in prep*) was used as the average estimate for the Chukchi Sea during the fall period. The corresponding group size value of 1.26, along with the same *f(0)* and *g(0)* values described above were used in the calculation. Densities from vessel based surveys in the Chukchi Sea during non-seismic periods and locations in September-November of 2006-2010 (Hartin et al. 2011) ranged from 0.0/mi$^2$ to 0.0114/mi$^2$ (0.0/km$^2$ to 0.0044/km$^2$) with a maximum 95 percent CI of 0.0871 mi$^2$ (0.0335 km$^2$).

***Harbor Porpoise*** densities were estimated from industry data collected during 2006-2010 activities in the Chukchi Sea. Prior to 2006, no reliable estimates were available for the Chukchi Sea and harbor porpoise presence was expected to be very low and limited to nearshore regions. Observers on industry vessels in 2006–2010, however, recorded sightings throughout the Chukchi Sea during the summer and early fall months. Density estimates from 2006-2010 observations during non-seismic periods and locations in July-August ranged from 0.0034/mi$^2$ to 0.0075/mi$^2$ (0.0013/km$^2$ to 0.0029/km$^2$) with a maximum 95 percent CI of 0.0356/mi$^2$ (0.0137/km$^2$) (Hartin et al. 2011). The average density from the summer season of those three years (0.0057/mi$^2$, 0.0022/km$^2$) was used as the average open-water density estimate while the high value (0.0075/mi$^2$, 0.0029/km$^2$) was used as the maximum estimate (Table 6-1). Harbor porpoise are not expected to be present in higher numbers near ice, so the open-water densities were used for ice-margin habitat in both seasons. Harbor porpoise densities recorded during industry operations in the fall months of 2006-2010 were slightly lower and ranged from 0.0/mi$^2$ to 0.0114/mi$^2$ (0.0/km$^2$ to 0.0044/km$^2$) with a maximum 95 percent CI of 0.0242/mi$^2$ (0.0275/km$^2$). The average of those years (0.0055/mi$^2$, 0.0021/km$^2$) was again used as the average density estimate and the high value 0.0114/mi$^2$ (0.0044/km$^2$) was used as the maximum estimate (Table 6-2).

The remaining five cetacean species that could be encountered in the Chukchi Sea during Shell's planned marine survey program include the humpback whale, killer whale, minke whale, fin whale, and narwhal. Although there is evidence of the occasional occurrence of these animals in the Chukchi Sea, it is unlikely that more than a few individuals will be encountered during the planned marine survey activities. Clarke et al. (2011b) and Hartin et al. (2011) reported humpback whale sightings; George and Suydam (1998) reported killer whales; Brueggeman et al. (1990), Hartin et al. (2011) and COMIDA (2011) reported minke whales; and Clarke et al. (2011b) and Hartin et al. (2011) reported fin whales. Narwhal sightings in the Chukchi Sea have not been reported in recent literature, but subsistence hunters occasionally report observations near Barrow, and Reeves et al. (2002) indicated a small number of extralimital sightings in the Chukchi Sea.

**TABLE 6-2 EXPECTED DENSITIES OF CETACEANS AND SEALS IN AREAS OF THE CHUKCHI SEA, ALASKA, FOR THE FALL (SEPTEMBER–OCTOBER) PERIOD. SPECIES LISTED UNDER THE U.S. ESA AS ENDANGERED ARE IN ITALICS.**

| | Open Water | | Ice Margin | |
|---|---|---|---|---|
| **Species** | **Average Density (# / km$^2$)** | **Maximum Density (# / km$^2$)** | **Average Density (# / km$^2$)** | **Maximum Density (# / km$^2$)** |
| **Odontocetes** | | | | |
| ***Monodontidae*** | | | | |
| Beluga | 0.0015 | 0.0030 | 0.0060 | 0.0120 |
| Narwhal | 0.0000 | 0.0000 | 0.0000 | 0.0001 |
| ***Delphinidae*** | | | | |
| Killer whale | 0.0001 | 0.0004 | 0.0001 | 0.0004 |
| ***Phocoenidae*** | | | | |
| Harbor porpoise | 0.0021 | 0.0044 | 0.0021 | 0.0044 |
| **Mysticetes** | | | | |
| *Bowhead whale* | 0.0219 | 0.0438 | 0.0438 | 0.0876 |
| *Fin whale* | 0.0001 | 0.0004 | 0.0001 | 0.0004 |
| Gray whale | 0.0080 | 0.0160 | 0.0080 | 0.0160 |
| *Humpback whale* | 0.0001 | 0.0004 | 0.0001 | 0.0004 |
| Minke whale | 0.0001 | 0.0004 | 0.0001 | 0.0004 |
| **Pinnipeds** | | | | |
| Bearded seal | 0.0107 | 0.0203 | 0.0142 | 0.0270 |
| Ribbon seal | 0.0007 | 0.0028 | 0.0007 | 0.0028 |
| Ringed seal | 0.2458 | 0.4070 | 0.3277 | 0.5427 |
| Spotted seal | 0.0049 | 0.0081 | 0.0065 | 0.0108 |

## Pinnipeds

Three species of pinnipeds under NMFS jurisdiction are likely to be encountered in the Chukchi Sea during Shell's planned marine survey program: ringed seal, bearded seal, and spotted seal. Each of these species, except for the spotted seal, is associated with both the ice margin and the nearshore area. The ice margin is considered preferred habitat (as compared to the nearshore areas) for ringed and bearded seals during most seasons. Spotted seals are often considered to be predominantly a coastal species except in the spring when they may be found in the southern margin of the retreating sea ice. However, satellite tagging has shown that they sometimes undertake long excursions into offshore waters during summer (Lowry et al. 1994, 1998). Ribbon seals have been reported in very small numbers within the Chukchi Sea by observers on industry vessels (Patterson et al. 2007, Hartin et al. 2011).

***Ringed seal*** and ***bearded seals*** "average" and "maximum" summer ice-margin densities (Table 6-1) were available in Bengtson et al. (2005) from spring surveys in the offshore pack ice zone (zone 12P) of the northern Chukchi Sea. However, corrections for bearded seal availability, *g(0)*, based on haulout and diving patterns were not available. Densities of ringed and bearded seals in open water are expected to be somewhat lower in the summer when preferred pack ice habitat may still be present in the Chukchi Sea. Average and maximum open-water densities have been estimated at 3/4 of the ice margin densities during both seasons for both species. The

fall density of ringed seals in the offshore Chukchi Sea has been estimated as 2/3 the summer densities because ringed seals begin to reoccupy nearshore fast ice areas as it forms in the fall. Bearded seals may also begin to leave the Chukchi Sea in the fall, but less is known about their movement patterns so fall densities were left unchanged from summer densities. For comparison, the ringed seal density estimates calculated from data collected during summer 2006-2010 industry operations ranged from 0.0359/mi$^2$ to 0.1206/mi$^2$ (0.0138/km$^2$ to 0.0464/km$^2$) with a maximum 95 percent CI of 0.4111/mi$^2$ (0.1581/km$^2$) (Hartin et al. 2011). These estimates are lower than those made by Bengtson et al. (2005) which is not surprising given the different survey methods and timing.

Little information on ***spotted seal*** densities in offshore areas of the Chukchi Sea is available. Spotted seal densities in the summer were estimated by multiplying the ringed seal densities by 0.02. This was based on the ratio of the estimated Chukchi populations of the two species (Table 4-1). Chukchi Sea spotted seal abundance was estimated by assuming that 8 percent of the Alaskan population of spotted seals is present in the Chukchi Sea during the summer and fall (Rugh et al. 1997), the Alaskan population of spotted seals is 59,214 (Allen and Angliss 2012), and that the population of ringed seals in the Alaskan Chukchi Sea is ~208,000 animals (Bengtson et al. 2005). In the fall, spotted seals show increased use of coastal haulouts so densities were estimated to be 2/3 of the summer densities.

Four ***ribbon seal*** sightings were reported during industry vessel operations in the Chukchi Sea in 2006-2010 (Hartin et al. 2011). The resulting density estimate of 0.0013/mi$^2$ (0.0007/km$^2$) was used as the average density and 4 times that was used as the maximum for both seasons and habitat zones.

**Area Potentially Exposed to Sounds ≥160 dB re 1µPa rms from Airguns used during Site Clearance and Shallow Hazards Surveys**

Site clearance and shallow hazards surveys may occur in three survey areas of the Chukchi Sea Lease Area. These three survey areas are the Burger prospect (Survey Area 2), Crackerjack prospect (Survey Area 1), and an area northeast of Burger (Survey Area 3; Fig. 1-2). The precise survey sites within the survey areas at these prospects have not yet been determined, but there are five notional locations at Burger, three at Crackerjack, and one northeast of Burger. The five potential survey sites at Burger range in size from 23 km$^2$ to 40 km$^2$ (9 mi$^2$ to 15 mi$^2$) while the three potential sites at Crackerjack range from 119 km$^2$ to 35 km$^2$ (46 mi$^2$ to 14 mi$^2$). The single site northeast of Burger may be ~119 km$^2$ (46 mi$^2$).

Shell plans to use the same 4x10 in$^3$ airgun configuration that was used during site clearance and shallow hazards surveys in the Chukchi Sea in 2008 and 2009. Measurements during these two years occurred at three locations: Honeyguide (west of the Crackerjack prospect), Crackerjack, and Burger. The distances to various threshold radii from those measurements are shown in Table 6-3. The 160 dB (rms) radius that was measured at the Burger location was the largest of the three sites. As a cautionary approach, the Burger site distance (Table 6-3) plus a 25 percent inflation factor (equaling 2,250 m) was used to estimate the total area that may be ensonified to 160 dB (rms) by pulsed seismic sounds at all of the potential survey sites.

**TABLE 6-3 MEASURED DISTANCES (IN METERS) TO RECEIVED SOUND LEVELS FROM A 4 X 10 IN3 AIRGUN ARRAY AT THREE LOCATIONS IN THE ALASKAN CHUKCHI SEA.**

| | Received Sound Level (dB re 1 µPa rms) | | | |
|---|---|---|---|---|
| | 190 | 180 | 160 | 120 |
| **Location** | | | | |
| Honeyguide | 41 | 100 | 600 | 22,000 |
| Crackerjack | 50 | 160 | 1,400 | 24,000 |
| Burger | 39 | 150 | 1,800 | 31,000 |

The current operations plan calls for site clearance and shallow hazards surveys to begin at the Burger prospect. Adding the 2.25 km 160 dB (rms) radius to the perimeter of all five of the notional survey grids at that site results in a total area at Burger of 477 $km^2$ being exposed to pulsed seismic sound ≥160 dB (rms). This is approximately 40 percent of the total area that may be exposed to seismic sounds during the survey activities and it has been attributed to the July–August period. Adding the 2.25 km 160 dB (rms) radius to the perimeter of the three notional survey areas at Crackerjack and the one northeast of Burger results in a total area of 826 $km^2$ being potentially exposed to pulsed seismic sounds ≥160 dB (rms). Since these areas would likely be surveyed after the Burger sites are completed they have been attributed to the September–October period. The total area potentially exposed is then 1,303 $km^2$ (477 $km^2$ + 826 $km^2$).

**Area Potentially Exposed to Sounds ≥120 dB re 1µPa rms during Well-Site Equipment Recovery and Maintenance**

As described in sections 1 and 2, Shell plans to conduct equipment recovery and maintenance at the Burger A well site where drilling took place in 2012. During this work, a vessel will stay on location at or near the well site using dynamic positioning thrusters while remotely operated vehicles or divers are used to perform the required work within the MLC cellar at Burger A. Sounds produced by the vessel while in dynamic positioning mode will be continuous in nature and are thus evaluated at the ≥120 dB (rms) level.

In 2011, Statoil conducted geotechnical coring operations in the Chukchi Sea using the vessel *Fugro Synergy*. Measurements were taken using bottom founded recorders at 50 m (164 ft), 100 m (328 ft), and 1 km (0.6 mi) away from the borehole while the vessel was in dynamic positioning mode (Warner and McCrodan 2011). Sound levels measured at the recorder 1 km (0.6 mi) away ranged from 119 dB (rms) to 129 dB (rms). A propagation curve fit to the data and encompassing 90 percent of all measured values during the period of strongest sound emissions estimated sound levels would drop below 120 dB at 2.3 km (1.4 mi).

Acoustic measurements of the *Nordica* in dynamic positioning mode while supporting Shell's 2012 drilling operation in the Chukchi Sea were made from multiple recorders deployed to monitor sounds from the overall drilling operation. Distances to these recorders ranged from 1.3 km (0.8 mi) to 7.9 km (4.9 mi) and maximum sound pressure levels ranged from 112.7 dB (rms) to 129.9 dB (rms). Preliminary analyses of these data indicate the maximum 120 dB (rms) distance was approximately 4 km (2.5 mi) from the vessel. These same recorders measured sounds produced by the *Tor Viking II* while it operated near the *Discoverer* drill rig in 2012. The nature of the operations conducted by the *Tor Viking II* during the reported measurement periods

varied and included activities such as anchor handling, circling, and possibly holding position using dynamic positioning thrusters. Distances to the 120 dB (rms) level were estimated at 10 km (6 mi), 13 km (8 mi), and 25 km (15.5 mi) during these various measurement periods.

The vessel from which equipment recovery and maintenance will be conducted has not yet been determined. Under most circumstances, sounds from dynamic positioning thrusters are expected to be well below 120 dB (rms) at distances greater than 10 km (6 mi). However, since some of the activities conducted by the *Tor Viking II* at the Burger A well site in 2012 may have included dynamic positioning, the 13 km (8 mi) distance has been selected as the estimated ≥120 dB distance used in the calculations of potential Level B harassment below. A circle with a radius of 13 km (8 mi) results in an estimated area of 531 $km^2$ (205 $mi^2$) that may be exposed to continuous sounds ≥120 dB (rms).

The equipment recovery and maintenance work at the well site may occur during either or both of the seasonal periods and may take place over as many as 28 days. Therefore, the entire area potentially exposed to continuous sounds ≥120 dB (rms) from dynamic positioning thrusters has been applied to densities of marine mammals during both seasonal periods.

**Area Potentially Exposed to Sounds from other Marine Survey Instruments**

As described in section 1 of this IHAA, a number of other marine survey instruments are planned to be used during the site clearance and shallow hazard surveys and ice gouge surveys. These include single-beam bathymetric sonar, multi-beam bathymetric sonar, dual frequency side-scan sonar, and shallow sub-bottom profiler. Representative instruments of these types were measured during Statoil's 2011 site survey program in the Chukchi Sea (Warner and McCrodan 2011). Operating frequencies, beam widths, and distances to 160 dB (rms) threshold levels for these high frequency instruments are summarized in Table 6-4. Due to the rapid attenuation of these higher frequency sounds and the narrow beam-widths where most of the sound energy is present, the impact from operating these instruments is not expected to be any greater than the operation of the vessel itself. Therefore, estimates of take by harassment have not been calculated for these marine survey activities.

**TABLE 6-4 OPERATING FREQUENCIES, BEAM WIDTHS, AND DISTANCES TO 160 DB (RMS) SOUND LEVELS FROM MARINE SURVEY INSTRUMENTS MEASURED IN THE CHUKCHI SEA. NOMINAL SOURCE LEVELS WERE BACK-PROPAGATED FROM THE NEAREST MEASUREMENT LOCATION ASSUMING SPHERICAL SPREADING OR USING REGRESSION FITS TO MEASUREMENTS FROM MULTIPLE DISTANCES (SEE WARNER AND MCCRODAN 2011 FOR ADDITIONAL INFORMATION).**

| Instrument type | Model | Center Frequency | Frequency Range | Beam width | Nominal Source Level dB re 1 μPa (rms) | Source Distance to Nearest Measurement | In-beam 160 dB distance | Out-of-beam 160 dB distance |
|---|---|---|---|---|---|---|---|---|
| Single-beam Sonar | Simrad EA502 | 12 kHz | 8-20 kHz | < 10° | 218.0 | 30 m | 40 m | 40 m |
| Multi-beam Bathymetric Sonar | Kongsberg EM2040 | 220 kHz | 200 - 240 kHz | < 2° | 187.4 | 30 m | 0 m | 0 m |
| Side-scan Sonar | GeoAcoustics 159D | 110 kHz | 100-120 kHz | < 2° | 211.5 | 22 m | 230 m | NA |
| Sub-bottom Profiler | Kongsberg SBP300 | 3-7 kHz | 3-7 kHz | 15° | 195.9 | 30 m | 30 m | 3 m |

## Potential Number of "Takes by Harassment"

This subsection provides estimates of the number of individuals potentially exposed to pulsed seismic sounds ≥160 dB re 1 μPa rms during site clearance and shallow hazards surveys as well as continuous sound levels ≥120 dB re 1 μPa rms from dynamic positioning thrusters during equipment recovery and maintenance at the Burger A well site. The estimates are based on a consideration of the number of marine mammals that might be present during operations in the Chukchi Sea and the anticipated area exposed to those sound levels.

The number of individuals of each species potentially exposed to received levels of pulsed sounds ≥160 dB (rms) and continuous sounds ≥120 dB (rms) was estimated by multiplying;

- the anticipated area to be ensonified to the specified levels in each season (summer and fall) and habitat zone (open water and ice margin) to which a density applies, by
- that expected species density.

The numbers of individuals potentially exposed were then summed for each species across the two seasons and habitat zones.

An additional calculation was made that assumes the entire population of marine mammals within the 531 $km^2$ (205 $mi^2$) area exposed to continuous sounds ≥120 dB (rms) during the equipment recovery and maintenance activity is different every day during that 28 day period. To do this, the 28 days were split evenly between the July–August and September–October periods (14 days in each period). The area ensonified by continuous sounds on each day was then multiplied by 14 before being multiplied by the appropriate species density within each season.

Some of the animals estimated to be exposed, particularly migrating bowhead whales, might show avoidance reactions before being exposed to sounds at the specified threshold levels. Thus, these calculations actually estimate the number of individuals potentially exposed to the specified sounds levels that would occur if there were no avoidance of the area ensonified to that level.

As described above, vessel and equipment limitations will result in very little activity occurring in or near sea ice; however, if ice is present near the areas of activity, some sounds produced by the activities may remain above disturbance threshold levels in ice margin habitats. Therefore, open water densities have been used to estimate potential "take by harassment" in 90 percent of the area expected to be ensonified above disturbance thresholds while ice margin densities have been used in the remaining 10 percent of the ensonified area. Species with an estimated average number of individuals exposed equal to zero are included below for completeness, but are not likely to be encountered.

**Site Clearance and Shallow Hazards Surveys**

Estimates of the average and maximum number of individual marine mammals that may be exposed to pulsed airgun sounds ≥160 dB (rms) by site clearance and shallow hazards surveys are shown by season and habitat in Table 6-5. Species with an estimated average number of individuals exposed equal to zero are included here for completeness, but are not likely to be encountered. The average and maximum estimates of the number of individual bowhead whales exposed to pulsed airgun sounds ≥160 dB (rms) are 21 and 41, respectively. The estimates for gray whales are quite similar at 19 and 38, respectively; although the seasons during which individuals of these two species are likely to be present near the operations differ (Table 6-5). Few other cetaceans are likely to be exposed to airgun sounds ≥160 dB, but maximum estimates have been included to account for chance encounters.

Ringed seals are expected to be the most abundant animal in the Chukchi Sea and the average and maximum estimates of the number exposed to ≥160 dB by airgun sounds are 391 and 647, respectively (Table 6-5). Estimated exposures of other seal species are substantially less than those for ringed seals.

**TABLE 6-5 THE NUMBER OF POTENTIAL EXPOSURES OF MARINE MAMMALS TO RECEIVED SOUND LEVELS IN THE WATER OF AIRGUN PULSES ≥160 DB (RMS) DURING PLANNED SITE CLEARANCE AND SHALLOW HAZARDS SURVEYS IN SUMMER (JULY–AUGUST) AND FALL (SEPTEMBER–OCTOBER) IN THE CHUKCHI SEA, ALASKA, 2013.**

| | Number of Individuals Potentially Exposed to Shallow Hazards Survey Sounds ≥160 dB | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Summer | | | | | | Fall | | | | | | | |
| | Open Water | | Ice Margin | | Total | | Open Water | | Ice Margin | | Total | | Grand Total | |
| | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. |
| **Odontocetes** | | | | | | | | | | | | | | |
| ***Monodontidae*** | | | | | | | | | | | | | | |
| Beluga | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 1 | 2 | 3 | 2 | 5 |
| Narwhal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| ***Delphinidae*** | | | | | | | | | | | | | | |
| Killer whale | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| ***Phocoenidae*** | | | | | | | | | | | | | | |
| Harbor porpoise | 1 | 1 | 0 | 0 | 1 | 1 | 2 | 3 | 0 | 0 | 2 | 4 | 3 | 5 |
| **Mysticetes** | | | | | | | | | | | | | | |
| *Bowhead whale* | 1 | 1 | 0 | 0 | 1 | 1 | 16 | 33 | 4 | 7 | 20 | 40 | 21 | 41 |
| *Fin whale* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Gray whale | 11 | 22 | 1 | 2 | 12 | 25 | 6 | 12 | 1 | 1 | 7 | 13 | 19 | 38 |
| *Humpback Whale* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Minke whale | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| **Pinnipeds** | | | | | | | | | | | | | | |
| Bearded seal | 5 | 9 | 1 | 1 | 5 | 10 | 8 | 15 | 1 | 2 | 9 | 17 | 14 | 27 |
| Ribbon seal | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 1 | 2 | 1 | 5 |
| Ringed seal | 158 | 261 | 23 | 39 | 181 | 300 | 183 | 303 | 27 | 45 | 210 | 348 | 391 | 647 |
| Spotted seal | 3 | 5 | 0 | 1 | 4 | 6 | 4 | 6 | 1 | 1 | 4 | 7 | 8 | 13 |

**Equipment Recovery and Maintenance at the Burger A Well Site**

Estimates of the average and maximum number of individual marine mammals that may be exposed to continuous sounds ≥120 dB (rms) are shown by season and habitat in Table 6-6. These values represent the ensonified area multiplied by the densities just one time per season and therefore do not account for animal movements into or out of the ensonified area that might occur during the course of each season. The number of individuals that may occur at some point in time within the area exposed to sounds ≥120 dB from a stationary vessel at the Burger A well site during each season is likely to vary greatly by species, oceanographic conditions, and other factors. It is possible that the turnover of animals within the ensonified area would be greater during the fall season than the summer season since many of the species present in the fall are migrating through the Chukchi Sea. However, wide ranging foraging patterns of some species may result in a similar amount of turnover within the ensonified area during the summer period as during migratory movements in the fall period. In either case, it is likely an overestimate to assume that the entire population of marine mammals within the 531 $km^2$ (205 $mi^2$) ≥120 dB (rms) ensonified area around the site would be replaced every day (*i.e.*, a completely new set of marine mammals is present on a daily basis). Regardless, that is the assumption that has been made in calculating the estimates shown in Table 6-7 which result from multiplying the 531 $km^2$ (205 $mi^2$) ≥120 dB (rms) ensonified area by 14 (days) before being multiplied by the density estimates for each season. The numbers shown in Table 6-6 are best interpreted as a low-end estimate of the number of individuals potentially exposed to continuous sounds ≥120 dB (rms) while the numbers shown in Table 6-7 are best interpreted as high-end estimates.

Based on the average density estimates and the two calculation methods described above, the number of bowhead whales that may occur within the area ensonified to continuous sounds ≥120 dB (rms) may be between 13 and 189 (Tables 6-6 and 6-7). Using the maximum density estimates that range would be between 27 and 377. The range of estimates for gray whales using the average densities is from 18 to 251 individuals while using the maximum densities provides a range from 36 to 502 individuals (Tables 6-6 and 6-7). The maximum estimate for beluga whales is 48 individuals (Table 6-7).

Since ringed seals are expected to be the most abundant animals in the area the calculations result in the largest estimated number of individuals exposed. The lowest estimate for ringed seals is 336 individuals while the highest estimate is 7,792 individuals. Many fewer bearded and spotted seals are expected to occur near the activities and only a handful of ribbon seals might potential be present.

**TABLE 6-6 THE NUMBER OF POTENTIAL EXPOSURES OF MARINE MAMMALS TO RECEIVED SOUND LEVELS IN THE WATER OF ≥120 DB (RMS) FROM DYNAMIC POSITIONING THRUSTERS DURING PLANNED EQUIPMENT REMOVAL AND MAINTENANCE ACTIVITIES IN SUMMER (JULY–AUGUST) AND FALL (SEPTEMBER–OCTOBER) IN THE CHUKCHI SEA, ALASKA, 2013.**

| | Number of Individuals Potentially Exposed to Dynamic Positioning Sounds ≥120 dB | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Summer | | | | | | Fall | | | | | | | |
| | Open Water | | Ice Margin | | Total | | Open Water | | Ice Margin | | Total | | Grand Total | |
| | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. |
| **Odontocetes** | | | | | | | | | | | | | | |
| ***Monodontidae*** | | | | | | | | | | | | | | |
| Beluga | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 2 | 2 | 5 |
| Narwhal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| ***Delphinidae*** | | | | | | | | | | | | | | |
| Killer whale | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| ***Phocoenidae*** | | | | | | | | | | | | | | |
| Harbor porpoise | 1 | 1 | 0 | 0 | 1 | 2 | 1 | 2 | 0 | 0 | 1 | 2 | 2 | 5 |
| **Mysticetes** | | | | | | | | | | | | | | |
| *Bowhead whale* | 1 | 1 | 0 | 0 | 1 | 1 | 10 | 21 | 2 | 5 | 13 | 26 | 13 | 27 |
| *Fin whale* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Gray whale | 12 | 25 | 1 | 3 | 14 | 27 | 4 | 8 | 0 | 1 | 4 | 8 | 18 | 36 |
| *Humpback Whale* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Minke whale | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| **Pinnipeds** | | | | | | | | | | | | | | |
| Bearded seal | 5 | 10 | 1 | 1 | 6 | 11 | 5 | 10 | 1 | 1 | 6 | 11 | 12 | 22 |
| Ribbon seal | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 5 |
| Ringed seal | 175 | 290 | 26 | 43 | 201 | 333 | 117 | 194 | 17 | 29 | 135 | 223 | 336 | 557 |
| Spotted seal | 4 | 6 | 1 | 1 | 4 | 7 | 2 | 4 | 0 | 1 | 3 | 4 | 7 | 11 |

**TABLE 6-7 THE NUMBER OF POTENTIAL EXPOSURES OF MARINE MAMMALS, INCLUDING A DAILY MULTIPLIER FOR THE ENTIRE 28 DAY OPERATIONAL PERIOD, TO RECEIVED SOUND LEVELS IN THE WATER OF ≥120 DB (RMS) FROM DYNAMIC POSITIONING THRUSTERS DURING PLANNED EQUIPMENT REMOVAL AND MAINTENANCE ACTIVITIES IN SUMMER (JULY–AUGUST) AND FALL (SEPTEMBER–OCTOBER) IN THE CHUKCHI SEA, ALASKA, 2013.**

| | Number of Individuals Potentially Exposed to Dynamic Positioning Sounds ≥120 dB | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Summer | | | | | | Fall | | | | | | | |
| | Open Water | | Ice Margin | | Total | | Open Water | | Ice Margin | | Total | | Grand Total | |
| | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. | Avg. | Max. |
| **Odontocetes** | | | | | | | | | | | | | | |
| ***Monodontidae*** | | | | | | | | | | | | | | |
| Beluga | 7 | 13 | 3 | 6 | 10 | 19 | 10 | 20 | 4 | 9 | 14 | 29 | 24 | 48 |
| Narwhal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| ***Delphinidae*** | | | | | | | | | | | | | | |
| Killer whale | 1 | 3 | 0 | 0 | 1 | 3 | 1 | 3 | 0 | 0 | 1 | 3 | 1 | 6 |
| ***Phocoenidae*** | | | | | | | | | | | | | | |
| Harbor porpoise | 15 | 19 | 2 | 2 | 16 | 22 | 14 | 29 | 2 | 3 | 16 | 33 | 32 | 54 |
| **Mysticetes** | | | | | | | | | | | | | | |
| *Bowhead whale* | 9 | 17 | 1 | 2 | 10 | 19 | 146 | 293 | 33 | 65 | 179 | 358 | 189 | 377 |
| *Fin whale* | 1 | 3 | 0 | 0 | 1 | 3 | 1 | 3 | 0 | 0 | 1 | 3 | 1 | 6 |
| Gray whale | 173 | 345 | 19 | 38 | 192 | 384 | 54 | 107 | 6 | 12 | 59 | 119 | 251 | 502 |
| *Humpback Whale* | 1 | 3 | 0 | 0 | 1 | 3 | 1 | 3 | 0 | 0 | 1 | 3 | 1 | 6 |
| Minke whale | 1 | 3 | 0 | 0 | 1 | 3 | 1 | 3 | 0 | 0 | 1 | 3 | 1 | 6 |
| **Pinnipeds** | | | | | | | | | | | | | | |
| Bearded seal | 71 | 135 | 11 | 20 | 82 | 156 | 71 | 135 | 11 | 20 | 82 | 156 | 164 | 311 |
| Ribbon seal | 5 | 19 | 1 | 2 | 5 | 21 | 5 | 19 | 1 | 2 | 5 | 21 | 10 | 42 |
| Ringed seal | 2454 | 4064 | 364 | 602 | 2817 | 4666 | 1644 | 2723 | 244 | 403 | 1888 | 3126 | 4705 | 7792 |
| Spotted seal | 49 | 81 | 7 | 12 | 56 | 93 | 33 | 54 | 5 | 8 | 38 | 62 | 94 | 156 |

## Summary

Effects on marine mammals are generally expected to be restricted to avoidance of the area around the planned activities and short-term changes in behavior, falling within the MMPA definition of "Level B harassment".

### *Cetaceans*

The average estimates without a daily multiplier for the stationary operations suggest a total of 34 bowhead whales may be exposed to sounds at or above the specified levels (Table 6-8). This number is <1 percent of the BCB population of >15,750 assuming 3.4 percent annual population growth from the 2001 estimate of >10,545 animals (Zeh and Punt 2005) which is supported by a 2004 population estimate of 12,631 by Koski et al. (2010). Including a daily multiplier brings the average estimate up to 209 individual bowhead whales with a maximum of 418 based on the maximum density estimates along with the daily multiplier (Table 6-9). The total estimated number of gray whales that may be exposed to sounds from the activities ranges from 74 to 540. Many fewer beluga whales and harbor porpoises are likely to be exposed to sounds during the activities. The small numbers of other whale species that may occur in the Chukchi or Beaufort seas are unlikely to be present around the planned operations but chance encounters may occur. The few individuals would represent a very small proportion of their respective populations.

### *Pinnipeds*

Ringed seal is by far the most abundant species expected to be encountered during the planned operations. The best (average) estimate of the numbers of ringed seals exposed to sounds at the specified received levels during the planned activities is 727 not including a daily multiplier, and 5,096 if a daily multiplier is included. Both of which represent <3 percent of the estimated Chukchi Sea population. Many fewer individuals of other pinniped species are estimated to be exposed to sounds at the specified received levels, also representing small proportions of their populations. Pinnipeds are unlikely to react to continuous sounds until received levels are much stronger than 120 dB (rms), so it is probable that a smaller number of these animals would actually be appreciably disturbed.

**TABLE 6-8 THE TOTAL NUMBER OF POTENTIAL EXPOSURES OF MARINE MAMMALS TO PULSED AIRGUN SOUNDS ≥160 DB (RMS) OR CONTINUOUS SOUNDS ≥120 DB (RMS) DURING THE PLANNED ACTIVITIES IN THE CHUKCHI SEA, ALASKA, 2013.**

| | Total Number of Individuals Potentially Exposed to Sounds ≥120 dB or ≥160 dB | |
|---|---|---|
| **Species** | **Average** | **Maximum** |
| **Odontocetes** | | |
| ***Monodontidae*** | | |
| Beluga | 4 | 10 |
| Narwhal | 0 | 10 |
| ***Delphinidae*** | | |
| Killer whale | 0 | 10 |
| ***Phocoenidae*** | | |
| Harbor porpoise | 5 | 10 |
| **Mysticetes** | | |
| *Bowhead whale* | 34 | 68 |
| *Fin whale* | 0 | 10 |
| Gray whale | 37 | 74 |
| *Humpback Whale* | 0 | 10 |
| Minke whale | 0 | 10 |
| **Pinnipeds** | | |
| Bearded seal | 26 | 49 |
| Ribbon seal | 2 | 10 |
| Ringed seal | 727 | 1204 |
| Spotted seal | 15 | 16 |

**TABLE 6-9 THE TOTAL NUMBER OF POTENTIAL EXPOSURES OF MARINE MAMMALS TO PULSED AIRGUN SOUNDS ≥160 DB (RMS) OR CONTINUOUS SOUNDS ≥120 DB (RMS), INCLUDING A DAILY MULTIPLIER FOR THE ENTIRE 28 DAY OPERATIONAL PERIOD AT THE BURGER A WELL SITE, DURING THE PLANNED ACTIVITIES IN THE CHUKCHI SEA, ALASKA, 2013.**

| | Total Number of Individuals Potentially Exposed to Sounds ≥120 dB or ≥160 dB | |
|---|---|---|
| **Species** | **Average** | **Maximum** |
| **Odontocetes** | | |
| ***Monodontidae*** | | |
| Beluga | 26 | 53 |
| Narwhal | 0 | 10 |
| ***Delphinidae*** | | |
| Killer whale | 2 | 11 |
| ***Phocoenidae*** | | |
| Harbor porpoise | 35 | 59 |
| **Mysticetes** | | |
| *Bowhead whale* | 209 | 418 |
| *Fin whale* | 2 | 11 |
| Gray whale | 270 | 540 |
| *Humpback Whale* | 2 | 11 |
| Minke whale | 2 | 11 |
| **Pinnipeds** | | |
| Bearded seal | 178 | 338 |
| Ribbon seal | 11 | 47 |
| Ringed seal | 5096 | 8439 |
| Spotted seal | 102 | 161 |

# 7. THE ANTICIPATED IMPACT OF THE ACTIVITY ON THE SPECIES OR STOCK

The reasonably expected or reasonably likely impacts of the planned marine surveys on marine mammals will be related primarily to acoustic effects. Petroleum development and associated activities in marine waters introduce sound into the environment. The acoustic sense of marine mammals probably constitutes their most important distance receptor system, and underwater sounds could (at least in theory) have several types of effects on marine mammals.

## 7.1 Noise Characteristics and Effects

The effects of sound on marine mammals are highly variable, and can be categorized as follows (based on Richardson et al. 1995a):

1. The sound may be too weak to be heard at the location of the animal, *i.e.,* lower than the prevailing ambient noise level, the hearing threshold of the animal at relevant frequencies, or both.
2. The sound may be audible but not strong enough to elicit any overt behavioral response. This has been demonstrated upon exposure of bowhead whales to low levels of seismic, drilling, dredge, or icebreaker sounds (Richardson et al. 1986; 1990; 1995a,b,).
3. The sound may elicit reactions of variable conspicuousness and variable relevance to the well being of the animal. These can range from subtle effects on respiration or other behaviors (detectable only by statistical analysis) to active avoidance reactions.
4. Upon repeated exposure, animals may exhibit diminishing responsiveness (habituation), or disturbance effects may persist. The latter is most likely with sounds that are highly variable in characteristics, unpredictable in occurrence, and associated with situations that the animal perceives as a threat.
5. Any man made sound that is strong enough to be heard has the potential to reduce (mask) the ability of marine mammals to hear natural sounds at similar frequencies, including calls from conspecifics, echolocation sounds of odontocetes, and environmental sounds such as ice or surf noise.
6. Very strong sounds have the potential to cause temporary or permanent reduction in hearing sensitivity. Effects of non-explosive sounds on hearing thresholds of some marine mammals have been studied. Data are available for two species of odontocetes exposed to a single strong noise pulse lasting one second (Ridgway et al. 1997 and pers. comm.) and for three species of pinnipeds exposed to moderately strong sound for 20-22 minutes (Kastak et al. 1999). Received sound levels must far exceed the animal's hearing threshold for any temporary threshold shift (TTS) to occur. The TTS threshold depends on duration of exposure; the sound level necessary to cause TTS is higher for short sound exposures than for long sound exposures. Received levels must be even higher to risk permanent hearing impairment (probably at least 10 dB above the TTS threshold).

## 7.2 Summary of Potential Effects of Exposure to Underwater Sounds from Airguns

**Tolerance**

Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. Numerous studies have also shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response. That is often true even in cases when the 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 react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. In general, pinnipeds, small odontocetes, and sea otters seem to be more tolerant of exposure to airgun pulses than are baleen whales.

**Masking**

Masking effects of underwater sounds on marine mammal calls and other natural sounds are expected to be limited. Masking effects of pulsed sounds (even from larger arrays of airguns than proposed in this project) on 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 the seismic pulses (*e.g.*, Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999; Nieukirk et al. 2004). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), a more recent study reports that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen et al. 2002). That has also been shown during recent work in the Gulf of Mexico (Tyack et al. 2003). Bowhead whale calls are frequently detected in the presence of seismic pulses, although the number of calls detected may sometimes be reduced in the presence of airgun pulses (Richardson et al. 1986; Greene et al. 1999; Blackwell et al. 2009a). Bowhead whales in the Beaufort Sea may decrease their call rates in response to seismic operations, although movement out of the area might also have contributed to the lower call detection rate (Blackwell et al. 2009a,b). Additionally, there is increasing evidence that, at times, there is enough reverberation between airgun pulses such that detection range of calls may be significantly reduced. In contrast, Di Iorio and Clark (2009) found evidence of increased calling by blue whales during operations by a lower-energy seismic source, a sparker. Masking effects of seismic pulses are expected to be negligible given the low number of cetaceans expected to be exposed, the intermittent nature of seismic pulses and the fact that ringed seals (the most abundant species in the area) are not typically vocal during this period.

**Disturbance Reactions**

***Baleen Whales***—Baleen whale responses to pulsed sound have been studied more thoroughly than responses to continuous sound. Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns may react by deviating from their normal migration route. In the case of the migrating gray and bowhead whales, observed changes in behavior

appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors. Baleen whale responses to pulsed sound however, may depend on the type of activity in which the whales are engaged. Some evidence suggests that feeding bowhead whales may be more tolerant of underwater sound than migrating bowheads (Miller et al. 2005; Lyons et al. 2009; Christie et al. 2010).

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160–170 dB re 1 μPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 2.8 to 9.0 mi (4.5 to 14.5 km) from the source. For the much smaller airgun array used during the planned site clearance and shallow hazards surveys, distances to received levels in the 160–170 dB re 1 μPa rms range are estimated to be 0.53–1.8 km (0.2–0.69 mi). Baleen whales within those distances may show avoidance or other strong disturbance reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and studies have shown that some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa rms. Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with avoidance occurring out to distances of 12-19 mi (20–30 km) from a medium-sized airgun source (Miller et al. 1999; Richardson et al. 1999). However, more recent research on bowhead whales (Miller et al. 2005) corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources. In summer, bowheads typically begin to show avoidance reactions at a received level of about 160–170 dB re 1 μPa rms (Richardson et al. 1986; Ljungblad et al. 1988; Miller et al. 1999).

Malme et al. (1986, 1988) studied the responses of feeding eastern gray whales to pulses from a single 100 in.$^3$ (1,639 cm$^3$) airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50 percent of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10 percent of feeding whales interrupted feeding at received levels of 163 dB. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast, and on observations of the distribution of feeding Western Pacific gray whales off Sakhalin Island, Russia during a seismic survey (Yazvenko et al. 2007).

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration and much ship traffic in that area for decades (Appendix A in Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987). Populations of both gray whales and bowhead whales grew substantially during this time. In any event, the brief exposures to sound pulses from the proposed airgun source are highly unlikely to result in prolonged effects.

***Toothed Whales***—Few systematic data are available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized

above have been reported for toothed whales. However, systematic work on sperm whales is underway (Tyack et al. 2003), and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (*e.g.*, Stone 2003; Smultea et al. 2004; Moulton and Miller 2005).

Seismic operators and marine mammal observers sometimes see dolphins and other small toothed whales near operating airgun arrays, but in general there seems to be a tendency for most delphinids to show some limited avoidance of seismic vessels operating large airgun systems. However, some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when large arrays of airguns are firing. Nonetheless, there have been indications that small toothed whales sometimes move away, or maintain a somewhat greater distance from the vessel, when a large array of airguns is operating than when it is silent (*e.g.*, Goold 1996a,b,c; Calambokidis and Osmek 1998; Stone 2003). The beluga may be a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys during seismic operations in the southeastern Beaufort Sea recorded much lower sighting rates of beluga whales within 6-12 mi (10–20 km) of an active seismic vessel. These results were consistent with the low number of beluga sightings reported by observers aboard the seismic vessel, suggesting that some belugas might be avoiding the seismic operations at distances of 6-12 mi (10–20 km) (Miller et al. 2005).

Captive bottlenose dolphins and (of more relevance in this project) 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. 2002, 2005). However, the animals tolerated high received levels of sound (pk–pk level >200 dB re 1 μPa) before exhibiting aversive behaviors.

Reactions of toothed whales to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for mysticetes. A ≥170 dB disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids (and pinnipeds), which tend to be less responsive than other cetaceans. However, based on the limited existing evidence, belugas should not be grouped with delphinids in the "less responsive" category.

***Pinnipeds***—Pinnipeds are not likely to show a strong avoidance reaction to the airgun sources that will be used. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior. Ringed seals frequently do not avoid the area within a few hundred meters of operating airgun arrays (Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). However, initial telemetry work suggests that avoidance and other behavioral reactions by two other species of seals to small airgun sources may at times be stronger than evident to date from visual studies of pinniped reactions to airguns (Thompson et al. 1998). Even if reactions of the species occurring in the present study area are as strong as those evident in the telemetry study, reactions are expected to be confined to relatively small distances and durations, with no long-term effects on pinniped individuals or populations. As for delphinids, a ≥170 dB disturbance criterion is considered appropriate for pinnipeds, which tend to be less responsive than many cetaceans.

## Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds 180 and ≥190 dB re 1 μPa (rms), respectively (NMFS 2000). Those criteria have been used in defining the safety (shut down) radii during seismic survey activities in the Arctic in recent years. However, those criteria were established before there were any data on the minimum received levels of sounds necessary to cause temporary auditory impairment in marine mammals. In summary;

- the 180 dB criterion for cetaceans is probably quite precautionary, *i.e.*, lower than necessary to avoid TTS, let alone permanent auditory injury, at least for belugas and delphinids.
- the minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS.
- the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage.

NMFS is presently developing new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS and other relevant factors in marine and terrestrial mammals (NMFS 2005b; D. Wieting in Orenstein et al. 2004). New science-based noise exposure criteria are also proposed by a group of experts in this field, based on an extensive review and syntheses of available data on the effect of noise on marine mammals (Southall et al., 2007) and this review seems to confirm that the current 180 dB and 190 dB are conservative, in most cases.

Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the planned activities to avoid exposing them to underwater sound levels that might, at least in theory, cause hearing impairment. In addition, many cetaceans are likely to show some avoidance of the proposed activities. In those cases, the avoidance responses of the animals themselves will reduce or (most likely) avoid any possibility of hearing impairment.

Non-auditory physical effects might also occur in marine mammals exposed to strong underwater sound. Possible types of non-auditory physiological effects or injuries that theoretically might occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (*i.e.*, beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds. However, as discussed below, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to industrial sound sources and beaked whales do not occur in the proposed study area. It is unlikely that any effects of these types would occur during the proposed project given the brief duration of exposure of any given mammal, and the planned monitoring and mitigation measures (see below). The following subsections discuss in somewhat more detail the possibilities of TTS, permanent threshold shift (PTS), and non-auditory physical effects.

***Temporary Threshold Shift***—TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold

rises and a sound must be stronger in order to be heard. At least in terrestrial mammals, TTS can last from minutes or hours to (in cases of strong TTS) days. For sound exposures at or somewhat above the TTS threshold, hearing sensitivity in both terrestrial and marine mammals recovers rapidly after exposure to the noise ends. Few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple impulses of sound. [There are, however, recent data on TTS in dolphins caused by multiple pulses of sonar sound—Mooney et al. (2009).]

The distinction between TTS and PTS is not absolute. Although mild TTS is fully reversible and is not considered to be injury, exposure to considerably higher levels of sound causes more "robust" TTS, involving a more pronounced temporary impairment of sensitivity that takes longer to recover. There are very few data on recovery of marine mammals from substantial degrees of TTS, but in terrestrial mammals there is evidence that "robust" TTS may not be fully recoverable, *i.e.*, TTS can grade into PTS (Le Prell *in press*).

The received energy level of a single seismic pulse that caused the onset of mild TTS in the beluga, as measured without frequency weighting, was ~186 dB re 1 $\mu Pa^2 \cdot s$ or 186 dB sound exposure level (SEL) (Finneran et al. 2002).[1] The rms level of an airgun pulse (in dB re 1 μPa measured over the duration of the pulse) is typically 10–15 dB higher than the SEL for the same pulse when received within a few kilometers of the airguns. Thus, a single airgun pulse might need to have a received level of ~196–201 dB re 1 μPa rms in order to produce brief, mild TTS. Exposure to several strong seismic pulses that each has a flat-weighted received level near 190 dB rms (175–180 dB SEL) could result in cumulative exposure of ~186 dB SEL (flat-weighted) or ~183 dB SEL ($M_{mf}$-weighted), and thus slight TTS in a small odontocete. That assumes that the TTS threshold upon exposure to multiple pulses is (to a first approximation) a function of the total received pulse energy, without allowance for any recovery between pulses.

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. However, no cases of TTS are expected given the moderate size of the source, and the likelihood that baleen whales (especially migrating bowheads) would avoid the activities before being exposed to levels high enough for there to be any possibility of TTS.

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from prolonged exposures to sound suggested that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001; cf. Au et al. 2000). For harbor seal, which is closely related to the ringed seal, TTS onset apparently occurs at somewhat lower received energy levels than for odontocetes.

NMFS (1995, 2000) concluded that cetaceans and pinnipeds should not be exposed to pulsed underwater noise at received levels exceeding, respectively, 180 and 190 dB re 1 μPa (rms). NMFS is in the process of developing an EIS to establish new sound exposure criteria for marine mammals (NMFS 2005b). New criteria are likely to include a time component in addition to

[1] If the low-frequency components of the watergun sound used in the experiments of Finneran et al. (2002) are downweighted as recommended by Southall et al. (2007) using their $M_{mf}$-weighting curve, the effective exposure level for onset of mild TTS was 183 dB re 1 $\mu Pa^2 \cdot s$ (Southall et al. 2007).

sound pressure level which has been the only metric used previously when developing mitigation measures for industrial sound exposure for marine mammals. Due to the relatively small sound radii expected to result from the proposed activities, marine mammals would be unlikely to incur TTS without remaining very near the activities for some unknown time period. Given the proposed mitigation and the likelihood that many marine mammals are likely to avoid the proposed activities, exposure sufficient to produce TTS is unlikely to occur.

***Permanent Threshold Shift* (PTS)** —When PTS occurs; there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges.

There is no specific evidence that exposure to underwater industrial sound associated with oil exploration can cause PTS in any marine mammal. However, given the possibility that mammals might incur TTS, there has been further speculation about the possibility that some individuals occurring very close to such activities might incur PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. Relationships between TTS and PTS thresholds have not been studied in marine mammals, but are assumed to be similar to those in humans and other terrestrial mammals. PTS might occur at a received sound level at least several decibels above that inducing mild TTS.

It is highly unlikely that marine mammals could receive sounds strong enough (and over a sufficient duration) to cause permanent hearing impairment during the proposed activities. Marine mammals are unlikely to be exposed to received levels of sound strong enough to cause even slight TTS. Given the higher level of sound necessary to cause PTS, it is even less likely that PTS could occur. In fact, even the levels immediately adjacent to the sound sources may not be sufficient to induce PTS, even if the animals remain in the immediate vicinity of the activity. The planned monitoring and mitigation measures, including measurement of sound radii and visual monitoring when mammals are seen within "safety radii", will minimize the already-minimal probability of exposure of marine mammals to sounds strong enough to induce PTS.

***Non-auditory Physiological Effects***—Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, and other types of organ or tissue damage. If any such effects do occur, they probably would be limited to unusual situations when animals might be exposed at close range for unusually long periods. It is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop.

Until recently, it was assumed that diving marine mammals are not subject to the bends or air embolism. This possibility was first explored at a workshop (Gentry [ed.] 2002) held to discuss whether the stranding of beaked whales in the Bahamas in 2000 (Balcomb and Claridge 2001; NOAA and USN 2001) might have been related to bubble formation in tissues caused by exposure to noise from naval sonar. However, the opinions were inconclusive. Jepson et al. (2003) first suggested a possible link between mid-frequency sonar activity and acute and chronic tissue damage that results from the formation in vivo of gas bubbles, based on the beaked whale stranding in the Canary Islands in 2002 during naval exercises. Fernández et al. (2005a) showed those beaked whales did indeed have gas bubble-associated lesions as well as fat embolisms. Fernández et al. (2005b) also found evidence of fat embolism in three beaked whales that stranded 62 mi (100 km) north of the Canaries in 2004 during naval exercises. Examinations

of several other stranded species have also revealed evidence of gas and fat embolisms (*e.g.*, Arbelo et al. 2005; Jepson et al. 2005a; Méndez et al. 2005). Most of the afflicted species were deep divers. There is speculation that gas and fat embolisms may occur if cetaceans ascend unusually quickly when exposed to aversive sounds, or if sound in the environment causes the destabilization of existing bubble nuclei (Potter 2004; Arbelo et al. 2005; Fernández et al. 2005a; Jepson et al. 2005b). Even if gas and fat embolisms can occur during exposure to mid-frequency sonar, there is no evidence that that type of effect occurs in response to the types of sound produced during the proposed exploratory activities. Also, most evidence for such effects has been in beaked whales, which do not occur in the proposed project area.

Available data on the potential for underwater sounds from industrial activities to cause auditory impairment or other physical effects in marine mammals suggest that such effects, if they occur at all, would be temporary and limited to short distances. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in those ways. Marine mammals that show behavioral avoidance of the proposed activities, including most baleen whales, some odontocetes (including belugas), and some pinnipeds, are especially unlikely to incur auditory impairment or other physical effects.

**Standings and Mortality**

Marine mammals close to underwater detonations of high explosive can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Underwater sounds from airguns are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death or stranding. However, the association of mass standings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey, has raised the possibility that beaked whales exposed to strong pulsed sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding. The potential for stranding to result from exposure to strong pulsed sound suggests that caution be used when exposing marine mammals to pulsed or other underwater sound. Most of the stranding events associated with exposure of marine mammals to pulsed sound however, have involved beaked whales, which do not occur in the proposed area. Additionally, the sound produced from the proposed activities will be at much lower levels than those reported during stranding events.

## 7.3 Summary of Potential Effects of Exposure to Continuous Underwater Sounds from Dynamic Positioning Thrusters

The potential effects of sounds from the dynamic positioning thruster used during equipment recovery and maintenance at the Burger A well site might include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical effects (Richardson et al. 1995a). It is unlikely that there would be any cases of temporary or especially permanent hearing impairment, or non-auditory physical effects.

**Tolerance**

Numerous studies have shown that underwater sounds from industry activities are often readily detectable in the water at distances of many kilometers. Numerous studies have also shown that marine mammals at distances more than a few kilometers away often show no apparent response

to industry activities of various types. This is often true even in cases when the 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 react behaviorally to underwater sound such as airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. In general, pinnipeds, small odontocetes, and sea otters seem to be more tolerant of exposure to some types of underwater sound than are baleen whales.

**Disturbance Reactions**

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. Based on NMFS (2001, p. 9293), we assume that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations".

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small 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, impacts on the animals could be significant. In predicting the quantity and types of impacts of noise 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. This practice, however, 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 degree by industrial sounds are based on behavioral observations during studies of several species. Detailed studies have been done on humpback, gray, and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, small toothed whales, and sea otters.

***Baleen Whales***—Richardson et al. (1995b) reported changes in surfacing and respiration behavior, and the occurrence of turns during surfacing in bowhead whales exposed to playback of underwater sound from drilling activities. These subtle behavioral effects were temporary and localized, and occurred at distances up to 1.2-2.5 mi (2-4 km). Safety radii for the planned activities are expected to be small and are not expected to result in significant disturbance to baleen whales.

Some bowheads appeared to divert from their migratory path after exposure to projected icebreaker sounds. Other bowheads however, tolerated projected icebreaker sound at levels 20 dB and more above ambient sound levels. The source level of the projected sound however, was much less than that of an actual icebreaker, and reaction distances to actual ice breaking may be much greater than those reported here for projected sounds.

Brewer et al. (1993) and Hall et al. (1994) reported numerous sightings of marine mammals including bowhead whales in the vicinity of offshore drilling operations in the Beaufort Sea. One bowhead whale sighting was reported within ~400 m of a drilling vessel although most other

bowhead sightings were at much greater distances. Few bowheads were recorded near industrial activities by aerial observers. After controlling for spatial autocorrelation in aerial survey data from Hall et al. (1994) using a Mantel test, Schick and Urban (2000) found that the variable describing straight line distance between the rig and bowhead whale sightings was not significant, but that a variable describing threshold distances between sightings and the rig was significant. Thus, although the aerial survey results suggested substantial avoidance of the operations by bowhead whales, observations by vessel-based observers indicate that at least some bowheads may have been closer to industrial activities than was suggested by results of aerial observations.

Richardson et al. (2008) reported a slight change in the distribution of bowhead whale calls in response to operational sounds on BP's Northstar Island. The southern edge of the call distribution ranged from 0.47 to 1.46 mi (0.76 to 2.35 km) farther offshore, apparently in response to industrial sound levels. This result however, was only achieved after intensive statistical analyses, and it is not clear that this represented a biologically significant effect.

Patenaude et al. (2002) reported fewer behavioral responses to aircraft overflights by bowhead compared to beluga whales. Behaviors classified as reactions consisted of short surfacing, immediate dives or turns, changes in behavior state, vigorous swimming, and breaching. Most bowhead reaction resulted from exposure to helicopter activity and little response to fixed-wing aircraft was observed. Most reactions occurred when the helicopter was at altitudes ≤492 ft (≤150 m) and lateral distances ≤820 ft (≤250 m). Restriction on aircraft altitude will be part of the mitigation measures during the proposed marine survey activities and likely to have little or no disturbance effects on baleen whales. Any disturbance that did occur would likely be temporary and localized.

Southall et al. (2007 Appendix C) reviewed a number of papers describing the responses of marine mammals to non-pulsed sound. In general, little or no response was observed in animals exposed at received levels from 90-120 dB rms. Probability of avoidance and other behavioral effects increased when received levels were 120-160 dB rms. Some of the relevant reviews of Southall et al. (2007) are summarized below.

Baker et al. (1982) reported some avoidance by humpback whales to vessel noise when received levels were 110-120 dB rms, and clear avoidance at 120-140 dB (sound measurements were not provided by Baker but were based on measurements of identical vessels by Miles and Malme 1983).

Malme et al. (1983, 1984) used playback of sound from helicopter overflight and drilling rigs and platforms to study behavioral effects on migrating gray whales. Received levels exceeding 120 dB induced avoidance reactions. Malme et al. (1984) calculated 10 percent, 50 percent, and 90 percent probabilities of gray whale avoidance reactions at received levels of 110, 120, and 130 dB re 1 μPa, respectively.

Malme et al. (1986) observed the behavior of feeding gray whales during four experimental playbacks of drilling sounds (50 to 315 Hz; 21-minutes (min) overall duration and 10 percent duty cycle; source levels 156 to 162 dB re 1 μPa-m). In two cases for received levels of 100 to 110 dB re 1 μPa, no behavioral reaction was observed. Avoidance behavior was observed in two cases where received levels were 110 to 120 dB re 1 μPa.

Richardson et al. (1990) performed 12 playback experiments in which bowhead whales in the Alaskan Arctic were exposed to drilling sounds. Whales generally did not respond to exposures in the 100 to 130 dB re 1 μPa range, although there was some indication of minor behavioral changes in several instances.

McCauley et al. (1996) reported several cases of humpback whales responding to vessels in Hervey Bay, Australia. Results indicated clear avoidance at received levels between 118 to 124 dB re 1 μPa in three cases for which response and received levels were observed and measured.

Palka & Hammond (2001) analyzed line transect census data in which the orientation and distance off transect line were reported for large numbers of Minke whales. Minor changes in locomotion speed, direction, and/or diving profile were reported at ranges from 1,847 to 2,352 ft (563 to 717 m) at received levels (RLs) of 110 to 120 dB re 1 μPa.

Frankel & Clark (1998) conducted playback experiments with wintering humpback whales using a single speaker producing a low-frequency "M-sequence" (sine wave with multiple-phase reversals) signal in the 60 to 90 Hz band with output of 172 dB re 1 μPa at 1 m. For 11 playbacks, exposures were between 120 and 130 dB re 1 μPa and included sufficient information regarding individual responses. During eight of the trials, there were no measurable differences in tracks or bearings relative to control conditions, whereas on three occasions, whales either moved slightly away from (n = 1) or towards (n = 2) the playback speaker during exposure. The presence of the source vessel itself had a greater effect than did the M-sequence playback.

Finally, Nowacek et al. (2004) used controlled exposures to demonstrate behavioral reactions of northern right whales to various non-pulse sounds. Playback stimuli included ship noise, social sounds of conspecifics, and a complex, 18-min "alert" sound consisting of repetitions of three different artificial signals. Ten whales were tagged with calibrated instruments that measured received sound characteristics and concurrent animal movements in three dimensions. Five out of six exposed whales reacted strongly to alert signals at measured received levels between 130 and 150 dB re 1 μPa (*i.e.*, ceased foraging and swam rapidly to the surface). Two of these individuals were not exposed to ship noise and the other four were exposed to both stimuli. These whales reacted mildly to conspecific signals. Seven whales, including the four exposed to the alert stimulus, had no measurable response to either ship sounds or actual vessel noise.

***Toothed Whales***—Most toothed whales have the greatest hearing sensitivity at frequencies much higher than that of baleen whales and may be less responsive to low-frequency sound commonly associated with industry activities. Richardson et al. (1995b) reported that beluga whales did not show any apparent reaction to playback of underwater drilling sounds at distances greater than 656–1,312 ft (200-400 m). Reactions included slowing down, milling, or reversal of course after which the whales continued past the projector, sometimes within 164-328 ft (50-100 m). The authors concluded (based on a small sample size) that playback of drilling sound had no biologically significant effects on migration routes of beluga whales migrating through pack ice and along the seaward side of the nearshore lead east of Pt. Barrow in spring.

At least six of 17 groups of beluga whales appeared to alter their migration path in response to underwater playbacks of icebreaker sound (Richardson et al. 1995b). Received levels from the icebreaker playback were estimated at 78-84 dB re 1 μPa in the 1/3-octave band centered at 5,000 Hz, or 8-14 dB above ambient. If beluga whales reacted to an actual icebreaker at received levels of 80 dB, reactions would be expected to occur at distances on the order of 6 mi (10 km). Finley et al. (1990) also reported beluga avoidance of icebreaker activities in the Canadian High

Arctic at distances of 22 to 31 mi (35 to 50 km). In addition to avoidance, changes in dive behavior and pod integrity were also noted. Beluga whales have also been report to avoid active seismic vessels at distances of 6-12 mi (10-19 km) (Miller et al. 2005). It is likely that at least some beluga whales may avoid the vicinity of the proposed activities thus reducing the potential for exposure to high levels of underwater sound.

Patenaude et al. (2002) reported that beluga whales appeared to be more responsive to aircraft overflights than bowhead whales. Changes were observed in diving and respiration behavior, and some whales veered away when a helicopter passed at ≤820 ft (≤250 m) lateral distance at altitudes up to 492 ft (150 m). However, some belugas showed no reaction to the helicopter. Belugas appeared to show less response to fixed-wing aircraft than to helicopter overflights.

In reviewing responses of cetaceans with best hearing in mid-frequency ranges, which includes toothed whales, Southall et al. (2007) reported that combined field and laboratory data for mid-frequency cetaceans exposed to nonplused sounds did not lead to a clear conclusion about received levels coincident with various behavioral responses. In some settings, individuals in the field showed profound (significant) behavioral responses to exposures from 90 to 120 dB re 1 μPa, while others failed to exhibit such responses for exposure to received levels from 120 to 150 dB re 1 μPa. Contextual variables other than exposure received level, and probable species differences, are the likely reasons for this variability. Context, including the fact that captive subjects were often directly reinforced with food for tolerating noise exposure, may also explain why there was great disparity in results from field and laboratory conditions, exposures in captive settings generally exceeded 170 dB re 1 μPa before inducing behavioral responses. Below we summarize some of the relevant material reviewed by Southall et al. (2007).

LGL and Greeneridge (1986) and Finley et al. (1990) documented belugas and narwhals congregated near ice edges reacting to the approach and passage of icebreaking ships. Beluga whales responded to oncoming vessels by (1) fleeing at speeds of up to 20 kilometers per hour (km/hr) from distances of 12 to 50 mi (19 to 80 km), (2) abandoning normal pod structure, and (3) modifying vocal behavior and/or emitting alarm calls. Narwhals, in contrast, generally demonstrated a “freeze” response, lying motionless or swimming slowly away (as far as 23 mi/37 km down the ice edge), huddling in groups, and ceasing sound production. There was some evidence of habituation and reduced avoidance 2 to 3 days after onset.

The 1982 season observations by LGL & Greeneridge (1986) involved a single passage of an icebreaker with both ice-based and aerial measurements on 28 June 1982. Four groups of narwhals (n = 9 to 10, 7, 7, and 6) responded when the ship was 4.0 mi (6.4 km away) with received levels of ~100 dB re 1 μPa in the 150- to 1,150-Hz band. At a later point, observers sighted belugas moving away from the source at >12.4 mi (> 20 km) with received levels of ~90 dB re 1 μPa in the 150- to 1,150-Hz band. The total number of animals observed fleeing was about 300, suggesting approximately 100 independent groups (of three individuals each). No whales were sighted the following day, but some were sighted on 30 June, with ship noise audible at spectrum levels of approximately 55 dB re 1 μPa/Hz (up to 4 kHz).

Observations during 1983 (LGL & Greeneridge 1986) involved two icebreaking ships with aerial survey and ice-based observations during seven sampling periods. Narwhals and belugas generally reacted at received levels ranging from 101 to 121 dB re 1 μPa in the 20- to 1,000-Hz band and at a distance of up to 65 km. Large numbers (100s) of beluga whales moved out of the area at higher received levels. As noise levels from icebreaking operations diminished, a total of

45 narwhals returned to the area and engaged in diving and foraging behavior. During the final sampling period, following an 8-hour quiet interval, no reactions were seen from 28 narwhals and 17 belugas (at received levels ranging up to 115 dB re 1 μPa).

The final season (1984) reported in LGL & Greeneridge (1986) involved aerial surveys before, during, and after the passage of two icebreaking ships. During operations, no belugas and few narwhals were observed in an area approximately 17 mi (27 km) ahead of the vessels, and all whales sighted over 12-50 mi (19 to 80 km) from the ships were swimming strongly away. Additional observations confirmed the spatial extent of avoidance reactions to this sound source in this context.

Awbrey & Stewart (1983) played back semi-submersible drillship sounds (source level: 163 dB re 1 μPa-m) to belugas in Alaska. They reported avoidance reactions at 985 ft and 4,921 ft (300 m and 1,500 m) and approach by groups at a distance of 3,927 yd (3,500 m) with received levels ~110 to 145 dB re 1 μPa over these ranges assuming a 15 log R transmission loss. Similarly, Richardson et al. (1990) played back drilling platform sounds (source level: 163 dB re 1 μPa-m) to belugas in Alaska. They conducted aerial observations of eight individuals among ~100 spread over an area several hundred meters to several kilometers from the sound source and found no obvious reactions. Moderate changes in movement were noted for three groups swimming within 656 ft (200 m) of the sound projector.

Finally, two recent papers deal with important issues related to changes in marine mammal vocal behavior as a function of variable background noise levels. Foote et al. (2004) found increases in the duration of killer whale calls over the period 1977 to 2003, during which time vessel traffic in Puget Sound, and particularly whale-watching boats around the animals, increased dramatically. Scheifele et al. (2005) demonstrated that belugas in the St. Lawrence River increased the levels of their vocalizations as a function of the background noise level (the "Lombard Effect").

Several researchers conducting laboratory experiments on hearing and the effects of nonplused sounds on hearing in mid-frequency cetaceans have reported concurrent behavioral responses. Nachtigall et al. (2003) reported that noise exposures up to 179 dB re 1 μPa and 55-min duration affected the trained behaviors of a bottlenose dolphin participating in a TTS experiment. Finneran and Schlundt (2004) provided a detailed, comprehensive analysis of the behavioral responses of belugas and bottlenose dolphins to 1-s tones (received levels 160 to 202 dB re 1 μPa) in the context of TTS experiments. Romano et al. (2004) investigated the physiological responses of a bottlenose dolphin and a beluga exposed to these tonal exposures and demonstrated a decrease in blood cortisol levels during a series of exposures between 130 and 201 dB re 1 μPa. Collectively, the laboratory observations suggested the onset of behavioral response at higher received levels than did field studies. The differences were likely related to the very different conditions and contextual variables between untrained, free-ranging individuals vs. laboratory subjects that were rewarded with food for tolerating noise exposure.

***Pinnipeds***—Pinnipeds generally seem to be less responsive to exposure to industrial sound than most cetaceans. Pinniped responses to underwater sound from some types of industrial activities such as seismic exploration appear to be temporary and localized (Harris et al. 2001, Reiser et al. 2009b).

Blackwell et al. (2004) reported little or no reaction of ringed seals in response to pile-driving activities during construction of a man-made island in the Beaufort Sea. Ringed seals were observed swimming as close as 150 ft (46 m) from the island and may have been habituated to the sounds which were likely audible at distances <1.9 mi (<3.0 km) underwater and 0.3 mi (0.5 km) in air. Moulton et al. (2003) reported that ringed seal densities on ice in the vicinity of a man-made island in the Beaufort Sea did not change significantly before and after construction and drilling activities.

Southall et al. (2007) reviewed literature describing responses of pinnipeds to non-pulsed sound and reported that the limited data suggest exposures between ~90 and 140 dB re 1 μPa generally do not appear to induce strong behavioral responses in pinnipeds exposed to nonplused sounds in water; no data exist regarding exposures at higher levels. It is important to note that among these studies of pinnipeds responding to non-pulse exposures in water, there are some apparent differences in responses between field and laboratory conditions. In contrast to the mid-frequency odontocetes, captive pinnipeds responded more strongly at lower levels than did animals in the field. Again, contextual issues are the likely cause of this difference.

Jacobs and Terhune (2002) observed harbor seal reactions to AHDs (source level in this study was 172 dB re: 1 μPa-m) deployed around aquaculture sites. Seals were generally unresponsive to sounds from the AHDs. During two specific events, individuals came within 43 and 44 m of active AHDs and failed to demonstrate any measurable behavioral response; estimated received levels based on the measures given were ~120 to 130 dB re 1 μPa.

Costa et al. (2003) measured received noise levels from an Acoustic Thermometry of Ocean Climate (ATOC) program sound source off northern California using acoustic data loggers placed on translocated elephant seals. Subjects were captured on land, transported to sea, instrumented with archival acoustic tags, and released such that their transit would lead them near an active ATOC source (at 3,081 ft [939-m] depth; 75-Hz signal with 37.5- Hz bandwidth; 195 dB re 1 μPa-m max. source level, ramped up from 165 dB re 1 μPa-m over 20 min) on their return to a haulout site. Received exposure levels of the ATOC source for experimental subjects averaged 128 dB re 1 μPa (range 118 to 137) in the 60- to 90-Hz band. None of the instrumented animals terminated dives or radically altered behavior upon exposure, but some statistically significant changes in diving parameters were documented in nine individuals. Translocated northern elephant seals exposed to this particular non-pulse source began to demonstrate subtle behavioral changes at ~120 to 140 dB re 1 μPa exposure RLs.

Kastelein et al. (2006) exposed nine captive harbor seals in a ~80 x 100 ft (~24 × 30 m) enclosure to non-pulse sounds used in underwater data communication systems (similar to acoustic modems). Test signals were frequency modulated tones, sweeps, and bands of noise with fundamental frequencies between 8 and 16 kHz; 128 to 130 [± 3] dB re 1 μPa-m source levels; 1- to 2-s duration (60-80 percent duty cycle); or 100 percent duty cycle. They recorded seal positions and the mean number of individual surfacing behaviors during control periods (no exposure), before exposure, and in 15-min experimental sessions (n = 7 exposures for each sound type). Seals generally swam away from each source at received levels of ~107 dB re 1 μPa, avoiding it by ~5 m, although they did not haul out of the water or change surfacing behavior. Seal reactions did not appear to wane over repeated exposure (*i.e.*, there was no obvious habituation), and the colony of seals generally returned to baseline conditions following exposure. The seals were not reinforced with food for remaining in the sound field.

## 7.4 Summary of Potential Effects of Exposure to Underwater Sounds from Bathymetric Sonar and Echosounder Signals

Bathymetric sonar equipment planned for use during the 2013 marine surveys include a dual-frequency side scan sonar, single-beam echo sounders, a multibeam echo sounder, and an ultra-short baseline acoustic positioning system. These sonar devices emit very short pulses with most of the energy in medium to high frequencies (3 to +240 kHz). The signal from multibeam and side scan sonars is narrow in fore-aft extent and wider in the cross-track extent. Single beam units typically have a narrow conical beam project directly below the vessel. Any given mammal at depth near the trackline would be in the main beam for only a fraction of a second. Therefore, marine mammals that encounter these sonar devices at close range are unlikely to be subjected to repeated pulses because of the narrow fore–aft width of the beam, and will receive only limited amounts of pulse energy because of the short pulses. Similarly, Kremser et al. (2005) noted that the probability of a cetacean swimming through the area of exposure when a multi-beam sonar emits a pulse is small. An animal would have to occur near the transducer at close range and be swimming at the same speed and direction as the vessel in order to be subjected to sound levels that could cause TTS.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally are more powerful than the equipment proposed for the current surveys, (2) have longer pulse duration, and (3) are directed close to horizontally vs. downward for the proposed equipment. The area of possible influence of the bathymetric sonar is much smaller, a narrow band oriented in the cross-track direction below the source vessel. In assessing the possible impacts of a similar multibeam system (the 15.5 kHz Atlas Hydrosweep multibeam bathymetric sonar), Boebel et al. (2004) noted that the critical sound pressure level at which TTS may occur is 203.2 dB re 1 μPa (rms). The critical region included an area of 43 m (141 ft) in depth, 46 m (151 ft) wide athwartship, and 1 m (3 ft) fore-and-aft. In the more distant parts of that (small) critical region, only slight TTS would be incurred.

Recent measurements of underwater sound propagation from equipment similar to that proposed for the 2013 surveys indicated relatively low sound levels and small sound radii (Mouy and Hannay 2008; Zykov and Sneddon 2008; Warner and McCroden 2011). The small disturbance radii indicate that it would be extremely unlikely that any marine mammal would approach the operating bathymetric sonar close enough be affected in a biologically significant manner.

**Masking**

Marine mammal communications will not be masked appreciably by the bathymetric sonar signals given the low duty cycle of the sonar and the brief period when an individual mammal is likely to be within the sonar beam. Furthermore, the bathymetric sonar equipment proposed for the 2013 marine surveys will not overlap with the predominate frequencies in baleen whale calls, further reducing any potential for masking in that group.

Odontocetes generally have better hearing capabilities at higher frequencies than baleen whales. Hearing range is known to extend to 80–150 kHz for some species. Some odontocetes are also capable of hearing low frequencies (*e.g.*, <500 Hz) but their sensitivity at these low frequencies seems poor (Richardson et al. 1995a). Beluga whale is the only odontocete likely to occur in the proposed survey area, although harbor porpoise occurrence appears to be increasing in the Chukchi Sea and small numbers of harbor porpoise could occur in the survey areas. The

relatively high frequency of the proposed bathymetric sonar equipment will be above the best hearing frequencies of beluga whales and harbor porpoises, and will be unlikely to produce any masking effects for these species. Additionally, these species would have to be very close to the sound source due to the small radii of sound propagation from these low energy sources.

**Behavioral Responses**

Behavioral reactions of free-ranging marine mammals to military and other sonars appear to vary by species and circumstance. Observed reactions have included silencing and dispersal by sperm whales (Watkins et al. 1985), increased vocalizations and no dispersal by pilot whales (Rendell and Gordon 1999), and previously mentioned beaching by beaked whales. Also, Navy personnel have described observations of dolphins' bow-riding adjacent to bow-mounted mid-frequency sonars during sonar transmissions. During exposure to a 21–25 kHz whale-finding sonar with a source level of 215 dB re 1 μPa·m, gray whales showed slight avoidance (~200 m or 656 ft) behavior (Frankel 2005).

However, all of those observations are of limited relevance to the present situation. Pulse durations from the Navy sonars were much longer than those of the bathymetric sonars to be used during the proposed study, and a given mammal would have received many pulses from the naval sonars. During Shell's planned, the individual pulses will be very short, and a given mammal would not receive many of the downward-directed pulses as the vessel passes by.

Captive bottlenose dolphins and a beluga whale exhibited changes in behavior when exposed to 1 s pulsed sounds at frequencies much lower than those that will be emitted by the bathymetric sonar to be used by Shell, and to shorter broadband pulsed signals. Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure (Schlundt et al. 2000; Finneran et al. 2002; Finneran and Schlundt 2004). The relevance of those data to free-ranging odontocetes is uncertain, and in any case, the test sounds were quite different in either duration or bandwidth as compared with those from bathymetric sonar.

We are not aware of any data on the reactions of pinnipeds to sonar sounds at frequencies similar to those of the bathymetric sonar equipment. Additionally, pinniped hearing sensitivity is probably low at the relatively high frequencies of the proposed sonars. Based on observed pinniped responses to other types of pulsed sounds, and the likely brevity of exposure to the bathymetric sonar sounds, pinniped reactions to the sonar sounds are expected to be limited to startle or otherwise brief responses of no lasting consequence to the animals.

As noted earlier, NMFS (2001) has concluded that momentary behavioral reactions "do not rise to the level of taking". Thus, brief exposure of cetaceans or pinnipeds to small numbers of signals from a bathymetric sonar system would not result in a "take" by harassment.

**Hearing Impairment and Other Physical Effects**

Given recent stranding events that have been associated with the operation of naval sonar, there is concern that mid-frequency sonar sounds can cause serious impacts to marine mammals (see above). However, the sonars proposed for use by Shell are quite different from sonars used for navy operations. Pulse duration of the sonars is very short relative to the naval sonars. Also, at any given location, an individual cetacean or pinniped would be in the beam of the sonar for much less time given the generally downward orientation of the beam and its narrow fore-aft beam width. (Navy sonars often use near-horizontally-directed sound.) Those factors would all

reduce the sound energy received from the bathymetric sonar relative to that from the sonars used by the Navy.

## 7.5 Summary of Potential Effects of Exposure to Underwater Sounds from Sub-bottom Profiler Signals

A shallow, sub-bottom profiler (operating between 2 and 35 kHz) is planned for use during the 2013 marine surveys. As discussed above for bathymetric sonar, the sub-bottom profiler is a relatively low energy source compared to Navy sonar. Laurinolli et al. (2007) measured sound threshold levels for similar equipment (Datasonics CAP6000 profiler) in the Beaufort Sea in 2007 and reported that underwater sound propagation ranged from 1 to 260 m (3 to 853 ft) for the 160 to 120 dB rms sound level radii. Measurements of a Kongsberg SBP300 in the Chukchi Sea by Warner and McCroden (2011) showed the 160 dB distance to be 30 m when directly in the pulsed beam and 3 m when out of the narrow beam.

**Masking**

Marine mammal communications will not be masked appreciably by the sub-bottom profiler signals given its relatively low duty cycle, directionality, and the brief period when an individual mammal is likely to be within its beam. The frequencies of sonar signals will not overlap with the predominant low frequencies in baleen whale calls, further reducing potential for masking for those species.

The only odontocetes likely to occur in the proposed survey area are beluga whale and possibly harbor porpoise. Belugas can hear sounds ranging from 1.2 to 120 kHz with their peak sensitivity from ~10–15 kHz, which may overlap with some of the frequencies used by the sub-bottom profiling equipment (Fay 1988). However, the sub-bottom profiling equipment operates at low energy levels and sound propagation is limited and unlikely to be audible to most beluga whales.

**Behavioral Responses**

Marine mammal behavioral reactions to sonar pulses are discussed above, and responses to the sub-bottom profiler are likely to be similar to those for other pulsed sources if received at the same levels. Responses to these sounds are expected to be much less than to even small airgun arrays which have stronger source levels and greater propagation distances. Behavioral responses to the sub-bottom profiler are not expected unless marine mammals are very close to the source. NMFS (2001) has concluded that momentary behavioral reactions “do not rise to the level of taking”. Thus, brief exposure of cetaceans to small numbers of signals from the sub-bottom profiler would not result in a “take” by harassment.

**Hearing Impairment and Other Physical Effects**

Source frequencies of the sub-bottom profilers are much lower than those of the sonars described above. As with the bathymetric sonar, the sub-bottom profiler pulses are brief and concentrated in a downward beam. A marine mammal would be in the beam of the sub-bottom profiler only briefly, reducing its received sound energy. Thus, it is unlikely that the sub-bottom profiler will produce pulse levels strong enough to cause hearing impairment or other physical injuries even in an animal that is (briefly) in a position near the source.

## 7.6 Summary of Potential Effects of Exposure to sounds from Aircraft

A helicopter may be used intermittently, if at all, to support a crew change or resupply to a vessel during performance of marine surveys or the equipment recovery and maintenance. During any flight the helicopter could encounter marine mammals both in the water and hauled out on ice. However, the aircraft will follow strict rules regarding altitude and lateral distance to mammals in water or hauled-out in order reduce the likelihood of any impacts.

Under calm conditions, rotor and engine sounds are coupled into the water within a 26°(degree) cone beneath the aircraft. Some of the sound will transmit beyond the immediate area, and some sound will enter the water outside the 26º area when the sea surface is rough. However, scattering and absorption will limit lateral propagation in the shallow water.

Dominant tones in noise spectra from helicopters are generally below 500 Hz (Greene and Moore 1995). Harmonics of the main rotor and tail rotor usually dominate the sound from helicopters; however, many additional tones associated with the engines and other rotating parts are sometimes present.

Because of doppler shift effects, the frequencies of tones received at a stationary site diminish when an aircraft passes overhead. The apparent frequency is increased while the aircraft approaches and is reduced while it moves away.

Aircraft flyovers are not heard underwater for very long, especially when compared to how long they are heard in air as the aircraft approaches an observer. Helicopters flying to and from any vessel will generally maintain straight-line routes at altitudes of 1,500 ft (457 m) above sea level (ASL), thereby limiting the received levels at and below the surface.

# 8. THE ANTICIPATED IMPACT OF THE ACTIVITY ON THE AVAILABILITY OF THE SPECIES OR STOCKS OF MARINE MAMMALS FOR SUBSISTENCE USES

Subsistence hunting continues to be an essential aspect of Inupiat Native life, especially in rural coastal villages. The Inupiat participate in subsistence hunting activities in and around the Chukchi Sea. The animals taken for subsistence provide a significant portion of the food that will last the community through the year. Marine mammals represent on the order of 60-80 percent of the total subsistence harvest. Along with the nourishment necessary for survival, the subsistence activities strengthen bonds within the culture, provide a means for educating the young, provide supplies for artistic expression, and allow for important celebratory events. In this IHA application Shell specifically discusses the potential impact from the geophysical surveys, equipment recovery and maintenance planned in the Chukchi Sea, to subsistence use of the bowhead whale, beluga, and seals, which are the primary marine mammals harvested that are also covered under this authorization of incidental take by NMFS.

***Bowhead Whale*** Activities associated with Shell's planned surveys would have no or negligible effects on bowhead whales. Noise and general activity associated with geophysical surveys and operation of vessels has the potential to harass bowhead whales. However, as noted above in Section 7, though temporary diversions of the swim path of migrating whales have been documented, the whales have generally been observed to resume their initial migratory route. Any effects on the bowhead whale, as a subsistence resource, would be negligible. Geophysical

surveys and vessel noise could in some circumstances affect subsistence hunts by placing the animals further offshore or otherwise at a greater distance from villages thereby increasing the difficulty of the hunt or retrieval of the harvest, or creating a safety risk to the whalers. Residents of Barrow hunt bowheads during the spring and fall migration. However, bowhead hunts by residents of Wainwright, Point Lay and Point Hope take place almost exclusively in the spring and are typically curtailed when ice begins to break up which is prior to the date Shell would commence the 2013 activities. From 1974 through 2009, bowhead harvests by these Chukchi Sea villages occurred only in the spring between early April and mid-June (Suydam and George, 2012). A Wainwright whaling crew harvested the first fall bowhead in 90 years or more on October 8, 2010, and again in October of 2011. Fall whaling by Chukchi Sea villages may occur in the future, particularly if bowhead quotas are not completely filled during the spring hunt, and fall weather is accommodating.

During the survey period most marine mammals are expected to be dispersed throughout the area, except during the peak of the bowhead whale migration thru the Chukchi Seas, which occurs from late August into October. Bowhead whales are expected to be in the Canadian Beaufort Sea during much of the time, therefore, are not expected to be affected by the geophysical surveys and vessel noise prior to the start of the fall subsistence hunt. After the conclusion of the subsistence hunt, bowheads may travel in proximity to the survey area and hear sounds from sonar, high resolution profilers, and associated vessel sounds; and may be displaced by these activities.

In 2013, Shell's operations will commence July 1 and will be adjusted to avoid conflict with subsistence activities and mitigated to limit effects on bowhead behavior or movements in the Chukchi Sea. Shell has developed and proposes to implement a number of mitigation measures which include a proposed 4MP (Attachment A), employment of subsistence advisors in the villages, and implementation of a Communications Plan (with operation of Com Centers). These are further described below in Section 12.3. Therefore, any behavioral responses of avoidance of activity areas by bowheads in the Chukchi Sea are anticipated to be minor and short term and would have no or negligible effect on the subsistence resource or subsistence hunts for bowhead.

***Beluga***—Belugas typically do not represent a large proportion of the subsistence harvests by weight in the communities of Wainwright and Barrow, the nearest communities to Shell's planned 2013 activities in the Chukchi Sea. Barrow residents hunt beluga in the spring normally after the bowhead hunt) in leads between Point Barrow and Skull Cliffs in the Chukchi Sea primarily in April-June, and later in the summer (July-August) on both sides of the barrier island in Elson Lagoon / Beaufort Sea (MMS 2008), but harvest rates indicate the hunts are not frequent. Wainwright residents hunt beluga in April-June in the spring lead system, but this hunt typically occurs only if there are no bowheads in the area. Communal hunts for beluga are conducted along the coastal lagoon system later in July-August.

Belugas typically represent a much greater proportion of the subsistence harvest in Point Lay and Point Hope. Point Lay's primary beluga hunt occurs from mid-June through mid-July, but can sometimes continue into August if early success is not sufficient. Point Hope residents hunt beluga primarily in the lead system during the spring (late March to early June) bowhead hunt, but also in open water along the coastline in July and August. Belugas are harvested in coastal waters near these villages, generally within a few miles from shore. The southern extent of Shell's proposed surveys is Icy Cape which lies over 30 miles (48 km) to the north of Point Lay, and therefore the surveys would have no or negligible effect on beluga hunts.

The survey vessel may be resupplied via another vessel from onshore support facilities and may traverse areas that are sometimes used for subsistence hunting of belugas. Disturbance associated with vessel and potential aircraft traffic could therefore potentially affect beluga hunts. However, all of the beluga hunt by Barrow residents in the Chukchi Sea, and much of the hunt by Wainwright residents would likely be completed before Shell activities would commence.

In 2013, Shell's operations will commence July 1 and will be adjusted to avoid conflict with subsistence activities and mitigated to limit effects on beluga behavior or movements in the Chukchi Sea. Shell has developed and proposes to implement a number of mitigation measures which include a proposed 4MP (Attachment A), employment of subsistence advisors in the villages, and implementation of a Communications Plan (with operation of Com Centers). These are further described below in Section 12.3. Therefore, any behavioral responses of avoidance of activity areas by beluga in the Chukchi Sea are anticipated to be minor and short term and would have no or negligible effect on the subsistence resource or subsistence hunts for beluga.

***Seals***—Seals are an important subsistence resource and ringed seals make up the bulk of the seal harvest. Most ringed and bearded seals are harvested in the winter or in the spring before Shell's 2013 activities would commence, but some harvest continues during open water and could possibly be affected by Shell's planned activities. Spotted seals are also harvested during the summer. Most seals are harvested in coastal waters, with available maps of recent and past subsistence use areas indicating seal harvests have occurred only within 30-40 mi (48-64 km) off the coastline. Shell's planned offshore surveys; equipment recovery and maintenance would occur outside state waters and are not likely to have an impact on subsistence hunting for seals. Resupply vessel and air traffic between land and the operations vessels could potentially disturb seals and, therefore, subsistence hunts for seals, but any such effects would be minor due to the small number of and the fact that most seal hunting is done during the winter and spring. Any effects on subsistence hunts for seals would be negligible and temporary lasting only minutes after the vessel or aircraft has passed. Any effects on the seals as a subsistence resource, or effects on subsistence hunts for seals would be negligible. These mitigation measures which include employment of subsistence advisors in the villages and implementation of a Communications Plan, (with operation of Communication Centers) are described below in Section 12.3.

# 9. ANTICIPATED IMPACT ON HABITAT

Shell's planned 2013 geophysical surveys, and equipment recovery and maintenance activity will not result in any permanent impact on habitats used by marine mammals, or to their prey sources. The primary potential impacts on the habitat and prey resources that are reasonably expected or reasonably likely are associated with elevated sound levels from survey equipment, the survey vessel and aircraft, and some seafloor disturbance or temporary increased turbidity in the MLC during equipment recovery maintenance. The amount and duration of disturbed or turbid conditions will depend on the grain size and consolidations of the sediments. The effects on the habitat from the planned surveys are expected to be negligible as they will be confined to very small areas within the Chukchi Sea, and will be ephemeral or short-term.

## 9.1 Potential Impacts on Habitat due to Sound Generation

### Zooplankton

Sound energy generated by geophysical survey activities will not negatively impact the diversity and abundance of zooplankton. The primary generators of sound energy are sonar, high resolution profiling and the marine vessel. No appreciable adverse impact on zooplankton populations will occur due in part to large reproductive capacities and naturally high levels of predation and mortality of these populations. Any mortality or impacts on zooplankton as a result of Shell's operations is insignificant as compared to the naturally-occurring reproductive and mortality rates of these species. This is consistent with previous conclusions that crustaceans (such as zooplankton) are not particularly sensitive to sound produced by seismic sounds (Wiese 1996). Impact from sound energy generated by the surveys would have less impact, as these activities produce lower sound energy levels (Burns et al. 1993).

### Benthos

Sound energy generated by the survey activities will not appreciably affect diversity and abundance of plants or animals on the seafloor. This is expected due in part to large reproductive capacities and naturally high levels of predation and mortality of these populations.

Any mortalities or impacts that might occur as a result of Shell's operations is insignificant compared to the naturally-occurring high reproductive and mortality rates. This is consistent with previous DOI conclusions that the effect of seismic exploration on benthic organisms probably would be immeasurable (USDI/MMS 2007). Impact from sound energy generated by the surveys would have less impact, as these activities produce lower sound energy levels (Burns et al. 1993).

### Fish

Fish react to sound and use sound to communicate (Tavolga et al. 1981). Experiments have shown that fish can sense both the intensity and direction of sound (Hawkins 1981). Whether or not fish can hear a particular sound depends upon its frequency and intensity. Wavelength and the natural background sound also play a role. The intensity of sound in water decreases with distance as a result of geometrical spreading and absorption. Therefore, the distance between the sound source and the fish is important. Physical conditions in the sea, such as temperature thermoclines and seabed topography, can influence transmission loss and thus the distance at which a sound can be heard. The impact of sound energy from survey activities will be negligible and temporary. Fish typically move away from sound energy above a level that is at 120dB or higher (Ona 1988).

Based on previous survey operations conducted by Statoil in the Chukchi Sea in 2011 (Hartin et al. 2011) sounds produced by the survey vessel in active DP had a radius of ~2.3 km. At this intensity level, fish may avoid the vessel while in DP mode. This avoidance behavior is temporary and limited to periods when noise levels exceed 120dB. In general, fish show greater reactions to a spike in sound energy levels, or impulse sounds, rather than a continuous high intensity signal (Blaxter et al. 1981).

Fish sensitivity to impulse sound varies depending on the species of fish. Cod, herring and other species of fish with swim bladders have been found to be relatively sensitive to sound, while mackerel, flatfish, and many other species that lack swim bladders have been found to have poor hearing (Hawkins 1981, Hastings and Popper 2005). An alarm response in these fish is elicited when the sound signal intensity rises rapidly compared to sound rising more slowly to the same level (Blaxter et al. 1981).

## 9.2 Potential Impacts from Seafloor Disturbance during Equipment Recovery and Maintenance

There will be some seafloor disturbance or temporary increased turbidity in the MLC seabed sediments during equipment removal and site maintenance activities. The amount and duration of disturbed or turbid conditions will depend on sediment material and consolidation and specific activity. The vessel conducting the activity would hold station with DP while equipment removal and site maintenance is conducted.

### Benthos

The impact of seabed disturbance would be limited to within the excavation of the MLC. Sessile organisms within the area were disturbed during the excavation-activity of 2012.

The MLC was created in the 2012 season and therefore few organisms are expected to have colonized the area by 2013.

Because the MLC was excavated in 2012 the impacts to populations of benthic organisms in the Chukchi Sea during 2013 will be negligible and restricted to a very small area of the MLC, an already disturbed location of the seafloor.

# 10. ANTICIPATED IMPACT OF HABITAT LOSS OR MODIFICATION

The effects of the planned activities are expected to be negligible, as described in Section 9. It is estimated that only a small portion of the animals utilizing the areas of the proposed activities would be temporarily displaced.

During the period of the activities (July through October), most marine mammals would be dispersed throughout the area. The peak of the bowhead whale migration through the Chukchi Sea typically occurs in mid-September and October, and efforts to reduce potential impacts during this time, such as conducting the majority of the activities during August and September which will provide effective protection of the bowhead migration and subsistence hunt. The timing of the surveys will take place when the whales are present in relatively low numbers. Starting in late August bowheads may travel in proximity to the aforementioned activity areas and hear sounds from vessel traffic and marine surveys. Small numbers of feeding gray whales may also be present proximal to activities in the Chukchi Sea. The numbers of cetaceans and pinnipeds that might be subject to displacement are small in relation to abundance estimates for the mammals addressed under this IHA.

In addition, feeding does not appear to be an important activity by bowheads migrating through the eastern and central part of the Alaskan Chukchi Sea in most years. In the absence of important feeding areas, the potential diversion of a small number of bowheads is not expected to have any significant or long-term consequences for individual bowheads or their population. Bowheads, gray, or beluga whales are not predicted to be excluded from any habitat nor are any seals predicted to be excluded from any habitat by the surveys.

The proposed activities are not expected to have any habitat-related effects that would produce long-term affects to marine mammals or their habitat due to the limited extent of the acquisition and operation areas and timing of the activities.

# 11. THE AVAILABILITY AND FEASIBILITY (ECONOMIC AND TECHNOLOGICAL), METHODS, AND MANNER OF CONDUCTING SUCH ACTIVITY OR MEANS OF EFFECTING THE LEAST PRACTICABLE IMPACT UPON AFFECTED SPECIES OR STOCK, THEIR HABITAT, AND OF THEIR AVAILABILITY FOR SUBSISTENCE USES, PAYING PARTICULAR ATTENTION TO ROOKERIES, MATING GROUNDS, AND AREAS OF SIMILAR SIGNIFICANCE

Two main mitigations regarding activities in the Chukchi Sea are proposed: (1) the timing and locations for active survey acquisition, equipment recovery and maintenance work; and (2) curtailing activities when the marine mammal observers sight visually (from shipboard) the presence of marine mammals within identified ensonified zones. Details of the proposed mitigations are discussed further in the 4MP that is included as Attachment A to this application.

# 12. 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 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. A PLAN MUST INCLUDE THE FOLLOWING

## 12.1 A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation

Shell is preparing to implement a (POC) pursuant to BOEM Lease Sale Stipulation No. 5, which requires that all exploration operations be conducted in a manner that prevents unreasonable conflicts between oil and gas activities and the subsistence activities and resources of residents of the North Slope. This stipulation also requires adherence to USFWS and NMFS regulations, which require an operator to implement a POC to mitigate the potential for conflicts between the proposed activity and traditional subsistence activities (50 CFR § 18.124(c)(4) and 50 CFR § 216.104(a)(12)).

The POC relies upon the Beaufort and Chukchi Sea Communication Plans to identify the measures that Shell has developed in consultation with North Slope subsistence communities and will implement during its planned 2013 activities to minimize any adverse effects on the availability of marine mammals for subsistence uses. In addition, the POC will detail Shell's communications and consultations with local subsistence communities concerning its planned 2013 program, potential conflicts with subsistence activities, and means of resolving any such conflicts (50 CFR § 18.128(d) and 50 CFR § 216.104(a) (12) (i), (ii), (iv)). Shell continues to document its contacts with the North Slope subsistence communities, as well as the substance of its communications with subsistence stakeholder groups.

The POC will be, and has been in the past, the result of numerous meetings and consultations between Shell, affected subsistence communities and stakeholders, and federal agencies. The POC identifies and documents potential conflicts and associated measures that will be taken to minimize any adverse effects on the availability of marine mammals for subsistence use. Outcomes of POC meetings are typically included in updates attached to the POC as addenda and distributed to federal, state, and local agencies as well as local stakeholder groups that either adjudicate or influence mitigation approaches for Shell's open water programs.

Meetings for Shell's 2013 drilling and open water marine surveys programs in the Beaufort and Chukchi Seas occurred in Kaktovik, Nuiqsut Barrow, Wainwright, and Point Lay, during October of 2012. Shell met with the marine mammal commissions and committees including the Alaska Eskimo Whaling Commission (AEWC), Eskimo Walrus Commission (EWC), Alaska Beluga Whale Committee (ABWC), Alaska Ice Seal Committee (AISC), and the Alaska Nanuuq Commission (ANC) on December 17 and 18, 2012 in a co-management meeting. In March 2013,

Shell revised its 2013 program to suspend plans for drilling, delete the proposed geotechnical program entirely, and remove survey activities from the Beaufort Sea. As a result, Shell has revised the proposed open water marine surveys program for 2013, thereby necessitating the additional community meetings that must be held this spring in Chukchi Sea villages to present changes to the 2013 season. Shell plans to conduct POC meetings in Chukchi Sea villages May 20-23 and May 29-31, 2013, dependent on abilities to schedule meetings around subsistence activities. Shell will supplement the IHA application with a POC addendum promptly after completing the village POC visits. Throughout 2013 Shell anticipates continued engagement with the marine mammal commissions and committees active in the subsistence harvests and marine mammal research.

Following the 2013 season, Shell intends to have a post-season co-management meeting with the commissioners and committee heads to discuss results of mitigation measures and outcomes of the preceding season. The goal of the post-season meeting is to build upon the knowledge base, discuss successful or unsuccessful outcomes of mitigation measures, and possibly refine plans or mitigation measures if necessary.

Shell has, and will continue to attend 2013 Conflict Avoidance Agreement (CAA) negotiation meetings in support of their 2013 activities in the Chukchi Sea. Shell remains committed to a CAA process and will demonstrate this by making a good-faith effort to negotiate an agreement every year it has planned activities. However, Shell does not assume that a CAA is required to mitigate the planned activities of the 2013 program, nor necessary for the issuance of an IHA to Shell by NMFS.

## 12.2 A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation.

As noted above, additional community meetings will be held this spring in Chukchi Sea villages to present the proposed addition of site clearance and shallow hazard surveys and equipment recovery and maintenance at the Burger A. well site. These meetings will be documented as prior meetings and included as an addendum to the POC report.

## 12.3 A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing

The following mitigation measures, plans and programs, are integral to this POC and were developed during consultation with potentially affected subsistence groups and communities. These measures, plans, and programs to monitor and mitigate potential impacts to subsistence users and resources will be implemented by Shell during its exploration activities in the Chukchi Sea.

The mitigation measures Shell has adopted and will implement during its geophysical surveys, equipment recovery and maintenance activities are listed and discussed below. These mitigation measures reflect Shell's experience conducting exploration activities in the Alaska Arctic OCS since the 1980s and its ongoing efforts to engage with local subsistence communities to better understand their concerns and develop appropriate and effective mitigation measures to address

those concerns. This most recent version of Shell's planned mitigation measures was presented to community leaders and subsistence user groups starting in January 2009 and has evolved since in response to information learned during the consultation process.

**Subsistence Mitigation Measures**

To minimize any cultural or resource impacts from its exploration operations, Shell will implement the following additional measures to ensure coordination of its activities with local subsistence users to minimize further the risk of impacting marine mammals and interfering with the subsistence hunt:

**Communication**

- Shell has developed a Communication Plan and will implement this plan before initiating open water marine surveys operations to coordinate activities with local subsistence users, as well as Village Whaling Captains' Associations, to minimize the risk of interfering with subsistence hunting activities, and keep current as to the timing and status of the bowhead whale hunt and other subsistence hunts. The Communication Plan includes procedures for coordination with Com Centers to be located in coastal villages along the Chukchi Sea during Shell's proposed activities.
- Shell will employ local SAs from Chukchi Sea villages that are potentially impacted by Shell's open water marine surveys. The SAs will provide consultation and guidance regarding the whale migration and subsistence activities. There will be one per village, working approximately 8-hours per day and 40-hours per week during the survey season. The subsistence advisor will use local knowledge (Traditional Knowledge) to gather data on subsistence lifestyle within the community and to provide advice in ways to minimize and mitigate potential negative impacts to subsistence resources during the survey season. Responsibilities include reporting any subsistence concerns or conflicts; coordinating with subsistence users; reporting subsistence-related comments, concerns, and information; coordinating with the Com Center personnel; and advising how to avoid subsistence conflicts. SAs will have a handbook that will specify work tasks in more detail.

**Vessel Travel**

- The survey and equipment recovery vessels will enter the Chukchi Sea through the Bering Strait on or after July 1, minimizing effects on marine mammals and birds that frequent open leads and minimizing effects on spring and early summer bowhead whale hunting.
- All vessels transit routes will avoid known fragile ecosystems, including the Ledyard Bay Critical Habitat Unit, and will include coordination through Com Centers.
- PSOs will be aboard the vessels used to conduct surveys and equipment recovery.
- When within 900 ft (274 m) of whales, vessels will reduce speed to at least 5 knots, avoid separating members from a group and avoid multiple changes of direction.
- Vessel speed is to be reduced during inclement weather conditions in order to avoid collisions with marine mammals.

- Shell will communicate and coordinate with the Com Centers regarding all vessel transit.

**Aircraft Travel**

- Aircraft shall not operate below 1,500 ft (457 m) unless the aircraft is engaged in approach, landing or taking off, in poor weather (fog or low ceilings), or in an emergency situation, while over land or sea to minimize disturbance to mammals and birds.
- Aircraft will not operate within 0.5 mi (0.8 km) of walrus or polar bears when observed on land or ice within 1,000 ft (300 m) of marine mammals or below 1,500 ft (457 m) altitude (except during takeoffs and landings or in emergency situations) while over land or sea. This flight will also help avoid disturbance of and collisions with birds.

## 12.4 What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation

In the fall 2012 Shell met with the potentially affected communities of the Chukchi Sea to introduce the 2013 open water marine surveys. These meetings served to facilitate early identification of key issues and permitting requirements. As noted above, due to the proposed changes for 2013 additional community meetings will be held this spring in the Chukchi Sea villages to present the proposed addition of site clearance and shallow hazard surveys and equipment recovery and maintenance at the Burger A well site.

Through the SA and Com and Call Center program for 2013, Shell will continue to stay in contact with the potentially affected communities. The SA provides the residents of the communities a way to communicate where and when subsistence activities will occur so that industry may avoid conflicts with planned subsistence activities. The Com and Call Center protocols enable industry to inform residents daily of industry activities and planned movements. These programs provide for two-way communication and foster opportunities for mitigation of industry activities that may in some way potentially conflict with planned subsistence activities.

## 13. 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 THE POPULATION 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

The proposed 4MP for the activities in the Chukchi Sea is included as Attachment A of this application.

## 14. SUGGESTED MEANS OF LEARNING OF, ENCOURAGING, AND COORDINATING RESEARCH OPPORTUNITIES, PLANS, AND ACTIVITIES RELATING TO REDUCING SUCH INCIDENTAL TAKING AND EVALUATING ITS EFFECTS

Various agencies and programs may undertake marine mammal studies in the Chukchi Sea during the course of the 2013 open water season. It is unclear if these studies might be relevant to Shell's proposed activities. Shell is prepared to share information obtained during implementation of our 4MP with a variety of groups who may find the data useful in their research. A suggested list of recipients includes:

- The North Slope Borough Department of Wildlife Management (T. Hepa)
- The USFWS Office of Marine Mammal Management (C. Perham, C. Putnam and J. MacCracken)
- The BOEM Aerial Surveys of Arctic Marine Mammals Program (J. Denton)
- National Oceanic and Atmospheric Association, National Marine Mammal Laboratory (R. Angliss)
- Alaska Eskimo Whaling Commission (G. Noongwook - Savoonga)
- Beluga Whale Committee (W. Goodwin - Kotzebue)
- Alaska Ice Seal Commission (J. Goodwin-Kotzebue)
- Inupiat Community of the Arctic Slope (D. Lampe - Barrow)
- Alaska Nanuq Commission (J. Omelak)
- North Slope Science Initiative (J. Payne)
- Alaska Department of Natural Resources (S. Longan)
- Alaska Department of Fish and Game

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# Attachment A
# Marine Mammal Monitoring and Mitigation Plan

# MARINE MAMMAL MONITORING AND MITIGATION PLAN

**for**

**Open Water Marine Surveys and Equipment Recovery and Maintenance**
**Alaskan Chukchi Sea, 2013**

**Submitted by**

**Shell Gulf of Mexico Inc.**

**to**

**National Marine Fisheries Service**
Office of Protected Resources
1315 East–West Hwy, Silver Spring, MD 20910-3282

**Monitoring Plan Prepared by**

Alaska Research Associates, Inc.

2000 W International Airport Rd, Suite C1
Anchorage, AK 99502

**April 2013**

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# Introduction

Shell plans to conduct geophysical surveys (i.e., open water marine surveys) designed to gather additional data relative to site clearance and shallow hazards and ice gouge in select areas of the Alaskan Chukchi Sea in 2013. In addition, Shell plans to conduct equipment recovery and maintenance activity at the Burger- A exploratory drill site in the Chukchi Sea. These marine surveys are continuations of similar data acquisition programs conducted by Shell in previous years that are designed to gather data on features of the seabed and sub seafloor topography in select areas of the Chukchi Sea. In conjunction with these proposed activities, Shell plans to implement a marine mammal monitoring and mitigation program (4MP).

Ice gouge surveys investigate the depth and distribution of ice gouges into the seabed and, site clearance and shallow hazard surveys focus on the upper 1,000 m of the seabed within select areas of interest near offshore drilling locations and potential pipeline corridors. The types of equipment used to conduct these surveys are focused on limited areas and emit low-level, very-high to low frequency acoustic impulse sounds or low-level, low frequency continuous sounds during discrete time periods over very limited areas of the ocean bottom and intervening water column.

Shell's 4MP is a combination of active monitoring of the area of operations and the implementation of mitigation measures designed to minimize project impacts to marine resources. If marine mammals are observed within or about to enter specific safety radii around the proposed survey activities, mitigation will be initiated by vessel-based protected species observers (PSOs). The size of the 180 and 190 dB re 1 μPa (rms) safety radii from the same airgun array (40 cubic inches) proposed for use in 2013 have been measured three times in recent years near the 2013 survey locations. These previous measurements are described in detail below in the section *Mitigation Measures during Survey Activities* (Table 1). The most conservative of these previously measured radii will be used for the purpose of implementing mitigation at the commencement of 2013 site clearance and shallow hazard survey activities. Shell will conduct sound source measurements of the airgun array at the beginning of survey operations in 2013 to verify the size of the various marine mammal exclusion zones. These newly-measured radii will be used for mitigation purposes as soon as they become available. An initial sound source analysis will be supplied to NMFS and the site clearance and shallow hazards survey operators within 120 hours of completion of the measurements. A more detailed report describing the sounds produced by the airguns will be provided to NMFS as part of the 90-day report following the end of the survey.

Vessel-based monitoring during airgun activity and periods when airguns are not active will provide information on the numbers of marine mammals potentially affected by the survey activities and facilitate real time mitigation to prevent impacts to marine mammals by industrial sounds or activities. Vessel-based PSOs onboard the survey vessel will record the numbers and species of marine mammals observed in the area and any observable reaction of marine mammals to the survey activities.

In addition to vessel-based monitoring of Shell's 2013 marine surveys, PSOs will be staffed aboard the vessel used for equipment recovery and maintenance activities at the Burger- A exploratory drill site. Monitoring by PSOs aboard this platform will include active watches around the vessel during stationary periods as it operates in dynamic-positioning (DP) mode. PSOs will conduct watches prior to the deployment of equipment, and also during maintenance

operations to ensure that there are no marine mammals present in areas immediately adjacent to the vessel.

A regional acoustics program will characterize the sounds produced by airguns, other survey and equipment recovery and maintenance activities, and document the potential reactions of marine mammals in the area to the activities. The 2013 Chukchi acoustics program is similar to that which was implemented during Shell's marine surveys in recent years and also during exploratory drilling activities in 2012. A regional acoustics monitoring program also will be implemented in the Beaufort Sea despite the absence of Shell-operated activities in the Beaufort Sea during 2013. The Beaufort Sea regional acoustic program will be implemented in 2013 to collect additional information for Shell's ongoing investigation into the fall migration of bowhead whales during a year with potentially reduced industry activities.

Ice gouge surveys are planned along ~1,000 km of trackline and site clearance and shallow hazards surveys are planned along ~3,200 km of trackline in the Chukchi Sea during 2013.

Marine Survey equipment to be used includes:

- Single-beam Echo Sounder, or similar;
- Dual-frequency side scan sonar, or similar;
- Multibeam Echo Sounder, or similar;
- 3.5 kHz Shallow Sub-bottom Profiler, or similar, CHIRP only;
- Magnetometer; and

Shallow hazard surveys use the equipment listed above plus:

- 4 x 10 cubic inches ($in^3$) airgun source;
- 48- channel Streamer (Deep Penetration Profiler); and,
- 24- channel Streamer (Medium Penetration Profiler).

Shell plans to conduct marine surveys from a single vessel with another vessel likely serving as support for crew changes and resupply. Timing of the work will depend on weather, ice conditions, and avoidance of subsistence activities. The marine surveys are planned to occur from July through October. The broad timeframe is required because surveys need to occur at specific sites and it is not possible to know precise dates that the sites will be accessible. Work would begin in July in accessible areas of the Chukchi Sea. An additional vessel will be utilized to conduct equipment recovery and maintenance activities at the Burger- A exploratory drill site over a period of ~28 days during the open-water season.

The 4MP developed for Shell's planned activities support the protection of marine mammal resources in the area, fulfills reporting obligations to the Bureau of Ocean Energy Management (BOEM), Bureau of Safety and Environmental Enforcement (BSEE), the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), and establishes a means for gathering additional data on marine mammals for future operations planning.

## Marine Mammal Monitoring

Shell's 4MP is a combination of active monitoring of the area of operations and the implementation of mitigation measures designed to minimize project impacts to marine resources. Monitoring will provide information on the numbers of marine mammals potentially affected by the exploration operations and facilitate real time mitigation to prevent injury of marine mammals by industrial sounds or activities. These goals will be accomplished in the Chukchi Sea during 2013 by conducting vessel-based monitoring from all ships with sound sources (at a minimum), manned aerial surveys if a suitable aircraft can be arranged, aerial photographic surveys (again, contingent upon aircraft availability), and an acoustic monitoring program to document underwater sounds and the vocalizations of marine mammals in the region. Similar to other programs, Shell will characterize the sounds produced by marine surveys and well-site activities, as well as monitor marine mammals from the survey vessel and equipment recovery vessel to provide information on impacts that may be specific to these operations.

Visual monitoring by Protected Species Observers (PSOs) during active marine survey operations, and periods when these surveys are not occurring, will provide information on the numbers of marine mammals potentially affected by these activities and facilitate real time mitigation to prevent impacts to marine mammals by industrial sounds or operations. Vessel-based PSOs onboard the survey vessel will record the numbers and species of marine mammals observed in the area and any observable reaction of marine mammals to the survey activities in the Chukchi Sea. Additionally, monitoring by PSOs aboard the vessel utilized for equipment recovery and maintenance activities at the Burger- A well site will ensure that there are no interactions between marine mammals and these operations. PSOs aboard the vessel will monitor adjacent areas while the vessel operates from a stationary position in DP mode.

The acoustics monitoring program will characterize the sounds produced by marine surveys and will document the potential reactions of marine mammals in the area to those sounds and activities. Recordings of ambient sound levels and vocalizations of marine mammals along the Chukchi Sea coast and offshore will also be used to interpret potential impacts to marine mammals around the marine survey and equipment recovery and maintenance activity, in addition to subsistence use areas closer to shore. Although these monitoring programs were designed primarily to understand the impacts of exploratory drilling in the Chukchi Sea they will also provide valuable information about the potential impacts of the 2013 marine surveys on marine mammals in the area.

## Vessel-Based Marine Mammal Monitoring Program

## Introduction

The vessel-based operations of Shell's 4MP are designed to meet the requirements of Incidental Harassment Authorization (IHA) and Letter of Authorization (LOA) permits issued by NMFS and USFWS, respectively, and to meet any other stipulation agreements between Shell and other agencies or groups. The objectives of the program will be:

- to ensure that disturbance to marine mammals and subsistence hunts is minimized and all permit stipulations are followed,
- to document the effects of the proposed survey activities on marine mammals, and

- to collect baseline data on the occurrence and distribution of marine mammals in the study area.

The 4MP will be implemented by a team of experienced PSOs, including both biologists and Inupiat personnel. PSOs will be stationed aboard the marine survey vessel and the vessel used to facilitate equipment recovery and maintenance work at the Burger- A exploratory well site through the duration of the projects. Reporting of the results of the vessel-based monitoring program will include the estimation of the number of "takes" as stipulated in the IHA and LOA.

The vessel-based portion of Shell's 4MP will be required to support the survey activities in the Chukchi Sea. The survey dates and specific operating areas are described above, but will also depend somewhat upon ice and weather conditions.

The vessel-based work will provide:

- the basis for real-time mitigation, if necessary, as required by the various permits that Shell receives;
- information needed to estimate the number of "takes" of marine mammals by harassment, which must be reported to NMFS and USFWS;
- data on the occurrence, distribution, and activities of marine mammals in the areas where the survey program is conducted;
- information to compare the distances, distributions, behavior, and movements of marine mammals relative to the survey vessel at times with and without various activities, and;
- a communication channel to coastal communities including Inupiat whalers and other subsistence users.

The 4MP will be operated and administered to be consistent with monitoring programs conducted during seismic and shallow hazards surveys, geotechnical coring operations, and exploratory drilling in 2006–2012 or such alternative requirements as may be specified in the authorizations issued this project. Any other stipulations from agreements between Shell and agencies or groups such as BOEM, BSEE, USFWS, the North Slope Borough (NSB), and the Alaska Eskimo Whaling Commission (AEWC) will also be fully incorporated. All PSOs will be provided training through a program approved by NMFS and Shell, as described below. At least one observer on each project vessel will be an Inupiat who will have the additional responsibility of communicating with coastal communities and directly with Inupiat whalers during the whaling season.

## Mitigation Measures during Survey Activities

Shell's planned marine surveys and equipment recovery and maintenance activity incorporate both design features and operational procedures for minimizing potential impacts on marine mammals and on subsistence hunts. The design features and operational procedures have been described in the IHA and LOA applications submitted to NMFS and USFWS, respectively, and are summarized below. Survey design features include:

- timing and locating survey activities to avoid interference with the annual spring beluga hunt at Point Lay and the fall bowhead whale hunt;

- identifying transit routes and timing to avoid other subsistence use areas and communicate with coastal communities before operating in or passing through these areas, and;
- limiting the size of the sound sources to minimize energy introduced into the marine environment;
- establishing precautionary safety radii based on previous measurements of a similar sound source in the area for implementation prior to completion of sound source measurements in 2013, and;
- monitoring by PSOs aboard the stationary vessel used for equipment recovery and maintenance activity.

The potential disturbance of marine mammals during survey and, equipment recovery and maintenance activity will be minimized further through the implementation of several ship-based mitigation measures if mitigation becomes necessary. General mitigation measures, per the NMFS IHA and USFWS LOA stipulations, will be implemented by PSOs aboard all vessels to reduce potential impacts to marine mammals from vessels movements and also from activities based from stationary vessels operating in DP. These general mitigation measures include reductions in vessel speed and alterations in vessel course to avoid marine mammals and maximize the distance between vessels and animals. PSOs aboard the stationary vessel positioned at the equipment recovery and maintenance site will monitor areas adjacent to the vessel to ensure that they are clear of marine mammals during activities.

**Safety and Disturbance Zones**

Under current NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around industrial sound sources are customarily defined as the distances within which received sound levels are ≥180 dB re 1 μPa (rms) for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. These safety criteria are based on an assumption that sound energy received at lower received levels will not injure these animals or impair their hearing abilities, but that higher received levels might have some such effects. Disturbance or behavioral effects to marine mammals from underwater sound may occur after exposure to sound at distances greater than the safety radii (Richardson et al. 1995).

Safety and disturbance radii for the sound levels produced by the 40 cubic-inch array and the single mitigation airgun (10 cubic inches) to be used during the 2013 site clearance and shallow hazards survey activities were measured at the Honeyguide and Burger prospect areas a total of three separate times between 2008 and 2009 (Table 1). The most conservative of these measurements will be implemented at the commencement of 2013 airgun operations to establish marine mammal exclusion zones used for mitigation (Table 2). Shell will conduct sound source measurements of the airgun array at the beginning of survey operations in 2013 to verify the size of the various marine mammal exclusion zones. The acoustic data will be analyzed as quickly as reasonably practicable in the field and used to verify and adjust the marine mammal exclusion zone distances. The field report will be made available to NMFS and the PSOs within 120 hrs of completing the measurements. The mitigation measures to be implemented at the 190 and 180 dB (rms) sound levels will include power downs and shut downs as described below.

**Table 1. Previous measurements of the ≥190, 180, and 160, dB (rms) distances (in km) for sound pulses from the 40–in3 array and the 10–in3 mitigation airgun deployed from Cape Flattery Mt. Mitchell at the Honeyguide and Burger prospect areas, Alaskan Chukchi Sea, 2008 and 2009. Values in bold represent the largest of previous measurements and will be implemented for mitigation purposes at the commencement of 2013 survey operations (Table 2) until 2013 SSV results are available.**

| Received Sound Level (dB rms) | *Cape Flattery* 2008[1] | | *Mt. Mitchell* 2009a[2] | | *Mt. Mitchell* 2009b[3] | |
|---|---|---|---|---|---|---|
| | 4-airgun array (40 in$^3$) | Mitigation airgun (10 in$^3$) | 4-airgun array (40 in$^3$) | Mitigation airgun (10 in$^3$) | 4-airgun array (40 in$^3$) | Mitigation airgun (10 in$^3$) |
| ≥190 | **0.050** | 0.008 | 0.041 | **0.023** | 0.039 | 0.008 |
| ≥180 | **0.160** | 0.032 | 0.099 | **0.052** | 0.146 | 0.034 |
| ≥160 | 1.400 | 0.440 | 0.597 | 0.278 | **1.770** | **0.569** |

[1] Measured at the Burger prospect area (Hannay and Warner 2009)

[2] Measured at the Honeyguide prospect area (Warner et al. 2009)

[3] Measured at the Burger prospect area (Warner et al. 2009)

**Table 2. Distances of the ≥190, 180, and 160, dB (rms) isopleths (in km) to be used for mitigation purposes at the beginning of 2013 airgun operations in the Chukchi Sea until 2013 SSV results are available.**

| Received Sound Level (dB rms) | 4-airgun array (40 in$^3$) | Single mitigation airgun (10 in$^3$) |
|---|---|---|
| ≥190 | 0.050 | 0.023 |
| ≥180 | 0.160 | 0.052 |
| ≥160 | 1.770 | 0.569 |

Sounds produced by the other equipment that Shell plans to use during marine surveys have been measured previously (JASCO Applied Sciences 2010, Hartin et al. 2011) and are not expected to produce enough sound within relevant frequencies to have more than negligible impacts on marine mammals in the immediate area of the surveys. However, an acoustics contractor will perform direct measurements of the received levels of underwater sound versus distance and direction for these other energy sources using calibrated hydrophones. The acoustic data will be analyzed as quickly and as reasonably practicable in the field and used to verify and adjust the safety distances if necessary. The field report will be made available to NMFS and the PSOs within 120 hrs of completing the measurements. The mitigation measures to be implemented at the 190 and 180 dB (rms) sound levels will include power downs and shut downs as described below.

## Power Downs and Shut Downs

A power down is the immediate reduction in the number of operating energy sources from all firing to some smaller number (e.g., single mitigation airgun). A shut down is the immediate cessation of firing of all energy sources. The array will be immediately powered down whenever a marine mammal is sighted approaching close to or within the applicable safety zone of the full array, but is outside the applicable safety zone of the single mitigation source. If a marine mammal is sighted within or about to enter the applicable safety zone of the single mitigation airgun, the entire array will be shut down (i.e., no sources firing).

### Ramp Ups

A ramp up of an airgun array provides a gradual increase in sound levels, and involves a step-wise increase in the number and total volume of airguns firing until the full volume is achieved. The purpose of a ramp up (or "soft start") is to "warn" cetaceans and pinnipeds in the vicinity of the airguns and to provide time for them to leave the area and thus avoid any potential injury or impairment of their hearing abilities.

During the proposed shallow hazards survey program, the seismic operator will ramp up the airgun arrays slowly. Full ramp ups (i.e., from a cold start after a shut down, when no airguns have been firing) will begin by firing a single airgun in the array (i.e., the mitigation airgun). A full ramp up, after a shut down, will not begin until there has been a minimum of 30 min of observation of the safety zone by PSOs to assure that no marine mammals are present. The entire safety zone must be visible during the 30-minute lead-in to a full ramp up. If the entire safety zone is not visible, then ramp up from a cold start cannot begin. If a marine mammal(s) is sighted within the safety zone during the 30-minute watch prior to ramp up, ramp up will be delayed until the marine mammal(s) is sighted outside of the safety zone or the animal(s) is not sighted for at least 15-30 minutes: 15 minutes for small odontocetes and pinnipeds, or 30 minutes for baleen whales and large odontocetes.

During turns and transit between seismic transects, at least one mitigation airgun will remain operational. The ramp-up procedure still will be followed when increasing the source levels from one air gun to the full arrays. However, keeping one airgun firing will avoid the prohibition of a cold start during darkness or other periods of poor visibility. Through use of this approach, seismic operations can resume upon entry to a new transect without a full ramp up and the associated 30-minute lead-in observations. PSOs will be on duty whenever the airguns are firing during daylight, and during the 30-min periods prior to ramp-ups as well as during ramp-ups. Daylight will occur for 24 h/day until mid-August, so until that date PSOs will automatically be observing during the 30-minute period preceding a ramp up. Later in the season, PSOs will conduct active watches during ramp up periods during darkness as well.

## Protected Species Observers

Vessel-based monitoring for marine mammals will be done by trained PSOs throughout the period of survey activities to comply with expected provisions in the IHA and LOA that Shell receives. The observers will monitor the occurrence and behavior of marine mammals near the survey vessel during all daylight periods during operation, and during most daylight periods when operations are not occurring. PSO duties will include watching for and identifying marine mammals; recording their numbers, distances, and reactions to the survey operations; and documenting "take by harassment" as defined by NMFS.

### Number of Observers

A sufficient number of PSOs will be required onboard the survey vessel to meet the following criteria:

- 100% monitoring coverage during all periods of survey operations in daylight;
- maximum of 4 consecutive hours on watch per PSO;
- maximum of ~12 hours of watch time per day per PSO.

PSO teams will consist of Inupiat observers and experienced field biologists. An experienced field crew leader will supervise the PSO team onboard the survey vessel. The total number of PSOs may decrease later in the season as the duration of daylight decreases assuming NMFS does not require continuous nighttime monitoring. Shell currently plans to have 4 to 5 PSOs aboard the survey vessel.

**Crew Rotation**

Depending on the duration of the activities, Shell may conduct crew changes during the season. During crew rotations detailed hand-over notes will be provided to the incoming crew leader by the outgoing leader. Other communications such as email, fax, and/or phone communication between the current and oncoming crew leaders during each rotation will also occur when possible. In the event of an unexpected crew change Shell will facilitate such communications to insure monitoring consistency among shifts.

**Observer Qualifications and Training**

Crew leaders and most other biologists serving as observers in 2013 will be individuals with experience as observers during recent seismic, site clearance and shallow hazards, and other monitoring projects in Alaska (e.g., exploratory drilling in 2012) or other offshore areas in recent years.

Biologist-observers will have previous marine mammal observation experience, and field crew leaders will be highly experienced with previous vessel-based marine mammal monitoring and mitigation projects. Resumes for those individuals will be provided to NMFS for review and acceptance of their qualifications. Inupiat observers will be experienced in the region and familiar with the marine mammals of the area. All observers will complete a NMFS approved observer training course designed to familiarize individuals with monitoring and data collection procedures. A marine mammal observers' handbook, adapted for the specifics of the planned survey program will be prepared and distributed beforehand to all PSOs (see below).

Observers will complete a two or three-day training and refresher session on marine mammal monitoring, to be conducted shortly before the anticipated start of the 2013 open-water season. Any exceptions will have or receive equivalent experience or training. The training session(s) will be conducted by qualified marine mammalogists with extensive crew-leader experience during previous vessel-based seismic monitoring programs.

Primary objectives of the training include:

- review of the marine mammal monitoring plan for this project, including any amendments specified by NMFS or USFWS in the IHA or LOA, by BOEM, BSSE or by other agreements in which Shell may elect to participate;
- review of marine mammal sighting, identification, and distance estimation methods;
- review of operation of specialized equipment (reticle binoculars, night vision devices, and GPS system);
- review of, and classroom practice with, data recording and data entry systems, including procedures for recording data on marine mammal sightings, monitoring operations, environmental conditions, and entry error control. These procedures will be implemented through use of a customized computer database and laptop computers;
- review of the specific tasks of the Inupiat Communicator.

**PSO Handbook**

A PSO's Handbook will be prepared for Shell's 2013 vessel-based monitoring program. Handbooks contain maps, illustrations, and photographs, as well as text, and are intended to provide guidance and reference information to trained individuals who will participate as PSOs. The following topics will be covered in the PSO Handbook for the Shell project:

- summary overview descriptions of the project, marine mammals and underwater noise, the marine mammal monitoring program (vessel roles, responsibilities), the NMFS IHA and USFWS LOA and other regulations/permits/agencies, the Marine Mammal Protection Act;
- monitoring and mitigation objectives and procedures, including safety radii;
- responsibilities of staff and crew regarding the marine mammal monitoring plan;
- instructions for ship crew regarding the marine mammal monitoring plan;
- data recording procedures: codes and coding instructions, PSO coding mistakes, electronic database; navigational, marine physical, field data sheet;
- list of species that might be encountered: identification, natural history;
- use of specialized field equipment (reticle binoculars, NVDs, etc.);
- reticle binocular distance scale;
- table of wind speed, Beaufort wind force, and sea state codes;
- data quality-assurance/quality-control, delivery, storage, and backup procedures;
- safety precautions while onboard;
- crew and/or personnel discord; conflict resolution among PSOs and crew;
- drug and alcohol policy and testing;
- scheduling of cruises and watches;
- communications;
- list of field gear that will be provided;
- suggested list of personal items to pack;
- suggested literature, or literature cited; and
- copies of the NMFS IHA and USFWS LOA when available.

## Monitoring Methodology

The observer(s) will watch for marine mammals from the best available vantage point on the survey vessels, typically the bridge. The observer(s) will scan systematically with the unaided eye and 7×50 reticle binoculars, supplemented with 20×60 image-stabilized Zeiss Binoculars or Fujinon 25 x 150 "Big-eye" binoculars, and night-vision equipment when needed. Personnel on the bridge will assist the marine mammal observer(s) in watching for marine mammals.

PSOs aboard the stationary vessel used to conduct equipment recovery and maintenance activity will focus their attention on areas immediately adjacent to the vessel and where active operations are occurring to ensure these areas are clear of marine mammals and that there are no direct interactions between animals and equipment or project personnel. The observer(s) aboard the marine survey vessel will give particular attention to the areas within the marine mammal exclusion zones around the source vessel. These zones are the maximum distances within which received levels may exceed 180 dB re 1 μPa (rms) for cetaceans, or 190 dB re 1 μPa (rms) for other marine mammals. Information to be recorded by PSOs will include the same types of information that were recorded during recent monitoring programs associated with Industry activity in the Arctic (e.g., Ireland et al. 2009; Reiser et al. 2010, 2011). When a mammal sighting is made, the following information about the sighting will be recorded:

- Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if determinable), bearing and distance from observer, apparent reaction to activities (e.g., none, avoidance, approach, paralleling, etc.), closest point of approach, and pace.
- Time, location, speed, and activity of the vessel, sea state, ice cover, visibility, and sun glare.
- The positions of other vessel(s) in the vicinity of the observer location.

The ship's position, speed of the vessel, water depth, sea state, ice cover, visibility, and sun glare will also be recorded at the start and end of each observation watch, every 30 minutes during a watch, and whenever there is a substantial change in any of those variables.

Distances to nearby marine mammals will be estimated with binoculars (Fujinon 7×50 binoculars) containing a reticle to measure the vertical angle of the line of sight to the animal relative to the horizon. Observers may use a laser rangefinder to test and improve their abilities for visually estimating distances to objects in the water. However, previous experience has shown that a civilian grade laser rangefinder was not able to measure distances to seals more than about 70 m (230 ft) away. The device was very useful in improving the distance estimation abilities of the observers at distances up to about 600 m (1968 ft)—the maximum range at which the device could measure distances to highly reflective objects such as other vessels. Humans observing objects of more-or-less known size via a standard observation protocol, in this case from a standard height above water, quickly become able to estimate distances within about ±20% when given immediate feedback about actual distances during training.

When a marine mammal is seen within the safety radius applicable to that species, the marine survey crew will be notified immediately so that mitigation measures called for in the applicable authorization(s) can be implemented.

### Monitoring At Night and In Poor Visibility

Night-vision equipment (Generation 3 binocular image intensifiers or equivalent units) will be available for use when/if needed. Past experience with night-vision devices (NVDs) in the Chukchi Sea and elsewhere has indicated that NVDs are not nearly as effective as visual observation during daylight hours (e.g., Harris et al. 1997, 1998; Moulton and Lawson 2002).

### Field Equipment

Shell will provide or arrange for the following specialized field equipment for use by PSOs aboard the survey vessel: reticle binoculars, 20×60 image-stabilized Zeiss Binoculars, GPS unit, laptop computer(s), night vision binoculars, digital still and possibly digital video cameras.

### Field Data-Recording, Verification, Handling, and Security

The observers will record their observations directly into computers running a custom designed software package. Paper datasheets will be available as backup if necessary. The accuracy of the data entry will be verified in the field by computerized validity checks as the data are entered, and by subsequent manual checking of the database printouts. These procedures will allow initial summaries of data to be prepared during and shortly after the field season, and will facilitate transfer of the data to statistical, graphical or other programs for further processing. Quality control of the data will be facilitated by (1) the start-of-season training session, (2) subsequent supervision by the onboard field crew leader, and (3) ongoing data checks during the field season.

The data will be sent off of the ship to Anchorage each day (if possible) and backed up regularly onto CDs and/or USB disks, and stored at separate locations on the vessel. If possible, data sheets will be photocopied daily during the field season. Data will be secured further by having data sheets and backup data CDs carried back to the Anchorage office during crew rotations.

In addition to routine PSO duties, observers will have available Traditional Knowledge and Natural History datasheets and voice recorders to document observations that are not captured by the sighting or effort data. Copies of these records will be available to observers for reference if they wish to prepare a statement about their observations. If prepared, this statement would be included in the 90-day and final reports documenting the monitoring work.

### Field Reports

Throughout the survey program, observers will prepare a report each day or at such other intervals as NMFS, USFWS, BOEM, BSEE or Shell may require, summarizing the recent results of the monitoring program. The reports will summarize the species and numbers of marine mammals sighted. These reports will be provided to NMFS and to the survey operators.

### Reporting

The results of the 2013 vessel-based monitoring, including estimates of "take by harassment", will be presented in 90-day and final technical reports. Reporting will address the requirements established by NMFS and USFWS.

The technical report(s) will include:

- summaries of monitoring effort: total hours, total distances, and distribution of marine mammals through the study period accounting for sea state and other factors affecting visibility and detectability of marine mammals;
- analyses of the effects of various factors influencing detectability of marine mammals including sea state, number of observers, and fog/glare;
- species composition, occurrence, and distribution of marine mammal sightings including date, water depth, numbers, age/size/gender categories, group sizes, and ice cover;
- analyses of the effects of survey operations:
    - sighting rates of marine mammals during periods with and without airgun activities (and other variables that could affect detectability);
    - initial sighting distances versus airgun activity state;
    - closest point of approach versus airgun activity state;
    - observed behaviors and types of movements versus airgun activity state;
    - numbers of sightings/individuals seen versus airgun activity state;
    - distribution around the survey vessel versus airgun activity state;
    - multiple estimates of "take by harassment."

## Acoustic Monitoring Plan

### Sound Source Measurements

The objectives of the sound source measurements planned for 2013 will be (1) to measure the distances at which broadband received levels reach 190, 180, 170, 160, and 120 dB re 1 μPa (rms) during marine surveys and equipment recovery and maintenance activity at the Burger- A exploratory well site, and from vessels used during these activities. The measurements of airguns and other marine survey equipment will be made by an acoustics contractor at the beginning of the surveys. Data from survey equipment will be previewed in the field immediately after download from the hydrophone instruments. An initial sound source analysis will be supplied to NMFS and the vessel within 120 hours of completion of the measurements, if possible. The report will indicate the distances to sound levels based on fits of empirical transmission loss formulae to data in the endfire and broadside directions. A more detailed report will be issued to NMFS as part of the 90-day report following completion of the acoustic program.

# Acoustic "Net" Array in Chukchi Sea

## Background and Objectives

This section describes acoustic studies that were undertaken from 2006 through 2012 in the Chukchi Sea as part of the Joint Monitoring Program that will be continued by Shell during marine survey and equipment recovery and maintenance activity in 2013. The acoustic "net" array used during the 2006–2012 field seasons in the Chukchi Sea was designed to accomplish two main objectives. The first was to collect information on the occurrence and distribution of marine mammals (including beluga whale, bowhead whale, walrus and other species) that may be available to subsistence hunters near villages located on the Chukchi Sea coast and to document their relative abundance, habitat use, and migratory patterns. The second objective was to measure the ambient soundscape throughout the eastern Chukchi Sea and to record received levels of sounds from industry and other activities further offshore in the Chukchi Sea.

## Technical Approach

A net array configuration similar to that deployed in 2007–2012 is again proposed for 2013. The basic components of this effort consist of autonomous acoustic recorders deployed widely across the US Chukchi Sea through the open water season and then the winter season. These precisely calibrated systems will sample at 16 kHz with 24-bit resolution, and are capable of recording marine mammal sounds and making anthropogenic noise measurements. The net array configuration will include a regional array of 24 Autonomous Multichannel Acoustic Recorders (AMAR) deployed July-October off the four main transect locations: Cape Lisburne, Point Hope, Wainwright and Barrow as shown in Figure 1. These will be augmented by six AMARs deployed August 2013 – August 2014 at Hanna Shoal. Six additional AMAR recorders will be deployed in a hexagonal geometry at 16 km from the nominal Burger- A exploratory well location to monitor directional variations of equipment recovery/ maintenance and support vessel sounds in addition to examining marine mammal vocalization patterns in the vicinity of these activities. One new recorder will be placed 32 km northwest of the Burger A well site to monitor for sound propagation toward the south side of Hanna Shoal, which acoustic and satellite tag monitoring has identified as frequented by walrus in August. Marine survey activities will occur in areas within the coverage of the net array. All of these offshore systems will capture marine survey and equipment recovery/maintenance sounds, where present, over large distances to help characterize the sound transmission properties in the Chukchi Sea. They will continue to provide a large amount of information related to marine mammal distributions in the Chukchi Sea.

In early October, all of the regional recorders will be retrieved except for the six Hanna Shoal recorders, which will continue to record on a duty cycle until August 2014. An additional set of nine Aural winter recorders will be deployed at the same time at the same locations that were instrumented in winter 2012 - 2013 (Figure 2). These recorders will sample at 16 kHz on a 17% duty cycle (40 minutes every 4 hours). The winter recorders deployed in previous years have provided important information about bowhead, beluga, walrus and several seal species migrations in fall and spring.

### Analysis and Reporting

The Chukchi acoustic net arrays will produce an extremely large dataset comprising several Terabytes of acoustic data. The analyses of these data require identification of marine mammal vocalizations. Because of the very large amount of data to be processed, the analysis methods

will incorporate automated vocalization detection algorithms that have been developed over several years. While the hydrophones used in the net array are not directional, and therefore not capable of accurate localization of detections, the number of vocalizations detected on each of the sensors provides a measure of the relative spatial distribution of some marine mammal species, assuming that vocalization patterns are consistent within a species across the spatial and geographic distribution of the hydrophone array. These results therefore provide information such as timing of migrations and routes of migration for belugas and bowheads.

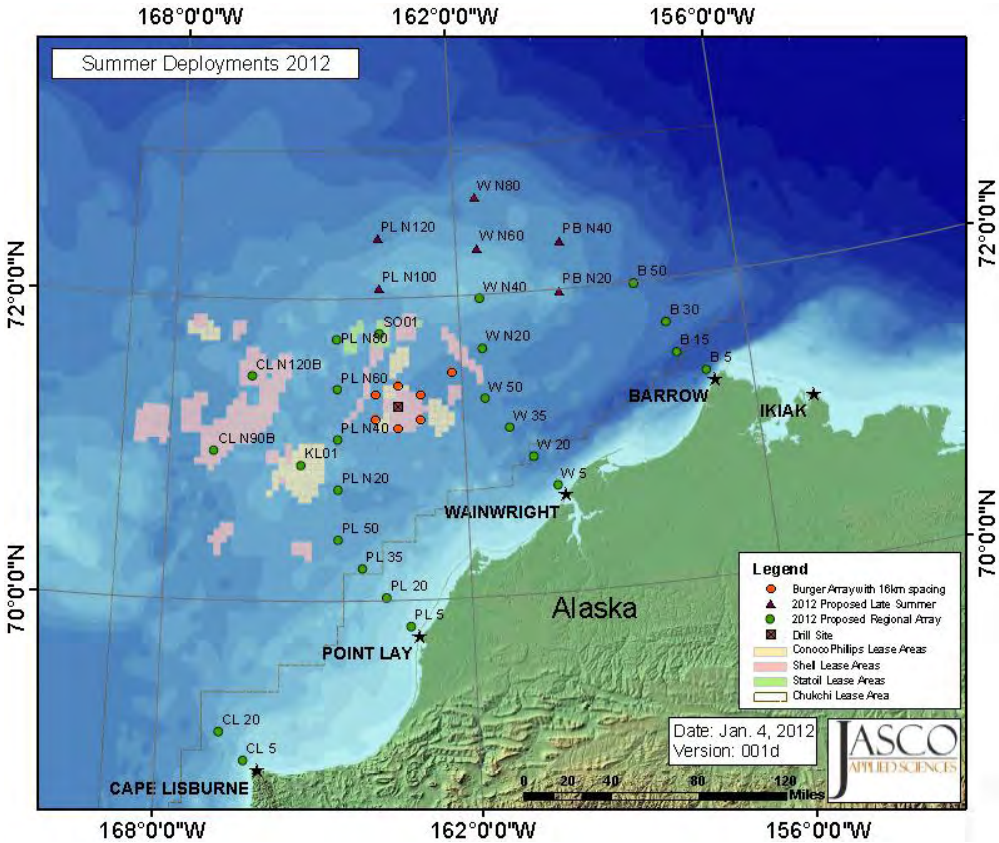


Figure 1. Proposed open water deployment locations of acoustic recorders in the eastern Chukchi Sea, Alaska, 2013.

A second purpose of the Chukchi net array is to monitor the amplitude of sound propagation from Shell's exploration and related support activities over a very large area. Analysis of all acoustic data will be prioritized to address the primary questions. The primary data analysis questions are to (a) determine when, where, and what species of animals are acoustically detected on each recorder (b) analyze data as a whole to determine offshore distributions as a function of time, (c) quantify spatial and temporal variability in the ambient sound energy, and (d) measure received levels of survey activities. The detection data will be used to develop spatial and temporal animal detection distributions. Statistical analyses will be used to test for changes in animal detections and distributions as a function of different variables (e.g., time of day, season, environmental conditions, ambient sound energy, marine-survey activities, or vessel sound levels).

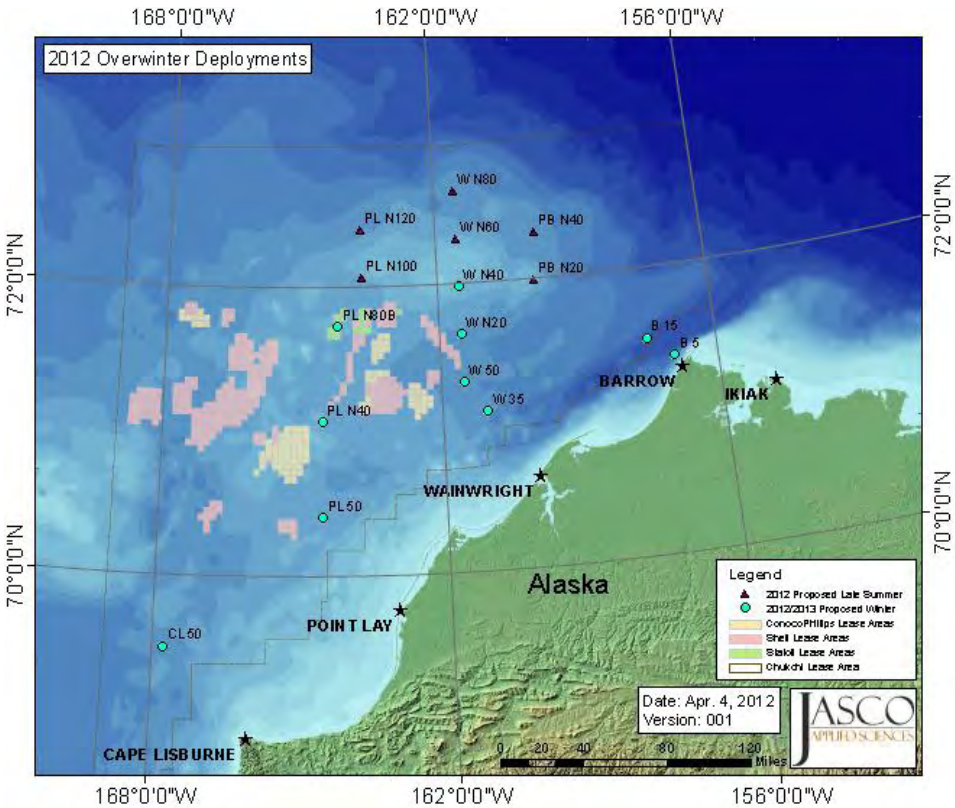


Figure 2. Proposed winter deployment locations of acoustic recorders in the eastern Chukchi Sea, Alaska 2013. The Hanna Shoal recorders (triangles) are deployed in August. The winter recorders (dots) are deployed in early October.

## Acoustic Study of Bowhead Call Distributions in the Beaufort Sea

Shell plans to deploy arrays of acoustic recorders in the Beaufort Sea in 2013, similar to that which was done in 2007–2012. As in previous years, the recorders (DASARs, or directional autonomous seafloor acoustic recorders) will be supplied by Greeneridge Sciences. These directional acoustic systems permit localization of bowhead whale and other marine mammal vocalizations. The purpose of the array will be to further understand, define, and document the timing and location of the bowhead migration corridor in a year with less anthropogenic activity near the DASAR arrays (compared with 2012). Data collected in 2013 can then be compared to years with many more anthropogenic activities, such as 2012 or potentially 2014.

### Objective

The objectives of this study are mainly to provide information on bowhead migration paths along the Alaskan coast, particularly with respect to industrial operations, and to determine whether and to what extent there are changes in the distribution of calls due to industrial sound levels from sources such as vessels or a site clearance and shallow-hazard survey operation. Using passive acoustics with directional autonomous recorders, the locations of calling whales will be observed for a six- to ten-week continuous monitoring period at five coastal sites (subject to favorable ice and weather conditions). An example of the whale call locations measured from a similar array of DASARs in 2008 is presented in Figure 3 (Blackwell et al. 2010). The main goal

of the 2013 data collection are to gather baseline data in an area that will likely experience higher levels of anthropogenic activity in the future.

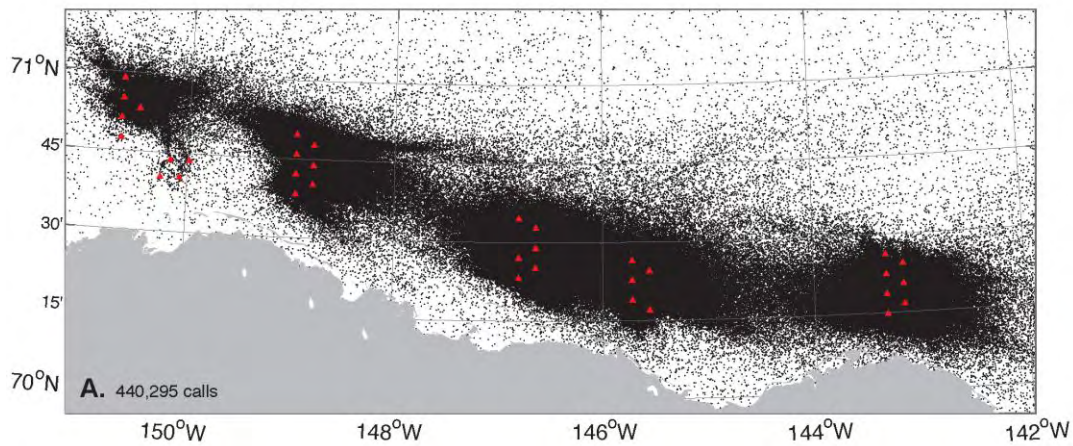


Figure 3. Bowhead whale call locations determined from the received bearings at five arrays of DASARs in the Beaufort Sea in 2008.

## Monitoring Plan

Shell plans to conduct the whale migration monitoring using the passive acoustics techniques developed and used successfully since 2001 for monitoring the migration past the Northstar production island northwest of Prudhoe Bay and from Kaktovik to Harrison Bay during the 2007 through 2012 migrations. Those techniques involved using DASARs to measure the bearings to bowhead calls and, when two or more recorders detected the same call, obtaining the calling whale's location by triangulation. A total of about a million whale calls were successfully located during the years 2007–2011.

In attempting to assess the responses of bowhead whales to the planned industrial operations, it will be essential to monitor whale locations at sites both near and far from potential industry activities. Shell plans to monitor at five sites along the Alaskan Beaufort coast, as shown in Figure 4. The sites are the same as used since 2007. The eastern-most site (site 5 in Figure 4) is just east of Kaktovik ~62 mi [~100 km] west of the Sivulliq drilling area and the western-most site (site 1) is in the vicinity of Harrison Bay (~112 mi [~180 km] west of Sivulliq). Site 2 is located west of Prudhoe Bay (~73 mi [~117 km] west of Sivulliq). Site 4 is ~10 mi (~16 km) east of the Sivulliq drilling area and site 3 is ~20 mi (~32 km) west of Sivulliq.

The proposed geometry of the DASAR array at each site is shown in Figure 4, while Figure 5 zooms in on the two sites (3 and 4) adjacent to the Sivulliq prospect where drilling took place in 2012. In 2007–2011 each array was comprised of seven DASARs placed at the vertices of five stacked equilateral triangles with 7-km (4.3-mi) sides, as exemplified by sites 2, 3, or 5 in Figure 4 DASARs were labeled A–G from south to north.

In 2012 the following changes were made in the DASAR layout of sites 1 and 4 and these same recorder locations will also be used in 2013:

- At site 1 the three adjacent DASARs that have detected the most calls in 2007–2011 (1D, 1E, and 1F) were kept in place, to continue collecting data that can be compared with previous years. The remaining four DASARs (1A, 1B, 1C, and 1G) were moved to site 4 (see below). These four low-performance DASAR locations have, on average (2007–2011), detected as little as 1/100$^{th}$ of the calls detected at high-performance locations.
- At site 4 the four central DASARs (4A, 4C, 4E, and 4G) were moved to their mirror-image position east of DASARs 4B, 4D, and 4F. This is shown in Figures 4 and 5. The main reason for doing this was to improve our ability to detect whale calls by placing these DASARs farther away from the 2012 drilling operation, where background sound levels were likely lower. The four DASARs removed from site 1 were added to the northern end of site 4 (4J, 4K, 4L, and 4M in Figure 5). This was done to improve the detection of calls from whales that choose a more northern route while migrating westward past the drilling operation in 2012.

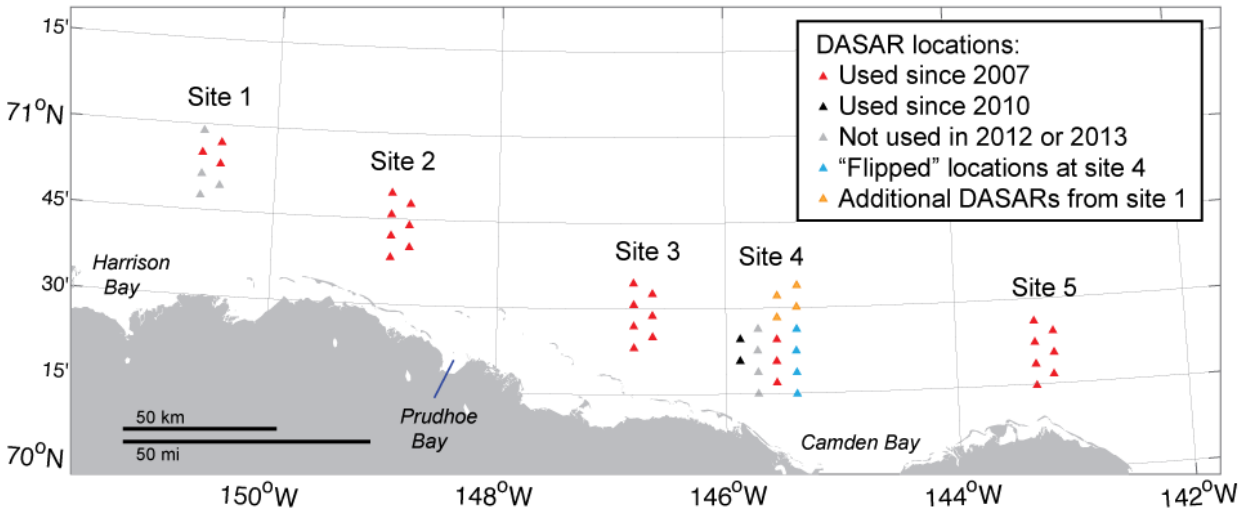


Figure 4. The Alaskan Beaufort Sea coast showing the five DASAR arrays (sites 1–5) for whale call location studies. DASAR deployments in 2013 are planned for all but the gray locations. See text for more information.

In addition, a small array of three DASARs with 2 km spacing—referred to as a triplet—will be deployed northwest of the Sivulliq drillsite, with the closest DASAR 6 km from the drillsite. The triplet DASARs are shown in Figure 5 as small brown triangles.

DASARs will be installed at planned locations using a GPS. However, each DASAR's orientation, once deployed on the bottom, is unknown and must be determined to know how to reference the bearings measured to the whales. That is, where is true north relative to the DASAR orientation? Also, the internal clocks used to sample the acoustic data typically drift slightly, but linearly, by an amount of up to about three minutes after six weeks of autonomous operation. Synchronizing DASARs to within a second is essential for identifying identical whale calls received on two or more DASARs. Solving these two problems is accomplished by

transmitting known sounds at known times from known locations (by GPS) at three points around each DASAR at the beginning and at the end of the operational period. Each set of transmissions requires about two minutes. With 12 calibration locations for a 7-DASAR array, calibration of a "standard" site will take 4 hrs. Calibration of site 4 will take longer, on the order of ~12 hours in good weather.

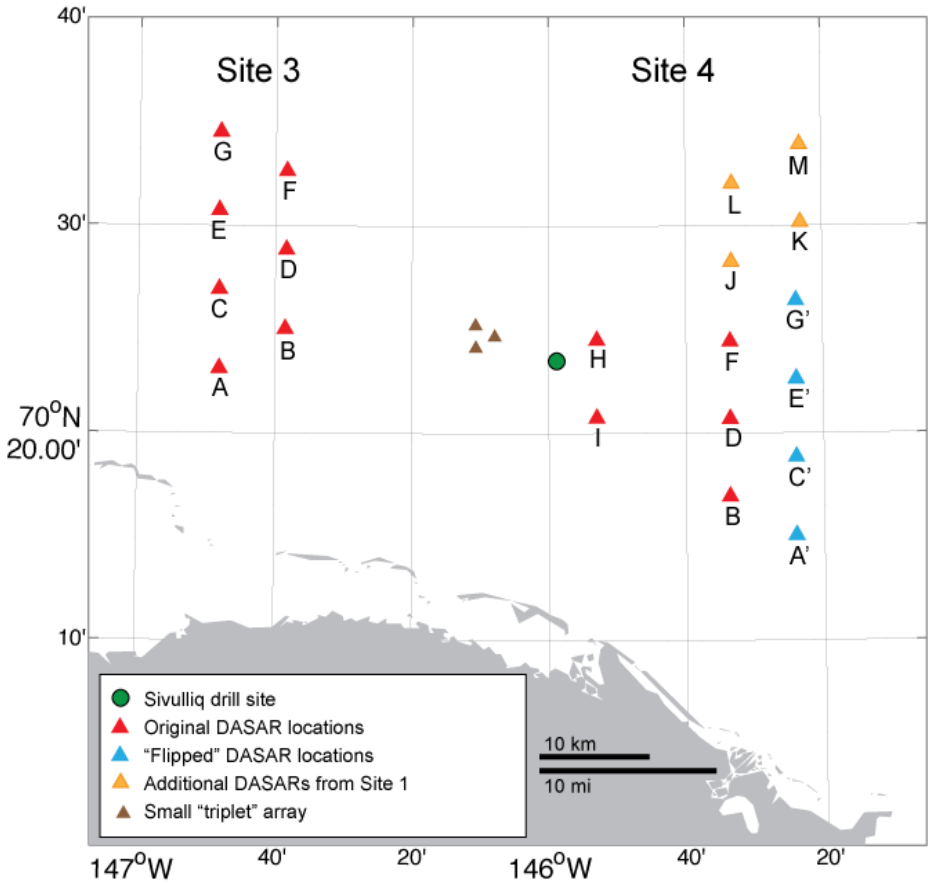


Figure 5. DASAR deployments at sites 3 and 4. DASARs are shown with triangles and the Sivulliq drill site is shown with a green dot. All DASARs will remain in place over the entire season.

The calibration transmissions are made using a J9 projector easily deployed and retrieved over the side of a vessel by a single person. Maximum source level is 150 dB re 1 µPa at 1 m. The received level at a distance of 328 ft (100 m) will be ~110 dB, a level less than any known to cause disturbance to marine life.

Bowhead migration begins in late August with the whales moving westward from their feeding sites in the Canadian Beaufort Sea. It continues through September and well into October. We are planning to deploy the DASAR arrays in August 2013 and retrieve them in early October, before they become inaccessible because of ice.

Whale call analysis will be done using an automated algorithm developed by Dr. Aaron Thode at Scripps Institution of Oceanography and described in Thode et al. (2012). Concurrently, about 10% of the collected data will also be analyzed manually, to provide a dataset with which to train the automated algorithm and then check its performance. During the manual analysis analysts will examine spectrograms in one-minute periods, looking for patterns identifying a whale call.

The analyst will then confirm that a sound is indeed a whale call by listening to it. The call's bearing is then calculated and stored for localization if the same call is detected by other DASARs in the array being analyzed. The overall distribution and timing of the calls as well as call numbers at each DASAR will be compared to the call numbers obtained in previous years at the same locations.

As in previous years, DASAR records will be analyzed for broadband background levels and the frequency composition of the recorded sounds will be determined. In addition to being influenced by anthropogenic activities, background levels are tightly linked to sea state. Therefore, even in the complete absence of anthropogenic sound sources, background sound levels show substantial variation over time. For each DASAR, narrowband spectral densities (1 Hz intervals, 1.7 Hz bandwidth, 23.5% overlap) will be determined for a one-min period about every 5 min. One-third octave band and broadband levels will be derived from the narrowband spectral densities. These narrowband, one-third octave, and broadband data will provide a continuous record, with 1 min resolution, of the levels of low-frequency underwater sounds at each location.

The narrowband data will also be summarized over periods of interest to derive "statistical spectra" showing, for each frequency, the levels exceeded during various percentages of the 1-min samples. This type of analysis is useful for describing the frequency composition of sounds received at a particular location over long periods of time (like the entire deployment of the recorder) or, alternatively, during particular shorter-term events.

Analysis of all acoustic data will be prioritized to address the primary questions. The primary data analysis questions are to (a) determine when and where bowhead whales are acoustically detected on each DASAR, (b) analyze data as a whole to determine the distribution of bowhead calls as a function of time and industrial activities, and (c) quantify spatial and temporal variability in the ambient noise. The bowhead detection data will be used to develop spatial and temporal animal distributions.

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