United States
Environmental Protection
Agency

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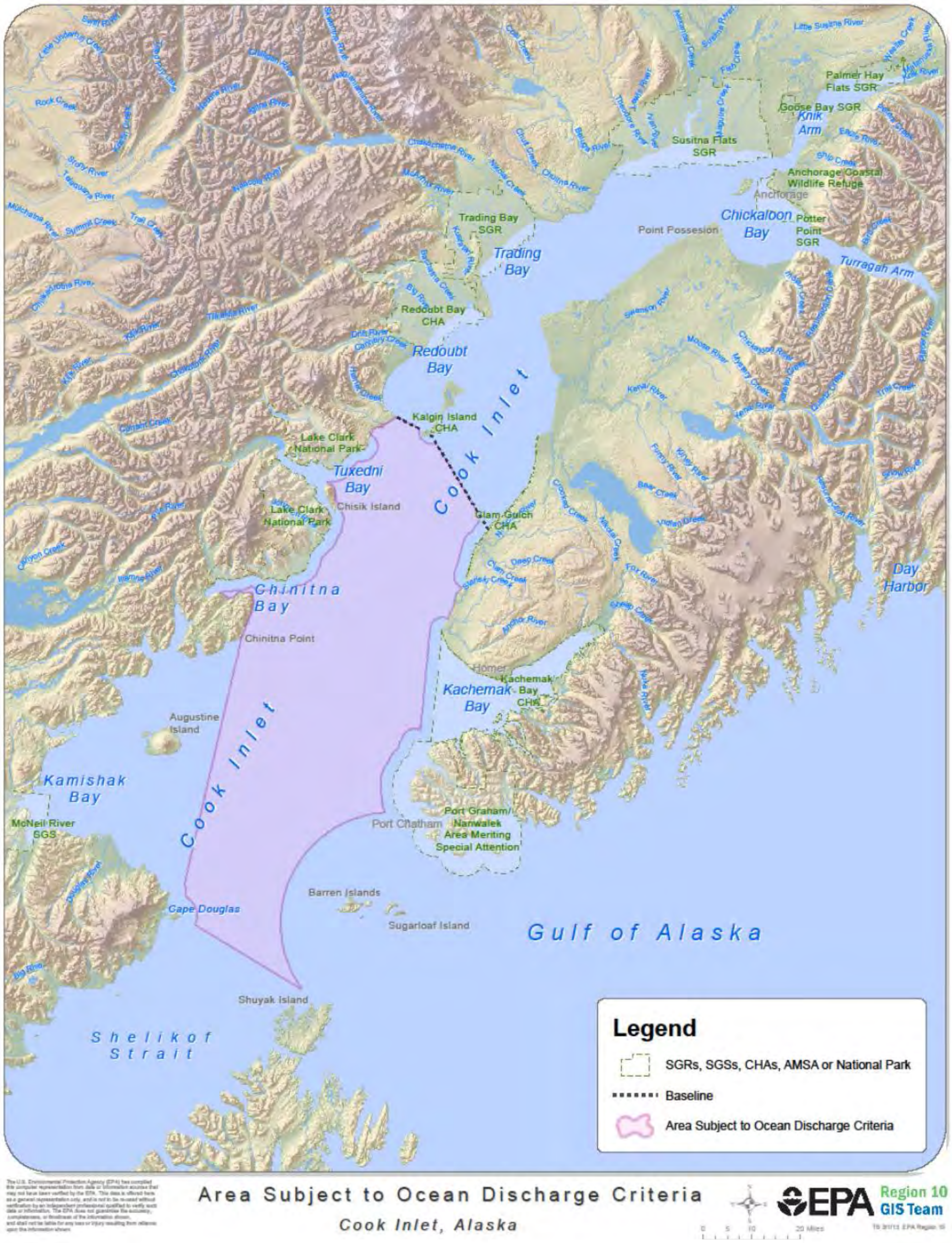
FINAL
OCEAN DISCHARGE CRITERIA EVALUATION FOR THE COOK INLET EXPLORATION NPDES GENERAL PERMIT



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1.0 INTRODUCTION

1.1 PURPOSE OF EVALUATION

The U.S. Environmental Protection Agency (EPA) intends to issue a National Pollutant Discharge Elimination System (NPDES) general permit under Clean Water Act (CWA) § 402 for discharges from oil and gas exploration facilities operating in the federal waters of Cook Inlet, Alaska. CWA § 403(c) requires that CWA § 402 permits comply with EPA's Ocean Discharge Criteria for preventing unreasonable degradation of the marine environment of the territorial seas, the contiguous zones and the oceans. The purpose of this Ocean Discharge Criteria Evaluation (ODCE) is to discuss and evaluate the discharges from oil and gas exploration facilities.

This ODCE evaluates EPA's general permit and its potential to cause unreasonable degradation of the marine environment within the territorial seas, contiguous zones and the oceans within the coverage areas. For simplicity, in this document the permit is referred to as the *Permit*.

This document evaluates the impacts of waste water discharges associated with the Permit from exploration activities. The Permit does not cover development and production activities, and their associated discharges. As such, development and production operations are outside the scope of the activities this ODCE considers, and are not discussed in this document.

EPA's Ocean Discharge Criteria (40 Code of Federal Regulations [CFR] Part 125, Subpart M) set forth specific determinations of unreasonable degradation that must be made prior to permit issuance. *Unreasonable degradation of the marine environment* is defined (40 CFR 125.121[e]) as follows:

1. Significant adverse changes in ecosystem diversity, productivity, and stability of the biological community within the area of discharge and surrounding biological communities,
2. Threat to human health through direct exposure to pollutants or through consumption of exposed aquatic organisms, or
3. Loss of aesthetic, recreational, scientific, or economic values, which are unreasonable in relation to the benefit derived from the discharge.

This determination is to be made on the basis of considering the following 10 criteria (40 CFR 125.122):

1. The quantities, composition, and potential for bioaccumulation or persistence of the pollutants to be discharged;
2. The potential transport of such pollutants by biological, physical or chemical processes;
3. The composition and vulnerability of the biological communities that may be exposed to such pollutants, including the presence of unique species or communities of species, the presence of species identified as endangered or threatened pursuant to the Endangered Species Act (ESA), or the presence of those species critical to the structure or function of the ecosystem, such as those important for the food chain;

4. The importance of the receiving water area to the surrounding biological community, including the presence of spawning sites, nursery/forage areas, migratory pathways, or areas necessary for other functions or critical stages in the life cycle of an organism;
5. The existence of special aquatic sites including, but not limited to, marine sanctuaries and refuges, parks, national and historic monuments, national seashores, wilderness areas, and coral reefs;
6. The potential impacts on human health through direct and indirect pathways;
7. Existing or potential recreational and commercial fishing, including finfishing and shellfishing;
8. Any applicable requirements of an approved Coastal Zone Management Plan;
9. Such other factors relating to the effects of the discharge as may be appropriate;
10. Marine water quality criteria developed pursuant to section 304(a)(1).

If the Regional Administrator determines that the discharges will not cause unreasonable degradation to the marine environment, an NPDES permit may be issued. If the Regional Administrator determines that the discharge will cause unreasonable degradation of the marine environment, an NPDES permit may not be issued.

If the Regional Administrator has insufficient information to determine, prior to permit issuance, that there will be no unreasonable degradation to the marine environment, an NPDES permit will not be issued unless the Regional Administrator, on the basis of the best available information, determines that all of the following are true (40 CFR 125.123(c)):

1. Such discharge will not cause irreparable harm[1] to the marine environment during the period in which monitoring will take place, and
2. There are no reasonable alternatives to the on-site disposal of these materials, and
3. The discharge will be in compliance with certain specified permit conditions (40 CFR 125.122).

1.2 SCOPE OF EVALUATION

This document evaluates the impacts of discharges as provided by the Permit for oil and gas exploration facilities in federal waters in Cook Inlet.

This document relies extensively on information provided in the C*ook Inlet Planning Area Oil and Gas Lease Sales 191 and 199 Final Environmental Impact Statement* (MMS 2003); the general permit fact sheet; *Final Ocean Discharge Criteria Evaluation for the NPDES General Permit for Oil and Gas Extraction Facilities in Federal and State Waters in Cook Inlet* (USEPA 2006); the *Ocean Discharge Criteria Evaluation for the Forest Oil Osprey Platform, Redoubt Shoal Unit Development Project* (SAIC 2001); and the *Environmental Assessment for the New Source NPDES Forest Oil Redoubt Shoal Unit Production Oil and Gas Development Project* (SAIC 2002).

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[1] *Irreparable harm* is defined as "significant undesirable effects occurring after the date of permit issuance, which will not be reversed after cessation or modification of the discharge" (40 CFR 125.121[a]).

For more detailed information concerning certain topics, where appropriate, this document will refer to these publications. The information this ODCE presents is a synthesis of the information in these documents in addition to findings published in scientific literature.

1.2.1 Coverage Area of the Permit and Applicability of this ODCE

This document evaluates the impacts of wastewater discharges to be authorized by the Permit for oil and gas exploration facilities pursuant to CWA § 403(c), which applies to discharges into the territorial sea, waters of the contiguous zone, or the oceans. As Figure 1 illustrates, the federal waters subject to this ODCE are the waters south of the baseline near Kalgin Island. Waters north of Kalgin Island and landward of any baseline within the bays in southern Cook Inlet are coastal waters not subject to the ODCE regulations and are not analyzed in this document.

The Permit will cover exploration facilities in the federal waters of Cook Inlet, except the prohibited areas section 1.2.2 describes.

1.2.2 Prohibited Areas of the Permit

EPA continues the discharge prohibitions in the EPA issued 2007 Permit in the following areas:

- In water depths less than the 10-meter mean lower low water (MLLW) isobath.
- Shoreward of the 5.5-meter isobath adjacent to either (1) the Clam Gulch Critical Habitat Area or (2) from the Crescent River northward to a point one-half mile north of Redoubt Point.
- In Kamishak Bay, west of a line from Cape Douglas to Chinitna Point.
- In Chinitna Bay, inside of the line between the points of the shoreline at latitude 59°52’45’’ N, longitude 152°48’18” W on the north and latitude 59°46’12” N, longitude 153°00’24” W on the south.
- In Tuxedni Bay, inside of the lines on either side of Chisik Island.
    - From latitude 60°04’06” N, longitude 152°34’12” W on the mainland to the southern tip of Chisik Island (latitude 60°05’45” N, longitude 152°33’30” W).
    - From the point on the mainland at latitude 60°13’45” N, longitude 152°32’42” W to the point on the north side of Snug Harbor on Chisik Island (latitude 60°06’36” N, longitude 152°32’54” W).

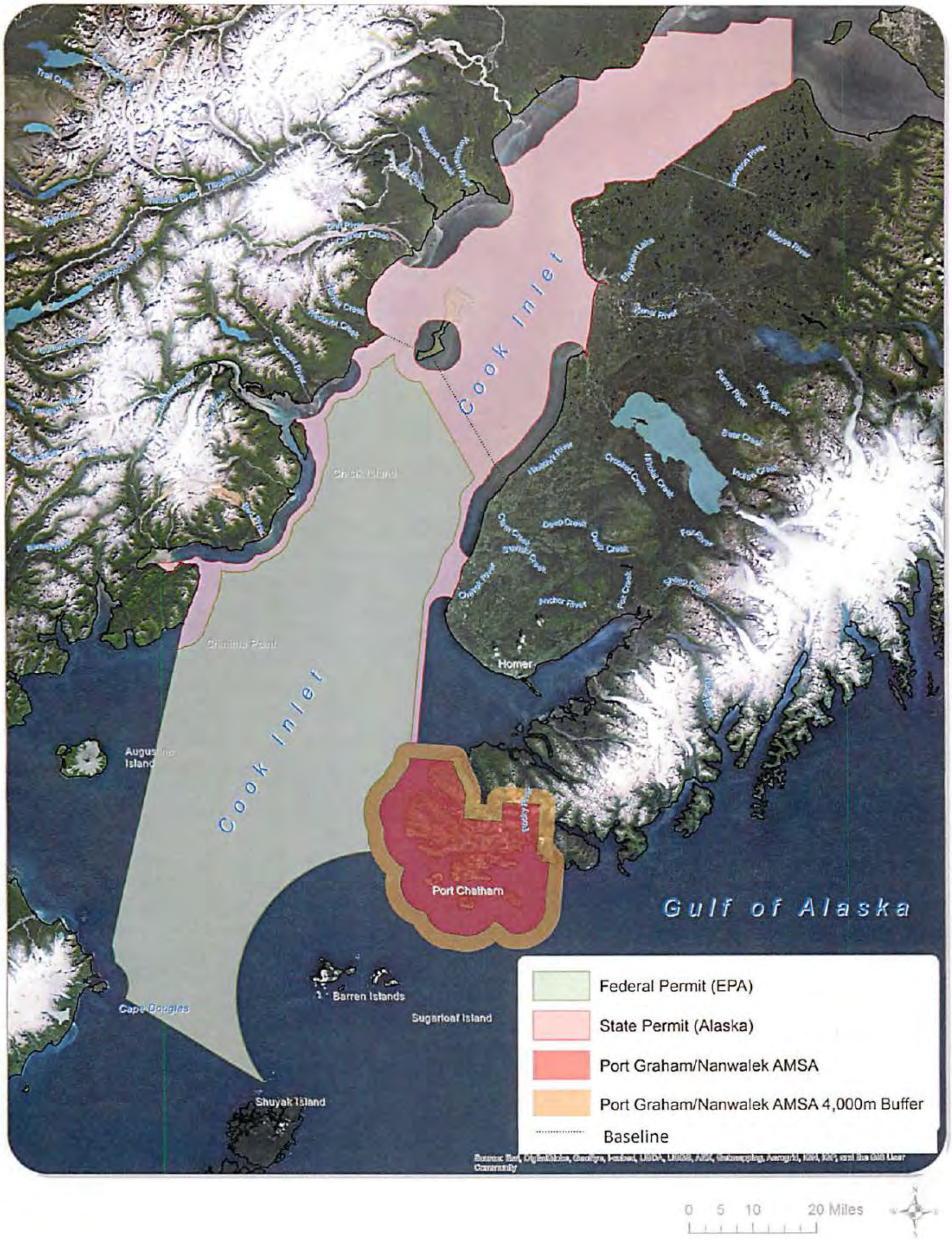


Figure 1: Coverage Area for Permit

The Permit prohibits discharges in water depths less than 10 meters for exploration facilities because discharges to shallow waters are less likely to be dispersed than discharges to deeper water. This prohibition reduces the potential to impact the abundant aquatic life generally found in shallow waters.

The Permit prohibits discharges in parts of Chinitna, Tuxedni, and Kamishak bays because they are either areas of high resource value, or are adjacent to areas of high resource value. In addition, Kamishak Bay is a known net depositional environment where drilling fluid solids, cuttings, and other pollutants would likely accumulate if discharges are authorized in that area (Atlas et al. 1983; MMS 2000).

In addition to the discharge prohibitions described above, the Permit would prohibit discharges in the following areas:

- In Shelikof Strait south of a line between Cape Douglas (at 58°51’ N, 153°15’ W) on the west and the northernmost tip of Shuyak Island on the east side (at 58°37’ N, 152°22’ W).
- Within 20 nautical miles of Sugarloaf Island as measured from a centerpoint at 58°33’ N and 152°02’ W.
- Within the boundaries or within 4,000 meters of a coastal marsh (the seaward edge of a coastal marsh is defined as the seaward edge of emergent wetland vegetation), river delta, or river mouth, or a State Game Refuge (SGR), State Game Sanctuary (SGS), Critical Habitat Area (CHA), Area Meriting Special Attention (AMSA) or National Park.

The Shelikof Strait area described above was outside of the 2007 Permit coverage area. However, because the National Marine Fisheries Service (NMFS) has designated Shelikof Strait as a special aquatic foraging area for the Stellar Sea Lion (see 58 Federal Register [FR] 45278 [September 27, 1993]; and also 50 CFR 226.12(c)(1)), the 2007 Permit prohibited discharges in Shelikof Strait and the Permit continues this prohibition.

The 2007 Permit prohibited discharges within 4,000 meters of a coastal marsh, river delta, or river mouth, or a SGR, SGS, AMSA or CHA to afford better protection of these sensitive areas. In the Permit, EPA proposes to retain this prohibition. EPA is not aware of any plans for oil and gas activities in those areas. Furthermore, discharges within the buffer zone can be avoided with modern drilling technologies, such as directional or extended reach drilling techniques. The following SGRs, SGSs, CHAs, AMSA and National Park are in the Permit coverage areas:

Clam Gulch CHA
Kachemak Bay CHA
Lake Clark National Park
Kalgin Island CHA
Trading Bay SGR
Redoubt Bay CHA
Susitna Flats SGR
Port Graham/Nanwalek AMSA

2.0 DESCRIPTION OF EXPLORATION ACTIVITIES

2.1 BACKGROUND

Oil and gas exploration and development in the Cook Inlet basin began with discoveries in the late 1950s and 1960s. Most of these activities have occurred on state lands and offshore in state waters. Exploration peaked around 1967 (MMS 2003). There were major discoveries offshore about this time with the McArthur River Field, which is ongoing and has produced over 1,000 billion cubic feet (ft^3) of gas and over 600 million barrels of oil. Of the 1.2 billion barrels produced, approximately 50 percent comes from the McArthur River, 20 percent from the Swanson River, and 30 percent from the other fields combined (MMS 2003).

Exploration and production has been declining in recent decades but new exploration activities are ongoing. The last commercial gas discoveries in Cook Inlet were the Cannery Loop and Pretty Creek gas fields discovered in 1979. While most of the emphasis has been in quest of oil, the last major oil discoveries were West McArthur River in 1990, with a reserve estimate of 3 million barrels, and Tyonek Deep in 1991, with a reserve estimate of 25 million barrels. More recent discoveries by Forest Oil at Redoubt Shoal had an estimated production potential of 100 million barrels of oil. With these few exceptions, the overall production of Cook Inlet has declined sharply since the days of the “big discoveries” in the 1960s and oil production, which peaked at 230,000 barrels per day (bbl/day) in 1970, declined to 33,000 bbl/day by 1997 (MMS 2003).

Seven oil fields on the Kenai Peninsula are producing about 30,000 barrels of oil per day. Seventeen gas fields currently produce more than 485 million ft^3 of gas per day. In 1999 Cook Inlet gas fields produced nearly 11 million barrels of oil and 177 billion ft^3 of natural gas. Offshore fields are tapped by 15 production platforms, with three of these platforms shut in as a result of low production volumes. Fields on the Kenai Peninsula and offshore in Cook Inlet have produced a cumulative of 1.2 billion barrels of crude oil and 5.9 trillion ft^3 of natural gas.

Gas reserves in Cook Inlet in 1970 stood at about 8 trillion ft^3 and production was about 145 billion ft^3 per year. This excess of gas played against market conditions and there was little incentive to develop additional gas fields. These reserves have been slowly consumed over time. The reserve to production time for the gas industry in the lower 48 states is about 7 years, with new resources being added at about the same rate. In the past, the overabundance of gas in the Cook Inlet basin has been a disincentive for exploration. Present economic conditions make gas profitable and a stimulus for increased exploration (Jepson 2001).

In Cook Inlet, almost all of the known reserves are contained in large or giant fields (more than 1 trillion ft^3). The next phase of exploration and development of Cook Inlet basin should see a greater number of smaller independent companies. The increased activity from independents is expected to drive exploration and development costs lower, especially for gas. More natural gas discoveries are expected as a result of the added exploration activity by independents in quest of the more abundant gas fields along with some oil discoveries. Most of the past oil and gas discoveries in the Cook Inlet basin are still producing and there are a few sites—all onshore—that are inactive and shut in, which include Albert Kaloa, Birch Hill, Pretty Creek, and West Fork. The North Trading Bay Unit, which is located offshore in Trading Bay, produced oil from 1967–1992, but now produces natural gas (MMS 2003).

2.2 EXPLORATION IN FEDERAL WATERS

Although five lease sales have been held for tracts in federal waters within the Cook Inlet Outer Continental Shelf (OCS) Planning Area over the past 34 years, the lower Cook Inlet area is still considered to be relatively unexplored and to have potential undiscovered oil resources. In October 1977, Sale CI resulted in 88 leases being issued. In September 1981, Sale 60 resulted in 13 leases being issued. A re-offering sale, Sale RS-2, was held in August 1982, but no bids were received and no leases resulted from this sale. Sale 149, held in June 1997, resulted in two leases issued. Sale 191 was held in May 2004, and no bids were submitted. Two special interest Cook Inlet Sales, 211 and 219, were scheduled under the federal OCS 2007-2012 Leasing Program. On July 8, 2008, the Minerals Management Service (MMS; reorganized in 2011 as the Bureau of Ocean Energy Management, or BOEM) issued a Request for Information (RFI) for Cook Inlet Sale 211 and received three comments, but no industry nominations identifying specific leasing interest. In 2008 MMS decided not to proceed with the Sale 211 presale process. On March 2, 2011, the decision to cancel Sale 219 was published in the Federal Register. There are currently no active federal OCS leases in Cook Inlet, but an RFI issued on March 27, 2012, confirmed interest in Lease Sale 244, tentatively scheduled for November 2016 (BOEM 2012).

Between 1978 and 1985, a total of 13 exploratory wells were drilled on federal leases in the Cook Inlet Planning Area, one of which was in Shelikof Strait, and all failed to find commercial quantities of oil or gas and have been permanently plugged and abandoned. Water depths for these exploration efforts ranged from between 115 and 546 feet, and all were drilled from temporary structures using jackup rigs in shallower waters and semisubmersibles and drill ships in the deeper waters.

Future exploration and delineation well drilling could take place from a semisubmersible, jackup or other type of bottom-founded unit. Water depth will be a significant factor in selecting the appropriate drilling unit. In the southern portion of the Cook Inlet OCS, most depths within the last lease sale, in 2004, ranged between 250 and 300 feet. Semisubmersible drilling units could carry out exploratory drilling throughout much of this area. Floating drilling units are also used when drilling in deep waters (USEPA 1993). In shallower waters, less than 200 feet deep, jackup rigs could be used. In the shallower portions of Cook Inlet, larger jackup rigs could remain on-site throughout the winter or spend the season in an ice-free port such as Homer in Kachemak Bay. In water less than 100 feet deep, a bottom-founded platform could be used. Section 2.3 provides a more detailed discussion on the types of drilling rigs.

The average total depth of exploration and delineation wells drilled in state waters between 2001 and 2009 was more than 8,600 feet (Stokes 2010). The drilling of each exploratory or delineation well would generate about 500 barrels of drilling fluids and approximately 600 dry tons of drill cuttings for disposal (BOEM 2012).

2.3 THE DRILLING PROCESS

Offshore drilling activities are divided into two phases: exploratory drilling and development drilling. During the exploration phase of drilling operations, the goal is to identify areas within a formation that have the potential for hydrocarbon reserves and to delineate the size and extent of the oil or gas field. Exploration activities are most commonly conducted from mobile platforms. Once an area is determined to have recoverable hydrocarbons, the drilling operations move toward development of the hydrocarbons. While these two business operations are strategically different, the drilling processes are similar (USEPA 1993). The Permit covers discharges from exploration facilities only.

Exploration activities in Cook Inlet to date have been undertaken by drill ships, jackup rigs, and semisubmersible rigs. Drill ships and ship-shaped barges are vessels equipped with drilling rigs that float on the surface of the water, and maintain their position by dynamic positioning and anchors on the seafloor. A jackup rig consists of a drill rig attached to a barge. Once the barge reaches its desired location, support legs are attached and jacked downward to the seafloor. Once the legs reach the seafloor, the downward pressure of the jacking process lifts the barge out of the water. Semisubmersible rigs are mounted to a hull with adjustable ballast, allowing the hull to be raised or lowered within the water. The rig floats on top of the water when not in use. Once the hull is flooded, it sinks to a depth that allows the rig to remain stable against wave motion (USEPA 1993). These drilling operations will result in similar if not identical types of discharges.

In the drilling process, preparing the first few hundred feet of a well is called "spudding in." This typically requires a large diameter pipe, called the conductor casing, to be hammered, jetted, or placed on the seafloor, depending on the composition of the substrate (USEPA 1993). Once the conductor casing and surface casing are cemented in place, they guide the drill string down from the drill rig to the borehole that will become the exploration well. To prevent well blowouts, blowout preventers (i.e., hydraulically operated high-pressure safety valves) are attached at or near the top of the well (the wellhead) usually on the seafloor. The drill string consists of lengths of pipe threaded together to connect the torque-producing motor with the drill bit. During exploration drilling, drilling fluid (or drilling "mud") is pumped down the annular space within the drill pipe and ejected from the drill bit into the well. The drilling fluids lift cuttings off the bottom of the well away from the drill bit, and circulate the cuttings back to the surface. Drilling fluids are composed of water-based, oil-based, or synthetic-based materials (see discussion in section 3). The drill cuttings and fluid are sent through a series of shaker tables and separators to remove the majority of solids and cuttings from the fluid.

The processed drilling fluid is then returned to a tank for reconditioning and reuse in the drilling process. Barium sulfate (barite) is added to drilling fluid as a weighting agent, which counteracts reservoir pressures, and to prevent water from seeping into the well from the surrounding rock formation (Neff 2008; USEPA 2000).

Only cuttings generated with water-based drilling fluids (WBFs) or synthetic-based drilling fluids (SBFs) are authorized for discharge under the Permit and are typically discharged to open water via a discharge pipe (outfall). During or following the drilling process, drilling fluids may need to be replaced or disposed of, which again is done using one of two methods. If the drilling fluids are water-based, free of oil, and meet the effluent limitations the Permit establish, they can be disposed of through an outfall. If the fluids contain oil either because of their type (i.e., oil-based) or because of drilling operations, they cannot be discharged and alternate disposition of the material is necessary, e.g. placed in containers and disposed of onshore.

As the borehole is drilled deeper, drilling is stopped periodically to run and cement additional sections or "strings" of steel casing. The casing keeps the walls of the borehole from collapsing and reduces the probability of the drill string becoming stuck. Other than the open hole that is being drilled (before each successive string of casing is run), the drill string operates within the casing. To keep each string of casing in place, cement is pumped down through the new string of casing, forced out of the open hole and back up the annular space outside of the casing, between it and the open hole (or prior string of casing), to fill the voids and keep the casing in place. The drilling process continues once the cement is set outside the casing. The initial casing may be on the order of 30 inches in diameter and is gradually stepped down in size as the hole deepens, with each smaller string essentially hung from the larger string above it. The addition of casing string may continue until final well depth is reached. Drilling may be conducted "open hole" without a casing if a stable formation is encountered in the process. At the end of the entire operation, cement is used to plug the well after it has been fully characterized and tested.

The discharge of drilling fluids and cuttings is an intermittent process that generally occurs only during active drilling operations. The discharge of cuttings ceases during the process of adding more pipe to the drill string or conducting cementing operations. In these times, it is possible that drilling fluids continue to be discharged (whenever the drilling fluid is being circulated). The discharge of drilling fluids and cuttings happens for approximately 50 percent of the time the rig is “on station.”

On the rig, drainage waters from rainfall runoff from deck surfaces, and wash-down water generated during deck cleaning are discharged via an outfall. Showers, laundry, and liquid galley waste generate gray water. Treated sewage generates sanitary waste. These wastes may be combined, treated, and discharged through one of several configurations. Desalination wastewater (brine), treated bilge water, and ballast water are wastewaters that are also discharged via the outfall. Solid food waste is generally incinerated aboard the rig, while other solid wastes, such as trash and debris are stored and disposed of on land. Cooling water discharges may occur through the discharge pipe or shunted directly to the sea from the individual pieces of equipment associated with the cooling system. The design of the blowout preventer is such that the fluid used to open it after it has been closed for testing must be forced through the system and discharged at the unit itself.

2.4 SUMMARY

Oil and gas exploratory operations are conducted to determine the nature of potential hydrocarbon reserves. Drilling is the main activity during exploratory operations and the two major wastewater discharges from exploratory operations are drill cuttings and drilling fluids. Other discharges include deck drainage; sanitary waste; domestic waste; non-contact cooling water; desalination unit wastes; ballast water; bilge water; blowout preventer fluid; boiler blowdown; fire control system test water; excess cement slurry; and mud, cuttings, and cement at the seafloor.

In general, exploratory facilities do not discharge waterflood waste water, produced water, or well treatment fluids and the Permit does not authorize these discharges.

3.0 DISCHARGED MATERIALS, ESTIMATED QUANTITIES, AND MODELED BEHAVIOR

This section discusses the composition and quantity of potential discharges authorized by the Permit to the coverage area section 1.0 described. The information presented here is also reflected in EPA's *Final Development Document for Effluent Limitation Guidelines and New Source Performance Standards for the Offshore Subcategory of the Oil and Gas Extraction Point Source Category* (USEPA 1993), and information from the most recently drilled exploration wells in Cook Inlet. This section also presents the results of modeling that estimates dilution and settling of solids under a variety of receiving water conditions.

3.1 AUTHORIZED DISCHARGES

Offshore oil and gas exploration activities are generally characterized as short-term at any particular location and typically involve only a small number of wells. These activities, however, do generate numerous waste streams that are commonly discharged from the drilling rig into the ocean. These waste streams are related to the drilling process, equipment maintenance, personnel housing, and include:

- Discharge 001 – Drilling Fluids and Drill Cuttings
- Discharge 002 – Deck Drainage
- Discharge 003 – Sanitary Wastes
- Discharge 004 – Domestic Wastes
- Discharge 005 – Desalination Unit Wastes
- Discharge 006 – Blowout Preventer Fluid
- Discharge 007 – Boiler Blowdown
- Discharge 008 – Fire Control System Test Water
- Discharge 009 – Non-Contact Cooling Water
- Discharge 010 – Uncontaminated Ballast Water
- Discharge 011 – Bilge Water
- Discharge 012 – Excess Cement Slurry
- Discharge 013 – Mud, Cuttings, Cement at the Seafloor

The Permit authorizes discharges of these waste streams to Cook Inlet, which are discussed further below. At the end of this section, Table 3.4 lists anticipated discharge quantities based on assumptions of the numbers of wells to be drilled under the Permit. The Permit would also authorize geotechnical activities that may occur during exploration activities. These activities would likely include soil stability investigations to determine subsea characteristics. Geotechnical boring discharges, depending on depth, might only include cuttings. Deeper borings could require the use of drilling fluids.

3.1.1 Drill Cuttings

Drill cuttings are rock particles broken loose by the drill bit and carried to the surface by drilling fluids that circulate through the borehole. The cuttings are composed of the naturally occurring solids found in subsurface geologic formations and, to a much lesser extent, bits of cement used during the drilling process. Discharged drill cuttings usually contain about 10 to 15 percent adsorbed drilling mud solids (Neff 2008). A shale shaker and other solids control equipment separate cuttings from the drilling fluids. Drilling fluids are circulated back down the borehole.

The cuttings are discharged to the sea through an outfall. This discharge may contain small amounts of drilling fluids that remain adhered to the surface of the cuttings after the solids separation process. The main source of pollutants in drill cuttings are associated with the drilling fluids that adhere to the rock particles (USEPA 2000). Therefore, based on the effluent limitations guideline (ELG) for Best Available Technology Economically Achievable (BAT); Best Conventional Pollutant Control Technology (BCT); and Best Practicable Control Technology Currently Available (BPT), the Permit, like the 2007 Permit, applies the same limits to the drill cuttings discharges as the drilling fluid discharges.

The Permit authorizes the discharge of drill cuttings generated using WBFs and SBFs to federal waters (see Figure 1). The use of SBFs is a type of pollution prevention technology because the drilling fluids are not disposed of through bulk discharge at the end of drilling. Instead, the drilling fluids are brought back to shore and refurbished for reuse. In addition, drilling with SBFs allows operators to drill a slimmer well and results in less erosion of the well during drilling than when WBFs are used. Thus, the volume of discharged drill cuttings is reduced. The Permit would require permittees to remove SBFs from the drill cuttings prior to discharge, which is not required when WBFs are used.

While the ELGs do not specify the types of SBF, the ELGs include limits for sediment toxicity and biodegradation, which encourage operators to use fluids that are less toxic having a higher biodegradation rate. Because drill cuttings are allowed to be discharged when using SBFs, the Permit contains the following limits and specifies the analytical methods for SBFs:

- For stock synthetic fluids prior to combination with other components of the drilling fluid system, the Permit imposes limits on polynuclear aromatic hydrocarbons (PAHs), sediment toxicity (10-day), and biodegradation rate.
- Combined fluid components are limited for formation oil contamination and measured using gas chromatography/mass spectrometry (GC/MS).
- Drilling fluids that adhere to drill cuttings are limited for sediment toxicity (4-day), and formation oil contamination as measured by either a reverse phase extraction test or GC/MS.

3.1.2 Drilling Fluids

Drilling fluids are an *emulsion*. An emulsion is a mixture in which one liquid, termed the *dispersed* phase, is uniformly distributed (usually as minute globules) in another liquid called the *continuous* phase.

The term *drilling fluids* refers to a suspension of solids and dissolved materials in a water, oil, or synthetic base, and may also be referred to as *drilling muds*. This document uses the term *drilling fluids* throughout but notes that *drilling muds* may be used in technical documents and materials cited as references. For the Permit, there is no significant difference between these terms. Large amounts of barite are used in drilling fluids, particularly when drilling deep wells or penetrating geopressured strata (Neff 2010). The amount of barite added to drilling fluids generally increases from about 0.05 pounds per gallon (lb/gal) near the surface to as much as 17 lb/gal near the bottom of a deep well; thus, barite makes up from 15 to more than 60 percent of the concentration by weight of low- and high-density drilling fluids, respectively, used to drill typical offshore wells (National Research Council 1983).

The Permit only authorizes the discharge of WBFs. Operators may choose to use oil-based or synthetic-based drilling fluid during exploration activities, but those drilling fluids cannot be discharged under the Permit and the discharge prohibition extends to all cuttings generated with oil-based drilling fluids. Since the discharge of oil-and synthetic-based drilling fluids and cuttings associated with oil-based fluids is prohibited, these fluids are not discussed further. A detailed discussion of oil- and synthetic-based drilling fluids can be found in the *Environmental Assessment of Final Effluent Limitations Guidelines and Standards for Synthetic-Based Drilling Fluids and other Nonaqueous Drilling Fluids in the Oil and Gas Extraction Point Source Category* (USEPA 2000).

Drilling fluids are specifically formulated for each well to meet unique physical and chemical requirements and to perform specific functions. The well location, depth, rock type, and other conditions are all considered to develop a drilling fluid with the appropriate viscosity, density, sand content, and gel strength. During exploratory drilling, fluids are pumped down the borehole and circulated back to the surface, and are designed to perform one or more of the following primary functions:

- Remove cuttings and transport them to the surface.
- Cool and clean the drill bit.
- Lubricate the drill string.
- Maintain the stability of uncased sections of the borehole.
- Counterbalance formation pressure to prevent formation fluids (i.e., oil, gas and water) from entering the well prematurely (Berger and Anderson 1992).

Because of the costs of transporting and formulating drilling fluids, they are recirculated and reused to the extent feasible during the drilling process. The operator may need to discharge drilling fluids under a variety of circumstances, including fouling of the drilling fluid over time, significant changes in the required type of fluid, changes in drilling phases, and well completion/closure. An important factor governing the need to discharge fluids is the constraint of solids storage on the vessel. The slurry tanks are sized such that the vessel integrity is maintained, but storage capacity may not be sufficient to store and reuse all drilling fluids throughout the well drilling process.

Neff (2010) found that WBFs have become less toxic since 1989 because operators have replaced toxic ingredients with less toxic ingredients (e.g., replacing chrome lignosulfonate with chrome-free flocculants. The metals that sometimes were present in WBFs used before 1993 at concentrations substantially (>100-fold) greater than natural concentrations in marine sediments are barium, chromium, lead, and zinc (PERF 2005). With wider use of low-trace-metal barite for drilling muds, average mercury and cadmium concentrations in WBFs have declined, though concentrations sometimes are slightly higher than natural concentrations in clean marine sediment (Neff 2010).

Neff (2010) also noted that some of the concentrations of copper, lead, and zinc detected in some older WBF could have been attributed to corrosion inhibitors/sulfide scavengers, (e.g., zinc carbonate, zinc sulfonate) that had been intentionally added to the drilling muds. These compounds could also have been from drill pipe dope and drill collar compound used to lubricate the joints in the drill pipe (Ayers et al. 1980). Neff (2010) also notes that older types of pipe dope and pipe thread compound contained percent-level concentrations of metallic copper, lead, and zinc, to ensure electrical conductivity between lengths of drill pipe. These metal-containing components in WBF for offshore drilling have largely been replaced with additives that do not contain elevated concentrations of metals (Neff 2010). Therefore, it is expected that concentrations of copper, lead, and zinc in WBF would be lower than the concentrations evaluated in the ELG Development Document (USEPA 1993).

3.1.2.1 Water-Based Drilling Fluids (WBFs)

In WBFs, water is the suspending medium for solids and is the continuous phase. These fluids are composed of approximately 50 to 90 percent water by volume, with additives comprising the rest. WBFs are used most frequently because they are the least expensive, although they are not always the most effective. WBFs have limited lubricity and cause reactivity with some shale formations. In deep holes or high-angle directional drilling, WBFs are not able to provide sufficient lubricity to avoid sticking of the drill pipe. Reactivity with clay shale can cause destabilization of the borehole.

There are eight generic types of WBFs (USEPA 1993).

1. <u>Potassium/polymer fluids</u> are inhibitive fluids because they do not change the formation after it is cut by the drill bit. This fluid is used in soft formations such as shale, where sloughing may occur.
2. <u>Seawater/lignosulfonate fluids</u> are inhibitive fluids that maintain viscosity by binding lignosulfonate cations onto the broken edges of clay particles. This fluid is used to control fluid loss and to maintain the borehole stability. This type of fluid can be easily altered to address complicated drilling conditions, like high temperature in the geologic formation.
3. <u>Lime (or calcium) fluids</u> are inhibitive fluids that change viscosity as calcium binds clay platelets together to release water. This fluid can maintain more solids and is used in hydratable, sloughing shale formations.
4. <u>Nondispersed fluids</u> are used to maintain viscosity, to prevent fluid loss, and to provide improved penetration, which may be impeded by clay particles in dispersed fluids.
5. <u>Spud fluids</u> are non-inhibitive fluids that are used in approximately the first 300 meters of drilling. This is the most basic fluid mixture, and it contains mostly seawater and few additives.
6. <u>Seawater/freshwater gel fluids</u> are inhibitive fluids used in early drilling to provide fluid control, shear thinning, and lifting properties for removing cuttings from the hole. Prehydrated bentonite is used in both seawater and freshwater fluids, while attapulgite is used in seawater when fluid loss is not a concern.
7. <u>Lightly treated lignosulfonate freshwater/seawater fluids</u> resemble seawater/ lignosulfonate liquids, except that their salt content is less. Lignosulfonate or caustic soda controls the viscosity and gel strength of this fluid.
8. <u>Lignosulfonate freshwater fluids</u> are similar to the fluids described in 2 and 7 above, except the lignosulfonate content is higher. This fluid is used for high temperature drilling.

3.1.2.2 Composition and Additives

The composition of drilling fluids can be adjusted over a wide range from one borehole to the next, as well as during the course of drilling a single hole when encountering different formations. In addition to the variability among WBFs depending on the character of the borehole, additives can be adjusted depending on particular needs within the drilling process. Table 3-1 shows several common water-based drilling fluid formulations that have been used in offshore drilling operations in the past.

The list below presents some of the more common additives and is followed by a more detailed discussion of the additives.

1. <u>Weighting materials</u>, primarily barite (barium sulfate), are commonly used to increase the density of the drilling fluid in order to equilibrate the pressure between the borehole and formation when drilling through particularly pressurized zones.
2. <u>Corrosion inhibitors</u> such as iron oxide, aluminum bisulfate, zinc carbonate, and zinc chromate protect pipes and other metallic components from acidic compounds encountered in the formation.
3. <u>Dispersants</u>, including iron lignosulfonates, break up solid clusters into small particles so that the fluid can carry them.
4. <u>Flocculants</u>, primarily acrylic polymers, cause suspended particles to group together so they can be removed from the fluid at the surface.
5. <u>Surfactants</u>, like fatty acids and soaps, are used to defoam and emulsify the drilling fluid.
6. <u>Biocides</u>, typically organic amines, chlorophenols, or formaldehydes, kill bacteria that may produce toxic hydrogen sulfide gas.
7. <u>Fluid loss reducers</u> include starch and organic polymers. These limit the loss of drilling fluid to under-pressurized or high-permeability formations (USEPA 1987).

Table 3-1. Generic Fluid Formulations (USEPA 1985

Seawater/Potassium/Polymer Fluid		**Seawater/Freshwater Gel Fluid**	
Components	**lb/bbl**	**Components**	**lb/bbl**
KCl	5–50	Attapulgite or Bentonite Clay	10–50
Starch	2–12	Caustic	0.5–3
Cellulose Polymer	0.25–5	Cellulose Polymer	0–2
XC Polymer	0.25–2	Drilled Solids	20–100
Drilled Solids	20–100	Barite	0–50
Caustic	0.5 –3	Soda Ash/Sodium Bicarbonate	0–2
Barite	0–450	Lime	0 –2
Seawater	As Needed	Seawater/Freshwater	As Needed
Seawater Lignosulfonate Fluid		**Lime Fluid**	
Components	**lb/bbl**	**Components**	**lb/bbl**
Attapulgite or Bentonite	10–50	Lime	2–20
Lignosulfonate	2–15	Bentonite	10–50
Lignite	1–10	Lignosulfonate	2–15
Caustic	1–5	Lignite	0–10
Barite	25–450	Barite	25–180
Drilled Solids	20–100	Caustic	1–5
Soda Ash/Sodium Bicarbonate	0–2	Drilled Solids	20–100
Cellulose Polymer	0.25–5	Soda Ash/Sodium Bicarbonate	0–2
Seawater	As Needed	Freshwater	As Needed

lb/bbl = pounds per barrel

3.1.2.2.1 Barite

Barite is a chemically inert mineral that is heavy and soft, and is the principal weighting agent in WBFs. Barite is composed of over 90 percent barium sulfate, which is virtually insoluble in seawater, and is used to increase the density of the drilling fluid to control formation pressure (Perricone 1980, cited in Neff 1981). Barite can also contain quartz, chert, silicates, other minerals, and trace levels of metals. Barite has been shown to contain varying concentrations of metals of toxic concern, particularly cadmium and mercury. Barite ore, the natural source of barium sulfate, has also been shown to contain varying concentrations of metals depending on the characteristics of the deposit from where the barite was mined. The presence of potentially toxic trace elements in drilling fluids and adherence to cuttings is a concern. Barite is known to contain trace contaminants of several toxic heavy metals such as mercury, cadmium, arsenic, chromium, copper, lead, nickel, and zinc (USEPA 2000). EPA's statistical analysis of the American Petroleum Institute/USEPA Metals Database described in the ELG Development Document (EPA 821-R-93-003, January 1993 [USEPA 1993]) for the Offshore Category indicated that there was some correlation between cadmium and mercury and other trace metals in the barite. Specifically, EPA's evaluation showed a correlation between the concentration of mercury with the concentration of arsenic, chromium, copper, lead, molybdenum, sodium, tin, titanium and zinc; and the concentration of cadmium with concentrations of arsenic, boron, calcium, sodium, tin, titanium and zinc. In order to control the concentration of heavy metals in drilling fluids, EPA promulgated regulations applicable to the offshore subcategory of the oil and gas industry in 1993 (40 CFR 435 Subpart A) requiring that stock barite meet the criteria limits of 3 milligrams per kilogram (mg/kg) for cadmium and 1 mg/kg for mercury. Table 3-2 presents the metals concentrations in barite that were the basis for the cadmium and mercury limitations in the offshore subcategory.

Table 3-2. Metals Concentrations in Barite Used in Drilling Fluids

Metal	"Clean" Barite Concentrations (mg/kg)
Aluminum	9,069.9
Antimony	5.7
Arsenic	7.1
Barium	359,747.0
Beryllium	0.7
Cadmium	1.1
Chromium	240.0
Copper	18.7
Iron	15,344.3
Lead	35.1
Mercury	0.1
Nickel	13.5
Selenium	1.1
Silver	0.7
Thallium	1.2
Tin	14.6
Titanium	87.5
Zinc	200.5

Source: USEPA 1993; Table XI-6

The potential accumulation of metallic compounds in biota represents an issue of concern in the assessment of oil and gas impacts. Sublethal effects resulting from bioaccumulation of these highly persistent compounds are most often measured. Gross metal contamination from drill fluids might also cause mortality, particularly in benthic species. Sources of metals include drill fluids, formation waters, sacrificial anodes, and contamination from other minor sources. Drill fluids and formation waters are the primary sources of concern for arsenic, barium, chromium, cadmium, copper, mercury, nickel, lead, vanadium, silver, and zinc (USEPA 2006 citing Avanti 1991).

Field studies of metal concentrations in sediment around platforms suggest that enrichment of certain metals may occur in surface sediments around platforms. In the review of these studies conducted by Petrazzuolo (1983), enrichment of metals around platforms is generally distance dependent with maximum enrichment factors seldom exceeding 10. In platforms studied, enrichment of metals that could be attributed to drilling activities was either generally distributed 300 – 500 meters around the platform, or distributed downcurrent in a plume to a larger distance from the structure (USEPA 2006).

The concentrations of metals required to produce physiological or behavioral changes in organisms vary widely and are determined by factors such as the physiological characteristics of the water and sediments, the bioavailability of the metal, the organism's size, physiological characteristics, and feeding adaptations. Metals are accumulated at different rates and to different concentrations depending on the tissue or organ involved. Laboratory studies on metal accumulations as a result of exposure to drill fluids have been conducted. Maximum enrichment factors for the metals measured were generally low (< 10) with the exception of barium and chromium, which had enrichment factors of up to 300 and 36, respectively (USEPA 2006).

Depuration studies have shown that organisms tested have the ability to depurate some metals when removed from a zone of contamination. In various tests, animals were exposed to drill fluids from 4–28 days, followed by a 1–14 day depuration period. Uptake and depuration of barium, chromium, lead, and silver were monitored and showed a 40–90 percent decrease in excess metal in tissues following the depuration period. Longer exposure generally meant a slower rate of loss of the metal. In addition, if uptake was through food organisms rather than a solute, release of the excess metal was slowed (USEPA 2006).

The available laboratory data on metals accumulation are difficult to correlate with field exposure and accumulation. Petrazzuolo's review (1983) notes that in the field, bioaccumulation of metals in the benthos will result from exposure to the particulate components of drilling fluids. However, laboratory studies have almost always used either whole fluids or fluid-aqueous fractions, and thus are either over- or underestimating potential accumulation (USEPA 2006).

Field studies of metal accumulation in marine food webs off southern California have been conducted. These data have indicated that most metals measured (including chromium, copper, cadmium, silver, and zinc) do not increase with trophic level either in open water or in contaminated regions such as coastal sewage outfalls. Mercury, however, may be an exception to this, as biomagnification has been observed in a number of studies. Other studies have shown that croakers, scorpionfish, and sea urchins can detoxify inorganic metals through a protein synthesis process that excludes contaminants from cellular enzyme pools (USEPA 2006).

Bioaccumulation of metals in southern and central California offshore waters may not be a significant environmental problem. However, Petrazzuolo (1983) states that due to the persistence of metals, the high toxicity of some metals, the paucity of laboratory data on mercury, and the inability to correlate field and laboratory measures, a finding of no significant potential effect was inappropriate at that time (USEPA 2006).

While these studies discuss the potential for bioaccumulation, they are not specific to the Cook Inlet. The ICIEMAP study efforts in the Cook Inlet from 2008-2009 were comprehensive (Kinnetic Laboratories, Inc. 2010). Although the ICIEMAP study was focused on the discharge of produced water, it included parameters that are associated with the discharge of drilling fluids and drill cuttings. The results of the study did not show a correlation between the concentrations found in sediment and oil and gas activities in Cook Inlet.

3.1.2.2.2 Clay

Clay compounds are added to drilling fluids to control certain physical properties such as fluid loss, viscosity, yield point, and to eliminate borehole problems. The most commonly used commercial clay is sodium montmorillonite. Bentonite is another common additive used to increase the fluid's viscosity and gel strength, which increases the carrying capacity for solids removal from the borehole. Bentonite also greatly improves the filtration and filter cake properties of the fluid (Lyons 2009). The concentration of bentonite in typical WBFs is about 7 percent of the total drilling fluid system, which is about 4.1 percent of the barite fraction (Neff 2010). Bentonite is usually used in concentrations ranging from 5 to 25 lb/bbl; however, in the presence of concentrated brine or formation waters, attapulgite or sepiolite clays in concentration from 10 to 30 lb/bbl are substituted for bentonite (Perricone 1980, cited in Neff 1981).

3.1.2.2.3 Lignosulfonate

Lignosulfonate is used to control viscosity in drilling fluids by acting as a thinning agent or deflocculant for clay particles. Concentrations in drilling fluid range from 1 to 15 lb/bbl. It is made from the sulfite pulping of wood chips used to produce paper and cellulose. Ferrochrome lignosulfonate, the most commonly used form of lignosulfonate, is made by treating lignosulfonate with sulfuric acid and sodium dichromate. The sodium dichromate oxidizes the lignosulfonate and cross linking occurs. Chromate supplies the hexavalent chromium that is reduced during reaction to the trivalent state and complexes with the lignosulfonate. At high downhole temperatures, the chrome binds onto the edges of clay particles and reduces the formation of colloids. Ferrochrome lignosulfonate retains its properties in high-soluble salt concentrations and over a wide range of alkaline pH (USEPA 1993).

3.1.2.2.4 Caustic Soda

Sodium hydroxide is used to maintain the filtrate pH between 9 and 12. A pH of 9.5 provides maximum deflocculation and keeps the lignite in solution. A more basic pH lowers the corrosion rate and provides protection against hydrogen sulfide contamination by limiting microbial growth (Lyons 2009).

3.1.2.2.5 Spotting Compounds

Spotting compounds are used to help free stuck drill strings. A concentrated slug or “pill” of the spotting agent is pumped downhole and up the annular space between the borehole and drill pipe. After working to free the stuck pipe the pill is then pumped back to the surface. Some of these (e.g., vegetable oil or fatty acid glycerol) are easily broken down in the environment. The most effective and, consequently, most frequently used compounds are oil-based (diesel or mineral oil). Mineral oils can contribute potentially toxic organic pollutants to drilling fluids to which they are added. Data show that the concentration of organic pollutants in the drilling fluids is roughly proportional to the amount of mineral oil added. The Permit does not authorize the discharge of drilling fluids or cuttings that are contaminated with diesel fuel. The Permit authorizes the discharge of residual amounts of mineral oil pills, provided that certain precautionary measures are taken to minimize contamination of the drilling fluids.

3.1.2.2.6 Lubricants

Lubricants are added to the drilling fluid when high torque conditions are encountered on the drill string. These can be vegetable-, paraffinic-, or asphaltic-based compounds such as Soltex. Mineral oil-based lubricants might contribute to organic pollutant loading and, like spotting fluids, are not authorized for discharge under the Permit.

3.1.2.2.7 Zinc Carbonate

Zinc carbonate is used as a sulfide scavenger when formations containing hydrogen sulfide are expected to be encountered during drilling. The zinc sulfide and unreactive zinc compounds are discharged with the drilling fluid, thus contributing to the overall loading of zinc when they are used. While the potential need exists, most drilling activities do not encounter conditions that warrant the addition of sulfide scavengers (Lyons and Plisga 2005).

3.2 OTHER DISCHARGES

In addition to drilling fluids and drill cuttings, the Permit authorizes twelve other exploration waste streams. Note that the discussion for sanitary and domestic wastewater is combined in the discussion below.

3.2.1 Deck Drainage

Deck drainage refers to any wastewater generated from platform washing, deck washing, spillage, rainwater, and runoff from curbs, gutters, and drains, including drip pans and wash areas. This type of drainage could include pollutants such as detergents used in platform and equipment washing, oil, grease, and drilling fluids spilled during normal operations.

When water from rainfall or from equipment cleaning comes in contact with oil-coated surfaces, the water becomes contaminated and must be treated and disposed. Oil and grease are the primary pollutants identified in the deck drainage waste stream (USEPA 1993). In addition to oil, various other chemicals used in drilling operations could be present in deck drainage. These chemicals include drilling fluids, ethylene glycol, lubricants, fuels, biocides, surfactants, detergents, corrosion inhibitors, cleaners, solvents, paint cleaners, bleach, dispersants, coagulants, and any other chemical used in the daily operations of the facility (Dalton et al. 1985).

Untreated deck drainage can contain oil and grease in quantities ranging from 12 to 1,310 milligrams per liter (mg/L). The Permit does not, however, allow deck drainage discharges unless it complies with the effluent limitations specified in the Permit. Table 3-3 provides ranges for other pollutant quantities in untreated deck drainage.

Table 3-3. Pollutant Concentrations in Untreated Deck Drainage (USEPA 1993)

	Pollutant	Range
Conventional (mg/L)	pH	6.6–6.8
	BOD	<18–550
	TSS	37.2–220.4
	Oil and Grease	12–1,310
Nonconventional (µg/L)	Temperature (°C)	20–32
	TOC (mg/L)	21–137
	Aluminum	176–23,100
	Barium	2,420–20,500
	Boron	3,110–19,300
	Calcium	98,200–341,000
	Cobalt	< 20
	Iron	830–81,300
	Magnesium	50,400–219,000
	Manganese	133–919
	Molybdenum	< 10–20
	Sodium	151×10^4–568×10^4
	Tin	< 30
	Titanium	4–2,030
	Vanadium	< 15–92
	Yttrium	< 2–17

Table 3-3. Pollutant Concentrations in Untreated Deck Drainage (USEPA 1993)

	Pollutant	Range
Priority Metals (µg/L)	Antimony	< 4– < 40
	Arsenic	< 2– < 20
	Beryllium	< 1–1
	Cadmium	< 4–25
	Chromium	< 10–83
	Copper	14–219
	Lead	< 50–352
	Mercury	< 4
	Nickel	< 30–75
	Selenium	<3–47.5
	Silver	< 7
	Thallium	< 20
	Zinc	2,970–6,980
Priority Organics (µg/L)	Acetone	ND–852
	Benzene	ND–205
	m-Xylene	ND–47
	Methylene chloride	ND–874
	N-octadecane	ND–106
	Naphthalene	392–3,144
	o,p-Xylene	105–195
	Toluene	ND–260
	1,1-Dichloroethene	ND–26

* Ranges for four samples, two each, at two of the three facilities in the three-facility study EPA conducted. The study was conducted over 4 days in 1989 at three oil and gas production facilities that used granular filtration for treatment of produced water: Thums Long Beach Island Grissom, Shell Western E&B Inc. – Beta Complex, and Conoco's Maljamar Oil Field. (USEPA 1993).

ND=not detected; µg/L= micrograms per liter; °C= degrees Celsius; mg/L= milligrams per liter.

USEPA (1993) determined that the BPT for treatment of deck drainage is a sump and skim pile system. Oil and water are gravity-separated in the sump, and the oil is sent off-site to an oil treater. After treatment in an oil water separator, clean water is discharged, and oily water is stored aboard until transferred to an approved treatment and disposal site. The Permit requires that deck drainage contaminated with oil and grease is processed through an oil water separator prior to discharge, and also prohibits the discharge of free oil in deck drainage discharges.

3.2.2 Sanitary and Domestic Waste

While some platforms discharge sanitary and domestic wastes separately, many combine these waste streams prior to discharge. Therefore, this section will discuss sanitary waste, domestic waste, and the combined waste. Sanitary waste is human body waste discharged from toilets and urinals and treated with a marine sanitation device (MSD). The discharge consists of secondary treated chlorinated effluent. Domestic waste (gray water) refers to materials discharged from sinks, showers, laundries, safety showers, eyewash stations, and galleys. Gray water can include kitchen solids, detergents, cleansers, oil, and grease. Domestic waste includes solid materials such as paper and cardboard, which must be disposed of properly. Domestic waste is incinerated, reused to make drilling fluid, or discharged directly into receiving waters.

The volume of sanitary waste varies widely with time, occupancy, platform characteristics, and operational situation. Pollutants of concern in sanitary waste include biochemical oxygen demand (BOD), total suspended solids (TSS), fecal coliform bacteria, and residual chlorine.

The Permit allows the discharge of sanitary and domestic wastes, provided effluent limitations are met. Sanitary wastewater must be treated with an approved MSD prior to discharge, while domestic (gray) wastewater may be discharged after chlorination or directly.

Permittees indicate that sanitary and domestic wastewaters are discharged via the disposal caisson, and that any nonhazardous combustible domestic waste is incinerated aboard. Noncombustible domestic solid waste, such as metals and plastics, are stored and transferred to an approved landfill or other approved site.

3.2.3 Desalination Unit Waste

Desalination unit waste is residual high-concentration brine, associated with the process (distillation or reverse osmosis units) used in creating freshwater from seawater. The concentrate is similar to seawater in chemical composition; however, anion and cation concentrations are higher. Discharges from desalination units occur via the disposal caisson and may vary greatly in volume depending on the freshwater needs of the rig.

The Permit prohibits the discharge of free oil in this waste stream. If a sampling detects a sheen, as the Permit describes, the waste stream is not permitted to be discharged.

3.2.4 Blowout Preventer Fluid

As previously described, the blowout preventer is a device typically located below the seafloor designed to maintain the pressure in the well that the drilling fluid cannot control. Fluid used to operate the blowout preventer may be discharged in small quantities (less than 42 barrels per well (bbl/well) or approximately 7 barrels per testing event) when the blowout preventer is actuated on the hydraulic equipment. Testing of the blowout preventer device must be conducted periodically (typically on a weekly basis). In the case of Furie Operating Alaska, LLC (Furie), during drilling of their Kitchen Lights Unit, wells BOP equipment was tested biweekly and in accordance with American Petroleum Institute (API) Recommended Practice No. 53 and Alaska Oil and Gas Conservation Commission (AOGCC). The primary constituents of blowout preventer fluid are oil (vegetable or mineral) or seawater mixed with an antifreeze solution (ethylene glycol).

The Permit allows the discharge of this waste stream, but require that no free oil is detected using a sheen test, as the Permit describes.

3.2.5 Boiler Blowdown

Boiler blowdown is the discharge of water and minerals drained from boiler drums to minimize solids buildup in the boiler.

The Permit requires reporting of the total discharge volume of this waste stream and an inventory of the type and quantity of biocides or other chemicals that are added to the boiler system. Discharges of boiler blowdown water that contain no free oil as determined by the visual sheen test are authorized under the Permit.

3.2.6 Fire Control System Test Water

Fire control system test water is seawater that is released during the training of personnel in fire protection, and the testing and maintenance of fire protection equipment on the platform. Fire control system test water discharges occur as an overboard discharge. This test water may be treated with a biocide.

As a result of the limited quantitative data available on biocide concentrations in Alaskan offshore discharges, the Permit includes a requirement to report the quantities of biocide added to fire control system test water and to report the total discharge volume of this waste stream, including any biocides added to the system. When chemicals are added and the discharge is greater than 10,000 gpd, WET testing is required.

3.2.7 Non-Contact Cooling Water

Non-contact cooling water is seawater used for non-contact, once-through cooling of various pieces of machinery (e.g., power generators) on the drilling rig. Depending on the volume of WBFs discharged, non-contact cooling water might comprise the majority of the volume of the discharges that would be released under the Permit. The volume of non-contact cooling water depends on the configuration of heat exchange systems on the drilling rig. Some systems use smaller volumes of water that are heated to a greater extent, resulting in a higher temperature differential between waste water and receiving water. Other systems use larger volumes of water to cool equipment, resulting in a smaller difference between the temperature of waste water and receiving water. Depending on the heat exchanger materials and the system design, biocides or oxidizing agents may be needed to control biofouling on condenser tubes and intake and discharge conduits.

As a result of the limited quantitative data available on biocide concentrations in Alaskan offshore discharges, the Permit includes a requirement to report the quantities of biocide added to non-contact cooling water and to implement best management practices to minimize their use. When chemicals are added and the discharge is greater than 10,000 gpd, WET testing is required.

Discharges occur via numerous overboard outfalls from the ship. A small volume of non-contact cooling water is typically used to dilute discharges of drill cuttings.

3.2.8 Ballast Water

Ballast water is seawater added or removed to maintain the proper ballast floater level and ship draft. If a sheen test does not detect any free oil, as the Permit describes, then ballast water is considered uncontaminated and can be discharged without treatment. If ballast water is contaminated with oil, the Permit requires the waste stream to be treated through the oil water separator prior to discharge via the disposal pipe. When chemicals are added and the discharge is greater than 10,000 gpd, WET testing is required.

3.2.9 Bilge Water

Bilge water is seawater that collects in the lower internal parts of the drilling vessel hull. It becomes contaminated with oil and grease and with solids such as rust when it collects at low points in the bilges.

The Permit requires treatment through the oil-water separator prior to discharge at the disposal pipe. When chemicals are added and the discharge is greater than 10,000 gpd, WET testing is required.

3.2.10 Excess Cement

The discharge of excess cement slurry at the discharge pipe will result from equipment washdown after cementing operations at the seafloor surface. Excess cement slurry is discharged in small quantities during drill casing installation, varying based on drilling conditions and the casing and testing program in effect. The Permit requires reporting of the total discharge volume of this waste stream and require no discharge of free oil.

3.2.11 Drilling Fluid, Cuttings, and Cement at Seafloor

Drilling fluid, cuttings, and cement are materials discharged at the seafloor in the early phases of drilling operations, such as spudding the well, or during cementing operations before the casing is set. These discharges can also occur during well abandonment and plugging. This discharge also results from the marine riser disconnect on drill ships and semisubmersibles. Aside from cement, cement extenders, accelerators, and dispersants are the main chemicals added to this discharge.

The Permit requires reporting of the total discharge volume of this waste stream and require that there is no discharge of free oil in the drilling fluid, cuttings, and cement discharged at the seafloor.

In the case of drilling fluid, most of the discharged material (greater than 90 percent) sinks to the bottom near the well site (Thibodeaux et al. 1986). The distance of drilling fluid and associated materials such as drill cuttings from the discharge point depends on depth of water, lateral transport, particle size, and density of material (Thibodeaux et al. 1986). This distance is commonly estimated between 500 and 1,000 meters from the point of discharge (Neff 1987 as cited by PERF (2005); Thibodeaux et al. 1986). It is important to note that the deposition of the fines will generally take place on a larger geographical scale and have a resulting low-thickness layer on the seafloor when compared to the coarser particles (Rye et al. 1998). In well-mixed ocean waters, drilling fluids and cuttings are diluted 100-fold within 10 meters of the discharge and by 1,000-fold after a transport time of about 10 minutes at a distance of about 100 meters from the platform (PERF 2005).

How long the settled material remains at the site of deposition and transport of resuspended particles depends on environmental factors that govern sediment resuspension, transport, and dispersion. The redistribution of settled drilling solids depends on the shear between the bottom forms and the flowing seawater. If the sinking velocity of the particle is lower than 10^{-3} meters per second (m/s), the particle is expected to be brought into resuspension. This number is probably dependent on the sizes of the current velocities close to the bottom. A sinking velocity equal to 10^{-3} m/s corresponds to a particle size diameter equal to 35 µm (barite) or 50 µm (drill cuttings) (Rye et al. 1998).

Due to the varying environmental conditions that control sediment resuspension and transport, drilling solids may build up on the seafloor for extended periods at certain times of the year, but one major storm event may be sufficient to move the entire layer of solids that has formed. In low-energy areas the layer may remain for a year or longer (Snyder-Conn et al. 1990; Thibodeaux and Fang et al. 1986; Yunker et al. 1990). In a study of shallow, low-energy environments around the Stefansson Sound in the Alaskan Beaufort Sea, Snyder-Conn et al. (1990) found persistence of barium, chromium, lead and zinc at certain stations at all three discharge sites, in addition to elevated concentrations of aluminum at one of the three sites when sampled 2 to 4 years after the discharges.

3.2.12 Chemically Treated Seawater Discharges

Operators use a broad range of chemicals to treat seawater and freshwater used in offshore operations. The available literature shows that more than 20 biocides are commonly used. These include derivations of aldehydes, formaldehyde, amine salt, and other compounds. The toxicity of these compounds to marine organisms as measured with a 96-hour lethal concentration to 50 percent of test organisms (LC_{50}) test is reported to range from 0.4 mg/L to greater than 1,000 mg/L. Scale inhibitors are also used to treat seawater and freshwater. The scale inhibitors commonly used are amine phosphate ester and phosphonate compounds. Scale inhibitors are generally less toxic to marine life than biocides with 96-hour LC_{50} concentrations shown to be from 1,676 mg/L to greater than 10,000 mg/L. Ninety-six-hour LC_{50} values for corrosion inhibitors were reported to range from 1.98 mg/L to 1050 mg/L.

The 2007 Permit used generic Best Professional Judgment (BPJ)-based limits, based on available technology, to regulate chemically treated seawater and freshwater discharges, rather than attempting to limit the discharge of specific biocides, scale inhibitors and corrosion inhibitors. The Permit retains these limitations.

Many of the chemicals normally added to seawater or freshwater, especially biocides, have manufacturer's recommended maximum concentrations or EPA product registration labeling. In addition, information obtained from offshore operators demonstrates that it is unnecessary to use any of the chemical additives or biocides in concentrations greater than 500 mg/L.

Concentrations of treatment chemicals in discharges of seawater or freshwater are limited in the Permit to the most stringent of the following requirements:

- The maximum concentrations and any other conditions specified in the EPA product registration labeling if the chemical additive is an EPA-registered product.
- The maximum manufacturer's recommended concentration, when one exists.
- A maximum concentration of 500 mg/L.

The Permit contains BCT limits prohibiting the discharge of free oil for chemically treated seawater and freshwater discharges. They also contain a visual sheen monitoring requirement for miscellaneous discharges after they are run through an oil-water separator. The Permit also requires reporting of the total discharge volume of these waste streams.

3.3 ESTIMATED DISCHARGE QUANTITIES

Through 1985, thirteen exploration wells were drilled in federal waters of the Cook Inlet (BOEM 2012). Since 2002, there have been a total of eight wells drilled at the Osprey Platform (Redoubt Shoal Field in Alaska state waters), but two of these were for the injection of water to add pressure in the reservoir and boost oil production (Bradner 2011). Based on the sporadic history of exploratory drilling, the number of exploration wells that will be drilled within the coverage area of the Permit is unknown and the volumes of various discharges must be estimated.

The discharge rate of drill cuttings and drilling fluids during well drilling operations is variable. The volume of rock cuttings produced from drilling is primarily a function of the depth of the well and the diameter of the borehole (USEPA 2000). USEPA (1987) estimated that between 0.2 barrels and 2.0 barrels (8.4 to 84.0 gallons) of total drilling waste are produced for each vertical foot drilled. During exploratory drilling operations, bulk drilling fluid, usually about 100 - 200 barrels at a time, is discharged several times during well drilling, when the composition of the drilling fluid has to be changed substantially, or when the volume exceeds the capacity of the fluid tanks. Washed drill cuttings and a small volume of drilling fluid solids are continuously discharged during drilling operations; the discharge rate varies from about 25 to 250 bbl/day (MMS 2003). The Permit requires that the following effluent limitations be met for depth-dependent discharges of WBFs and cuttings:

- No discharge in depths of 0 to 10 meters (33 feet).

- 500 barrels (bbl)/hour (79 cubic meters [m^3]) at > 10 to 20 meters (> 33 to 66 feet).
- 750 bbl/hour (119 m^3) at > 20 to 40 meters (> 66 to 131 feet).
- 1,000 bbl/hour (159 m^3) at > 40 meters (> 131 feet).

The actual number of exploratory wells that will be drilled in the coverage area during the 5-year term of the Permit is not known; therefore, the volumes of various discharges must be estimated. EPA determined there is the potential to drill up to 12 wells in federal waters during the term of the Permit. This is a high-end estimate according to existing information (BOEM 2012). Four exploratory wells have been drilled in State waters during the term of the 2007 Permit. Furie completed these wells in the Kitchen Lights Unit (KLU). The first well was drilled to 15,298 feet over 2 seasons in 137 days and the last well was drilled to almost 10,000 feet in 53 days.

EPA has derived new per well discharge estimates based in part on Furie's information from the actual drilling of the four KLU wells and in part on the submitted NOI where drilling did not provide new information. EPA used the maximum reported value for drilling fluid discharge. For drill cuttings the maximum volume was calculated based on hole dimensions (varying diameters at depth) and utilized a 20% swell factor. For discharges that did occur during Furie's drilling, EPA determined a single well value by multiplying the number of days by the maximum average daily reported value. For outfalls from which Furie did not discharge, EPA provides a range from zero to the value anticipated in the NOI.

In reviewing the drilling information, it became apparent that the duration of drilling and total time a drill rig is on-site were underestimated in the draft ODCE. While this does not affect the above drilling discharges, it does impact discharges such as sanitary/domestic wastewater and deck drainage. To estimate these non-drilling discharges, EPA averaged the number of days from Furie's last three wells and rounded up to approximate the days on-site (80) and the drilling days (50).

Table 3-4. Estimated Discharge Quantities

Discharge	Discharge Quantities (bbls/well)	Discharge Quantities for 12 wells (bbls)
Drill Cuttings (001)	4,350	52,200
Drill Fluids (001)	15,600	187,200
Deck Drainage (002)	3040	36,480
Sanitary Waste (003)	8,220	98,640
Domestic Waste (004)	10,410	124,920
Desalination Brine (005) *	0 – 16,000	0 – 192,000
BOP Fluid (006) *	0 – 3,360	0 – 40,320
Boiler Blowdown (007) *	0 – 8,000	0 – 96,000
Fire Control Test Water (008)	1150	13,800
Non-Contact Cooling Water (009) *	0 – 4,000,000	0 – 4,000,000
Ballast water (010)	1,800,000	21,600,000**
Bilge Water (011) *	0 – 800	0 – 9,600
Excess Cement (012)	11,050	132,600
Fluids and Cuttings at Seafloor (013) *	0 – 35,000	0 – 420,000

* No reported discharge from Furie drilling so a range is provided
** If all 12 wells are drilled with jackup rigs

4.0 DESCRIPTION OF THE EXISTING PHYSICAL ENVIRONMENT

4.1 CLIMATE AND METEOROLOGY

The Cook Inlet area is characterized by three climate zones: the maritime zone, the continental zone, and the transition zone (Alaskool 2004). In the maritime zone areas, which encompass the coast and islands, annual precipitation averages about 60 inches. Mean maximum temperatures in the summer are in the upper 50s (degrees Fahrenheit, ^{o}F) and low means during winter are in the low 20s (^{o}F). Offshore winds average 12 - 18 knots, with winter extremes of 50 - 75 knots (Alaskool 2004).

In the lower Cook Inlet region, the climate is transitional from a maritime climate to a continental climate. Generally, lower Cook Inlet is a maritime climate, wetter and warmer than the upper Cook Inlet region, which exhibits some continental climatic features - that is, the upper Cook Inlet region is drier and cooler than the lower region (MMS 2003). Areas further from the coast may have continental zone characteristics, with annual precipitation from 10 - 15 inches, mean maximum summer temperatures in the mid- to upper 60s (^{o}F), and mean lows in the winter ranging from -10 to -30 ^{o}F. Surface winds tend to be lighter compared to coastal maritime areas.

Overland and Hiester (1980) define six Gulf of Alaska weather types that influence lower Cook Inlet. The Aleutian low-pressure center occurs most often. The Aleutian Low, a semipermanent low-pressure system over the Pacific Ocean, has a strong effect on the climate in the area. As this low-pressure area moves and changes in intensity, it brings storms with wind, rain, and snow (Wilson and Overland 1986). The other weather types are the low-pressure center over central Alaska; the stagnating low off the Queen Charlotte Islands; and the Pacific Anticyclone, also known as the East Pacific High (Overland and Hiester 1980). Generally, winter is characterized by an inland high-pressure cell with frequent storm progressions from the west along the Aleutian chain. During summer, a low-pressure cell is over the inland area, with fewer storms (MMS 2003). Spring and fall are characterized by a transition between these generalized patterns

Precipitation decreases from south to north along the Inlet. Kodiak is the wettest and Anchorage is drier (MMS 2003). Cook Inlet precipitation (SAIC 2001) averages less than 20 percent of that measured on the Gulf of Alaska side of the Kenai Mountains (NCG 2001). Homer, Kenai, and Anchorage all have substantially less precipitation than Kodiak due to the sheltering or rain shadow effect of the Kenai Mountains. Homer averages about 25.5 inches of precipitation annually, and Anchorage averages about 15.7 inches. The wettest months are September and October, with the relatively dry conditions in April through July. In the northern inlet, precipitation usually falls as snow from October to April and as rain the rest of the months. Farther south in the inlet, a greater percentage of the precipitation falls as rain (MMS 2003).

Winds in the area are strongly influence by mountains surrounding the Cook Inlet basin. During the months of September through April, prevailing winds are typically from the north or northwest. During May through August, winds prevail from the south. Mean speeds range from 5 knots in December to 7 knots in May (Brower et al. 1988). Site-specific, short-term data confirm the general trends described above. For example, winds measured at the West Foreland in 1999 and 2000 indicate that during September through April, prevailing winds are from the north-northeast and northeast. During June and July, winds prevail from the south-southwest and southwest. Extreme winds are commonly out of the northeast or south (SAIC 2001).

4.2 OCEANOGRAPHY

Cook Inlet is a 350-kilometer (217-mile) long semi-enclosed estuary that has a free connection to the open ocean (MMS 2003; MMS 2000) and a general northeast-southwest orientation. It is divided naturally into the upper and lower inlet by the East and West Forelands, where the Inlet is approximately 16 kilometers (10 miles) wide (SAIC 2001). Cook Inlet, and its channels, coves, flats, and marshes, are a mixture of terrestrial sources from numerous river drainages and marine waters of Shelikof Strait and the Gulf of Alaska (MMS 2003). Cook Inlet varies in width from about 100 kilometers (62 miles) near the entrance to less than 20 kilometers (12 miles) at its head (MMS 2000).

The circulation of water in Cook Inlet is influenced by several factors, including the shape of the Inlet, bathymetry, freshwater input from rivers, the Alaska Coastal Current (ACC), and tides. Okkonen et al. (2009) found that temperature and salinity gradients existed between lower and central Cook Inlet, between the east and west sides of the Inlet. This was evident from the hydrographic data that they acquired through this project (Okkonen et al. 2009).

Cook Inlet is long and narrow. It has shoals towards its head where it separates into two narrow shallow arms (Knik and Turnagain). The East and West Forelands constrict water flow and influence the movement of water between Central and Upper Cook Inlet. The Kachemak Bay is a large embayment on the east side. It has a deep channel and a spit that nearly bisects the bay at its midpoint. Kamishak Bay is a large embayment on the west side. It is relatively shallow and contains the Augustine Island volcano (Whitney, 2002).

Rivers discharging into the upper Inlet and along the west side make up the major freshwater inputs. It is likely that the ACC and these freshwater inputs account for most of the non-tidal influence on circulation in Upper and Middle Cook Inlet, except on the west side (Whitney, 2002). The fresher water from the upper Inlet flows south along the west side and it eventually meets with the westward-moving ACC near Augustine Island.

The northern edge of the ACC generally follows the 100 meter isobath around the mouth of Cook Inlet. The southward flowing water along the western boundary is generally trapped by the ACC. Most of the freshwater flow out of Cook Inlet narrows to a few kilometers in width as it passes Cape Douglas at the southern end of Cook Inlet (Okkonen et al., 2009).

Convergence zones, known as tidal rips, are formed when the tidal and freshwater flows interact with the bathymetry. These tidal rips are generally located above rapidly changing bathymetry. They often delineate strong gradients in water properties (e.g., temperature, salinity, and suspended sediments) as well as the speed of the current (Okkonen, 2004; Li et al., 2005). There are three main rips that are often evident in central Cook Inlet. They extend from the vicinity of the Forelands to beyond the southern tip of Kalgin Island. During the stages of the tidal cycle when the rips are strongest, they can accumulate debris, ice, and spilled oil along their axes. This material can become submerged and resurface downstream. The movement of material from one side of the rip to the other is inhibited (Whitney, 2002).

The lunar semidiurnal tide is the principal tidal influence in Cook Inlet. Due to the size, shape, and bathymetry of the Cook Inlet basin, a funneling effect and tidal resonance create some of the highest tidal amplitudes in the world. At the mouth of Cook Inlet, the mean tidal range varies from 11 feet at the Barren Islands to more than 27 feet at Anchorage (NOAA 2006). This large tidal exchange within Cook Inlet causes strong tidal currents. The average maximum surface current in Cook Inlet as a whole is three knots. Currents greater than 10 knots have been measured in local areas due to tidal influences (Li et al., 2005). The currents in the constricted area between the West and East Forelands accelerate to more than six knots during spring tides, with the associated tidal excursions sometimes exceeding 20 miles. Due to the large freshwater outflow from Upper Cook Inlet rivers south along the west side of the Inlet, the ebb tide excursions can be several miles faster. The difference contributes to the net southerly flow along the west side of Cook Inlet, especially when freshwater input is high. Figure 2 presents the factors described above on Cook Inlet circulation flows.

Currents may exceed 6.5 knots in the Forelands area, and have been reported at up to 12 knots in the vicinity of Kalgin Island and Drift River (KPB 2007). The mixing of incoming and outgoing tidewater, combined with freshwater inputs, are the main forces driving surface circulation (Figure 2; MMS 2003).

The Alaskan Stream and a parallel current in the western Gulf of Alaska called the Kenai Current or the ACC influence the lower portion of Cook Inlet (MMS 2003). The ACC flows along the inner shelf in the western Gulf of Alaska and enters Cook Inlet and Shelikof Strait (Schumacher and Reed 1980). The current is narrow (less than 30 kilometers [18.6 miles]) and high-speed (20 - 175 centimeters per second [cm/s] or 8 - 69 inches per second [in/s]) with flow that is driven by freshwater discharge and inner-shelf winds (MMS 2003). Peak velocities of 175 cm/s (69 in/s) occur in September through October (Johnson et al. 1988). The ACC transport volumes range from

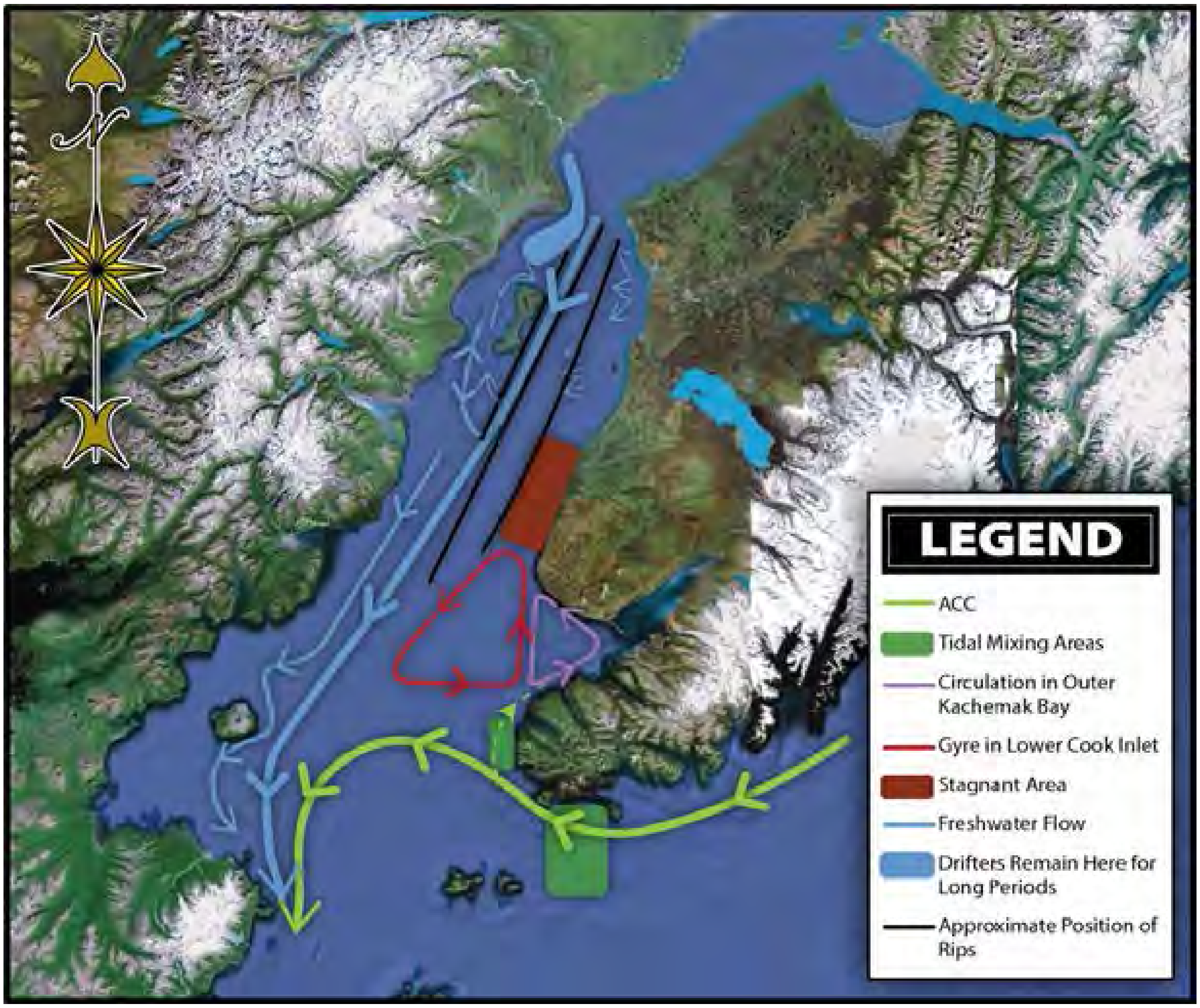


Figure 2. Circulation flows in Cook Inlet (permission granted by Scott Pegau, University of Alaska, Fairbanks [NUKA 2013])

0.1 - 1.2 million m^3 per second (m^3/s) or 106 - 317 million gallons per second, and varies seasonally in response to freshwater runoff fluctuations, regional winds, and atmospheric pressure gradients (Luick et al. 1987; Reed et al. 1987; Royer 1982; Schumacher and Reed 1980 and 1986; Schumacher et al. 1989). Oxygen isotope measurements in late summer show that glacial meltwater may provide much of the total freshwater runoff into the ACC (Kipphut 1990).

The bottom of Cook Inlet is extremely rugged with deep pockets and shallow shoals (KPB 2008). Upper Cook Inlet north of the Forelands is generally less than 120 feet deep; the deepest portion is in Trading Bay, east of the mouth of the McArthur River. Two channels extend southward on either side of Kalgin Island, joining west of Cape Ninilchik. This channel gradually deepens to the south, to about 480 feet, and then widens to extend across the mouth of Cook Inlet from Cape Douglas to Cape Elizabeth (KPB 2008). The 60-foot depth contour is generally located 2.5 to 3 miles offshore along lower Cook Inlet, but falls within 0.7 miles of shore for a length of about 3 miles near Cape Starichkof (KPB 2008). The southeast coast of the Kenai Peninsula consists of a series of deep, glacially carved fjords (KPB 2008). Beach substrate may be sand, hard or soft mud, gravel, or cobble (Pentec Environmental 2005).

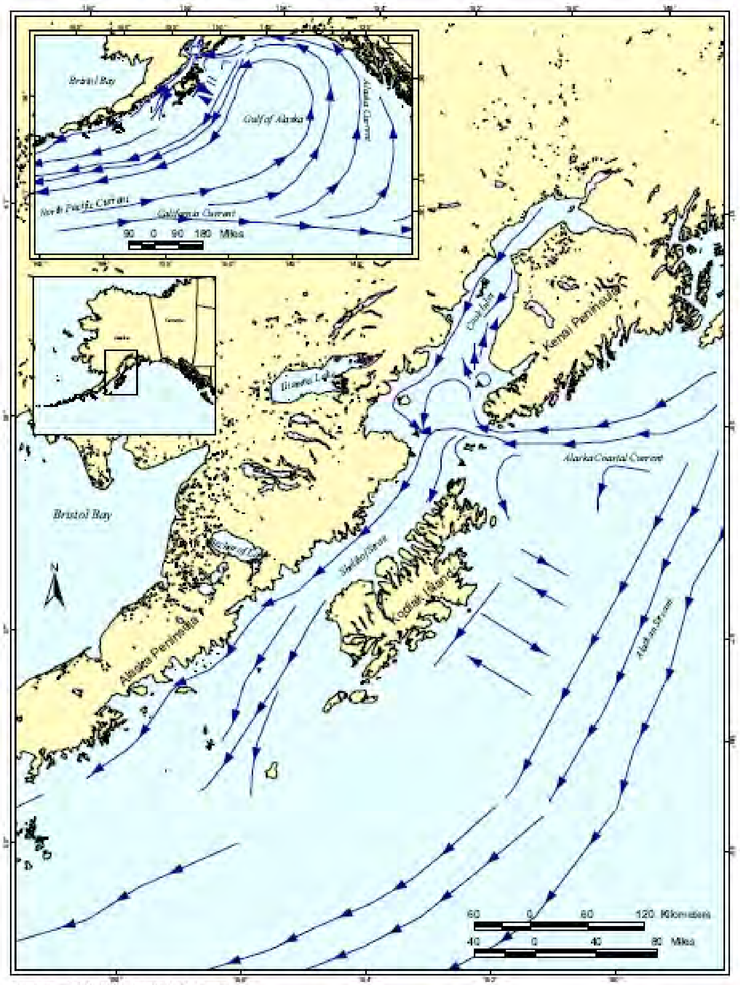
Tides in Cook Inlet are semidiurnal, with two unequal high tides and two unequal low tides per tidal day (24 hours, 50 minutes). The mean diurnal tidal range varies from 13.7 feet at the mouth of Cook Inlet to 29 feet in upper Cook Inlet (KPB 2008). Strong tidal currents and inlet geometry produce considerable cross currents and turbulence within the water column. Tidal bores with current speeds up to 5 m/s^{-1} have occurred in Turnagain Arm (Ezer et al. 2008). Current velocities are influenced by local shore configuration, bottom contour, and possibly wind effects in some shallow areas (MMS 2003).

Cook Inlet receives large quantities of glacial sediment from the Knik, Matanuska, Susitna, Kenai, Beluga, McArthur, Drift, and other rivers. Intense tidal currents redistribute the sediment. Most of this sediment is deposited on the extensive tidal flats or is carried offshore through Shelikof Strait and eventually deposited in the Aleutian trench beyond Kodiak (KPB 2007; MMS 2003).

Powered by the ACC, sediments of the Copper River drainage drift into lower Cook Inlet and Shelikof Strait where they eventually settle to the bottom. MMS survey results indicate that about 10 - 20 percent of the bottom sediments in the Cook Inlet area are from the Copper River (MMS 2000).

Copper River sediment in Cook Inlet is generally transported along the outer Kenai Peninsula into lower Cook Inlet, Kachemak Bay, and Shelikof Strait. Sediments transported down the west side of Cook Inlet are eventually deposited in the shallows of Kamishak Bay, deeper portions of outermost Cook Inlet, and Shelikof Strait (MMS 2000). Homer Spit is maintained by sediment transported from the north (KPB 2007).

The salinity of Cook Inlet is extremely complex. As noted above, Cook Inlet is an estuary (MMS 2000; MMS 2003). As such, three important factors influence the salinity within the Inlet: (1) a freshwater component responsible for introducing waters of low salinity; (2) a seawater component responsible for introducing waters of high salinity; and (3) a tidal component. In Cook Inlet, the tidal component is responsible for mixing freshwater inputs from rivers within the inlet and from the ACC entering the inlet at Kennedy Entrance (Okkonen et al. 2009).



Source: USDOI, MMS, Alaska OCS Region

Figure 3: Sediment Deposition (MMS 2003)

The salinity of Cook Inlet varies significantly south to north, primarily resulting from more and larger streams discharging freshwater into the upper Inlet (e.g., Mantanuska and Susitna rivers) compared to the lower Inlet and from the oceanic influence in the lower Inlet. Salinity values as low as 10 parts per thousand (ppt) have been measured at the surface in upper Cook Inlet (Smith 1993, cited in Foster et al. 2010) and as high as 32 ppt near the mouth of the inlet (Smith 1993, cited in Foster et al. 2010; Okkonen et al. 2009). Hydrographic surveys showed that in the central Inlet, mean salinities increase from surface to bottom, from north to south, and from west to east, indicating a mean southward baroclinic (density-driven) flow along the west side of Cook Inlet in the upper part of the water column (Okkonen et al. 2009).

Freshwater discharge in Cook Inlet remains high through the summer, though variable, and decreases from late September through November (Okkonen et al. 2009). While the ACC carries water into lower Cook Inlet throughout the year, the freshwater signal varies with seasonal changes in coastal precipitation and wind mixing. The resulting ACC salinity minimum occurs in late September/early October; about a month later than the salinity minimum occurs in central Cook Inlet. The north-south salinity gradient is strongest in late summer/early fall when river discharges and glacial outflows are high. Although salinity within the Inlet may vary seasonally due to freshwater drainage volumes, the upper Inlet is fresher than the lower Inlet in all seasons (Okkonen et al. 2009).

Seasonal changes in the freshwater inputs through the ACC and river discharge into Cook Inlet most likely control the non-tidal circulation in the lower portion of Cook Inlet (Okkonen et al. 2009), since freshwater inputs promote intensification of geostrophic currents. Thus, the seasonal evolution in freshwater transport is similar to the seasonal evolution of geostrophic currents. A typical seasonal river discharge profile somewhat resembles a step function (Okkonen et al. 2009). Following the winter discharge minimum, river discharge increases by more than an order of magnitude in May. In May, the estimated geostrophic currents are less than 0.2 m/s (Okkonen et al. 2009). The estimated geostrophic currents rise to over 1.0 m/s in the western Cook Inlet waters and 0.8 m/s in the ACC entering Cook Inlet (Okkonen et al. 2009). The strongest currents are in narrow bands in the fronts associated with the western Cook Inlet waters and the ACC. Because density gradients alter the phases of tidal currents, it can be inferred from the seasonal cycle of freshwater inputs to Cook Inlet (high inputs in summer and low inputs in winter) that density-driven currents will be weaker and the phases of the tidal currents will be more uniform across the Inlet during winter than in summer (Okkonen 2005).

The water temperature in upper Cook Inlet varies with season from 32 to 60 ^{o}F. Water temperatures of lower Cook Inlet, which is influenced by warmer, but more constant temperature waters entering from the Gulf of Alaska, range from 48° F to 50 °F (KPB 2007). Higher maximum water temperatures in upper Cook Inlet may be influenced by relatively warmer water draining from lowland streams and rivers during the warmest parts of the year. Kyle and Brabets (2001) indicate that basins with 25 percent or more of their area consisting of glaciers have the coldest water temperatures during the open-water season, mid-May to mid-October. Streams and rivers that drain lowlands have the warmest water temperatures.

The ice in Cook Inlet comes from five different sources: pack ice, shorefast ice, stamukhi (beach ice), estuary ice, and river ice (Mulherin et al. 2001). Pack ice forms in seawater and is formed by the direct freezing of seawater. Shorefast ice is formed from freezing of surrounding water, from ice being piled and refrozen. Mud exposed to the air by the ebbing tide can freeze, and when seawater contacts the frozen mud, stamukhi forms. Stamukhi are massive ice blocks created by repeated wetting and accretion of seawater, crushing and piling of ice blocks, and stranding of successive layers of ice that freeze together. Estuary ice forms from freshwater in estuaries and rivers. River ice is much stronger than sea ice and is generally unaffected by tidal action until spring breakup (Mulherin et al. 2001).

The primary factor for ice formation in upper Cook Inlet is air temperature, and the major influences in lower Cook Inlet are the ACC temperature and inflow rate (MMS 2003). Cook Inlet ice generally begins forming in October, covers a large area by November, and melts completely in the spring (Mulherin et al. 2001). On the east side of Cook Inlet, ice may extend to Anchor Point, and on the west side, to Cape Douglas (Mulherin et al. 2001). Ice concentrations or cover are sometimes found in Kamishak Bay extending outward to Augustine Island, as well as Chinitna, Tuxedni, and other western Cook Inlet bays (KPB 2007).

The Cook Inlet area includes many watersheds, including 11 that drain major mountain ranges (BLM 2006). These include the Kenai Mountains on the Kenai Peninsula, the Chugach Mountains adjoining the Municipality of Anchorage, the Talkeetna Mountains in the Matanuska-Susitna area, the Alaska Range in the northwest, and the Chigmit, Neacola and Tordillo mountains in the west (BLM 2006).

Freshwater sources include glaciers and icefields; glacial, runoff, and spring-fed streams; rivers; lakes; and wetlands. Glaciers and snowmelt provide a large portion of the input to watersheds in the Cook Inlet area (BLM

2006). In fact, glaciers cover 11 percent of the land area of the Cook Inlet basin, storing massive amounts of water as ice (Brabets and Whitman 2004).

Major rivers in the Matanuska-Susitna area include the Matanuska, Knik, Little Susitna, and Susitna rivers and their tributaries such as the Talkeetna and Yentna rivers; important lakes include Big, Nancy, Alexander, and Eklutna lakes (BLM 2006). In the Anchorage area, the primary rivers are Ship, Campbell, and Bird creeks, as well as the Eagle and Twentymile rivers. Larger rivers on the Kenai Peninsula include the Kenai, Ninilchik and Anchor rivers; and among the larger lakes are Tustumena, Kenai, and Skilak lakes. Important rivers on the west side of Cook Inlet include the Drift, McArthur, Theodore, McNeil, and Kamishak rivers (BLM 2006).

4.3 POTENTIAL HAZARDS

4.3.1 Volcanoes

The western shore of Cook Inlet contains seven volcanoes that have erupted in Holocene time (10,000 years ago). These are, from north to south, Hayes, Spurr, Redoubt, Iliamna, Augustine, Douglas, and Fourpeaked (about 8 miles southwest of Douglas). These volcanoes are part of the Aleutian Island Arc, a chain of volcanoes extending from south central Alaska to the far western tip of the Aleutian Islands.

The U.S. Geological Survey (USGS) monitors the four most active volcanoes (Spurr, Redoubt, Iliamna, and Augustine). Three of these volcanoes (Spurr, Redoubt, and Iliamna) are located to the west of Cook Inlet. Augustine is an island volcano in lower Cook Inlet; it is the most active volcano in the region. All but Iliamna have erupted several times in the past 150 to 200 years and may erupt again in the future (Waythomas et al. 1997; Waythomas and Waitt 1998). Because of their composition, volcanoes in the Cook Inlet region are prone to explosive eruptions. Augustine last erupted January 11 - 28, 2006, and Fourpeaked had its first historic eruption on September 17, 2007, with an ash plume to 20,000 feet (Alaska Volcano Observatory 2008). The largest volcanically generated flood last century was caused by the January 2, 1990, eruption of the Redoubt Volcano. The flood impacted the operation of the Drift River Oil Terminal (Combellick et al. 1995). The state allowed normal loading operations to resume upon installing a dike around the tank farm and support facilities to provide flood protection. This work was accomplished by August 1990 and the facility resumed operations. The most recent eruption of Redoubt came in March 2009 and closed the Drift River Oil Terminal after three major lahars inundated the Drift River Valley. In May 2012 interim permission was granted to Hilcorp Alaska, LLC to begin using the tank farm. Ash fall associated with the 2009 eruption forced the temporary closure of the Anchorage Airport (ADNR 2009a).

Another, and probably much smaller, flood came down the Chakachatna River in response to the 1953 eruption of Spurr. Floods caused by eruptions can impact any drainage on a volcano (Combellick et al. 1995). In the area of the lease sale, drainages that volcanigenic floods could impact include the Chakachatna River drainage (from Trading Bay to the McArthur River), Drift River drainage (from Montana Bill Creek to Little Jack Slough), Redoubt Creek, and the Crescent River. This is approximately half of the lease sale lands on the western shore of Cook Inlet. Drift River and Chakachatna River are the most likely to host floods. A very large debris avalanche came down Redoubt Creek and formed the land that now underlies Harriet Point in latest Pleistocene time (1 million years ago), but that drainage does not appear to have had a large flow since that time (Beget and Nye 1994). Large flows, some of which reached the present shoreline, came down Crescent River between about 3,600 and 1,800 years ago (Combellick et al. 1995). The most probable volcanically induced floods are small, water-rich floods, which depending on the local hydrographic conditions, could impact roads, pipelines, and other infrastructure (Combellick et al. 1995). Hazards in the immediate vicinity of an eruption include volcanic ash fallout and ballistics, lahars (mudflows) and floods, pyroclastic surges, debris avalanches, directed blasts, and volcanic gases. Lease areas in Cook Inlet would be out of the range of most of these eruption hazards, except during very large eruptions (on the scale of the 1980 Mount St. Helens eruption), which tend to be rare events (ADNR 2009a; Combellick et al. 1995).

During their periodic violent eruptions, the active glacier-clad stratovolcanoes produce abundant ash and voluminous mudflows that have threatened air traffic and onshore petroleum facilities (Combellick et al. 1995). These are examples of the two major categories of volcanic hazards that will continue to threaten activities in the region. Proximal hazards are those close to volcanoes and consist of a wide variety of flow phenomena on the flanks of volcanoes or in drainages which head on the volcanoes (Combellick et al. 1995). Distal hazards are those farther from volcanoes, such as ashfall and tsunamis (Combellick et al. 1995).

A proximal hazard of particular concern to the permit coverage area is flooding generated by the rapid emplacement of large volumes of hot volcanic ejecta onto snow and ice on the upper flanks of volcanoes. All the volcanoes in Cook Inlet, except Augustine, have permanent snow and ice stored in snowfields and glaciers on their upper flanks (Combellick et al. 1995). Other proximal volcanic hazards on the western shore of Cook Inlet are lava flows, block-and-ash flows, pyroclastic flows, and hot gas surges. The lands included in the lease area are far enough from the volcanoes that they are out of range of all but the very largest eruptions (eruptions on the scale of the 1980 Mount St. Helens or 1991 Mt. Pinatubo eruption). Eruptions this large are rare, although they are certainly possible and have happened at several of the Cook Inlet volcanoes, the most recent being the eruption of Mt. Katmai in 1912.

The most common distal hazard is ashfall, where volcanic ash (finely ground volcanic rock) is lofted into the atmosphere and stratosphere by explosive eruptions, drifts downwind, and falls to the ground. There have been dozens of such events from Cook Inlet volcanoes since 1900. In most cases, volcano ashfalls have been a few millimeters or less in thickness. The primary hazard of such ashfalls is damage to mechanical and electronic equipment such as engines, which ingest ash past the air filter, computers, and transformers, possibly causing electrical shorts. Ashfalls of a few millimeters should be expected throughout the Cook Inlet and Susitna basins with a long-term average frequency of a few every decade or two. Ashfalls thick enough to collapse buildings are possible but rare (Combellick et al. 1995).

4.3.2 Tsunamis and Seiches

A tsunami is a series of long ocean waves generated by the displacement of a large volume of water caused by earthquakes, volcanic eruptions, submarine landslides, or onshore landslides that rapidly release large volumes of debris into the water. Most tsunami waves affecting south central Alaska are generated along subduction zones bordering the Pacific Ocean where motion along a dip-slip fault and the elastic rebound of subducting crust, produced by an earthquake of magnitude greater than 6.5 on the Richter scale, causes vertical displacement of the seafloor. The great seismicity associated with the subduction zone of the Aleutian-Alaskan megathrust fault system makes the southern coastal region of Alaska, especially the Gulf of Alaska and the Aleutian Islands, highly susceptible to tsunamis (Costello 1985).

Tsunamis are typically not hazardous to vessels and floating structures on the open ocean because of their small wave heights (less than a few feet). They are, however, potentially very damaging to coastal regions and nearshore facilities because wave heights can increase significantly as tsunamis approach shallow water. High, breaking waves that reach the shoreline at high tide cause much more damage than waves that are low and nonbreaking or that occur at low tide (Combellick and Long 1983; MMS 1992).

Because of the shallow, elongated configuration of Cook Inlet and its narrow entrances, the hazard from distant tsunamis is low. The hazard from local tsunamis is also low because there are no active surface faults in the inlet, no adjacent steep slopes to serve as sources of massive slides into the inlet, and no evidence of thick, unstable seafloor deposits that could fail and create massive underwater slides. Local landslide-generated tsunamis, however, can be quite large and potentially damaging, as demonstrated by the series of 4.6 to 9.1 meter (15 to 30 foot) waves that reportedly hit Nanwalek and Port Graham on the east side of lower Cook Inlet as a result of a debris avalanche caused by the eruption of Augustine Volcano in 1883 (KPB 2011; Waythomas and Waitt 1998). Future eruptions of Augustine could potentially generate a tsunami in lower Cook Inlet if significant volumes of volcanic debris were to enter the sea rapidly (although this remains a topic of debate). Modeling studies indicate that a moderate wave is possible (with lead times of about 27 to 125 minutes), but the likelihood of a tsunami is considered low. None of the last five eruptions of Augustine Volcano, including the latest one in 2006, resulted in a tsunami; nevertheless, the West Coast and Alaska Tsunami Warning Center and the Alaska Volcano Observatory continue refining their public outreach strategy to deal with a volcanogenic tsunami because local consequences of such an event could be high (ADNR 2009; Neal et al. 2011; Waythomas and Waitt 1998).

Seiches are periodic oscillations of standing waves in partially or completely enclosed water-filled basins like lakes, bays, or rivers triggered by changes in wind stress or atmospheric pressure and, less commonly, by landslides and earthquakes (McCulloch 1966). In Alaska, they may also be generated by the collapse of deltas into deep glacial lakes (KPB 2011). An example is the Lituya Bay earthquake of 1958 (moment magnitude [Mw] 8.2), which caused a landslide at the head of Lituya Bay (on the Gulf of Alaska) and generated a seiche with a wave runup of about 530 meters (1,750 feet) (MMS 1992).

During the Great Alaska Earthquake of 1964 (Mw 9.2), tsunamis were generated by uplift of the seafloor and seiches were generated by landslides in semiconfined bays and inlets (McGarr and Vorhis 1968; MMS 1992). Because the Kenai Peninsula is susceptible to earthquakes with magnitudes greater than Mw 6.0, the Kenai Peninsula Borough mitigation plan rates the coastal communities and facilities in lower Cook Inlet (south of the Forelands) as highly vulnerable to tsunamis. Vulnerable communities include Port Graham, Nanwalek, Seldovia, Homer, Anchor Point, and Ninilchik. The tsunami risk for upper Cook Inlet, however, is low because of its relatively shallow depth and its distance from the lower end of the inlet (KPB 2011).

4.3.3 Marine and Seafloor Hazards

Cook Inlet has a maximum tidal range that can exceed 12 meters (39 feet) depending on location, which produces rapid tidal flows and strong riptides (Foster et al. 2010). High tidal-current velocities in upper Cook Inlet prevent deposition of clay and silt-size sediments, which largely remain in suspension. Bottom sediments in the permit coverage area are mainly gravel and sandy gravel with gravel content of 50 - 100 percent (Sharma and Burrell 1970, cited in Combellick et al. 1995). Similar deposits in lower Cook Inlet are thought to be reworked and redistributed coarse-grained glacial material (Rappeport 1981, cited in Combellick et al. 1995). These deposits show no evidence of gravitationally unstable slopes or soft, unconsolidated sediment (MMS 1995).

Several pipeline failures in upper Cook Inlet have been directly attributed to the current-sediment interaction. As the bottom sediments shift under the influence of bottom currents, sections of the pipeline are undermined and become unsupported. The pipeline may then flutter, which causes fatigue and failure.

4.3.4 Ice Hazards

During the winter months, ice forms up to 1 meter (3 feet) thick on upper Cook Inlet. This ice, propelled by the swift tidal currents, creates very large load stresses on the offshore platforms. Since the platforms are designed to withstand the ice loads, this should not present a problem. Ice is not as severe a problem in the southern part of the Inlet due to a higher salinity, less freshwater inflow, and a greater proportion of warm ocean waters.

Winter ice conditions combined with tidal action may occasionally hinder offshore operations in the upper Inlet from December through April (Sharma and Burrell 1970, cited in Combellick et al. 1995). During the winter of 1970–1971, Inlet ice extended as far south as Anchor Point and Cape Douglas. Although blocks of floe ice generally reach a thickness of 1.2 meters (3.9 feet) in Cook Inlet, grounding of these blocks forms large piles (stamukhi) that exceed 12 meters (39 feet) in thickness and, where floated, stamukhi have damaged ships in the Inlet (Evans et al. 1972, cited in Combellick et al. 1995). Numerous large erratic blocks in shallow, nearshore waters are hazards to ship navigation.

Three forms of ice normally occur in Cook Inlet: sea ice, beach ice, and river ice. Sea ice is the predominant type and is formed by freezing of the Inlet water from the surface downward. Because of the strong tidal currents, ice does not occur as a continuous sheet but as ice pans. Pans can form up to 1 meter (3 feet) thick and be 305 meters (1,000 feet) or greater across (SAIC 2001). They can also form pressure ridges reportedly up to 5.5 meters (18 feet) high (Gatto 1976). Sea ice generally forms in October or November, gradually increasing from October to February from the West Foreland to Cape Douglas, and melts in March to April (Brower el al. 1988). The primary factor for sea ice formation in upper Cook Inlet is air temperature, and for lower Cook Inlet it is the ACC temperature and inflow rate (Poole and Hufford 1982).

Beach ice, or stamukhi, forms on tidal flats as seawater contacts cold tidal muds. The thickness of beach ice is limited only by the range of the tides and has been noted to reach 9 meters (30 feet) in thickness. During cold periods, beach ice normally remains on the beach; however, during warm weather in combination with high tides, it can melt free and enter the Inlet. Blocks of beach ice that enter the Inlet are normally relatively small (less than several tens of feet across) and have relatively low strengths (SAIC 2001).

River ice can also occur in Cook Inlet. It is a freshwater ice that is similar to sea ice except that it is relatively harder. It is often discharged into the inlet during spring breakup (SAIC 2001).

4.3.5 Flood Hazards

In addition to volcanigenic flooding on the west side of Cook Inlet, flood hazards in the Cook Inlet area may result from glacial outburst (jökulhlaups), ice jams, and high rainfall. Glacial outburst occurs when glacial movement opens a pathway for water trapped behind a glacier to escape. Rivers are subject to large-magnitude outburst floods as a result of the sudden drainage of large, glacier-dammed lakes, particularly on the west side of Cook Inlet. Major rivers affected by outburst floods include Beluga, Chakachatna, Middle, McArthur, Big, and Drift rivers (Post and Mayo 1971). For example, in September 1982, over 95 percent of Strandline Lake drained, releasing about 700 million m^3 (185 billion gallons) of water. Strandline Lake has drained catastrophically into the Beluga River every 1 to 5 years since about 1954 (Sturm and Benson 1988). The most reliable predictor of outburst floods from Strandline Lake is the development of a calving embayment in the lobe of Triumvirate Glacier, which dams the lake (Combellick et al. 1995).

Ice jam flooding occurs during the spring breakup process when strong ice or constrictions in a river (bends or obstructions like islands or gravel bars) create jam points that cause moving ice along the breakup front to stop (NOAA 2011). It also occurs when low-density ice masses (frazil ice) become trapped and pile up under surface ice. The ice stoppage causes water levels to rise and flood the adjacent land. Ice jams are more often associated with single-channel rivers in interior and northern Alaska than in rivers of the Cook Inlet drainage basin, but a flood from an ice jam downstream of Skilak Lake in the Kenai River watershed (east of Cook Inlet) occurred in 1969 after an outburst from Skilak Glacier at the head of Skilak Lake, creating a record high river stage (74.25 meters [22.63 feet]) and causing severe damage in Soldotna.

Ice jams are unpredictable and have the potential to be worse than 100 or 500 year events, causing heavy damage to bridges, piers, levees, jetties, and other structures along the riverbank (ADNR 2009; Brabets et al. 1999; KPB 2011; NOAA 2011).

In January and February 2007 an ice jam flood occurred on the Kenai River, which was triggered by the release of the Skilak Glacier dammed lake (Kenai River Center 2007). The Kenai River at Skilak Lake rose about 3.8 feet, causing the ice cover to break up and form ice jams, and localized flooding in the Soldotna area. The rapid increases in water level and moving ice caused significant property damage.

Signs of impending outburst releases are high lake water levels, abundant calving into the lake, and water present on northern margins of the glacier, including small marginal lakes (National Weather Service, unpublished data, October 1995; cited in Combellick et al. 1995). Heavy rainfall may also cause the flooding in the Cook Inlet area. For example, heavy flooding of the Kenai River in September 1995 resulted from interaction of tropical moisture and a deep low-pressure center in the North Pacific Ocean; blockage of the eastward movement of this low by a high-pressure ridge in eastern Alaska and western Canada; saturated soil conditions; and greater than normal glacial melt due to preceding storms. Excess sediment deposition in channels due to rapid runoff decreased the carrying capacity of the streams. As a result, the lower Kenai River remained above flood stage for over 10 days. Crest water levels were 1.1 meters (3.6 feet) above flood stage at Kenai Keys and 0.76 meters (2.5 feet) above flood stage at Soldotna (National Weather Service, unpublished data, October 1995; cited in Combellick et al. 1995). An analysis of this flood indicates that it represents a 100-year event at Soldotna (USGS 1998 as cited in ADNR 2009b).

In August 2006, days of heavy rain caused major flooding of the Little Susitna River, Willow Creek, Montana Creek, Talkeetna River, and Moose Creek in the Matanuska-Susitna Borough. These rivers crested well above the flood stage, resulting in the evacuation of about 150 people, 46 borough roads and 6 major state roads flooded or damaged, 8 bridges damaged, closures and damage to the Parks Highway and Alaska Railroad, and over 150 homes flooded or damaged (MSB 2006).

The primary hazards to facilities from river flooding are high water levels, bank erosion, deposition at the river mouth, high bedload transport, and channel modification (Combellick et al. 1995). Seasonal flooding of lowlands and river channels is extensive along major rivers that drain into Cook Inlet. Thus, measures must be taken prior to facility construction and field development to prevent losses and environmental damage. Pre-development planning should include hydrologic and hydraulic surveys of spring breakup activity as well as flood frequency analyses. Data should be collected on water levels, ice floe direction and thickness, discharge volume and velocity, and suspended and bedload sediment measurements for analysis. Historical flooding observations should also be incorporated into a geologic hazard risk assessment. All inactive channels of a river must be analyzed for their potential for reflooding. Containment dikes and berms may be necessary to reduce the risk of flood waters that may undermine facility integrity.

5.0 DESCRIPTION OF THE EXISTING BIOLOGICAL ENVIRONMENT

This section provides an overview of the biological communities found within Cook Inlet. The general groups of aquatic organisms that inhabit the Cook Inlet include pelagic (living in the water column), epontic (living on the underside or within the sea ice), or benthic (living on or within the bottom sediments) plants and animals. The categories of offshore biological environment that will be discussed include the following:

- Plankton.
- Attached macro- and microalgae.
- Benthic invertebrates.
- Fishes (demersal and pelagic).
- Marine mammals.
- Coastal and marine birds.
- Threatened and endangered species.
- Essential fish habitat.

Each of these biological resources is assessed in terms of seasonal distribution and abundance, growth and production, environmental factors, and habitats.

5.1 PLANKTON, ALGAE AND BENTHIC INVERTEBRATES

Plankton can be divided into two major classes: phytoplankton and zooplankton. Plankton are the primary food base for other groups of marine organisms found within the Cook Inlet. The distribution, abundance, and seasonal variation of these organisms are strongly influenced by the physical environment.

5.1.1 Phytoplankton

5.1.1.1 Distribution and Abundance

Larrance and Chester (1979), examining phytoplankton species near surface waters of the lower Cook Inlet, indicated that 28 genera of phytoplankton as well as miscellaneous *Centric* spp. and *Pennate* spp. were present in the lower Cook Inlet. Of those species the diatom species *Thalassiosira* spp. and *Chaetoceros* spp. were prominent in the samples.

During summer months, lower Cook Inlet is among the most productive high-latitude shelf areas in the world (Sambrotto and Lorenzen 1986). Extreme tidal variation and severe turbidity limit the distribution and abundance of phytoplankton in northern Cook Inlet. Feely et al. (1981) report that the silt-laden waters entering Kachemak Bay are known to retard phytoplankton growth (e.g., primary productivity) by reducing light penetration. Further, Speckman et al. (2005) has described the relationship between chlorophyll levels and suspended sediments in the Cook Inlet water column as an inverse relationship.

During a limited study in the Cook Inlet area, Piatt (2002) determined that phytoplankton biomass varied among years and areas; however, a consistent finding was the lack of phytoplankton biomass in the western half of lower Cook Inlet. The same study found that standing stocks of phytoplankton were highest in stratified waters of outer Kachemak Bay in most years, although high production was observed in mixed waters off Kachemak Bay for 1 year of the study period (1998). The authors note that these findings were consistent with previous work by Larrance and Chester (1979) and lack of primary productivity was likely due to high sediment loads in the water that prevent light from penetrating surface layers.

Highlighting the relationship of the physical environment on phytoplankton distribution and abundance, Eslinger et al. (2001) described two types of spring phytoplankton blooms in the nearby Prince William Sound that appear to correspond with stratification. The first type of bloom appears during springs in which early, strong physical stratification developed. Eslinger et al. (2001) described this type of phytoplankton bloom to be intense and short-lived. The second type of bloom appears during springs in which slower, weaker stratification developed. This bloom was described as prolonged and requiring more time to peak when compared to the first type. Eslinger et al. (2001) concluded that the slower blooms led to prolonged periods of phytoplankton production, prolonged interaction with the springtime grazing of copepods and other zooplankton, and the incorporation of more organic matter into pelagic food webs. The typical conditions in Cook Inlet, which has strong tidal mixing, are probably similar to the prolonged spring blooms in Prince William Sound.

5.1.1.2 Growth and Production

The annual primary production in Cook Inlet is estimated in the range of 100 - 300 grams carbon per meter squared per year (MMS 1995: Section III.B-1). Phytoplankton production along open stretches of the Cook Inlet coast and in deeper waters not subject to upwelling processes is generally lower than for enclosed coastal areas. Primary productivity in lower Cook Inlet peaks in the spring (April–May), but remains high in outer Kachemak Bay throughout summer (Larrance and Chester 1979). Primary productivity remains high due to upwelling in lower Cook Inlet and provides a source of nutrient to fuel primary productivity (Larrance et al. 1977).

The growth rates of planktonic organisms are relatively rapid, and the generation lengths are relatively short. Computer modeling by Willette et al. (2001) suggests that phytoplankton populations replace themselves (i.e., the total biomass doubling or turnover time) in about 4 days. Further, the lag between a phytoplankton bloom and the retreating edge of the sea ice usually is only 2 to 3 weeks (Wang et al. 2004), indicating rapid reproductive response by the phytoplankton community once conditions for growth are available.

5.1.1.3 Environmental Factors

Phytoplankton production is usually limited to the photic zone*,* or the depth to which sunlight penetrates the water. The major environmental factors influencing phytoplankton production are temperature, light, and nutrient availability. Additional environmental factors may influence phytoplankton production on smaller scales within the Cook Inlet itself.

Environmental conditions on the east side of Cook Inlet, especially south of Deep Creek or Ninilchik, are substantially less rigorous than those observed on the west side of the inlet. These environmental factors include high turbidity, greater deposition rates, lower water and air temperatures, lower salinity, and larger quantities of ice and greater ice scour. The biological consequences of these conditions are a thinner euphotic zone, resulting in far less primary productivity, especially for phytoplankton.

Major factors responsible for initiating primary productivity are water stratification, incident radiation, and water clarity (Larrance and Chester 1979). Further, regional environmental and physical differences, even within the Cook Inlet itself, may support or inhibit primary production. For example, Lees et al. (2001) suggest that environmental conditions on the east side of Cook Inlet (e.g., TSS and turbidity; deposition rates; weather patterns; water and air temperatures; salinity; and quantities of ice and ice scour) are less rigorous than those observed on the west side of the inlet. Thus, primary production may be stronger on the east side of Cook Inlet rather than the west side (Lees et al. 2001).

Larrance and Chester (1979) indicate that no blooms occurred in the lower Cook Inlet unless the water column was thermally stratified, incident light averaged over 20 Einsteins per square meter (E/m^2) per day, and the euphotic zone was deeper than about 10 meters. Conditions allowing for the initiation of primary productivity occur first in Kachemak Bay where water resides in a gyre system relatively longer than in the central and western portions of the inlet (Larrance and Chester 1979). This longer residence time and lower mixing rate permits surface water to warm in the spring and retain phytoplankton populations where their concentrations can build to high levels.

Because the major component of Kachemak Bay water originates in the Gulf of Alaska, it does not contain the heavy load of suspended particles present in the upper Cook Inlet water which sweeps the western side. Kachemak Bay, therefore, is relatively clear prior to the spring bloom. In the western inlet, however, primary productivity is restricted due to waters that can remain highly turbid with silt and other nonliving particles until June when it cleared sufficiently to permit a phytoplankton bloom. The central inlet is an upwelling area (Abookire et al. 2000), which does not easily stratify. Nutrients (primarily nitrate, ammonium, and silicate) do not appear to decrease to limiting levels except in Kachemak Bay, and perhaps, to a lesser extent, in Kamishak Bay.

5.1.1.4 Phytoplankton Habitat

Phytoplankton production is limited primarily by temperature, available nutrients (particularly nitrogen), and light. The most productive area of Alaskan waters is the coastal zone. Primary productivity within the coastal zone was highest in the water column where diatoms were the most abundant organism. Phytoplankton production gradually increases after ice breakup, when light becomes available. A review of the available literature by Piatt (2002) indicates that the key to the initiation of phytoplankton blooms in the Cook Inlet is stratification of the water column. In addition, water transparency must be adequate to permit 1 percent of the light incident to the surface to penetrate deeper than about 10 meters (32.8 feet) (Larrance et al. 1977). Production declines after September when light availability limits photosynthesis.

5.1.2 Zooplankton

Fish, shellfish, marine birds, and some marine mammals consume zooplankton; thus, supporting higher trophic levels in the Arctic and sub-Arctic food webs. Zooplankton feed on phytoplankton, and their growth cycles respond to phytoplankton production. In the lower Cook Inlet, zooplankton populations vary seasonally with biomass reaching a low in the early spring and a peak in late spring and summer. Zooplankton are most abundant in the lower Cook Inlet when compared to the upper Cook Inlet (SAIC 2002).

5.1.2.1 Distribution and Abundance

There is a diverse zooplankton community in lower Cook Inlet. Zooplankton communities in Cook Inlet are composed of year-round populations, including copepods, chaetognaths and euphausiids, and seasonal residents such as crab, shrimp, clam, polychaete, and barnacle larvae and fish eggs (Kline 1994; Redburn et al.

1976). Sampling of zooplankton abundance in Shelikof Strait and surrounding shelf waters from March to October 1985 and then in Shelikof Strait during spring 1986–1989 determined that the zooplankton fauna was a mixture of oceanic and continental shelf taxa and strongly influenced by abundance of *Neocalanus plumchrus* and *Metridia pacifica*. Biomass of copepods showed some large interannual differences related to abundance of oceanic taxa (Incze et al. 1996). Dominant copepods may include the calanoid copepods *Pseudocalanus minutus* and *P. newmani.*

Some of the highest standing stocks of zooplankton in the Gulf of Alaska are found in Cook Inlet during spring and summer, following the spring phytoplankton bloom. Peak densities in excess of 1,000 milligrams per cubic meter (mg/m^3) are not unusual. Piatt (1994) found that zooplankton were most abundant (ea. 60–80 mg/m^3) on the northeast side of the entrance to Cook Inlet. Piatt (1994) determined that no significant variation in total zooplankton biomass across the entrance to the Cook Inlet existed between areas of low or high sea surface salinity. In some cases, when examined on a taxa level, the author determined that zooplankton varied significantly with location or salinity. For example, *Acartia longiremis* was common at all stations, but generally more abundant in the southwestern portion of the lower Cook Inlet. Similarly, *Centropages* spp., *Cladocera* spp., Euphausiid furcilia, and Appendicularia were all more abundant at southwestern stations and in higher salinity water (Piatt 1994).

5.1.2.2 Growth and Production

The growth rates of zooplankton are relatively rapid, and the generation lengths are relatively short. Zooplankton production reaches a peak during April–June, closely following the phytoplankton bloom period. Zooplankton biomass in Cook Inlet decreases considerably to the north of Kachemak Bay, with low populations present year-round off Nikiski (Redburn 1972, cited in Redburn et al. 1976).

The NORPAC committee (1960) has estimated summer zooplankton densities of 400 cubic centimeters (cm^3)/1,000m^3 adjacent to the Barren Islands based on a survey in 1955. Damkaer (written communication) compared zooplankton-settled volumes from samples collected from several stations in Cook Inlet and the outside waters. Kachemak Bay showed the highest biomass (31,000cm^3/1,000cm^3), measured in early May. Zooplankton biomass for most areas in lower Cook Inlet is probably lower than for the Barren Islands region (Redburn et al. 1976).

Computer modeling by Willette et al. (2001) suggests that the zooplankton populations replace themselves in about 16 days, based on the maximum mortality rate of zooplankton. These estimates are similar to the standard turnover times in textbooks for temperate, eutrophic coastal waters (Lalli and Parsons 1997).

5.1.2.3 Environmental Factors

While zooplankton are heterotrophic, many are major consumers of phytoplankton. Thus, many of the factors influencing phytoplankton primary productivity indirectly affect zooplankton populations. Through their consumption and processing of the phytoplankton, zooplankton species act as an important link in aquatic food webs by transporting organic material from primary production sources to larger, carnivorous predators, including species of whales that feed on pelagic zooplankton.

5.1.2.4 Zooplankton Habitat

Zooplankton standing stock generally fluctuates in response to phytoplankton production; thus, persistently high levels of phytoplankton production support a larger standing stock of zooplankton in lower Cook Inlet during spring and summer (Cooney 1986). Zooplankton, like phytoplankton, make excellent indicators of environmental conditions since population densities are sensitive to changes in water quality and environmental conditions. Population densities will decrease in response to low dissolved oxygen, low nutrient levels, high levels of toxic contaminants, poor food quality, and increase in and predation.

5.1.3 Attached Macroalgae and Microalgae

5.1.3.1 Macroalgae

Attached macroalgae (primarily kelp, *Laminaria* spp*.,* and macroscopic red and green algae) occur in state waters along nearshore areas containing suitable rocky substrate for attachment. Macroalgae are restricted to intertidal areas and subtidal waters receiving sufficient solar radiation to allow production in excess of metabolic requirements. The rocky intertidal and shallow subtidal floral communities in southwestern lower Cook Inlet are dominated by the brown algae *Fucus,* and kelp *(*mainly bull kelp, *Nereocystis luetkean)* and ephemeral red algae (mainly *Rhodymenia* spp.) (MMS 1995: Section III.B.1.b).

5.1.3.1.1 Distribution and Abundance

Over 170 seaweed species are currently known to occur in Cook Inlet (Foster et al. 2010). Sheath et al. (1996) sampled stream segments in the Cook Inlet drainage basin for algae abundance. This study found 40 species of lotic macroalgae with the major divisions in terms of species number being Chlorophyta (43 percent), Bacillariophyta (25 percent), Rhodophyta (13 percent) and Xanthophyta (13 percent). Filaments were the predominant form (60 percent of species). Distribution was determined to be patchy in the basin, with total cover varying from less than 1 percent to 90 percent of the stream bottom. Sheath et al. (1996) determined that lowland brown-water streams flowing through emergent wetlands tend to have the highest species diversity and abundance.

In Arctic and sub-Arctic Alaskan waters the distribution of kelp is limited by three main factors: ice gouging, sunlight, and hard substrate. Ice gouging restricts the growth of kelp to protected areas, such as behind barrier islands and shoals. Sunlight restricts the growth of kelp to the depth range where a sufficient amount penetrates to the seafloor, or water less than about 11 meters (36 feet) deep. Note that the critical depth may vary by species. Within outer Kachemak Bay, kelp beds with both dense canopy and understory layers extending to depths of 18 meters (60 feet or more) were widespread (Foster et al. 2010). Hard substrates, which are necessary for kelp holdfasts, restrict kelp to areas with low sedimentation rates. Macroalgae are unlikely to occur in shallow water areas lacking a rocky substrate. Benthic algae, however, have been noted in areas where rock substrates were lacking, but these algal beds did not contain the diverse epilithic fauna that characterized areas with suitable rocky substrate (Dunton et al. 1982; MMS 1990).

Quantitative surveys of intertidal and subtidal macrophyte communities in Cook Inlet are limited. Rosenthal et al. (1977) has documented the locations of major kelp beds. These large subtidal beds commonly consist of an upper canopy of *Alaria* and *Nereocystis* with an understory dominated by *Agarum* and *Laminaria* (Redburn et al. 1976). Only occasional drift specimens are found in the upper intertidal zone, which indicates that only marginal intertidal and subtidal populations exist (Redburn et al. 1976). Macrophyte distribution is generally continuous from the outer Kenai Peninsula to Ninilchik, excluding some parts of Kachemak Bay (Redburn et al. 1976). Vegetative cover in the littoral zone of the western shore of lower Cook Inlet is not well documented. Attached marine plants show a discontinuous range from Chisik Island on all the headlands having stable substrates southward to Cape Douglas; Augustine Island and the Barren Islands support lush macrophyte stands (USDOI 1976, cited in Redburn et al. 1976). Most of the seaweed species found along the northern Gulf of Alaska coast are documented for Cook Inlet, but specifics on their distribution are lacking.

Schoch and Chenolet (2004) determined that over the entire Kachemak Bay, kelp forests were found consistently in the same location (with the exception of one kelp forest overwhelmed by migrating sand), the total area of kelp forests varied significantly, and individual kelp beds varied in size and density. According to Schoch and Chenolet (2004), kelp forests were denser on the south shore than the north shore of the outer Kachemak Bay basin, and they observed no kelp forests in the inner bay during the study period. These results are consistent with Foster (2010), who described that within outer Kachemak Bay, kelp beds with both dense canopy and understory layers extending to depths of 18 meters (60 feet or more) were widespread.

North of Kachemak Bay as far as Anchor Point, on the east side of Cook Inlet, the moderately developed kelp beds extended to shallower depths and displayed a thinner canopy, and a more moderate understory (Foster 2010). In contrast, in Kamishak Bay, on the west side of Cook Inlet, kelps beds, limited to understory kelps, were rare to absent and restricted to lower intertidal depths (Foster 2010).

The reasons and dynamics for such changes are largely unknown. Some suggested causes may be due to natural fluctuations of grazer populations (Chenelot 2003). Others suggest climate change-related fluctuations in temperature, light, salinity, and nutrient regimes (Dayton et al. 1999). Turbidity and light attenuation may change because of accelerated glacial stream input and increased sedimentation rates caused by headland erosion. Disturbances due to human activities such as logging, fish processing, commercial fishing, sewage waste disposal, recreation and mariculture are also possible causes (Spurkland and Iken 2005).

5.1.3.1.2 Growth and Production

Kelp in Arctic and sub-Arctic water grows fastest in late winter and early spring due to higher concentrations of inorganic nitrogen in the water column (ADNR 2009a). Sediments trapped in the ice above the kelp block light and restrict growth while the presence of leads and cracks has the opposite effect (ADNR 2009a). Bull kelp is the predominant kelp species in the Cook Inlet area, and is also one of the largest fastest-growing marine algae, attaining lengths of 40 meters (131 feet) during the growing season (Schoch and Chenolet 2001). In Kachemak Bay, located outside Cook Inlet, a total of 30.6 square kilometers (km^2) (11.8 square miles [mi^2]) of kelp canopy was measured; an additional 17 km^2 (6.6 mi^2) were measured from Anchor Point to Point Pogibshi (Schoch and Chenolet 2001).

Recently, several large beds in Kachemak Bay have disappeared temporarily or permanently. The *Alaria fistulosa* bed at the entrance of Jakolof Bay disappeared in the late 1970s; the *Nereocystis luetkeana* bed of the Archimandritof Shoals off the Homer Spit disappeared in 2000, but showed signs of recovery in 2002; and the Seldovia Nereocystis luetkeana bed at Outside Beach showed partial clearance in 2002 (Spurkland and Iken 2005). Within macroalgal stands, biological processes have the most important effects on persistence and stability of community structure (Dayton et al. 1984). The distributional evidence of kelp beds points to geographic boundaries being imposed by physical requirements of light, temperature, and nutrients for individual species (Foster and Schiel 1986). Environmental stresses including low salinity, increased temperature, reduced light, and low nutrient levels can affect concentrations of chemical defenses in marine macroalgae (Van Alstyne et al. 2001). In addition, the recent findings of low levels of antibacterial defenses in Arctic invertebrates from Svalbard (Lippert et al. 2003) were attributed to the estuarine conditions of the study area (Spurkland and Iken 2005).

5.1.3.1.3 Environmental Factors

Kelp support a large invertebrate community. Physical, chemical, and biological factors affect dynamics of kelp beds and their annual fluctuations. These include water motion, temperature, salinity, nutrients, light intensity, available habitat, and invertebrate predation (Schoch and Chenolet 2001).

Spurkland and Iken (2011) determined that inorganic sedimentation, abrasion, and percent sand/silt substrate were significantly higher on the more exposed shore than the less exposed shore. Light intensity, salinity, nitrate concentrations, and hard substrate cover were significantly lower on the more exposed shore. Kelp bed communities on the more exposed shore contained only one kelp species, *Saccharina latissima*, versus five kelp species on the less exposed shore. Taxonomic richness and overall organism abundance were significantly lower on the more exposed shore. Salinity, nitrate, inorganic sedimentation, and abrasion were identified as important drivers of kelp communities that are dynamically influenced by glacial discharge.

5.1.3.1.4 Macroalgae Habitat

Macroalgae show a distinct and fixed pattern of vertical distribution in their habitat. Some of these plants inhabit the coast above high water mark, whereas others populate the intertidal zone or the sublittoral zone. Macroalgae populations occur naturally, but an increase in their biomass (especially if it is associated with a decrease in seagrass) could also be an indication of deteriorating water quality. Macroalgal biomass is most commonly limited by dissolved inorganic nitrogen, but can also be limited if high light attenuation prevents adequate light from reaching the bottom.

Hard substrates, which are necessary for kelp holdfasts, restrict kelp to areas with low sedimentation rates. Macroalgae are unlikely to occur in shallow water areas lacking a rocky substrate. Benthic algae, however, have been noted in areas where rock substrates were lacking, but these algal beds did not contain the diverse epilithic fauna that characterized areas with suitable rocky substrate (Dunton et al. 1982; MMS 1990).

Dames and Moore biologists (Lees and Rosenthal 1977) conducted intertidal and subtidal ecological investigations on the outer Kenai Peninsula in Kachemak Bay and at Spring Point, Chinitna Bay. Habitat types observed include lagoons; exposed and protected intertidal zones; and exposed subtidal and semiprotected subtidal habitats. Investigations showed many protected lagoons to be rich in eelgrass, and rocky habitats of the outer Kenai Peninsula and Kachemak Bay are particularly rich in algal specimens. Intertidal cover is slight to nonexistent north of Ninilchik (USDOI 1976, cited in Redburn et al. 1976). This condition results from both the largely unsuitable substrate (gravelly sand and sandy gravel) and the turbid waters of northern Cook Inlet. Markedly different conditions characterize Kachemak Bay. Windrows of drift algae are common along Hommer Spit and along inside shores of Kachemak Bay. Larger boulders in the low intertidal are relatively rich in the epilithic Ulva and Porphyra, with Balanus and Mytilus being the dominant attached invertebrates.

Kelp forests occurred along the south shore in narrow dense bands that reflect the steep bathymetry. The shallower bathymetry along the north shore of the outer basin provides more habitats, resulting in very large, but less dense, kelp forests (Schoch and Chenolet 2004).

5.1.3.2 Microalgae

While the mechanism of photosynthesis in microalgae is similar to that of higher plants, they are generally more efficient converters of solar energy because of their simple cellular structure. In addition, because the cells grow in aqueous suspension, they have more efficient access to water, CO_2, and other nutrients.

5.1.3.2.1 Distribution and Abundance

Spring and summer Cook Inlet populations of microalgae are dominated by diatoms and microflagellates, with chrysophytes and dinoflagellates (Larrance et al. 1977).

In general, attached microalgae are most likely to occur in areas not subjected to ice gouging and land fast ice, and where hard substrates suitable for attachment occur (MMS 1990). Benthic algae, however, have been noted in areas where rock substrates were lacking, but these algal beds did not contain the diverse epilithic fauna that characterized areas with suitable rocky substrate (Dunton et al. 1982).

Benthic microalgae occur in sediments and within the macroalgal communities. Benthic microalgae might be a significant source of primary productivity in nearshore areas, but in areas of kelp production, the contribution of benthic microalgae could be relatively small.

5.1.3.2.2 Growth and Production

Light appears to be the limiting factor controlling the distribution, development, and production of the ice-algal assemblage (MMS 1990). The ice-algal bloom usually occurs in April and May and occasionally in early June, while the open water phytoplankton bloom does not occur until ice breakup is under way.

5.1.3.2.3 Environmental Factors

These algae are the primary food source for a variety of animals, including amphipods, copepods, ciliates, various worms, and juvenile and adult fishes (MMS 1991).

5.1.3.2.4 Microalgae Habitat

Benthic microalgae occur in sediments and within the macroalgal communities. Benthic microalgae might be a significant source of primary productivity in nearshore areas, but in areas of kelp production, the contribution of benthic microalgae could be relatively small.

5.1.4 Benthic Invertebrates

Benthic invertebrates are organisms that live on the bottom of a waterbody (or in the sediment) and have no backbone. The size of benthic invertebrates ranges from microscopic (e.g., microinvertebrates, < 10 microns) to a few tens of centimeters or more in length (e.g., macroinvertebrates > 50 centimeters [19.7 inches]). Benthic invertebrates live either on the surface of bedforms (e.g., rock, coral, or sediment, epibenthos) or within sedimentary deposits (infauna), and comprise several types of feeding groups (e.g., deposit feeders, filter feeders, grazers, and predators).

Foster (2010) determined dominant benthic tax on the west side of Cook Inlet and the east side of lower Cook Inlet and Prince William Sound. Foster (2010) indicated that the dominant benthic taxa on the west side of Cook Inlet, in decreasing order of abundance, were prosobranch gastropods, bivalves, ascophoran and anascan bryozoans, and decapod crustaceans. In Kachemak Bay on the east side of lower Cook Inlet and in Prince William Sound, the prosobranch gastropods strongly dominated the fauna, followed by bivalves. Decapod crustaceans were also well represented in both regions.

5.1.4.1 Distribution and Abundance

The distribution, abundance, and seasonal variation of benthic species in Arctic and sub-Arctic Alaska waters are strongly correlated with physical factors (e.g., substrate composition, water temperature, depth, dissolved oxygen concentrations, pH, salinity, sediment carbon/nitrogen ratios, and hydrography). Larger invertebrate communities are found in nearshore lagoons. These communities include animals living in the bottom (infauna), animals living on or near the bottom (epibenthic), and those living in the water column (pelagic). During winter, epibenthic and pelagic species disappear, and then emerge again in spring, whereas infauna and some amphipods may be present year-round (ADNR 2009a).

In nearshore waters with depths less than 2 meters (6.6 feet), relatively few species are found because the ice in this region extends all the way to the seafloor during winter. Therefore, the abundance of most species is probably dependent on annual (or more frequent) colonization. Biomass and diversity in the inshore zone generally increase with depth, except in the shear zone between approximately 15 to 25 meters (49 to 82 feet). Intensive ice gouging occurs in this zone, which disturbs the sediments and presumably limits the abundance of infaunal species (Braun 1985). Ice gouging continues out to about 40 meters (131 feet) with decreasing intensity. Diversity and biomass of infauna increase beyond this zone with distance offshore, at least as far as the continental shelf boundary (200 meters [656 feet]) (MMS 1990).

Mollusks, polychaetes, and bryozoans dominate the infauna of seafloor habitats in Cook Inlet. Feder (1981) found over 370 invertebrate taxa in samples from lower Cook Inlet. Substrates consisting of shell debris generally have the most diverse communities and are dominated by mollusks and bryozoans (Feder and Jewett 1986). Mollusks and polychaetes occupy muddy-bottom substrates, while mollusks dominate sandy-bottom substrates. Nearshore infauna, where sediments are fine and sedimentation rates are high, consists mostly of mobile deposit-feeding organisms that are widely distributed through the area. Infaunal organisms are important trophic links for crabs, flatfishes, and other organisms common in the waters of Cook Inlet (SAIC 2002).

Crustaceans, mollusks, and echinoderms dominate epifauna (SAIC 2002). The percentage of sessile organisms in Cook Inlet is relatively low inshore and increases toward the continental shelf (Hood and Zimmerman 1986). Rocky-bottom areas consist of lush kelp beds with low epifaunal diversity; moderate kelp beds with well-developed sedentary and predator/scavenger invertebrates; and little or no kelp with moderately developed predator/scavenger communities and a well-developed sedentary invertebrate community (Feder and Jewett 1986).

5.1.4.2 Growth and Production

Available nutrition decreases as the distance from shore increases, resulting in decreased benthic productivity. Sediment grain size influence benthic species composition, suspension feeding species on coarser sediments, while deposit-feeding species prefer fine sediment. Nearshore habitats widely range in temperature and salinity. Many benthic organisms survive these fluctuations by digging into sediment or moving to a different area. Water currents in lagoon areas help move invertebrates toward shore to recolonize shallow areas after bottom fast ice moves out, exposing the onshore sediments (Griffiths and Dillinger 1980).

5.1.4.3 Environmental Factors

The abundance, diversity, biomass, and species composition of benthic invertebrates can be used as indicators of changing environmental conditions. The biomass of benthic invertebrates declines if communities are affected by prolonged periods of poor water quality, especially when anoxia and hypoxia are common. Benthic communities can change in response to the following:

- Nutrient enrichment leading to eutrophication.
- Bioaccumulation of toxins to lethal levels in molluscs (shellfish), crustaceans, polychaetes and echinoderms, causing the loss of herbivorous and predatory species.
- Lethal and sub-lethal effects of heavy metals and other toxicants derived from oil and gas activities. Dislodged epifauna and infauna from trawling and dredging, which may result in the collection and mortality of a substantial invertebrate bycatch.
- The replacement of the existing benthic community with species better physiologically suited to the modified conditions.
- Changes in the physical and biological characteristics and structure of habitats (i.e., their function), including supporting habitat such as seagrass meadows and sandy soft bottom areas.

Burrowing and tube-building by deposit-feeding benthic invertebrates (bioturbators) helps to mix the sediment and enhances decomposition of organic matter. Nitrification and denitrification are also enhanced because a range of oxygenated and anoxic micro-habitats are created. Loss of nitrification and denitrification (and increased ammonium efflux from sediment) in coastal systems is an important cause of hysteresis, which can cause a shift from clear water to a turbid state. The loss of benthic suspension-feeding macroinvertebrates can further enhance turbidity levels because these organisms filter suspended particles including planktonic algae, and they enhance sedimentation rates through biodeposition (i.e., voiding of their wastes and unwanted food).

The western side of Cook Inlet is “influenced by freshwater runoff and a high concentration of river-derived sediments carried from the upper inlet” (Feder and Jewett 1986). Feder and Jewett (1986) suggest that the turbid waters restrict primary productivity, especially in the early spring. This pattern of currents and turbidity appears to present a very effective barrier to transport and survival of planktonic larvae of marine invertebrates from the east side of the inlet to the west side but possibly, some types of larvae (e.g., razor clams) are able to move successfully across the inlet.

5.1.4.4 Benthic Invertebrates Habitat

In addition to high turbidity, Cook Inlet is characterized by extreme tidal fluctuations of up to 12.2 meters (40 feet) (NOAA 1999a) that produce strong currents in excess of 8 knots (Tarbox and Thorne 1996). The amount of protected benthic habitat is likely reduced by the periodic scouring or substrate movement caused by Cook Inlet currents that bottleneck at the Forelands, near the Osprey Platform (SAIC 2002).

5.2 FISHES

Few studies of marine fish in upper Cook Inlet have been published. The fish of central and lower Cook Inlet have been better studied, due in part to the numerous commercial fisheries in the area. Because of low phytoplankton productivity and the severe tidal currents, it is thought that upper Cook Inlet does not provide a plentiful primary food source or much safe habitat for fish (SAIC 2002). However, recent studies of beluga utilization of Cook Inlet may warrant further investigation of Cook Inlet forage fish (NMFS 2000).

5.2.1 Distribution and Abundance

The fishes occurring in the Arctic and sub-Arctic Alaska waters fall into three basic categories (MMS 2003):

1) Freshwater species that may occasionally enter marine waters.
2) Anadromous species that spawn in freshwater and migrate seaward as juveniles and adults.
3) Marine species that complete their entire life cycle in the marine environment.

Freshwater, anadromous, and marine fish species can also be described by two categories: pelagic and ground fishes. At least 52 species of nearshore fish have been described in Cook Inlet. Of those species, 50 species were reported in Kachemak Bay, 24 species at Chisik Island, and 12 species at Barren Island sampling locations (Piatt et al. 1999). The abundance and species composition of pelagic fish in Cook Inlet increased by about an order of magnitude while diversity decreased when sampled from North (Chisik) to South (Barrens) (Piatt and Roseneau 1997; Abookire and Piatt 2005). Trawls to sample groundfish found similar results (Piatt and Roseneau 1997). Common pelagic and ground fishes in Cook Inlet are discussed below with reference to distribution and abundance in Cook Inlet.

5.2.2 Pelagic fish

Pelagic fishes usually inhabit the water layers above the abyssal zone (water below 4,000 meters) and beyond the littoral zone (nearshore zone between high and low water marks). Common species in Cook Inlet are discussed below.

5.2.2.1 Pink Salmon

Pink salmon is typically the smallest salmon species in Cook Inlet, averaging between 3 and 5 pounds. Pink salmon enter their spawning streams between late June and October and typically spawn within a few miles of the shore, often within the intertidal zone. Most pink salmon spawn within a few miles of the coast, and spawning within the intertidal zone of the mouth of streams is very common. The eggs are buried in the gravel of stream bottoms and hatch in the water. In spring, the young emerge from the gravel and migrate downstream to salt water. Pink salmon stay close to the shore during their first summer, feeding on small organisms such as plankton, insects, and young fish. At about 1 year of age, pink salmon move offshore to ocean feeding grounds where their food consists mainly of plankton, fish, and squid. Return migration to freshwater takes place during the second summer with few exceptions (SAIC 2002). The even-year pink salmon return is typically stronger than the odd-year return in Cook Inlet (ADF&G 1986). According to Fox and Shields (2004) the largest commercial catch of pink salmon occurred in 1964 with 3,231,961 salmon caught, compared to 30,436 pink salmon in 1963 and 23,963 in 1965. The average catch for the monitoring period 1956–2003 was 632,554 pink salmon, although this value is an average value for the period, the actual values from year to year differ drastically due to the even- and odd-year cycling.

5.2.2.2 Chum Salmon

Chum salmon grow to an average weight of between 7 and 18 pounds. Adult chum salmon are not well represented in west side Susitna drainages of upper Cook Inlet. Chum production in the Susitna River declined in the mid-1980s to the mid-1990s, but a steady increase in production has been observed in upper Cook Inlet since the mid-1990s (Fox and Shields 2004). Chum salmon remain near shore during the summer where their diet consists of small insects and plankton. In the fall, they start moving offshore where they feed on plankton. Chum return to freshwater in the fall and spawn late in the year, from approximately mid-September through mid-November. Chum salmon enter the Cook Inlet region beginning in early July, and spawning continues through early August. Most chum salmon spawn in areas similar to those that the pink salmon use, but sometimes travel great distances up large rivers (e.g., up to 3,218 kilometers [2,000 miles] up the Yukon River). Chum salmon usually return to streams to spawn after 3 to 5 years at sea (SAIC 2002). According to Fox and Shields (2004), the highest commercially caught chum salmon in Cook Inlet occurred in 1982 when 1,432,940 chum salmon were harvested. The average catch for the monitoring period 1956–2003 was 534,651 chum salmon.

5.2.2.3 Sockeye Salmon

Sockeye salmon grow quickly and generally reach 4 to 8 pounds after 1 to 4 years. Approximately 50 percent of Susitna River sockeye are thought to be produced in the Yentna River tributary (Ivey and Sweet 2004). Sockeye salmon spawn in stream systems with lakes. Fry may reside up to 3 years in freshwater lakes before migrating to sea. Maturing sockeye salmon return to freshwater streams during the summer months. Adult sockeye return to Cook Inlet and the Shelikof Strait region in late June, and runs continue through early August. Watersheds with lakes produce the greatest number of sockeye salmon. Most sockeye spend two to three winters in the North Pacific Ocean before returning to natal streams to spawn and die (SAIC 2002). In terms of the economic value, sockeye salmon are the most important component of the upper Cook Inlet commercial salmon harvest (Shields and Dupuis 2013) According to Fox and Shields (2004), the largest commercial catch occurred in 1987 when 9,465,994 sockeye were harvested. The average catch for the monitoring period 1956–2003 was 2,439,017 salmon.

5.2.2.4 Coho Salmon

Coho salmon grow to approximately 8 to 12 pounds. Adult coho salmon are well represented throughout upper Cook Inlet (Rodrigues et al. 2006). The Susitna River drainage supports the largest coho stock in upper Cook Inlet (Rodrigues et al. 2006). Coho Salmon are usually the last of the five salmon species to return to spawn in natal stream gravels from July to November. Run timing is regulated by water temperature at spawning grounds; where temperatures are low and eggs develop slowly, spawners demonstrate early run timing to compensate, and where temperatures are warm, adults are late spawners. Fry emerge in May or June and live in ponds, lakes, and stream pools, feeding on drifting insects (SAIC 2002). Coho salmon may reside in-stream up to three winters before migrating to the sea where they typically remain for two winters before returning to spawn (ADF&G 1986). According to Fox and Shields (2004), the highest commercial catch occurred in 1994 when 583,793 coho were caught commercially in Cook Inlet. The average catch for the monitoring period 1956–2003 was 305,119 coho salmon.

5.2.2.5 Chinook Salmon

Chinook salmon are the largest of all Pacific salmonids commonly exceeding 30 pounds each. Chinook reach the Susitna River in approximately mid-May (ADF&G 1986). Soon after hatching, most juvenile chinook salmon migrate to sea, but some remain for a year in freshwater. Most chinook salmon return to natal streams to spawn in their fourth or fifth year (SAIC 2002). The Susitna River supports the largest chinook salmon run in upper Cook Inlet, which includes systems below the Forelands to the latitude of N 59º46′12″, near Anchor Point (ADF&G 1986). According to Fox and Shields (2004), chinook abundance peaked in 1987 with 39,431 salmon caught commercially in the Cook Inlet. The average for the monitoring period 1956–2003 was 17,713 chinook salmon.

5.2.2.6 Steelhead Trout

Steelhead trout (*O. mykiss irideus*) is a rainbow trout that has spent a part of its life in the sea. These fish are unevenly distributed throughout Cook Inlet. Spawning begins in about mid-April and generally continues throughout May and early June. Steelhead trout usually spawn more than once. Eggs are deposited in gravel during the spring and develop into alevins or sac fry. By midsummer, they emerge from the gravel and seek refuge along stream margins and protected areas. Usually, juveniles remain in the parent stream for about 3 years before they enter salt water (MMS 2003).

5.2.2.7 Cutthroat Trout

Cutthroat trout (*O. clarkii*) are the most common trout species in the region. Resident fish live in a wide variety of environments from small headwater tributaries and bog ponds to large lakes and rivers. Sea-run fish are usually found in river or stream systems with accessible lakes. It is unknown why some fish migrate to sea while others remain in freshwater. Adults spawn in small, isolated headwater streams from late April to early June, and young cutthroat trout emerge from the gravel in July. Sea-run cutthroat rear for 3 to 4 years in freshwater and then migrate to sea during May for a few days to more than 100 days before returning to their home stream (MMS 2003).

5.2.2.8 Bering Cisco

Bering cisco (*Coregonis laurettae*) have been reported in the Susitna River drainage (Thompson et al. 1986). Bering cisco enter river systems in the late summer. In 1982 spawning peaked mid-October in the Susitna River (SAIC 2002). Egg incubation occurs over winter and larvae move into northern Cook Inlet after ice-out in the spring from late April to May (Morrow 1980).

5.2.2.9 Dolly Varden Char

Dolly Varden Char (*Salvelinus malma*) that inhabit Cook Inlet can be anadromous or reside in freshwater. Non-resident Dolly Varden cycle seasonally between freshwater and marine environments. They often overwinter in freshwater drainages, and then disperse into coastal waters during summer to feed on small fishes and marine invertebrates (Morrow 1980). In Cook Inlet, Dolly Varden spawn annually in rivers during the fall from late August to October (Scott and Crossman 1973; Morrow 1980). Like other salmonids, Dolly Varden lay eggs in hollowed-out redds (shallow cavities dug into streambeds where salmonids spawn) located in swift-moving water; hatching occurs the following spring. Juvenile Dolly Varden remain in their natal streams for 2 to 3 years (SAIC 2002).

5.2.2.10 White Sturgeon

White sturgeon (*Acipenser transmontanus*) are anadromous fish found in northern Cook Inlet. They are believed to spend most of life near shore in water depths of 30 meters or less (98 feet). Although little is known about white sturgeon migrations while in salt water, one tagged specimen was captured 1,056 kilometers (656 miles) from where it was tagged (Morrow 1980). Most mature white sturgeon enter the estuaries and lower reaches of river systems in the spring. They spawn over rocky bottoms in swift water where the sticky eggs adhere to the river bottom. The amount of time needed for the eggs to hatch is not known (SAIC 2002). The adults return to sea after spawning (Morrow 1980).

5.2.2.11 Eulachon

Eulachon (*Thaleichthys pacificus*) are small anadromous forage fish (up to approximately 23 centimeters [9 inches] long) (MMS 1995) found throughout the Cook Inlet. Moulton (1997) reported that eulachon comprise 14.3 percent of the total catch in upper Cook Inlet. Fechhelm et al. (1999) report that eulachon comprised 26.4 and 44.8 percent of the total catch near Chisik Island in May and August 1998, respectively. Mature eulachon, typically 3 years old, spawn in May soon after ice-out in the lower reaches of streams and rivers. The Susitna River supports a run of eulachon estimated in the millions (Thompson et al. 1986). Females broadcast their eggs over sand or gravel substrates where the eggs anchor to sand grains. Eggs hatch in 30 to 40 days, depending on the water temperature. Eulachon larvae are then flushed out of the drainage and mature in salt water. As juveniles and adults, they feed primarily on copepods and plankton. As the spawning season approaches, eulachon gather in large schools at stream and river mouths. Most eulachon die after spawning (NMFS 2013a). Eulachon is most important as a food source for other fish, birds, and marine mammals. The Cook Inlet population also supports small dipnet fisheries in upper Cook Inlet (SAIC 2002).

5.2.2.12 Saffron cod

Saffron cod is an important prey for some marine mammals, fishes, and birds (MMS 1987b). These fish generally inhabit nearshore areas and enter rivers. Spawning occurs during the winter in nearshore waters (Morrow 1980). Their occurrence in the Cook Inlet is limited. Moulton (1997) report that saffron cod comprise 1.4 percent of the total catch during upper Cook Inlet tow sampling. Fechhelm et al. (1999) did not report saffron cod in Chisik Island area.

5.2.2.13 Pacific Herring

Pacific herring (*Clupea pallasi*) occur in large schools in the Cook Inlet region in early April and potentially through the early fall. Distribution and abundance in Cook Inlet is variable. These fish generally spawn during the spring. Spawning occurs in shallow, vegetated areas in intertidal and subtidal zones (MMS 2003). Female herring lay adhesive eggs over rock and seaweed substrates. Depending on water temperature, eggs hatch in 10 to 14 days. Herring stay near shore until cold winter water temperatures drive them offshore to deeper, warmer waters (WDFW 2011). The Cook Inlet herring fishery now targets Kamishak Bay on the west side of lower Cook Inlet. A small herring sac roe fishery has been suspended since the 1998 season because of low herring abundance. Alaska Department of Fish and Game (ADF&G) biologists observed about 8,100 tons of herring in the Kamishak Bay District in 2000; biomass must exceed a threshold of 8,000 tons before a commercial sac roe harvest can be considered for Kamishak Bay (SAIC 2002).

5.2.2.14 Pacific Sand Lance

Pacific sand lance (*Ammodytes hexapterus*) is a schooling fish that sometimes bury themselves in beach sand (Hart 1973). Pacific sand lance spawn within bays and estuaries, typically between December and March (SAIC 2002). Eggs are demersal, but will suspend in turbulent waters (Robards et al. 1999). Pacific sand lance larvae are found both offshore and in intertidal zones (Robards et al. 1999). Early juvenile stages are pelagic, while the adult burrowing behavior develops gradually (Hart 1973). Major food items of the sand lance include copepods, other small crustaceans, and eggs of many forms Simenstad et al. 1979; Field 1988. This species is commonly preyed upon by lingcod, chinook salmon, halibut, fur seals, and other marine animals (Hart 1973) and appears to be an important forage species. Pacific sand lance have been caught off Chisik Island, southwest of West Foreland (Fechhelm et al. 1999).

5.2.2.15 Capelin

Capelin (*Mallotus villosus* [Muller]) is a major forage fish of the Cook Inlet region. Populations of capelin are large and are generally found in pelagic waters. They are mainly filter feeders, thriving on planktonic organisms including euphausiids and copepods. They spawn on beaches and in deeper waters and require specific conditions (e.g., temperature, tide, and light) for successful spawning. Capelin eggs attach to beach and bottom gravels. They hatch, depending on temperature, within 15 to 55 days. These fish currently have no economic value to Alaska, but they are used extensively for food by other fish, marine mammals, and seabirds (MMS 2003).

5.2.3 Groundfish

Groundfish is a term used to describe fish species that inhabit the seafloor during a portion of their life cycle, typically as adults. It is important to note that groundfish may exist as free-swimming or planktonic larvae in a pelagic stage at some point during their life cycle. Groundfish in the pelagic stages may serve as forage species for larger fish, as well as marine birds and mammals.

5.2.3.1 Pacific Halibut

The Pacific halibut (*Hippoglossus stenolepis*) is a large flatfish that occurs throughout Cook Inlet. Halibut concentrate on spawning grounds along the edge of the continental shelf at water depths of 182 to 455 meters (597 to 1,493 feet) from November to March. Significant spawning sites in the vicinity of lower Cook Inlet are Portlock Bank, northeast of Kodiak Island, and Chirikof Island, south of Kodiak Island (IPHC 1998). Temperature influences the rate of development, but typically eggs hatch in 20 days at 5 °C (41 °F) (ADF&G 1986). As eggs develop into larvae, they float in the water column and drift passively with ocean currents. Halibut larvae's specific gravity decreases as they grow. Larvae that is 3- to 5-months old drifts in the upper 100 meters (328 feet) of water where they are pushed by winds to shallow sections of the continental shelf. At 6 months old, juveniles settle to the bottom in nearshore waters where they remain for 1 to 3 years (Best and Hardman 1982). Juvenile halibut then move further offshore (IPHC 1998). Halibut migrate seasonally from deeper water in the winter to shallow water in summer. Accordingly, the fishery is most active in deep areas early in the season (i.e., May) whereas activity can be as shallow as 20 meters (about 65 feet) during midsummer. A recreational fishery in central Cook Inlet targets Pacific halibut (SAIC 2002). The Sport Fish Division of the ADF&G estimates that 74,803 and 117,900 halibut were caught by sport fishermen in central Cook Inlet and lower Cook Inlet in 2012, respectively (ADF&G 2011).

5.2.3.2 Pacific Cod

Pacific cod (*Gadus macrocephalus*) are distributed over lower Cook Inlet. Abookire et al. (2001) found that Pacific cod were one of the most abundant species captured during sampling in Kachemak Bay. They are fast-growing bottom-dwellers that mature in approximately 3 years. They may reach lengths of up to 1 meter (3.3 feet) (Hart 1973). Cod spawn during an extended period through the winter and eggs may hatch in 1 week depending on water temperature. Cod are harvested offshore in the Gulf of Alaska by trawl, longline, pot, and jig gear. Cod move into deep water in autumn and return to shallow water in spring. Pacific cod populations sustain a rapid turnover due to predation and commercial fishing (SAIC 2002). The Gulf of Alaska stock is projected to decline as a result of poor year-classes produced from 1990 to 1994 (Witherell 1999). Pacific cod abundance, in terms of biomass and numbers of fish, was assessed by the Gulf of Alaska bottom trawl survey conducted every 2 to 3 years over the time span of 1984 through 2011. This survey indicated decreased biomass of Pacific cod from 1999–2007, before markedly increasing during the 2009 and 2011 surveys (Thompson et al. 2011).

5.2.3.3 Sablefish

Sablefish (*Anoplopama fimbria*) are also known as black cod. They are found within Cook Inlet; however, most are harvested in deep water outside of Cook Inlet. Regardless, sablefish are a valued commercial species. These fish probably spawn during the spring, but little is known about their spawning behavior or egg-larval development. They feed on a large variety of benthic and pelagic fauna (MMS 2003).

5.2.3.4 Starry Flounder

Starry flounder (*Platichthys stellatus*) have been caught in central Cook Inlet (Fechhelm et al. 1999) and are likely to occur in northern Cook Inlet. Starry flounder spawn from February through April in shallow water (Hart 1973). They generally do not migrate, although one starry flounder was caught 200 kilometers (124 miles) from where it was tagged (Hart 1973). Starry flounder tolerate low salinities, and some have been caught within rivers (SAIC 2002).

5.2.3.5 Arrowtooth Flounder and Yellowfin Sole

Arrowtooth flounder (*Atheresthes stomias*) and yellowfin sole (*Pleuronectes asper*) may also extend into Cook Inlet. Little is known about the life history of these flatfish (SAIC 2002). Arrowtooth flounder larvae have been taken from depths of 200 meters (about 650 feet) to the surface in June off British Columbia (Hart 1973). Both have been caught off Chisik Island in central Cook Inlet (Fechhelm et al. 1999).

5.2.3.6 Pacific Hake

Pacific hake (*Merluccius productus*) can be found throughout the Cook Inlet in small numbers. They could spawn up to several months in this region, with the pelagic eggs hatching in as little as 3 days depending on the size of the fish. Larvae hake consume copepods and other similarly sized organisms while adult hake consume euphausiids, sand lance, anchovies, and other forage fishes. Hake are prey for other marine fish, marine birds, and marine mammals (MMS 2003).

5.2.3.7 Walleye Pollock

Walleye pollock (Theragra chalcogramma) are found throughout the Cook Inlet. Fechhelm et al. (1999) determined that in lower Cook Inlet, most walleye pollock were caught in the Barren Island area and in Kachemak Bay, while relatively few were caught near Chisik Island. Walleye pollock spawn in the spring in large aggregations and there is some extended spawning in smaller numbers throughout the year. Eggs hatch in about 10 to 20 days. Adult fish consume shrimp, sand lance, herring, small salmon, and similar organisms they encounter. Walleye pollock are also cannibalistic (MMS 2003).

5.2.4 Other Nonendangered Fish

Smaller numbers of Atka mackerel, and other groundfish inhabit Cook Inlet. These species generally are found in the same habitats as the groundfish species described above (MMS 2003).

Other nonendangered fish and invertebrate species found in Cook Inlet include: Pacific Ocean perch, rock sole, Alaska plaice, Rex sole, Dover sole, Flathead sole, Shortraker rockfish, Rougheye rockfish, Northern rockfish, Thornyhead rockfish, Yellowhead rockfish, Dusky rockfish, threespine stickleback, and longfin smelt.

5.2.5 Growth and Production

A lack of overwintering habitat is the primary factor limiting Arctic and sub-Arctic fish populations (ADNR 1999). Spawning in the Arctic and sub-Arctic environment can take place only where there is an ample supply of oxygenated water during winter. Because of this and the fact that few potential spawning sites can meet this requirement, spawning often takes place in or near the same area where fishes overwinter (MMS 2008).

Work conducted by Moulton (1997) in upper Cook Inlet from the East and West Forelands to Fire Island, not including Chickaloon Bay, Turnagain Arm, or Knik Arm, found the greatest mean fish densities occurred along the northwest shoreline from the Susitna delta to the North Forelands and the adjacent mid-channel waters. The study also determined that fish densities were greater in upper Cook Inlet in June versus in July, and the lowest densities occurred along the southeastern shoreline from Moose Point to Boulder Point.

Limited information is available for the growth and production of salmon since ADF&G does not usually monitor juvenile salmon. Ocean growth of pink salmon is a matter of considerable interest because, although this species has the shortest life span among Pacific salmon, it also is among the fastest growing. Entering the estuary as fry at around 3 centimeters in length, maturing adults return to the same area 14–16 months later ranging in length from 45 to 55 centimeters.

5.2.6 Environmental Factors

The physical environment, mainly temperature and salinity, of the Arctic and sub-Arctic waters exerts a strong influence on the temporal and spatial distribution and abundance of fish, including forage fish species in Kachemak Bay (Abookire et al. 2000; MMS 1990; MMS 1991).

Because the feeding habits of marine fishes are similar to those of anadromous fishes, some marine fishes are believed to compete with migratory fishes for the same prey resources. Competition is most likely to occur in the nearshore brackish-water zone, particularly in or near the larger river deltas.

Infaunal prey density in the nearshore substrate is very low and provides little to no food for anadromous fishes. The nearshore feeding area also is much larger than that of freshwater habitats on the coastal plain (MMS 2003). For these reasons, both marine and anadromous fishes come to feed on the relatively abundant prey found in nearshore waters during summer.

In late summer when anadromous fishes are less abundant and their prey is more abundant, dietary overlap is common in nearshore waters (MMS 2003). Marine birds also compete for the same food resources during this time. Anadromous fishes do little to no feeding during their migration back to freshwater and when spawning, but some resume feeding during winter.

In the marine environment, pink salmon fry and juveniles are food for a host of other fishes and coastal seabirds. Sub-adult and adult pink salmon are known to be eaten by 15 different marine mammals, sharks, and other fishes such as Pacific halibut and humpback whales. Because pink salmon are the most abundant salmon in the North Pacific, it is likely they comprise a significant portion of the salmonids that marine mammals eat.

Additional factors such as prey availability and community structure, including associated bottom-up and top-down pressures within the Gulf of Alaska food web may affect fish populations. Bottom-up processes largely relate water temperature with crustacean densities and, thereby, influence predatory fishes higher in the trophic web. Conversely, top-down processes also contribute to the community structure of the region. Piscivorous predators may limit or slow the ability of depressed forage fish populations from increasing (MMS 2003).

5.2.7 Fish Habitat

Cook Inlet contains Essential fish habitat (EFH) for a total of 35 species including walleye pollock, Pacific cod, and salmon. Routine operations and accidents can affect EFH by damaging habitats used for breeding, spawning, feeding, or growth to maturity (SAIC 2002). Additional information regarding EFH can be found in section 5.6.

Fishery management plans are obliged to identify habitat areas of particular concern (HPC) within EFH. HPCs include living substrates in shallow water that provide food and rearing habitat for juvenile fish and spawning grounds that may be impacted by shore-based activities. Estuarine and nearshore habitats of Pacific salmon (e.g., eelgrass [*Zostera sp*.] beds) and herring spawning grounds (e.g., rockweed [*Fucus sp*.] and eelgrass) are HPCs that can be found in Cook Inlet. Offshore HPCs include areas with substrates that serve as cover for organisms including groundfish. Areas of deepwater coral are also considered HPC, but populations are concentrated off southeast Alaska, out of the project area. All anadromous streams qualify as HPC (SAIC 2002).

5.3 MARINE MAMMALS

5.3.1 Distribution and Abundance

Common marine mammals present in Cook Inlet include Beluga Whale, Minke Whale, Gray Whale, Killer Whale, Harbor Porpoise, Dall's Porpoise, Harbor Seal, Steller Sea Lion, and other nonendangered species. These species are discussed below with reference to distribution and abundance in Cook Inlet.

All marine mammals in U.S. waters, including those also protected under the ESA, are protected under the Marine Mammal Protection Act of 1972 (MMPA). In the act, it was the declared intent of Congress that marine mammals "be protected and encouraged to develop to the greatest extent feasible commensurate with sound policies of resource management, and that the primary objective of their management should be to maintain the health and stability of the marine ecosystem." Section 5.5 will discuss species of marine mammals that the ESA protects within the Cook Inlet.

5.3.1.1 Minke Whale (Balaenoptera acutorostrata)

Minke whales occur in the North Pacific from the Bering and Chukchi Sea south to near the equator (Leatherwood et al. 1982). Minke whales are relatively common in the nearshore waters of the Gulf of Alaska (Allen and Angliss 2013) but are not abundant in any other part of the eastern Pacific (Brueggeman et al. 1990, cited in Allen and Angliss 2013). Minke whales are unlikely to migrate into Cook Inlet, but it is possible (SAIC 2002).

Minke whales breed in temperate or subtropical waters throughout the year (SAIC 2002). Peaks of breeding activity occur in January and June (Leatherwood et al. 1982). Calving occurs in winter and spring (Stewart and Leatherwood 1985). Females are capable of calving each year (SAIC 2002), but a 2-year calving interval is more typical (Leatherwood et al. 1982). Minke whales in the North Pacific prey mostly on euphausiids and copepods (SAIC 2002), but also feed on schooling fishes including Pacific sand lance, northern anchovy, and squid (Leatherwood et al. 1982; Stewart and Leatherwood 1985).

No estimates of the number of minke whales in the North Pacific or Alaskan waters have been made (Hill and DeMaster 1999). The annual human-caused mortality is considered insignificant (SAIC 2002). Minke whales in Alaska are not listed as depleted under the MMPA or considered a strategic stock (Hill and DeMaster 1999).

5.3.1.2 Gray Whale (Eschrichtius robustus)

Gray whales historically inhabited both the North Atlantic and North Pacific oceans. A relic population survives in the western Pacific. The eastern Pacific or California gray whale population has recovered significantly and now numbers about 23,000 (Hill et al. 1997). The eastern Pacific stock was removed from the Endangered Species List in 1994 and is not considered a strategic stock by the NMFS (SAIC 2002).

The eastern Pacific gray whale breeds and calves in the protected waters along the west coast of Baja California, and the east coast of the Gulf of California from January to April (Jones and Swartz 1984). At the end of the breeding and calving season, most of these gray whales migrate about 8,000 kilometers (5,000 miles) north, generally along the west coast of North America, to the main summer feeding grounds in the northern Bering and Chukchi seas (SAIC 2002).

Gray whale occurrences in Cook Inlet are uncommon. As they move through the Gulf of Alaska on their northward and southward migrations, gray whales closely follow the coastline (Calkins 1986). They generally tend to bypass Cook Inlet as they pass through the Barren Islands and the waters south of Kodiak Island (Calkins 1986). A cow and a calf, however, were observed in lower Cook Inlet as recently as the summer of 2000 (Eagleton 2000, personal communication).

5.3.1.3 Killer Whale (Orcinus orca)

Killer whales occur along the entire Alaska coast (Dahlheim et al. 1997) from the Chukchi Sea, into the Bering Sea, along the Aleutian Islands, Gulf of Alaska, and into southeast Alaska (NMFS 2013b). Seasonal concentrations occur in Shelikof Strait and the waters around Kodiak Island (Calkins 1986). Killer whales are known to inhabit Cook Inlet waters during the summer and have been observed pursuing beluga whales in Cook Inlet (Eagleton 2000, personal communication). Killer whales using Cook Inlet are most likely from the Eastern North Pacific Northern Resident stock of killer whales (SAIC 2002). In 2000 the “resident” (i.e., fish consuming) stock minimum population estimate was 723 animals. In 2001 the “transient” (marine-mammal consuming) stock minimum population estimate was 346 animals (Angliss and Lodge 2004). Killer whales are rare in upper Cook Inlet. Shelden et al. (2003) reported 11 sightings of killer whales in upper Cook Inlet from the Susitna Flats east into Turnagain Arm and north into Knik Arm over the last 20 years. Two of these sightings were recorded in the southern portion of Knik Arm. There were no killer whale sightings during a recent marine mammal study in upper Cook Inlet and Knik Arm (Funk et al. 2005).

5.3.1.4 Harbor Porpoise (Phocoena phocoeana)

The harbor porpoise is distributed in waters along the continental shelf and is most frequently found in cool waters with high prey concentrations (Watts and Gaskin 1985). The range of the harbor porpoise within the eastern North Pacific Ocean is primarily restricted to coastal waters and extends from Point Barrow, along the coast of Alaska (SAIC 2002), and to the west coast of North America to Point Conception, California (Allen et al. 2011). They have been observed in Cook Inlet during winter months (Hansen and Hubbard 1999). Harbor porpoise densities are much greater in their southern range (Washington, northern Oregon, and California) than in Alaskan waters (MMS 2003). Harbor porpoises are not migratory. Little information on the population dynamics of harbor porpoises is known; however, they occur in Cook Inlet (Calkins 1983). In 2000 the minimum population estimates for the Gulf of Alaska stock was 25,536 animals (Angliss and Lodge 2004). Dahlheim et al. (2000) estimated 136 animals during vessel-based surveys for an average density of 0.72 harbor porpoises per 100 km^2 (38.6 mi^2) for all of Cook Inlet in 1991. Harbor porpoises occur in upper Cook Inlet throughout the year in small numbers but are more abundant in the lower inlet. The number of harbor porpoises in Knik Arm is unknown but appears to be low.

The major predators on harbor porpoises are great white sharks and killer whales. Unlike other delphinids, harbor porpoises forage independently, feeding on small schooling fishes such as northern anchovy and squid (SAIC 2002).

5.3.1.5 Dall's Porpoise (Phocoenoides dalli)

Dall's porpoises are widely distributed along the continental shelf (SAIC 2002) as far north as 65 °N (Buckland et al. 1993) and are abundant throughout the Gulf of Alaska (Calkins 1986). Dall's porpoises prefer water depths greater than 20 meters (66 feet) deep (SAIC 2002) and are commonly found in lower Cook Inlet (Calkins 1983). The only apparent gaps in their distribution in the Gulf of Alaska are in upper Cook Inlet and Icy Bay (Consiglieri et al. 1982). The current estimate for the Alaska stock of Dall's porpoises (SAIC 2002) is 83,400 animals (Hill and DeMaster 1999). Dall's porpoises (MMS 2003) feed on squid, crustaceans, and deepwater fish (Leatherwood and Reeves 1987).

5.3.1.6 Harbor Seal (Phoca vitulina richardsi)

Harbor seals range from Baja California; north along the western coast of the United States, British Columbia, and southeast Alaska; west through the Gulf of Alaska and the Aleutian Islands; and in the Bering Sea north to Cape Newenham and the Pribilof Islands. Hill and DeMaster (1999) estimated 29,000 individuals in the Gulf of Alaska stock (SAIC 2002). The Gulf of Alaska populations around Kodiak and Tugidak islands have grown since the early 1990s (Boveng et al. 2011) but overall, the stock numbers are declining (Hill and DeMaster 1999). They are distributed in coastal waters along virtually the entire lower Cook Inlet coastline and are generally nonmigratory. Current population estimates for Cook Inlet are 2,244 (MMS 2003).

Harbor seals inhabit estuarine and coastal waters, hauling out on rocks, reefs, beaches, and glacial ice flows. Haul out selection by Harbor seals was found to be related to prey availability and physical properties, tending toward sites of rock substrate and those that were near deep water (Montgomery et al. 2007) They are generally nonmigratory, but move locally with the tides, weather, season, food availability, and reproduction activities (ADF&G 2013; Bigg 1981; Scheffer and Slipp 1944). Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows (Montgomery et al. 2007). The mother and pup remain together until weaning occurs at about 1 month (ADF&G 2013). Little is known about breeding behavior in harbor seals. When molting, seals spend the majority of the time hauled out on shore, glacial ice, or other substrates. Harbor seals consume a variety of prey in estuarine and marine waters. Prey type varies regionally and seasonally in the Gulf of Alaska. Walleye pollock are the dominant prey in the eastern Gulf, and octopus are the dominant prey in the western Gulf (SAIC 2002).

5.3.1.7 Steller Sea Lion (Eumetopias jubatus)

The Steller sea lion is distributed around the North Pacific Ocean rim. The population is divided into western and eastern stock at 144 °W longitude. NMFS is scheduled to delist the Eastern stock as threatened and Endangered wildlife on December 4, 2013 (50 CFR Parts 223 and 224) . The western stock is the species includes Cook Inlet populations. This species is listed as “endangered” under the ESA and “depleted” under the MMPA.

In 1956–1960 the population of sea lions in the Gulf of Alaska and Aleutian Islands was estimated at 140,000 (Merrick et al. 1987). The number of Steller sea lions in the western stock declined by 75 percent between 1976 and 1990. The decline continued in the 1990s for the western stock in Alaska. Counts at trend sites during 2000 indicate that the number of sea lions in the Bering Sea/Aleutian Islands region has declined 10.2 percent between 1998 and 2000. The most recent minimum estimate of stocks (2001–2002) indicates that this population was roughly 34,779 animals, including pups (Angliss and Lodge 2004).

5.3.1.8 Other Nonendangered Marine Mammals

Occasionally, Pacific walruses are sighted in the Cook Inlet area. These unusual sightings generally occur in the winter or spring during years when the Bering Sea pack ice extends into the southern Bering Sea and near the Aleutian Islands. Stray walruses move through the passes into the Gulf of Alaska/Shelikof Strait into Cook Inlet (MMS 2003).

Other nonendangered marine mammals that rarely or infrequently occur in the Gulf of Alaska and Cook Inlet region (MMS 2003) include the short-finned pilot whale, Risso’s dolphin, northern right whale dolphin, North Pacific giant bottlenose whale, goosebeak whale, and Bering Sea beaked whale (Consiglieri et al. 1982).

5.3.2 Growth and Production

5.3.2.1 Beluga Whale

Beluga whale season has been estimated from mid-May to mid-July (Calkins 1983). Calving is believed to take place in Kachemak Bay in the lower inlet in April and May, off the Beluga and Susitna Rivers in May, and in Chikaloon Bay seasonally during the summer (Huntington 2000). With a 14- to 15-month gestation period, beluga whales generally breed on a 3-year cycle. While a third of the adult females are calving, a third is carrying a fetus, and the other third is not pregnant (often tending a calf that nurses for 1 to 2 years) (Braham 1984; Burns and Seaman 1985). Females reach sexual maturity in 4 to 7 years, while males are sexually mature in 7 to 9 years.

5.3.2.2 Minke Whale

Minke whales breed in temperate or subtropical waters throughout the year (SAIC 2002). Peaks of breeding activity occur in January and June (Leatherwood et al. 1982). Calving occurs in winter and spring (Stewart and Leatherwood 1985). Females are capable of calving each year (SAIC 2002), but a 2-year calving interval is more typical (Leatherwood et al. 1982).

5.3.2.3 Gray Whale

The eastern Pacific gray whale breeds and calves in the protected waters along the west coast of Baja California, and the east coast of the Gulf of California from January to April (Jones and Swartz 1984). At the end of the breeding and calving season, most of those gray whales migrate about 8,000 kilometers (5,000 miles) north, generally along the west coast of North America, to the main summer feeding grounds in the northern Bering and Chukchi seas (SAIC 2002).

5.3.2.4 Killer Whale

Killer whale peak breeding period is May through July (Consiglieri et al. 1982). However, some groups are known to calve year-round (Baird 2000). Males live 50–60 years and females may live to 90 years of age.

5.3.2.5 Harbor Porpoise

Little is known about harbor porpoise reproductive behavior, although mating occurs in summer and births occur between May and July (NMML, n.d.).

5.3.2.6 Dall's Porpoise

For both sexes of Dall's porpoise, the average age at physical maturity was determined to be 7.2 years (Ferrero and Walker 2006). Dall's porpoise calves are born in mid-summer after a 12-month gestation period. They are about 3 feet (0.9 meters) long. Calves and their mothers live separate from main porpoise herds for a time. Dall's porpoise mothers usually have calves every 3 years.

5.3.2.7 Harbor Seal

Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows. The mother and pup remain together until weaning occurs at about 1 month (ADF&G 2013). Little is known about breeding behavior in harbor seals.

5.3.2.8 Steller Sea Lion

Pitcher and Calkins (1981) determined that the timing for key Steller sea lion reproductive events in the Gulf of Alaska were birth, mid-May to mid-July; breeding, late-May to mid- or late-July; and implantation, late-September and October. Males mature between 3 and 8 years of age. Females mature between 2 and 8 years of age.

5.3.3 Environmental Factors

Stranding events, predation, availability of prey, disease, under-ice entrapment, and human impacts from subsistence/commercial fishing, by-catch, contamination, and anthropogenic noise disturbances can directly or indirectly affect marine mammal populations in Cook Inlet.

Stranding events are fairly common with 804 beluga whale stranding's and 129 reported mortalities in upper Cook Inlet (primarily Turnagain Arm) since 1988 (NMFS 2005b). Stranding events may occur due to predation from killer whales or from natural causes.

Recent studies have determined that diseases caused by viral, bacterial, and parasitic pathogens have caused documented cases of mortality in marine mammals. The best documented case of viral infection was the European Seal Epizootic that killed more than 20,000 animals and over 50 percent of the North Sea harbor seal population in 1988 and 1989. This disease reoccurred in 2002 with a similar estimated number of dead, and was caused by a distemper virus similar to the one that causes distemper in dogs. The virus had never been seen previously in marine mammals and is presumed to have evolved from the dog virus. Diseases in Cook Inlet beluga can be caused by bacteria, viruses, fungi, protozoans, and parasites (URS 2010). Limited information is available regarding beluga mortality in relation to disease, because mortality is sometimes attributed to other causes. Necropsies by Burek and Goertz (2010), however, identified disease as the primary cause of death in two Cook Inlet beluga whales (out of 34 examined carcasses).

Entrapment in ice in winter is an occasional cause of whale mortality. At least 41 blue whales were reported caught in the ice along the west coast of Newfoundland between 1869 and 1992. In 77 percent of these cases entrapment proved fatal for the animal (Sears and Calambokidis 2002).

5.4 COASTAL AND MARINE BIRDS

5.4.1 Distribution and Abundance

Migratory birds are a significant component of the marine ecosystem of the Cook Inlet. More than 100 species of birds may occur in Cook Inlet, including 39 species of seabirds; 35 loon, grebe, and waterfowl species; and 28 shorebird species (MMS 2003).

The Cook Inlet provides foraging, nesting, and rearing areas for several million birds each year. Surveys that Piatt (1994) conducted in lower Cook Inlet (ca. 12,500 km^2 [4826 mi^2]) estimated that during the 1992 survey period more than 2 million seabirds foraged within the 50-kilometer (31-mile) area of Barren Island in July, and these waters supported an average seabird biomass of 89.8 kg/km^2 (512 lb/mi^2). Transient shearwaters (64.4 kg/km^2 [367 lb/mi^2]) comprised most of this standing biomass, but coastal/shelf species (12.8 kg/km^2 [73 lb/mi^2]) and oceanic species (6.5 kg/km^2 [37 lb/mi^2]) contribute to make lower Cook Inlet one of the most productive areas for seabirds in Alaska (compare with 17.1 kg/km^2 [97.5 lb/mi^2] in Bering Strait, or 36.1 kg/km^2 [206 lb/mi^2] on the outer shelf of the southeast Bering Sea). Seabird densities were highest in the vicinity of the Barren and Shuyak islands and their associated shelf environments.

Common species that Piatt (1994) observed in lower Cook Inlet during the July study period included Short-tailed Shearwaters (*Puffinus tenuirostris;* 66 percent of birds observed), Fork-tailed Storm-petrel (7.3 percent), phalaropes (6.6 percent), Northern Fulmar (5.6 percent), Tufted Puffin (5.5 percent), murres (3.6 percent), Black-legged Kittiwake (2 percent) and murrelets (1.6 percent). The following groups of birds will be discussed below with reference to distribution and abundance in Cook Inlet: seabirds, shorebirds, waterfowl, and coastal birds of prey. Section 5.5 will discuss species of coastal and marine birds that the ESA protects within in the coverage area.

According to a literature review (MMS 2003), within the lower Cook Inlet area, the largest concentration of seabirds occurs in the Barren Islands. Recent counts and estimates of seabirds on the Barren Islands (Roseneau et al. 2000) indicate a total of nearly 420,000 breeding seabirds for these colonies. The authors suggest that actual populations might be substantially larger and the actual breeding population in Barren Islands could be at least 500,000 birds, and possibly more. Cook Inlet seabird colonies also occur at the Chisik-Duck Islands on the west side of the inlet (about 30,000 birds) and on Gull Island in Kachemak Bay (about 20,000 birds) (MMS 2003). Smaller colonies are present in Kamishak Bay and on northwestern Afognak and western Shuyak islands (Sowls et al. 1978).

Kachemak Bay was identified recently as a Western Hemisphere Shorebird Reserve because of its importance to shorebirds of the Pacific Flyway.

The most abundant waterfowl species in the lower Cook Inlet include scoters, long-tailed ducks, eiders, and goldeneyes (Agler et al. 1995 as cited in MMS 2003). Among the shorebirds, western sandpipers, rock sandpipers, and dunlins predominate in the lower inlet at various seasons (Gill and Tibbitts 1999).

5.4.1.1 Seabirds

Lower Cook Inlet is one of the most productive areas for seabirds in Alaska. Approximately 27 species, composed of an estimated 100,000 seabirds (USFWS 1992), occur in Cook Inlet, and about 18 species breed in the Inlet. Seabird breeding colonies occur along the coastline of the Gulf of Alaska and the lower Cook Inlet (DeGange and Sanger 1986; USFWS 1992). Species breeding in lower Cook Inlet include glaucous-winged gulls; black-legged kittiwake; common murre; pigeon guillemot; horned and tufted puffins; parakeet auklet; and red-faced, double-crested, and pelagic cormorants (SAIC 2002). Large seabird concentrations (about 30,000 birds) on the west side of Cook Inlet occur at the Chisik-Duck Islands (MMS 2003).

Large concentrations of seabirds occur in Cook Inlet and the Gulf of Alaska during the spring when returning breeding species and migrants from breeding grounds in the southern hemisphere move into the area. The numbers remain high throughout the summer and decline in the fall as they begin to migrate to their wintering grounds (DeGange and Sanger 1986). Seabird numbers in Cook Inlet are lowest during the winter (SAIC 2002). Major prey species for seabirds during the spring and summer seasons in the Cook Inlet area (MMS 2003) include capelin, pollock, sand lance, herring, euphausiid crustaceans, and squid (Baird and Moe 1978; Hatch 1984; Piatt 2002).

5.4.1.2 Shorebirds

Approximately 30 shorebird species occur as breeding birds and migrants in Cook Inlet. According to Ruthrauff et al. (2013), Cook Inlet is the world’s coldest site that regularly supports wintering populations of shorebirds, and it is also the most northerly nonbreeding location for shorebirds in the Pacific basin. Although shorebirds nest in Cook Inlet, the most important areas for shorebird use are the migratory stopover areas in the northern Gulf of Alaska/lower Cook Inlet where birds stop to rest and feed. An important location for shorebirds during migration is western Cook Inlet (DeGange and Sanger 1986). Specific important migratory habitat includes the intertidal zones of Drift River, Iniskin Bay, and Chinitna Bay. Kachemak Bay in lower Cook Inlet is also an important feeding and resting area for shorebirds during migration (SAIC 2002).

The Pribilof Islands rock sandpiper (*Calidris ptilocnemis*) winters along the intertidal mudflats from the Susitna River south to Redoubt Bay (Gill and Tibbets 1999). The sandpipers, which begin arriving in November and remain through mid-April, feed on a small bivalve (*Macoma balthica*) found in high densities in the intertidal area. The mean count of the Pribilof Island rock sandpiper during aerial surveys conducted in winter (1997 to 1999) was 17,530 birds (MMS 2003).

During spring migration, millions of shorebirds congregate at coastal intertidal mudflats to feed before continuing their northward migration. Most birds pass through the area between late April and mid-May with the peak of the migration in early May. The two most common species are dunlin and western sandpiper. Turnover is high, and birds probably only stop to feed and rest for a few days before continuing (SAIC 2002).

5.4.1.3 Waterfowl

The most abundant waterfowl species in lower Cook Inlet (MMS 2003) include scoters, long-tailed ducks, eiders, and goldeneyes (Agler et al. 1995 as cited in MMS 2003). Large numbers of waterfowl migrate through the Cook Inlet area in the spring (Arneson 1980; Gill and Tibbitts 1999). Waterfowl densities increase in winter and are higher in eastern Cook Inlet than on the western side (Arneson 1980).

A September aerial survey that Larned (2005) conducted in the lower Cook Inlet found that the most numerous of the seaducks were the surf and white-winged scooters. Populations of the surf and white-winged scooters were estimated at 3,734 and 2,876 birds, respectively. These species were found primarily in bays and along the shoreline from Chinitna Bay to Ursus cove, with a few further south near Douglas River. Sea ducks feed primarily on benthic invertebrates, including clams and mussels (Sanger and Jones 1984).

The September survey by Larned (2005) also targeted molting flocks of Steller’s eiders and mergansers. A total of seven flocks of Steller’s eiders in the vicinity of the Douglas River Delta were found. The largest flock was estimated at 1,800 birds, and the total of all Steller’s eider flocks was estimated at 2,190 birds. The author suggests that the shoals and reefs near the Douglas River in Kamishak Bay are an important molting habitat for Steller’s eiders, and likely the only important such habitat in Cook Inlet. Only a single congregation of molting mergansers was detected, estimated at 500 birds, also in the Douglas River area. No Steller’s eiders or mergansers were recorded along the eastern shoreline of Cook Inlet. The author concludes that the Douglas River Shoals is the only likely habitat in the surveyed portion of the lower Cook Inlet supporting a large molting population of mergansers (Larned 2005).

5.4.1.4 Coastal Birds of Prey

The bald eagle is a breeding, year-round resident along the coast of lower Cook Inlet (MMS 1995). Populations in southeastern Alaska have been stable or increasing. Bald eagles feed primarily on fish or act as scavengers (MMS 2003).

Peregrine falcons occur along the coast in the Gulf of Alaska south to British Columbia. Some nesting is known to occur on the Barren Islands (Bailey 1976). High nest site densities of peregrine falcons were also found along the southern coast of the Kenai Peninsula. Estimates for the Kenai Peninsula populations were more than 60 adults for the southern peninsula (Hughes and Sanger 1999).

5.4.2 Growth and Production

Some seabird populations in the Gulf of Alaska have declined markedly during the past few decades (Hatch and Piatt 1995; Piatt and Anderson 1996). These declines may be due to food stress including population declines, decreased productivity, changes in diet, and large-scale die-offs (Piatt 2002). The declines may also be due to environmental changes, such as the Exxon Valdez oil spill, and other factors that are less clearly understood (Piatt 2002).

Population trends in seabird colonies appear to be related to differences in food availability. In the late 1970s, a significant regime shift occurred in the Gulf of Alaska, characterized by changes in seawater temperature and decreases in abundance of forage fish. This shift resulted in reduced food availability to seabirds, lower reproductive success, large-scale die-offs, and long-term decreases in some populations (Piatt and Harding 2007). In fact, although the 1989 Exxon Valdez oil spill had a serious and immediate impact on seabird populations, effects of the regime shift are considered to have had an even more significant effect (Piatt and Harding 2007).

Studies of seabird colonies in the Cook Inlet area by Piatt (2002) indicated that the breeding biology of seabirds differed drastically among colonies based on geographic differences in forage fish abundance. For example, birds at Chisik Island struggled to reproduce, while those at Gull and Barren islands usually had few problems rearing young. Breeding and behavioral parameters were found to be similar among years during the study period (1995–1999) with the exception of 1998, when breeding success for all species was lower than the other years in the study. These patterns were noted to continue as seabird populations at Chisik Island continued declining and populations at Gull and Barren islands remained stable or increased with time.

Shorebird populations are primarily migratory, appearing in the Cook Inlet in early May and leaving by late May. Few shorebirds use the intertidal habitat of Knik Arm (URS 2006).

5.4.3 Environmental Factors

Shifts to earlier laying dates could result in overall decreased clutch size or chick survival if nutritional needs are outside the period of favorable food conditions (Visser et al. 2004). In this case, climate change could lead to mistiming, and failure of reproduction and certain marine and coastal bird populations could decline (MMS 2008).

The highest nesting densities generally occur in areas of mixed wet and dry habitats, whereas birds often move to wetter areas for broodrearing. Islands in river deltas provide the principal nesting habitat for several waterfowl and marine bird species. Shorebirds prefer well-drained gravelly areas for nesting, whereas loons use lakes, and geese prefer deeper ponds or wet tundra near lakes. Lagoons formed by barrier islands, bays, and river deltas provide important broodrearing and staging habitat for waterfowl, particularly molting oldsquaws. Peregrine falcons, bald eagles, and Canada geese nest primarily on bluffs. Arctic peregrine falcons are common in the Gulf of Alaska and are considered a species of special concern by the state of Alaska because of population declines (ARB 2011).

Emergent and wetland vegetation, such as various sedges, are the primary food types for most waterfowl. Invertebrates in brackish and freshwater flats and ponds are the principal food sources for shorebirds. Phalaropes, terns, auklets, murres, and kittiwakes feed on zooplankton (MMS 1982 and 1987a). Parakeet auklets also prey on a variety of pelagic invertebrates and occasional small fish. Thick-billed murres, common murres, black-legged kittiwakes, horned puffin, and pelagic cormorant prey on fish (sand lance, Arctic cod, and prickleback) during the nesting season (MMS 1982). The reproductive success of black-legged kittiwakes is greatly dependent on the availability of sand lance during the chick-rearing period (Frederiksen 2008). Black guillemots eat all kinds of animals from the sea, including crustaceans (crabs and shrimp), mollusks (clams and snails), and worms. The black-crowned night heron is an opportunistic feeder; its diet consists mainly of fish, though it is frequently rounded out by other items such as leeches, earthworms, and aquatic and terrestrial insects. It also eats crayfish, mussels, squid, amphibians, lizards, snakes, rodents, birds, eggs, carrion, plant materials, and garbage and refuse at landfills.

5.4.4 Coastal and Marine Bird Habitat

Piatt (1994) discusses that at small spatial scales (1 - 100 kilometers [0.6 - 62 miles]), seabirds may aggregate where food is concentrated at fronts (e.g., Piatt et al. 1991; Schneider et al. 1990), which may be defined as areas of high spatial gradient in thermodynamic properties such as temperature, density, or velocity (Schneider 1990). At both small and medium (100 - 1,000 kilometer [62 - 621 mile]) spatial scales, seabird species or "assemblages" may not necessarily be concentrated at fronts, but rather be segregated into different water masses which are themselves demarcated by fronts (Schneider et al. 1986 and 1987; Gould and Piatt 1993). Strong fronts may attract more seabirds than weak fronts (Schneider et al. 1987), seabird abundance may be correlated with the spatial extent or frequency of fronts (Haney and McGillivary 1985), and strongly demarcated water masses may promote greater segregation of seabird species than weakly defined ones (Elphick and Hunt 1993).

5.5 THREATENED AND ENDANGERED SPECIES

Section 7(a)(2) of the ESA requires federal agencies, in consultation with the agencies responsible for administering the ESA, the NMFS and the U.S. Fish and Wildlife Service (USFWS), to ensure that any action they authorize is not likely to jeopardize the continued existence and recovery of any species listed as threatened or endangered, or result in the destruction or adverse modification of critical habitat. An endangered species is a species that is in danger of extinction throughout all or a significant portion of its range. A threatened species is a species that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range (Tetra Tech 2006).

The threatened and endangered species listed below in Table 5-1 may be present near the project and are discussed below in relation to geographic boundaries and spatial distribution, critical habitat, life history, and population trends and risks.

Table 5-1. Species Listed Under the ESA within the Geographic Area Included in the Action

Species	Population/Stock	Present Status	*Federal Register* Notice	
Chinook Salmon (*Oncorhynchus tshawytscha*)	Snake River fall run	Threatened	57 FR 14653	04/22/92
	Snake River spring/summer run	Threatened	57 FR 14653	04/22/92
Sockeye Salmon (*Oncorhynchus nerka*)	Snake River	Endangered	56 FR 58619	11/20/91
Short-tailed Albatross (*Phoebastria albatrus*)	U.S. waters	Endangered	65 FR 46643	7/31/00
Steller's Eider (*Polysticta stelleri*)	Alaska	Threatened	62 FR 31748	6/11/97

Table 5-1. Species Listed Under the ESA within the Geographic Area Included in the Action

Species	Population/Stock	Present Status	*Federal Register* Notice	
Blue Whale (*Balaenoptera musculus*)	North Pacific	Endangered	35 FR 8495	6/2/70
Fin Whale (*Balaenoptera physalus*)	Northeast Pacific	Endangered	35 FR 8491 35 FR 8498	6/2/70 6/2/70
Humpback Whale (*Megaptera novaeangliae*)	Central/Western North Pacific	Endangered	35 FR 8491	6/2/70
Northern Right Whale (*Eubalaena japonica*)	Eastern North Pacific	Endangered	35 FR 8495 68 FR 17560	6/2/70 4/10/03
Sei Whale (*Balaenoptera borealis*)	North Pacific	Endangered	35 FR 8498	6/2/70
Sperm Whale (*Physeter macrocephalus*)	North Pacific	Endangered	35 FR 8495	6/2/70
Beluga Whale (*Delphinapterus leucas*)	Cook Inlet	Endangered	73 FR 62919	10/22/08
Northern Sea Otter (*Enhydra lutris*	Southwest Alaska	Threatened	70 FR 46366	8/9/05
Steller Sea Lion (*Eumetopias jubatus*)	Western (West of 144 W longitude) Eastern (East of 144 W longitude)	Endangered Threatened	62 FR 24355 62 FR 24345	5/5/97 5/5/97

5.5.1 SNAKE RIVER SPRING, SUMMER, and FALL CHINOOK SALMON (*Oncorhynchus tshawytscha*) and SNAKE RIVER SOCKEYE SALMON (*Oncorhynchus nerka*)

The critical habitat for the Snake River fall chinook salmon does not include any waters within the state of Alaska. EPA determined through communication with NMFS that according to the Regional Mark Processing Center Database the Snake River Chinook and Snake River Sockeye have not been detected in Cook Inlet (Wright 2012). This coupled with the conclusion by NMFS (2006) that "Snake River fall Chinook (Oncorhynchus tshawytscha), Snake River spring/summer Chinook salmon [. . .] and Snake River sockeye would occur in the project areas, rarely, if at all," led EPA to determine that it was highly unlikely that these species would be present in the Permit coverage area.

5.5.2 SHORT-TAILED ALBATROSS *(Phoebastria albatrus)*

The short-tailed albatross was listed as endangered in U.S. waters under the ESA on July 31, 2000 (65 FR 46643).

5.5.2.1 Geographic Range and Distribution

The short-tailed albatross once ranged throughout most of the North Pacific Ocean and Bering Sea with known nesting colonies on several islands within the territorial waters of Japan and Taiwan. The majority of breeding occurs on two remote islands in the western Pacific under Japanese jurisdiction. Approximately 80 to 85 percent of short-tailed albatrosses breed as part of a single colony, Tsubamezaki, on Torishima Island, which is an active volcano susceptible to mud slides and erosion (USFWS 2009). Recently, a new colony, Hatsunezaki, has formed on the northwest side of the island as a result of efforts by the Yamashina Institute for Ornithology in Japan (USFWS 2009). The location of this new colony presents a safer, more stable breeding area and, thus, is viewed as a significant conservation achievement for the species. The remaining known breeding birds nest in the Senkaku Island group almost exclusively on Minami-kojima (USFWS 2008). Other undocumented nesting colonies may also have existed in areas under U.S. jurisdiction on Midway Atoll and in the Aleutian Islands, but evidence for breeding on the Alaskan Aleutian Islands is lacking. Given the southerly location of known breeding grounds and midwinter constraints on breeding at high latitudes, Sherburne (1993), cited in 50 CFR 17, concluded that it is highly unlikely that short-tailed albatross ever reproduced in Alaska. Similarly, an analysis of Aleut middens by Yesner (1976) failed to find fledgling remains from over 400 samples.

As stated above, breeding colonies of the short-tailed albatross are currently known on two islands in the western North Pacific and East China Sea. The marine range within U.S. territorial waters includes Alaska's coastal shelf break areas and the marine waters of Hawaii for foraging. The extent to which the birds use open-ocean areas of the Gulf of Alaska, North Pacific Ocean, and Bering Sea is unknown (65 FR 46643). Short-tailed albatross frequent nearshore and coastal waters, with "many" birds being sighted within 10 kilometers (6 miles) of shore, and fewer birds ("several") observed within 5 kilometers (3 miles) of shore (65 FR 46643). However, the short-tailed albatross sighting dataset (1903–2003) shows no sightings within Cook Inlet and only one in Shelikof Strait (Drew 2005); the Permit coverage area is therefore not part of the typical range of this species (MMS 2003).

5.5.2.2 Critical Habitat

No critical habitat has been designated for short-tailed albatross. USFWS has determined that the designation of critical habitat for this species is not prudent because it would "not be beneficial to the species" (65 FR 46643). USFWS concluded that designation of critical habitat for potential and actual breeding areas within U.S. areas of jurisdiction on the Midway Atoll National Wildlife Refuge would not provide additional benefit or protection over that conferred through the jeopardy standard of section 7 of the ESA. With regard to the designation of critical habitat for foraging in the waters of United States, USFWS determined that there is no information available to support a conclusion that any specific marine habitat areas are uniquely important (65 FR 46643).

5.5.2.3 Life History

Short-tailed albatross are long-lived and slow to mature, with an average age at first breeding of 6 years old (USFWS 2009). Breeding is limited to the two Japanese islands of Torishima and Minami-kojima, with birds arriving in October. Breeding and egg-laying are initiated throughout the month and continue into late November. The chicks hatch in late December and January and are close to being full grown by late May or early June, at which time the adults begin to abandon the breeding colony and return to sea. The chicks fledge after the departure of the breeding adults and leave the colony by mid-July. Non-breeders and failed breeders disperse from the breeding colony in late winter through spring (USFWS 2009). The specific geographical and seasonal distribution patterns of the birds following departure from the breeding colonies has not been well understood until recently. Telemetry studies conducted by Suryan et al. (2007) found that the birds ranged widely throughout the North Pacific Ocean rim, spending time within the exclusive economic zones (EEZ) of Japan, Russia (Kuril Islands and Kamchatka Peninsula), and the United States (Aleutian Islands and Bering Sea, Alaska). However, albatrosses spent the greatest portion of time off the coast of Alaska, overlapping fisheries along the continental shelf break and slope regions.

5.5.2.4 Population Trends and Risks

The total population of short-tailed albatross in 2008–2009 is estimated to be 2,572 birds (USFWS 2009), over twice the number in 2000 (1,200 birds). Demographic information indicates that the breeding population on the island of Torishima is growing at an annual rate between 6.5 and 8.0 percent (H. Hasegawa, Toho University, personal communication in USFWS 2009). No information is available for the other breeding colony on the island of Minami-kojima.

The short-tailed albatross population is considered to be at risk due to the following factors (65 FR 46643; USFWS 2000):

- The primary breeding colony on Torishima Island is at risk due to the potential for habitat destruction from volcanic eruptions on the island and the destruction of nesting habitat and birds by frequent mud slides and erosion caused by monsoon rains.
- Direct harvest of birds at the breeding colonies in Japan at the beginning of the 20th century dramatically reduced the numbers of birds. Harvesting continued until the early 1930s. By 1949 there were no short-tailed albatross breeding at any of the historically known breeding sites, and the species was thought to be extinct.
- The world population is vulnerable to the effects of disease because of the small population size and extremely limited number of breeding sites.
- Oil spills pose a potential threat to the species' conservation and recovery due to damage related to oil contamination, which could cause physiological problems from petroleum toxicity and by interfering with the birds’ ability to thermoregulate. An oil spill in an area where a large number of birds were rafting, such as near breeding colonies, could significantly affect the population.
- Consumption of plastics at sea may be a factor affecting the species' conservation and recovery. Plastics can cause injury or mortality due to internal damage following ingestion, reduction in ingestion volumes, or dehydration.
- Mortality incidental to longline fishing in the North Pacific and Bering Sea. ESA consultations have determined that Alaskan groundfish and halibut fisheries are likely to adversely affect short-tailed albatrosses, but are not likely to result in an appreciable reduction in the likelihood of survival and recovery of the species.

5.5.3 STELLER'S EIDER (*Polysticta stelleri*)

The Alaskan breeding populations of Steller's eider were listed as threatened under the ESA on June 11, 1997 (62 FR 31748). Two breeding populations in Arctic Russia are not part of the ESA listing in the United States and are not addressed in this section.

5.5.3.1 Geographic Range and Distribution

The historical breeding range of the Alaska breeding population of Steller's eider is unclear; it may have extended discontinuously from the eastern Aleutian Islands to the western and northern Alaska coasts, possibly as far east as the Canadian border (USFWS 2001). In western Alaska, historical (pre-1970) data suggests that the birds formerly nested on the Yukon-Kuskokwim River Delta (Y-K Delta) and at least occasionally at other western Alaska sites, including the Seward Peninsula, St. Lawrence Island, and possibly the eastern Aleutian Islands and Alaska Peninsula (Flint and Herzog 1999; USFWS 2002). They spend the late fall and winter in shallow bays, feeding on mollusks and crustaceans. In the spring, Steller’s eiders remain concentrated in these bays to await the retreat of sea ice and opening of overwater migratory routes to their breeding areas in northern Alaska. Eiders may be present in Cook Inlet between October and April, and are frequently found in shallow nearshore marine waters along the Kenai Peninsula between Homer and Clam Gulch, and in Kachemak Bay, Iniskin Bay, Iliamna Bay, and Kamishak Bay (Larned 2006).

In recent times, breeding is known to occur in two general areas, beyond the boundaries of the Permit. These areas comprise the Arctic Coastal Plain on the Alaskan North Slope and, to a lesser extent, the Y-K Delta in western Alaska (USFWS 2001). The Arctic Coastal Plain, particularly the area surrounding Barrow, is extremely important to nesting Steller's eiders (USFWS 2002). Aerial surveys conducted from 1999 to 2002 in a 2,757 km^2 (1064.5 mi^2) area from Barrow south to Meade River recorded between 2 to over 100 breeding pairs for a maximum density of 0.08 birds per km^2 (2.1 birds/mi^2). In contrast, only seven nests were found on the Y-K Delta from 1994 to 2002 (USFWS 2002).

After breeding, Steller's eiders move to marine waters where they molt and individuals remain flightless for about 3 weeks. The birds, which presumably consist of members of both Alaskan and Russian populations, primarily molt outside of the Permit coverage area along the north side of the Alaska Peninsula, in Izembek Lagoon, Nelson Lagoon, Port Heiden, and Seal Islands (USFWS 2002). After molting, many Steller's eiders disperse to the Aleutian Islands, the south side of the Alaska Peninsula, Kodiak Island, and as far east as Cook Inlet. Wintering birds usually occur in waters less than 10 meters (30 feet) deep and are, therefore, usually found within 400 meters (1,312 feet) of shore, except where shallows extend further offshore in bays and lagoons (USFWS 2002).

The winter range from the Kodiak Island east to lower Cook Inlet overlaps the geographical area of the Permit. Birds from Alaskan and Russian breeding populations intermix on the wintering grounds; however, it is unclear what percent of the wintering birds comprise the ESA-listed population (Alaskan breeding population). According to USFWS, about 4.2 percent of the Steller's eiders in or near the Cook Inlet area are assumed to be from the Alaskan breeding population (MMS 2003).

5.5.3.2 Critical Habitat

Designated critical habitat for the Steller's eider includes five units located along the Bering Sea and north side of the Alaska Peninsula. These areas are the Delta, Kuskokwim Shoals, Seal Islands, Nelson Lagoon, and Izembek Lagoon (USFWS 2001). Within these areas, the primary habitat components that are essential include areas to fulfill the biological needs of feeding, roosting, molting, and wintering. Important habitats include the vegetated intertidal zone and marine waters up to 9 meters (30 feet), the underlying substrate and benthic community, the associated invertebrate fauna, and, where present, the eelgrass beds and associated biota (USFWS 2001).

No critical habitat is designated within the geographical area of the Permit for oil and gas exploration, development, and production facilities in Cook Inlet.

5.5.3.3 Life History

Steller's eiders exhibit strong fidelity to wintering (Jones 1965) and molting (Flint et al. 2000) areas. Courtship begins in late winter and most pair formation occurs prior to dispersal toward breeding grounds (McKinney 1965). Wintering aggregations on the Alaska Peninsula begin migrations in mid- to late-April, with large numbers departing from Izembek in a matter of days (Laubhan and Metzner 1999; McKinney 1965). Steller's eiders nest on tundra adjacent to small ponds or drained basins in locations generally near the coast, but ranging at least as far as 90 kilometers (56 miles) inland (USFWS 2002). Young hatch in late June and feed in wetland habitat on aquatic insects and plants until they are capable of flight in about 40 days. After breeding, Steller's eiders move to marine waters of southwest Alaska, including Cook Inlet, where they molt from late July to late October (Laubhan and Metzner 1999; Petersen 1980). After molting most birds disperse to winter in shallow, sheltered waters along the south side of the Alaska Peninsula, Kodiak Island, and as far east as Cook Inlet (USFWS 2002). The number of Steller’s eiders in Cook Inlet increases through early winter, peaking in January and February before the spring migration to nesting grounds occurs (Larned 2006). While in marine waters, Steller's eiders forage primarily on mollusks and crustaceans.

5.5.3.4 Population Trends and Risks

Evidence suggests that the breeding range of Steller’s eiders in Alaska has substantially contracted, with the species disappearing from much of its historical range in western Alaska (Dau et al. 2000). The size of the breeding population on the Alaskan North Slope shows considerable variation among years, and it is not known whether the population is currently declining, stable, or improving (65 FR 13262). Determining population trends for Steller's eiders is difficult due to the inherent problems of conducting aerial bird counts and the lack of a species-specific correction factor to apply to the resulting data (65 FR 13262). Counts conducted in 1992 indicate that at least 138,000 birds winter in southwest Alaska; however, the proportion belonging to the Alaska breeding population versus those from Russian breeding populations is uncertain (USFWS 2002). More specifically, Larned (2006) estimated winter populations of 1,247 and 4,284 Steller’s eiders in the eastern and western portions of Cook Inlet, respectively. High abundances were found along nearshore areas of the eastern portion of Cook Inlet from Anchor Point to 25 kilometers (15.5 miles) north of Ninilchik and from Homer Spit to Anchor Point. To the west, important areas include southern Kamishak Bay from Douglas River to Bruin Bay, including the shoreline between Bruin Bay and Ursus Cove, and a shoal 12 kilometers (7.5 miles) southeast of Bruin Bay and the mouth of Iniskin Bay.

The Alaska breeding population of the Steller's eider is considered to be at risk. The destruction or modification of habitat is not thought to have contributed to the decline of the species; however, the following factors are detailed in USFWS (2002):

- Exposure to lead through ingestion of spent lead shot when foraging may pose a significant health risk to Steller's eiders.
- Although there is no information to suggest that disease contributed to the decline of Steller's eiders, recent sampling suggests that Steller's eiders and other sea ducks in Alaska may have significant exposure rates to a virus in the family Adenoviridae.
- Changes in predation pressure in breeding areas are hypothesized as the reason for the near disappearance

of birds on the Y-K Delta. Recent studies within the primary breeding area on the North Slope near Barrow suggest that nest success is very poor and predation is thought to be the primary factor.

- Although hunting of Steller's eider is prohibited under the Migratory Bird Treaty Act, some intentional or unintentional shooting occurs.

5.5.4 BLUE WHALE (*Balaenoptera musculus*)

The blue whale was listed as endangered under the ESA on June 2, 1970 (35 FR 8495).

5.5.4.1 Geographic Boundaries and Spatial Distribution

Blue whales are found in all of the world's oceans from the Arctic to the Antarctic. Blue whales have been documented In the North Pacific Ocean (Mizroch et al. 1984), but additional information about the population(s) is not well known. The International Whaling Commission (IWC) has formally considered only one management stock for blue whales in the North Pacific; however, NMFS indicates that blue whales in the North Pacific probably exist in one of two stocks: the eastern North Pacific and the western North Pacific (NMFS 2010f and 2011d) In the eastern North Pacific, blue whales winter off southern and Baja California; during the spring and summer they are found from central California northward through the Gulf of Alaska. Historical areas of concentration in Alaska include the eastern Gulf of Alaska and the eastern and far western Aleutians (ADF&G 1994a).

Blue whales are believed to migrate away from coastlines and feed preferentially in deeper offshore waters (Gregr and Trites 2001; Mizroch et al. 1984). They are seldom seen in nearshore Alaska waters (ADF&G 1994a). These preferences make it highly unlikely that blue whales would frequent Cook Inlet waters within the coverage area of the Permit.

5.5.4.2 Critical Habitat

No critical habitat has been designated for the blue whale.

5.5.4.3 Life History

Blue whales are estimated to reach sexual maturity between 5 and 15 years of age, and may live as long as 70 to 80 years (Environment Canada 2004b; Mizroch et al. 1984). Reproduction generally occurs during the winter months. Females bear a single calf, following a gestation period of 10 to 12 months, and nursing continues approximately 6 to 7 months following birth (ADF&G 1994a; NMFS 1998). Weaning is thought to occur as the whales move from low-latitude wintering areas to high-latitude summer feeding grounds (NMFS 1998).

Blue whales appear to practice more selective behavior in feeding than other rorquals (those baleen whales that possess external throat grooves that expand during gulp feeding) and specialize in plankton feeding, particularly swarming euphausiids (krill) in the Antarctic. In the North Pacific, the species *Euphausia pacifica* and *Thysanoessa spinifera* are the main foods of blue whales (ADF&G 1994a; Rice 1986); however, more recent studies suggest blue whales feed primarily on the latter (Fiedler et al. 1998; Marine Fisheries Review 1999).

5.5.4.4 Population Trends and Risks

Historical abundance of blue whales prior to commercial harvesting operations is estimated to have been between 4,900 and 6,000 (ADF&G 1994a). Following protection status imposed in 1966 by the IWC, it was anticipated that whale stocks would begin to recover but there is no evidence to support that contention (NMFS 1998). In a recent study using photographic mark-recapture techniques, Calambokidis et al. (2010) estimates the current North Pacific population at 2,497 individuals. However, few sightings of blue whales have been reported in Alaskan waters. National Oceanic and Atmospheric Administration (NOAA) scientists documented the first confirmed occurrence in 30 years on July 15, 2004, 100 nautical miles southeast of Prince William Sound (Joling 2004).

The North Pacific blue whale is considered to be at risk due to the following factors:

- Commercial whaling harvested 9,500 blue whales from the North Pacific between 1910 and 1965 (Ohsumi and Wada 1974; ADF&G 1994a). Commercial whaling has been prohibited in the United States since 1972 and there has been IWC prohibition on taking blue whales since 1966 (NMFS 1998).
- Ship strikes have been implicated in the deaths of blue whales in the eastern North Pacific in 1980, 1986, 1987, and 1993. Additional mortality from unreported ship strikes is likely (NMFS 1998).
- The offshore drift gillnet fishery is the only fishery likely to take blue whales in the eastern North Pacific. Approximately 2,000 whales were taken off the west coast of North America between 1910 and 1965 (NMFS 1998).
- The potential exists for additional mortality due to habitat loss associated with sound derived from anthropogenic sources (Reeves et al. 1998).

5.5.5 FIN WHALE (*Balaenoptera physalus*)

Fin whales were first listed on June 2, 1970, under the Endangered Species Conservation Act of 1969 (35 FR 8491) and are currently designated as endangered in their entire range under ESA and "depleted" under the MMPA. Three stocks of fin whales are currently recognized in U.S. waters including Alaska (Northeast Pacific), California/Washington/Oregon, and Hawaii. However, new data from Mizroch et al. (2009) suggests the existence of two migratory stocks (eastern and western Pacific) and two to four stocks that occur in peripheral seas, including the Gulf of California, East China Sea, Sanriku-Hokkaido, and possibly in the Sea of Japan. These findings should be further evaluated to determine if a change in the management of currently recognized stocks is warranted (NMFS 2010a).

5.5.5.1 Geographic Boundaries and Distribution

In the North Pacific Ocean, fin whales can be found from above the Arctic Circle to lower latitudes of approximately 20 °N (Leatherwood et al. 1982). Rice (1974) reported summer distributions along nearshore areas from central Baja California to Japan, and extending north as far as the Chukchi Sea.

Fin whales are believed to feed preferentially along offshore waters, with preferred habitat encompassing a large area that includes the continental shelf break and offshore waters (Gregr and Trites 2001). They are rarely seen in inshore coastal waters. Fin whales regularly inhabit areas near the Permit coverage area, including Shelikof Strait, bays along Kodiak Island (especially Uganik and Uyak bays on the west side), and the Gulf of Alaska. Some or all of these areas are known feeding areas. Sighting data suggest that the distribution and abundance of fin whales in these areas vary seasonally, but there is documented use in the vicinity of Kodiak Island every month of the year except December and January (MMS 2003).

5.5.5.2 Critical Habitat

No critical habitat has been designated for the fin whale.

5.5.5.3 Life History

Fin whales tend to be more social than other rorquals, gathering in pods of two to seven whales or more. Reproductive activity generally occurs in winter following migration to warmer waters. Sexual maturity occurs at the ages of 6 to 10 years in males and 7 to 12 years in females, and species may live as long as 90 years (OBIS 2005). Ohsumi (1986, as cited in MMS 2003) found that the species exhibits a dramatic response to exploitation pressures. Data from the mid-1950s to 1975 indicate a decline in the average age of sexual maturity from 12 to 6 years in females and from 11 to 4 years in males. Ohsumi concluded the decline to be a density dependent response to intense harvesting of the population.

Fin whales feed on a variety of euphausiids (*Euphausia pacifica*, *Thysanoessa longipes*, *T. pinifera*, and *T. inermis*) and large copepods, primarily *Calanus cristatus* (Nemoto 1970). The species is also known to forage on schooling fish, such as herring, walleye pollock, and capelin (OBIS 2005).

5.5.5.4 Population Trends and Risks

For the entire North Pacific population, abundance estimates range from 42,000 to 45,000 individuals prior to commercial exploitation, and from 14,620 to 18,630 individuals in the early 1970s (Ohsumi and Wada 1974). In Alaska, surveys conducted in 1994 covering 2,050 nautical miles of track line south of the Aleutian Islands encountered only four fin whale groups. Results of surveys that Moore et al. (2002) conducted in the central-eastern Bering Sea and southeastern Bering Sea in 1999 and 2000 provided estimates of 3,368 and 683, respectively, although these are conservative, uncorrected estimates (i.e., no adjustments made for whales missed during the survey, etc.). Additional sighting cruises were conducted in coastal waters of western Alaska and the eastern and central Aleutian Islands in July to August 2001–2003 between the Kenai Peninsula (150 °W) and Amchitka Pass (178 °W) that detected 1,652 whales (Zerbini et al. 2006). Together these survey results combine for a minimum population estimate of 5,703 whales.

The risk of human-related mortality is relatively low for fin whales. Prior to 1999, no injuries or mortality associated with commercial fishing had been reported for the North Pacific stock. One mortality associated with the Gulf of Alaska pollock trawl fishery occurred in 1999. Ship strikes appear infrequent, with one strike in Uyak Bay reported between 1997 and 2001. Fin whales in the Alaska stock are not harvested for subsistence and no habitat-related limiting factors have been identified for this species (Angliss and Outlaw 2005).

5.5.6 HUMPBACK WHALE (*Megaptera novaeangliae*)

Humpback whales were listed as endangered throughout their range on June 2, 1970 under the ESA (35 FR 8491) and are considered "depleted" under the MMPA.

5.5.6.1 Geographic Boundaries and Distribution

The humpback whale is distributed worldwide in all ocean basins, although it is less common in Arctic waters. There are four recognized stocks of humpback whales in U.S. waters based on geographically distinct winter ranges (NMFS 2011a): Gulf of Maine stock, eastern North Pacific stock, central North Pacific stock, and the western North Pacific stock. The central and western North Pacific stocks inhabit Alaskan waters. In Alaskan waters, most humpbacks tend to concentrate in southeast Alaska, Prince William Sound, the area near Kodiak and Barren islands, the area between the Semidi and Shumagin islands, eastern Aleutian islands, and the southern Bering Sea (ADF&G 1994b). In inside waters off southeastern Alaska (i.e., Glacier Bay and Frederick Sound) photo-identification studies that Perry et al. (1999) summarized appear to show that humpback whales use discrete, geographically isolated feeding areas that individual whales return to year after year. These studies find little documented exchange in individual animals between Prince William Sound areas and the Kodiak Island area, as well as between the Kodiak Island area and southeast Alaska feeding areas, suggesting that while movement among these areas may occur, it is reasonably uncommon.

Although humpback whales can be observed year-round in Alaska, most animals migrate during the fall to temperate or tropical wintering areas where they breed and calve. Most whales that spend the summer in Alaskan waters are thought to migrate to overwinter in waters near Hawaii (ADF&G 1994b; Perry et al. 1999). Feeding occurs preferentially over continental shelf waters (Gregr and Trites 2001) and is often observed relatively close to shore, including major coastal embayments and channels (NMFS 2011a). In the summer, humpback whales are regularly present and feeding in areas near and within the Cook Inlet lease sale area, including Shelikof Strait, bays of Kodiak Island, and the Barren Islands, in addition to the Gulf of Alaska adjacent to the southeast side of Kodiak Island (especially Albatross Banks), the south sides of the Kenai and Alaska peninsulas, and south of the Aleutian Islands. There is some evidence of a discrete feeding aggregation of humpbacks in the Kodiak Island region. Humpbacks might also be present in some of these areas throughout the autumn. Within the proposed lease sale area, large numbers of humpbacks have been observed in late spring and early summer feeding near the Barren Islands. Humpbacks have also been observed feeding near the Kenai Peninsula north and east of Elizabeth Island (MMS 2003).

5.5.6.2 Critical Habitat

No critical habitat has been designated for the humpback whale anywhere throughout their range.

5.5.6.3 Life History

Humpback whales are seasonal migrants. The whales mate and give birth while in wintering areas outside of Alaskan waters. Sexual maturity occurs between the ages of 4 and 6 years, with mature females giving birth every 2 to 3 years (ADF&G 1994b). During spring, the whales migrate back to feeding areas in Alaskan waters, where they spend the summer (ADF&G 1994b; Perry et al. 1999).

Humpback whales use a variety of feeding behaviors to capture food, including underwater exhalation of columns of bubbles that concentrate prey, feeding in formation, herding prey, and lunge feeding (ADF&G 1994b). Based on their diet, humpbacks have been classified as generalists (Perry et al. 1999). They have been known to prey upon euphausiids (krill), copepods, juvenile salmonids (*Oncorhynchus* spp.), Arctic cod (*Boreogadus saida*), capelin (*Mallotus villosus*), Pacific herring (*Clupea harengus pallas*i), sand lance (*Ammodytes hexapterus*), walleye pollock (*Theragra chalcogramma*), pollock (*Pollachius vixens*), pteropods, and some cephalopods. On Alaska feeding grounds, humpback whales feed primarily on capelin, juvenile walleye pollock, sand lance, Pacific herring, and krill (Perry et al. 1999).

5.5.6.4 Population Trends and Risks

The population of humpback whales living in the North Pacific is estimated at 20,800–21,808 individuals (NMFS 2010b). Various researchers surveyed summer feeding areas of Alaska, and observations include 315 humpback whales in Prince William Sound, 615 in the Kodiak region, 410 in the Shumagin Islands, 1,175 in the central-eastern Bering Sea, 102 in the eastern Bering Sea, and 2,644 on the coastal shelf waters in the Gulf of Alaska/Aleutian Islands. The recent SPLASH survey observed “63 humpback whales in the Aleutian Islands, 491 in the Bering Sea, 301 in the western Gulf of Alaska (including the Shumagin Islands), and 1,038 in the northern Gulf of Alaska (including Kodiak and Prince William Sound)" (NMFS 2010b). A total of 6,000–19,000 whales were estimated for the waters near Alaska. Trends show that North Pacific humpback populations may be increasing by 5 to 10 percent per year (NMFS 2010b).

Historic and current risk factors influence the population and well-being of humpback whales. Commercial whaling harvested more than 28,000 animals from the North Pacific during the 20th century and may have reduced this population to as few as 1,000 individuals after the 1965 hunting season (NMFS 2011a). Presently, commercial fisheries may pose a risk to humpback whales. At least three mortalities or serious injuries were reported between 2002 and 2006. The rate of mortality or serious injury related to commercial fishing in Alaska (including entanglement and ship strikes) was 3.8 humpback whales per year between 2003 and 2007. Ship strikes pose a risk to humpback whales, with seven collisions occurring in southeast Alaska between 2003 and 2007 (NMFS 2010b).

Anthropogenic sources of noise are another source of risk to whale populations. Humpbacks exhibit variable responses to noise, and the level and type of response whales exhibit has been correlated to group size, composition, and apparent behaviors at the time of possible disturbance. Humpback whales have suffered severe mechanical damage to their ears from noise pulses from underwater blasting; whales exposed to playbacks of noise from drill ships, semisubmersibles, drilling platforms, and production platforms do not exhibit avoidance behaviors at noise levels up to 116 decibels (db) (Malme et al. 1985). Other potential risks to humpback whales include habitat degradation, exposure to contaminants, and resource competition.

5.5.7 NORTH PACIFIC RIGHT WHALE *(Eubalaena japonica)*

The northern right whale (*Balaena glacialis*) was listed as endangered under the ESA on June 2, 1970 (35 FR 8495). On April 10, 2003, the NMFS published a final rule that split the endangered northern right whale into two endangered species: North Atlantic right whale (*Eubalaena glacialis*) and North Pacific right whale (*Eubalaena japonica*) (68 FR 17560). On March 6, 2008, the North Pacific right whale was listed as a separate endangered species (73 FR 12024).

5.5.7.1 Geographic Boundaries and Distribution

The North Pacific stock of northern right whale has historically occurred across the North Pacific, north of 35 °N latitude, with concentrations of whales occurring in the Gulf of Alaska, eastern Aleutian Islands, south-central Bering Sea, Sea of Okhotsk, and the Sea of Japan (66 FR 17560).

Two populations of North Pacific right whale are thought to exist, one in the western North Pacific off Russia and the other in the eastern North Pacific off Alaska (MMC 2002). The distribution and status of neither population is well understood. The eastern population is more severely depleted than the western population, with the eastern population thought to number in the tens of individuals versus hundreds for the western population (MMC 2002; NMFS 2011b). Between 1900 and 1994, there have been only 29 reliable sightings of right whales in the eastern North Pacific. Since that time between 4 and 13 individuals have been sighted each year; all these sightings have occurred in an area approximately 200 nautical miles north of Unimak Pass in the southeastern Bering Sea (CBD 2000; MMC 2002; NMFS 2002).

Because the North Pacific eastern population is so small and infrequently sighted, little is known about their range and movements. The whales are thought to move northward to high latitudes in the spring, summer in the Bering Sea and Gulf of Alaska, and move southward in the fall and winter possibly as far south as Baja California (CBD 2000; NMFS 2002).

Historically, right whales often were observed in coastal waters where their slow speed and tendency to float after death resulted in their near-decimation by whalers in the 1800s. Recent whale sightings have all occurred within the shallower waters of the continental shelf (CBD 2000). No information currently exists regarding the presence of this species in Cook Inlet, Alaska.

5.5.7.2 Critical Habitat

On June 3, 1994, the NMFS designated critical habitat for the species of northern right whale (59 FR 28793), which as of April 10, 2003, became referred to as the North Atlantic right whale (68 FR 17560). The three areas designated as critical habitat are in the North Atlantic Ocean off the eastern United States. NMFS determined at that time that insufficient information was available to consider critical habitat designation for other stocks of northern right whale, including whales residing in the North Pacific.

On October 4, 2000, the Center for Biological Diversity petitioned the NMFS to designate a portion of the southeastern Bering Sea as critical habitat for the North Pacific right whale on the basis of annual sightings of whales in the area that suggests the area is a summer feeding ground for this severely depleted population (CBD 2000). On July 11, 2001, the Marine Mammal Commission responded to this request by recommending that NMFS proceed with designating the area as critical habitat and modify the boundaries as future data on population distribution becomes available (MMC 2002). However, on February 20, 2002, NMFS published notice that the Service had determined that the petitioned action to designate critical habitat was not warranted at this time (67 FR 7660), noting that because the essential biological requirements of the population in the North Pacific Ocean are not sufficiently understood, the extent of critical habitat cannot be determined. Currently, no critical habitat has been designated for the North Pacific right whale.

5.5.7.3 Life History

As noted in section 3.9.1, little is known about the movements of the eastern population of North Pacific right whale; although some authors believe they may move seasonally from areas in the Bering Sea and Gulf of Alaska southward, possibly as far as the waters off Baja California (CBD 2000; NMFS 2002). No sightings of a cow with a calf have been confirmed since 1900 (67 FR 7660).

Among baleen whales, right whales appear to have the most specialized feeding strategy. Studies conducted in the North Atlantic suggest that right whales require high densities of copepods concentrated in surface waters for effective feeding; the feeding requirements of an adult whale are estimated to be at least 4.07×10^5 kilo calories per day (CBD 2000). The feeding preferences of North Pacific right whales have not been determined; however, the NMFS has noted that these whales probably feed almost exclusively on calanoid copepods, a component of the zooplankton (67 FR 7660).

5.5.7.4 Population Trends and Risks

The pre-exploitation size of the population on North Pacific right whales has been estimated as likely exceeding 10,000 animals (67 FR 7660) to 19,000 animals (CBD 2000). The current population is thought to be very small, perhaps in the tens of animals (67 FR 7660) to low hundreds (NMFS 2005a). Periodic sightings and aerial and vessel survey efforts that NMFS conducted in the Bering Sea and Gulf of Alaska between 1997 and

2000 indicated that at least small groups of North Pacific right whales were using offshore waters in Bristol Bay (1996, 3–4 individuals; 1997, two sightings of 4–5 individuals including a juvenile; 2002, 7 individuals plus 1 calf), and elsewhere in the southeastern and central Bering Sea [1998, 6 individuals; 1999, 5 individuals and 2 individuals; 2000, 8 individuals (69 FR 30857)]. In 2004 researchers radio tagged two right whales in the Bering Sea and subsequent radio tracking efforts in September 2004 revealed a concentration of 25 North Pacific right whales among the Aleutian Islands feeding in shallow waters near humpback and fin whales. This observation was particularly noteworthy because of the size of the group, and because the group included three cow/calf pairs. Currently, no reliable estimates of abundance or population trends exist for the North Pacific stock.

Historic and current risk factors influence the population and well-being of right whales. Whaling records indicate that during the 19th century, pelagic whalers harvested over 15,000 North Pacific right whales. As early as the 1870s, the whale was noted as being rare (CBD 2000). It is difficult to assess risk to North Pacific right whale populations since so few animals are observed. Currently, it is expected that commercial fishing activities pose a risk to North Pacific right whales; however, the magnitude and nature of entanglements in fishing gear are not known. Approximately 57–62 percent of right whales in the North Atlantic bear scars and injuries indicative of fishing gear entanglement (NMFS 2005a). The extent of fisheries in the southeastern Bering Sea suggests that fishing gear entanglements may also pose a risk to the North Pacific right whale.

North Pacific right whales are slow-swimming and spend much of their time near the surface of the water, which makes them susceptible to ship strikes. While ship strikes are a significant source of mortality to right whales in the North Atlantic Ocean, it is unknown how often collisions occur in the North Pacific (Right Whale Listening Network, n.d.). Disturbance due to anthropogenic noise may affect right whales by changing normal behavior to temporarily or permanently avoid noise sources. Anthropogenically produced sounds may also raise background noise levels and mask the detection of sounds from other whales or natural sources. Information on the hearing capacity of right whales is not available; however, some authors have suggested that their hearing abilities are especially acute below 1 kiloHertz (CBD 2000). Other potential risks to the North Pacific right whale include habitat degradation, contaminants, military activities, and climate and ecosystem change.

5.5.8 SEI WHALE (*Balaenoptera borealis*)

The sei whale was listed as endangered under the ESA on June 2, 1970 (35 FR 8498). As such, the eastern North Pacific stock is considered as a "depleted" and "strategic" stock under the MMPA.

5.5.8.1 Geographic Boundaries and Distribution

Sei whales have historically occurred in all oceans of the world, migrating from low-latitude wintering areas to high-latitude summer feeding grounds (Fisheries and Oceans Canada 2005). In the eastern North Pacific, sei whales are common in the southwest Bering Sea to the Gulf of Alaska, and offshore in a broad arc between about 40 °N and 55 °N (Environment Canada 2004a; WWF 2013).

The sei whale prefers deeper offshore waters, with preferred habitat tending to occur in offshore areas that encompass the continental shelf break (Gregr and Trites 2001). Commercial whaling catch records off British Columbia indicate that less than 0.5 percent of sei whales were caught in waters over the continental shelf

(Environment Canada 2004a). These preferences make it unlikely that sei whales would frequent Cook Inlet waters within the geographic area covered by the Permit.

5.5.8.2 Critical Habitat

No critical habitat has been designated for the sei whale.

5.5.8.3 Life History

Sei whales reach sexual maturity between 5 and 15 years of age, and may live as long as 60 years. Like many other species of baleen whales, sei whales migrate from low-latitude wintering areas to high-latitude summer feeding grounds. Catch records suggest that whale migrations are segregated according to length (age), sex, and reproductive status. Pregnant females appear to lead the migration to feeding grounds, while the youngest animals arrive last and depart first (Environment Canada 2004a). Sei whales feed primarily on copepods, followed by small squid, euphausiids, and small pelagic fish (Trites and Heise 2005).

5.5.8.4 Population Trends and Risks

The pre-whaling abundance of sei whales in the North Pacific has been estimated to range from 42,000–62,000 animals (Ohsumi and Wada 1974; Tillman 1977). There are no current data on trends in sei whale abundance in the eastern North Pacific waters. A fact sheet prepared by NMFS (2012b) on the eastern North Pacific stock of sei whale suggests that the population is expected to have grown since being given protected status under the MMPA in 1976; however, continued unauthorized take, incidental ship strikes, and gill net mortality makes this uncertain.

Historic and current risk factors influence the population and well-being of sei whales. Commercial whaling activities took 61,500 whales in the North Pacific between 1947 and 1987. The practice of commercial whaling has been prohibited in the United States since 1972 and the IWC has prohibited harvesting sei whales since 1976 (ADF&G, undated). Risk to anthropogenic noise (i.e., underwater communication, navigation, ships, oil and gas exploration/development, military activity, and research) is unknown, but could cause hearing or tissue damage, altered behavioral responses, or mask biologically important communication signals in sei whales (NMFS 2011c). Ship collision risks are unknown but expected to be low risk to sei whales. Of 300 collisions reported between 1975 and 2002, only a few sei whale strikes were reported, none of which occurred in North Pacific waters; however, one strike was reported off the coast of Washington in the North Pacific between 2003 and 2008 (NMFS 2011c).

Whale harvesting, while mostly historic, has posed a significant risk on sei whale populations, and has resulted in the low populations currently observed. The IWC presently prohibits commercial whaling for sei wales, but Japan has maintained a scientific whaling program that harvested up to 100 whales per year between 1988 and 2009. A total of 592 sei whales were taken from the northwestern Pacific Ocean during that time period.

Loss of prey due to climate and ecosystem change poses an unknown but potentially high risk on sei whale populations. Increases in temperature may change availability of prey and affect whale migration, feeding patterns, and ability to use certain habitats for breeding or finding food. The risk of toxicity and bioaccumulation of contaminants and pollutants (e.g., PCBs, PAHs, DDT, DDE, dieldrin, mercury, and other metals) is unknown, but it appears that concentrations of organochlorine and metal compounds are lower in baleen whale tissues than other kinds of marine mammals. Other factors that pose low or unknown risks to sei whales include oil spills, disease, injuries from marine debris, research activities, predation, and resource competition (NMFS 2011c).

5.5.9 SPERM WHALE (*Physeter macrocephalus*)

The sperm whale was listed as endangered under the ESA on June 2, 1970 (35 FR 8495).

5.5.9.1 Geographic Boundaries and Distribution

Sperm whales inhabit all ocean basins, from equatorial to polar waters. Their distribution generally varies by gender and the age composition of groups, and is influenced by prey availability and oceanic conditions (Perry et al. 1999). In the North Pacific, sperm whales are distributed widely, with the northernmost boundary extending from Cape Navarin (62 °N) to the Pribilof Islands (Angliss and Lodge 2004). Mature females, calves, and immature whales of both sexes in the North Pacific are found in social groups and remain in tropical and temperate waters year-round from the equator to approximately 45 °N latitude (Perry et al. 1999; Angliss and Lodges 2004). Males lead a mostly solitary life after reaching sexual maturity between 9 and 20 years of age and are thought to move north in the summer to feed in the Gulf of Alaska, Bering Sea, and waters around the Aleutian Islands. Research has revealed considerable east-west movement between Alaska and the western North Pacific (Japan and Bonin islands), with little evidence of north-south movement in the eastern Pacific (Angliss and Lodge 2004; Perry et al. 1999).

The habitat preferred by sperm whales differs among the sexes and age composition of individual whales. The social groups comprised of females, calves, and immature whales have a broader habitat distribution than males; they are generally restricted to waters with surface temperatures greater than 15 °C (59 °F) and are rarely found in areas with water depths less than 200 to 1,000 meters (656 to 3,280 feet) (Gregr and Trites 2001). Males exhibit a tighter distribution over deeper waters along the continental shelf break, and are often found near steep drop-offs or other oceanographic features (e.g., offshore banks, submarine trenches and canyons, continental shelf edge), presumably because these areas have higher foraging potential (AKNHP 2013; Gregr and Trites 2001).

The distribution of sperm whale indicates that male sperm whales are the only sex that frequent Alaskan waters. Available evidence indicates that males are present offshore in the Gulf of Alaska during the summer, but they are very unlikely to be present in the Permit coverage area in Cook Inlet.

5.5.9.2 Critical Habitat

No critical habitat has been designated for the sperm whale.

5.5.9.3 Life History

Sperm whales appear to be organized in a social system that consists of groups of 10–40 adult females plus their calves, which remain year-round in tropical and temperate waters. Solitary males join these groups during the breeding season, which takes place in the middle of the summer (NMML 2013). Males reach sexual maturity between 9 and 20 years of age (Perry et al. 1999), but do not seem to take an actual part in breeding until their late 20s (ACS 2013). Female sperm whales reach sexual maturity at around 9 years of age and produce a calf approximately once every 5 years (NMFS 2013d).

Sperm whales feed primarily on medium-sized deepwater squid, with the remaining portion of their diet comprised of octopus, demersal and mesopelagic sharks, skates, and fish; feeding occurs year-round, usually at depths below 400 feet (ACS 2013; AKNHP 2013; NMFS 2013d; NMML 2013).

5.5.9.4 Population Trends and Risks

As of 2002, the world population of sperm whales was approximately 300,000 to 450,000, and the abundance in the Pacific was estimated to be 152,000 to 226,000. Using population estimates from models, it is expected that the world population is approximately 32 percent of historical numbers, and probably much lower in the Pacific where whaling was more prevalent than in other oceans (NMFS 2010d). Pre-whaling abundance estimates of sperm whale in the North Pacific are considered unreliable and range from 472,000 to 1,260,000 animals (Angliss and Lodge 2004; Perry et al. 1999). The abundance of whales in the North Pacific in the late 1970s was estimated to be 930,000 animals (Rice 1989). Approximately 102,112 sperm whales occur in the western North Pacific, but individual estimates for Alaska or other regions of the North Pacific are not available (NMFS 2010e).

Historic and current risk factors influence the population and well-being of sperm whales. Commercial whaling operations were responsible for harvesting 261,148 sperm whales between 1912 and 2006, with the vast majority (259,120) taken between 1946 and 1987 (NMFS 2010e). In addition to reducing overall numbers of animals, commercial whaling altered the male-to-female ratio by selective killing of the larger breeding age males (AKNHP 2013). Gear used in the modern fishing industry can pose an entanglement and trailing risk to marine mammals, with at least three serious injuries to sperm whales living in the Gulf of Alaska between 2002 and 2006 (NMFS 2010e). The average annual mortality rate based on observations from 1997 to 2001 is 0.4 whales per year. Most mortalities or injuries tend to occur with the longline fishery operating in the Gulf of Alaska waters east of Kodiak Island (AKNHP 2013).

Risk to anthropogenic noise (i.e., underwater communication, navigation, ships, military activity, and research) is unknown, but could cause hearing damage, altered behavioral responses, or mask biologically important signals including mating calls in sperm whales (NMFS 2010d). Ship collision risks are unknown but expected to be low risk to sperm whales. Sperm whales may be impacted by ship strikes, although their behavior suggests that they are at a lesser risk than other baleen whales that spend a greater proportion of their time in surface waters (NMFS 2011c). In a 2004 study, it was shown that of 292 recorded strikes, only 17 collisions occurred with sperm whales (Jensen and Silber 2004).

Other risks to sperm whales with low or unknown impacts include toxicity and bioaccumulation of contaminants and pollutants (e.g., PCBs, PAHs, DDT, DDE, dieldrin, mercury, other metals), oil spills, disease, injury from marine debris, research activities, predation, whale harvesting activities, and resource competition (NMFS 2010d).

5.5.10 BELUGA WHALE (*Delphinapterus leucas*)

Beluga whales are one of the two members of the family Monodontidae and are divided into five stocks on the basis of mitochondrial DNA analyses: Cook Inlet, Bristol Bay, eastern Bearing Sea, eastern Chukchi Sea, and Beaufort Sea (NMFS 2013c). The most vulnerable of these populations is the Cook Inlet stock, which was determined to be depleted under the MMPA in 2000 (65 FR 34590). The Cook Inlet population is the most isolated, spending the entire year in Cook Inlet (URS 2010). The Cook Inlet populations are known to spend the majority of the year in the northern portion of Cook Inlet. On October 22, 2008, NMFS listed the population as endangered under the ESA (73 FR 62919) and followed this action by designating critical habitat in Cook Inlet on April 11, 2011 (76 FR 20180).

5.5.10.1 Geographic Boundaries and Distribution

Beluga whales occur in Arctic waters of the northern hemisphere, living in openings within the pack ice in winter and migrating to shallow bays and estuaries in summer. Beluga whales in U.S. waters range from Yakutat to the Beaufort Sea. Some beluga stocks migrate over thousands of miles; for example, moving from the Bering Sea to the Mackenzie River estuary in Canada (ADF&G 1994e).

Movements during the summer and fall appear to be influenced by the timing and location of eulachon, salmon runs, other anadromous fish species (NMFS 2005b; URS 2010), water temperature, and the time of ice melt/freezing (Ezer et al. 2013) and tidal fluctuations (Ezer et al. 2008; Funk et al. 2005). Recent evidence has also shown a connection between low riverine discharge (relative to other locations within the northern Cook Inlet) and reduced beluga abundance (Ashford et al. 2013; Ezer et al. 2013; Goetz et al. 2007). During the summer and fall beluga whales are concentrated near the Susitna River mouth, Knik Arm, Turnagain Arm, and Chickaloon Bay. During the winter, beluga whales are concentrated in deeper waters in the mid-inlet to Kalgin Island, although occasional sightings are reported in the upper inlet in Knik and Turnagain arms. Tagging data indicate that at least a portion of the Cook Inlet stock remains in the inlet throughout the year (NMFS 2005b). In spring, Cook Inlet beluga whales move toward the upper portions of the inlet where they occur in coastal areas, particularly near the mouths of rivers (Moore et al. 2000; NMFS 2005b) and along tidal flats. Large groups may remain in and near the Susitna River, Little Susitna River, Beluga River and Turnagain Arm (Markowitz et al. 2005; Moore et al. 2000).

Beluga whales are known to move up rivers including those feeding Cook Inlet; individuals from northern stocks have been observed in the Yukon River as far upstream as Tanana, Rampart, and Fort Yukon (ADF&G 1994e). Moore et al. (2000) conclude that prey availability likely has the strongest influence on the distribution and relative abundance of belugas in Cook Inlet. The authors conclude that patterns and timing of eulachon and salmon runs seem to affect beluga feeding behavior. However, the impact on Cook Inlet belugas of a changing fish community could be difficult to quantify because the beluga diet is flexible and changes with season, location, sex, and age (Lowry et al. 1986; Stewart and Stewart 1989). To date, there has been no coordination between biologists counting fish runs (and thereby estimating the availability of some beluga prey) and those conducting surveys for belugas in Cook Inlet. Recent research has concluded that rather than prey availability, seasonal movements of Cook Inlet beluga whales can be correlated to the timing and relative discharge of riverine peak flows (Ashford et al. 2013; Ezer et al. 2013). Ashford et al. (2013) determined that the rates of river discharge explained over 90 percent of the inter-annual variability of beluga abundances within the Susitna Delta. Ashford et al. (2013) and Ezer et al. (2013) each suggest that as the relative flow rates declined in a particular river, Cook Inlet belugas moved away from the area of low flow and toward other areas. In the study by Ashford et al. (2013) as flow rates in the Susitna Delta declined, belugas tended to move toward the Knik Arm and Turnagain Arm. In the study conducted by Ezer et al. (2013), as the river flow in the Knik Arm decreased (relative to the flow rate in Turnagin Arm) belugas moved from the Knik to Turnagain Arm.

Additional factors likely influencing beluga whale distribution include predation pressure, sea ice cover, and other environmental parameters, reproduction, sex and age class, and human activities (Kingsley 2002; Rugh et al. 2000).

5.5.10.2 Critical Habitat

Effective May 11, 2011, two areas comprising 7,800 km^2 (3,013 mi^2) were designated as critical habitat for beluga whales (76 FR 20180). Area 1 includes 1,909 km^2 (738 mi^2) of Cook Inlet northeast of a line from the mouth of Threemile Creek to Point Possession. The area provides important foraging and calving habitats, experiencing the greatest concentrations of belugas from spring through fall. Area 2 comprises 5,891 km^2 (2,275 mi^2) and is to the south of Area 1. It includes nearshore areas along the west side of the Inlet and Kachemak Bay on the east side of the lower inlet. Critical habitat for beluga whales in Cook Inlet can be seen in Figure 3 below.

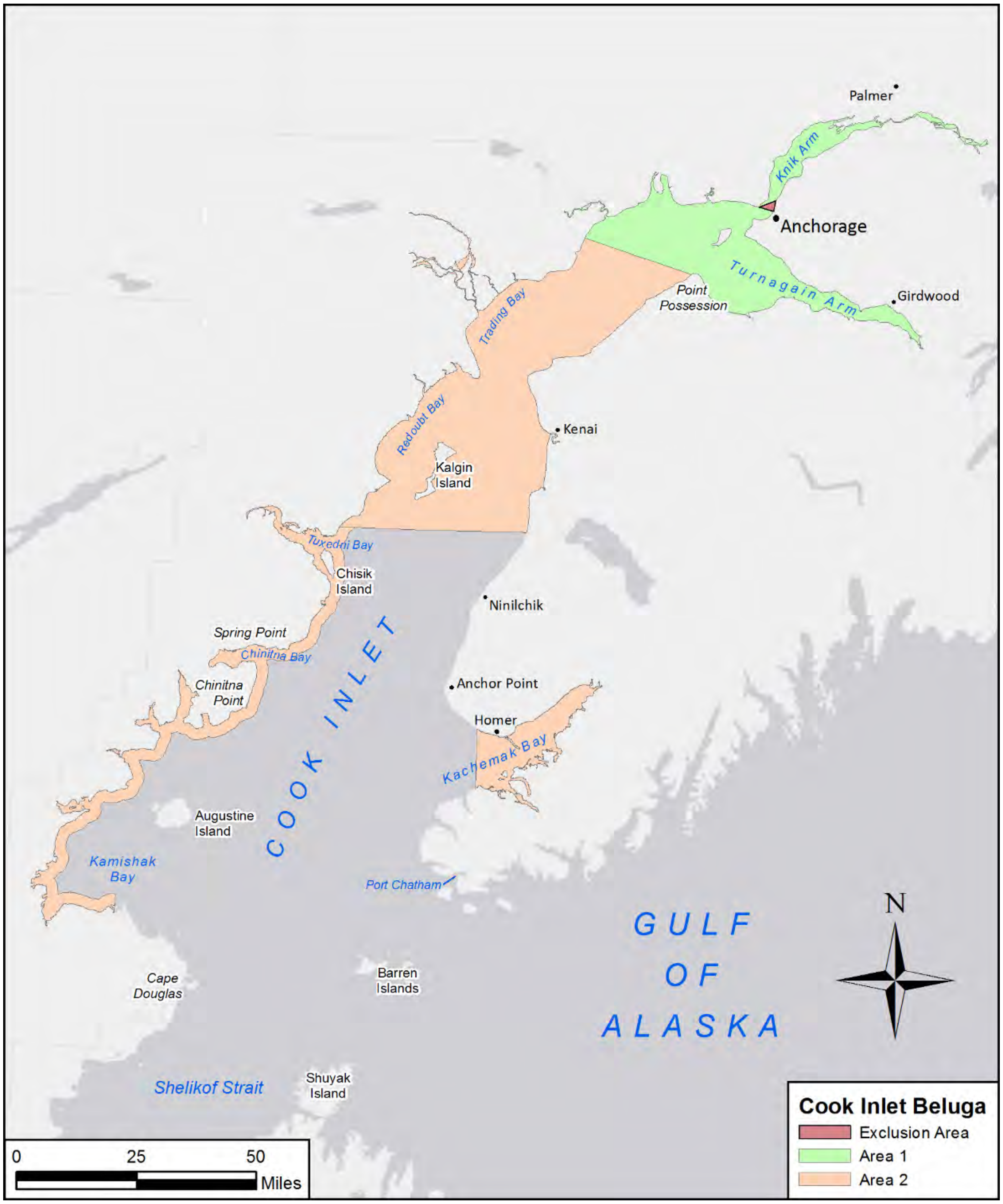


Figure 4: Critical Habitat for Beluga Whales in Cook Inlet

5.5.10.3 Life History

Beluga whales are small, with adult males generally ranging in size from 11 to 15 feet, and females reaching 12 feet (NMFS 2007). Calves are born dark gray to brownish-gray with the color lightening to a yellow-white in adulthood. Reports of sexual maturity range from 4 to 15 years, with males taking longer than females (NMFS 2005b). Calves are born in late spring and early summer, usually in the summer concentration areas following a 14-month gestation period (ADF&G 1994e). Adult females typically produce offspring once every 3 years. Members of the Cook Inlet stock have been observed calving in the Kachemak Bay, off the mouths of the Beluga and Susitna Rivers, and in the Turnagain Arm (NMFS 2005b).

Belugas are social and are frequently observed in groups ranging in size from 2 to 5, to pods of more than 100 individuals. They are known to vocalize using grunts, clicks, chirps, and whistles to navigate, find prey, and communicate. During summer months, they are often found in shallow waters and feed on schooling and anadromous fish including herring, capelin, eulachon, salmon and sculpins (ADF&G 1994e). They are also known to eat octopus, squid, crabs, shrimp clams, mussels and sandworms; belugas appear to have greater feeding success in areas with dense concentrations of prey (NMFS 2005b).

5.5.10.4 Population Trends and Risks

There are five distinct stocks of beluga whales in Alaska, including Cook Inlet, Bristol Bay, Eastern Bering Sea, Eastern Chukchi Sea, and the Beaufort Sea. Of these stocks the Cook Inlet is the only endangered population. NMFS reports that the population trends for the Beaufort Sea and Eastern Bering Sea stocks are unknown (NOAA 2011). The population of the Eastern Chukchi stock, consisting of 3,710 individuals, shows no evidence of decline, while NMFS considers the population of the Bristol Bay stock (2,467) to be increasing (Allen and Angliss 2011a). The most recent surveys of the Cook Inlet population (2010) resulted in 340 animals and are consistent with the continued declining trend for this stock (Allen and Angliss 2011b). In Sims et al. (2012) reported the range of median estimates (275–322) of belugas counted during the August survey to be within or above medians observed for similar surveys conducted in the 7 years prior (2005–2011 surveys). Despite survey results, this population has been noted to be experiencing a declining long-term trend (Ezer et al. 2013), as well as an apparent 4-year cycle related to the Pacific Decadal Oscillation. Ezer et al. (2013) suggest that variations in beluga counts from year to year may represent "observer error and detectability rather than interannual variations in the total number of Cook Inlet beluga whales." The authors suggest that in years where counts are lower, Cook Inlet beluga whale populations may be residing outside of their preferred habitat and may go undetected and thus, the number of animals undercounted.

Abundance estimates for Cook Inlet beluga whales over the last several decades have ranged from 150–1,300 whales. Rodrigues et al. (2006) notes that estimates of historical population levels of Cook Inlet beluga whales may be somewhat problematic. This is because many surveys conducted prior to 1994 were generally nonsystematic or incomplete, and failed to correct for whales not seen below the surface (Rugh et al. 2000). As a result, counts may have underestimated the number of beluga whales present in Cook Inlet.

Population trend analyses conducted on the Cook Inlet stock between June 1994 and June 1998 were constrained by the limited data available, but showed a high probability that a 40 percent decline in the population had occurred during the time period (65 FR 34590; NMFS 2005b). A 2006 status review predicted a 68 percent probability that the Cook Inlet stock will continue to decline and become extinct within the next 300 years. NMFS listed the Cook Inlet beluga whale as endangered under the ESA in 2008 (NMFS 2008a). NMFS reported unusual beluga whale mortality in 2003 (Vos and Shelden 2005), with 20 confirmed beluga deaths in Cook Inlet (the average number of beluga whale deaths per year, excluding Alaska Native harvests from 1994–2002, was 9.6 deaths per year).

NMFS included the Cook Inlet beluga whale stock on the candidate list of threatened and endangered species in 1988 (53 FR 33516). No further action was taken immediately following, although NMFS received two petitions in 1999 to list the Cook Inlet stock under the ESA (65 FR 38778), resulting in the Cook Inlet stock being designated as "depleted" under the MMPA (65 FR 34590). Subsequent investigations assessed natural and human-induced sources of potential impacts that included:

- Habitat capacity and environmental change.
- Stranding events.
- Predation.
- Subsistence harvest.
- Commercial fishing.
- Oil and gas development.

The investigations concluded that subsistence harvests presented the most immediate threat to the stock. Although NMFS found that other potential sources of impact could have some negative effect on recovery, none were considered significant (65 FR 38778). Between 2000 and 2005 co-management agreements between NMFS and the Cook Inlet Marine Mammal Council (Council) have allowed one to two beluga whales to be harvested annually. As a result of a high number of mortalities in 2004 (20 whales), NMFS requested that the Council refrain from harvest that year. NMFS developed the *Draft Conservation Plan for the Cook Inlet Beluga Whale (Delphinapterus leucas)* in 2005 to establish goals and objectives that can be achieved cooperatively to promote the recovery of the Cook Inlet beluga whale population. The goals and objectives apply to a range of potential sources of impacts including those identified above as well as shoreline development, vessel traffic, and noise. The lack of evidence that the population is recovering even with the co-management agreements in place led NMFS to announce in March 2006 that they would be reviewing the status of Cook Inlet beluga stock under the ESA.

Researchers have noted that effects from oil and gas activities, including noise pollution and noise from seismic surveys, could impact marine mammals. Potential effects of seismic activities range from disturbance that may lead to displacement from feeding or breeding areas, to auditory damage and potential mortality (Compton et al. 2008). Physical damage to marine mammals may include damage to body tissues resembling decompression sickness ("the bends") and auditory damage (Compton et al. 2008). Symptoms resembling decompression sickness may result from the initiation of bubble growth caused by sound, or from hypothesized behavioral changes to normal dive profiles (such as a faster ascent rate). Auditory damage is the physical reduction in hearing sensitivity due to exposure to high-intensity sound and can be either temporary (temporary threshold shift [TTS]), or permanent (permanent threshold shift [PTS]) depending on the exposure level and duration. Other than physical damage, the key auditory effect is the increase in background noise levels, such that the ability of an animal to detect a relevant sound signal is diminished, which is known as auditory masking. Masking marine mammal vocalizations used for finding prey, navigation, and social cohesion may compromise the ecological fitness of populations.

Richardson et al. (1995) authored one of the most cited reports on beluga hearing and responses to noise generated from oil and gas activities, geophysical surveys, dredging, construction, and the operation of vessels and aircraft. Richardson et al. (1995) notes confounding factors (such as a change in prey distribution) make it difficult to discern if noise impacts or other factors cause changes in mammal behavior. Further, interactive factors such as differing levels of tolerance, either of different individuals or of the same individuals under subtly different circumstances, confound easy resolution of the question of defining *significant disturbance* for marine mammals, just as in human social studies.

Popov et al. (2013) reported TTS in beluga whale hearing after studying the effects of loud noise exposure on one male and one female beluga whale. Popov et al. (2013) found that the highest TTS with the longest recovery duration was produced by noises of lower frequencies (11.2 and 22.5 kHz) and appeared at a test frequency of +0.5 octave. Although Moore et al. (2000) notes that low frequency (i.e., long wavelength) sound travels poorly in shallow water, so transmission of these sounds in upper Cook Inlet is expected to be confined to relatively short ranges.

Researchers determined that the longer the noise exposure, the longer it took the animals’ hearing to recover; however, the whales’ hearing always recovered completely within a day. Maximum exposure in the Popov et al. (2013) study was 30 minutes of noise exposure. Popov et al. (2013) noted that there was a considerable TTS difference between the two subjects despite the animals being the same age and their initial or baseline hearing being equally as good. Popov et al. (2013) acknowledge that the differences between the male and female subject could not be statistically evaluated at each of the exposure and recording conditions because of the absence of measurement repetition. However, Popov et al. (2013) do suggest that “the general tendency suggested higher susceptibility of the female rather than the male subject to the fatiguing noise.”

5.5.11 NORTHERN SEA OTTER (*Enhydra lutris kenyoni*)

USFWS issued a final rule listing the southwest Alaska distinct population segment of the northern sea otter as threatened under the ESA on August 9, 2005 (70 FR 46366).

5.5.11.1 Geographic Boundaries and Distribution

The overall range of the sea otter extends from northern Japan to southern California. There are three recognized subspecies of *Enhydra lutris. E. lutris kenyoni,* referred to as the northern sea otter, has a range that extends from the Aleutian Islands in southwestern Alaska to the coast of the state of Washington (USFWS 2005).

Northern sea otters occur in nearshore waters, which allow them access to subtidal and intertidal foraging habitats (Angliss and Lodge 2002). Visual observation of 1,251 dives by sea otters in southeast Alaska indicates that foraging activities typically occurs in water depths ranging from 2 to 30 meters (7 to 98 feet), although foraging at depths up to 100 meters (328 feet) was also observed (Bodkin et al. 2004).

Sea otter movements are influenced by local climatic conditions such as storm events, prevailing winds, and in some areas, tidal conditions. They tend to move to protected or sheltered waters during storm events of high winds (USFWS 2005). The animals usually do not migrate and seldom travel unless an area has become overpopulated and food is scarce (ADF&G 1994d).

The home ranges of sea otters in established populations are relatively small. Sexually mature females have home ranges of 8 to 16 kilometers (5 to 10 miles). Breeding males remain for all or part of the year within the bounds of their territory, which constitutes a length of coastline from 100 meters (328 feet) to 1 kilometer (0.6 miles). Male sea otters that do not hold territories may move greater distances between resting and foraging areas than territorial males (USFWS 2005).

Sea otters are found in lower Cook Inlet and Kachemak Bay at all times of the year (Klein 2011, personal communication).

5.5.11.2 Critical Habitat

On October 8, 2009, approximately 15,164 km^2 (5,855 mi^2) of critical habitat was designated for the northern sea otter (74 FR 51988). Five distinct units were identified, including: Unit 1 – Western Aleutian, Unit 2 – Eastern Aleutian, Unit 3 – South Alaska Peninsula, Unit 4 – Bristol Bay, and Unit 5 – Kodiak, Kamishak, Alaska Peninsula. The Bristol Bay unit is further subdivided into three subunits (Amak Island, Izembek Lagoon, and Port Moller/Herendeen Bay). Unit 5, the largest of the designated areas, ranges from Castle Cape in the west to Tuxedni Bay in the east, and includes the Kodiak Archipelago. It contains all the primary constituent elements (PCEs) necessary for the conservation of the southwest Alaska northern sea otter population and thus, is subject to special management considerations and protections to minimize the risk of oil and other hazardous-material spills from commercial shipping (74 FR 51988).

Activities in the west side of lower Cook Inlet will occur within the Kamishak Bay Unit of designated critical habitat, which extends as far north as Tuxedni Bay. The critical habitat extends from the mean high tide line seaward for a distance of 100 meters, or to a water depth of 20 meters. Critical habitat provides the physical and biological features (the PCEs) essential to the conservation of this species. The PCEs of sea otter critical habitat are: (1) shallow, rocky areas less than 2 meters (6.6 feet) in depth where marine predators are less likely to forage; (2) nearshore waters within 100 meters (328.1 feet) from the mean high tide line that may provide protection or escape from marine predators; (3) kelp forests, which occur in waters less than 20 meters (65.6 feet) in depth that provide protection from marine predators; and (4) prey resources within the areas identified by PCEs 1, 2, and 3 that are present in sufficient quantity and quality to support the energetic requirements of the species (Klein 2011, personal communication). Critical habitat for northern sea otter can be seen in Figure 5 below.

5.5.11.3 Life History

Sea otters mate at all times of the year, and young may be born in any season; however, in Alaska, most pups are born in late spring (ADF&G 1994d). Females typically give birth in the water, although they have been observed giving birth on shore (USFWS 2005). Male sea otters appear to reach sexual maturity at 5 to 6 years of age, and have a life span of about 10 to 15 years. Female sea otters reach sexual maturity at 3 to 4 years of age and have a life span of about 15 to 20 years (USFWS 2005). Sea otters are gregarious and may become concentrated in an area, sometimes resting in pods of fewer than 10 to more than 1,000 animals (ADF&G 1994d).

The search for food is one of the most important daily activities of sea otters, as large amounts are required to sustain the animal in healthy condition. Sea urchins, crabs, clams, mussels, octopus, other marine invertebrates, and fishes make up the normal diet of sea otters (ADF&G 1994d).

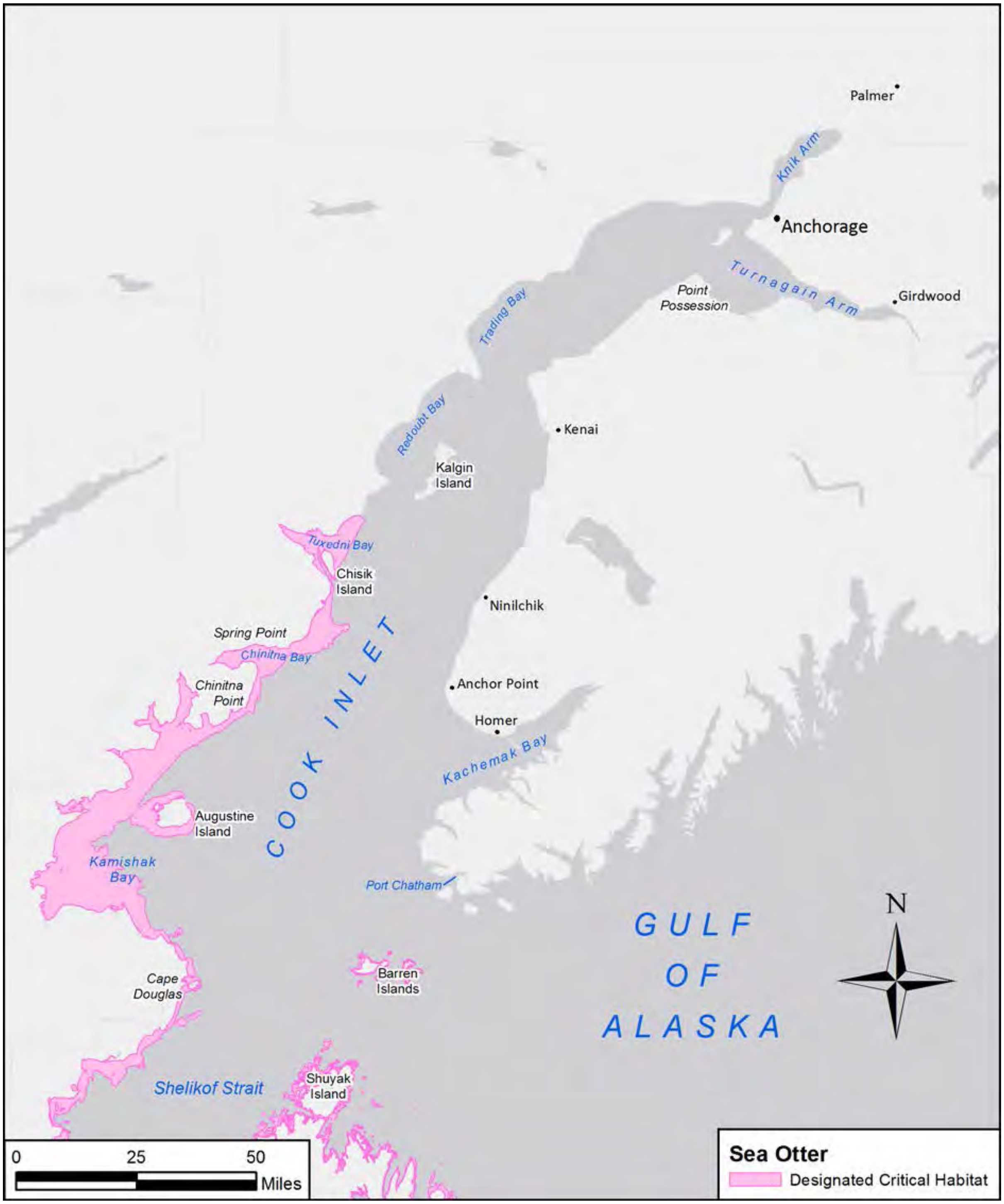


Figure 5: Northern Sea Otter Critical Habitat in Cook Inlet

5.5.11.4 Population Trends and Risks

Prior to commercial exploitation, the world population of sea otter in the North Pacific Ocean was estimated to be between 150,000 and 300,000 individuals (USFWS 2005). Over the 170 years of commercial exploitation, sea otters were hunted to the brink of extinction, first by Russian and later by American fur hunters. Sea otters became protected under the International Fur Seal Treaty of 1911; at that time the entire population may have been reduced to between 1,000 and 2,000 animals (USFWS 2005).

By the 1980s, sea otters in southwest Alaska had increased in abundance and recolonized much of their former range. However, aerial surveys conducted in 2000 indicated widespread declines throughout the Aleutian Islands, particularly in the central Aleutians. Doroff et al. (2003) estimated that sea otter populations had decreased approximately 70 percent from a similar survey conducted in 1992. Despite the dramatic declines in the Aleutians, populations in the Kodiak Archipelago do not appear to follow the same trend (Burn and Doroff 2005). At present, the population in southwest Alaska is estimated at 53,674 animals (USFWS 2010); 54 percent (28,955 animals) of this total occurs within the Kodiak Archipelago. Throughout the remainder of their range, sea otter populations have declined in the range of 39 percent to 74 percent.

5.5.12 STELLER SEA LION *(Eumetopias jubatus)*

The NMFS listed Steller sea lion as threatened, by emergency interim rule, on April 5, 1990 (55 FR 12645). The emergency rule listing, which had a 240-day duration, was followed by a final listing of Steller sea lion as threatened on November 26, 1990 (55 FR 49204). On May 5, 1997, the NMFS issued a final rule that reclassified Steller sea lions into two distinct population segments (62 FR 24355). The Steller sea lion population west of 144 °W longitude (a line intersecting the Alaskan coastline near Cape Suckling) was reclassified as endangered; the sea lion population to the east of this line retained its ESA-listing status as threatened; both stocks are therefore designated as "depleted" under the MMPA.

Demarchi et al. (2012) have noted the Steller sea lion short-term response to noise, although the same author notes the limited body of information available on this topic. Demarchi et al. (2012) examined response to military explosions on a winter haulout complex located in southern Vancouver Island, Canada, over a period spanning from 1997 to 2010. Acoustic measurements confirmed that in-air noise reached levels capable of causing pinniped disturbance (i.e., > 109 dBF peak), but not injuries such as a PTS in hearing (i.e., < 149 dBF peak). Sea lions showed a significant increase in activity following blasting and were commonly displaced from haulouts. Within minutes of the disturbance, however, activity levels dropped sharply, and displaced animals usually began returning to haulouts. Activity levels on the day after blasting were similar to levels on days prior to blasting. The authors acknowledge the limited body of research done on this topic for Steller sea lions (Demarchi et al. 2012.

5.5.12.1 Geographic Boundaries and Distribution

The Steller sea lion is distributed around the North Pacific Ocean rim from northern Hokka, Japan, along the western North Pacific northward through the Kuril Islands and Okhotsk Sea, then eastward through the Aleutian Islands and central Bering Sea, and southward along the eastern North Pacific to the Channel Islands, California (NMFS 2008b). Two distinct populations (western and eastern) are thought to occur within this range, with the dividing line being designated as 144 °W longitude (62 FR 24355).

There is designated critical habitat for Steller sea lion and other habitat considered as critical habitat by the NMFS within the lease sale area: at Cape Douglas, the Barren Islands, and marine areas adjacent to the southwestern Kenai Peninsula, and at the extreme southern end of Cook Inlet. There is additional critical habitat—including rookeries, haulouts, and marine foraging areas for the western population stock—in areas near the lease sale area, including Shelikof Strait and areas along the southern side of the Alaska Peninsula (MMS 2003).

5.5.12.2 Critical Habitat

In 1993 NMFS issued a final rule designating critical habitat for the Steller sea lion, including all U.S. rookeries, major haulouts in Alaska, horizontal and vertical buffer zones (5.5 kilometers [3.4 miles]) around these rookeries and haulouts, and three aquatic foraging areas in North Pacific waters: Sequam Pass, southeastern Bering Sea shelf, and Shelikof Strait (58 FR 45269). This final rule was amended on June 15, 1994, to change the name of one designated haulout site from Ledge Point to Gran Point and to correct the longitude and latitude of 12 haulout sites, including Gran Point (59 FR 30715).

Critical habitat includes a terrestrial zone that extends 3,000 feet (0.9 kilometers) landward from the baseline or base point of each major rookery and major haulout in Alaska. Critical habitat includes an air zone that extends 3,000 feet (0.9 kilometers) above the terrestrial zone of each major rookery and haulout area measured vertically from sea level. Critical habitat within the aquatic zone in the area east of 144 °W longitude (ESA threatened population) extends 3,000 feet (0.9 kilometers) seaward in state- and federally managed waters from the base point of each rookery or major haulout area. Critical habitat within the aquatic zone in the area west of 144 °W longitude (ESA endangered population) extends 20 nautical miles (37 kilometers) seaward in state- and federally managed waters from the baseline or base point of each rookery or major haulout area (58 FR 45269). Critical habitat in Cook Inlet can be seen in Figure 5 below.

5.5.12.3 Life History

The breeding season for Steller sea lions is from May to July, where the animals congregate at rookeries and the males defend territories, mating occurs, and the pups are born. Nonreproductive animals congregate to rest at more than 200 haulout sites where little or no breeding occurs. Bulls become sexually mature between 3 and 8 years of age, but typically are not able to gain sufficient size and successfully defend territory within a rookery until 9 to 10 years of age. Females reach sexual maturity and mate between 4 and 6 years of age and typically bear a single pup each year. Sea lions continue to gather at both rookeries and haulout sites throughout the year, outside of the breeding season (NMML 2004). Habitat types that typically serve as rookeries or haulouts include rock shelves; ledges; slopes; and boulder, cobble, gravel, and sand beaches. Seasonal movements occur generally from exposed areas in summer to protected areas in winter (ADF&G 1994c).

When foraging in marine habitats, Steller sea lions typically occupy surface and mid-water ranges in coastal regions. They are opportunistic predators and feed on a variety of fish (walleye pollock, Atka mackerel (*Pleurogrammus monopteryguius*), Pacific herring, capelin, sand lance, Pacific cod (*Gadus macrocephalus*), salmon, and invertebrates (squid, octopus) (ADF&G 1994c; NMFS 2008b).

Figure 6: Steller Sea Lion Critical Habitat in Cook Inlet

5.5.12.4 Population Trends and Risks

In 1980 the world population of Steller sea lion was estimated to be between 245,000 and 290,000 (Loughlin et al. 1992). The western population of Steller sea lion declined approximately 5.0 percent per year over the period of 1991 to 2000, while the eastern population has increased at about 1.7 percent per year (Loughlin and York 2000). Based on data collected in 2003 and 2004, Fritz and Stinchcomb (2005) cautiously concluded that the decline of the western population within the Alaskan territory has slowed and showed a modest increase estimated at 2.4 to 4.2 percent. More recent surveys appear to confirm the stability of the population. Fritz et al. (2008a) found the Stellar sea lion population remained unchanged between 2004 (N=23,107) and 2007 (N=23,118) throughout much of its range from Cape St. Elias to Tanaga Island (145° W to 178° W). Aerial surveys conducted in 2008 also supported these findings (Fritz et al. 2008b)

A substantial amount of research has been devoted to determining the cause(s) of the Steller sea lion decline, whose number has dropped by more than 80 percent in the last three decades in Alaskan waters (National Academies 2002). Currently, there is no consensus on a single causal factor, and it is likely that many factors could have contributed to the decline of this species (NMML 2004). The hypotheses can be divided into two categories (National Academies 2002); those that propose factors that would affect the overall health and fitness of sea lions and those that propose factors that would directly kill sea lions regardless of their general health. The first four items listed below fall into the former category; the last five items fall within the latter category.

- Reduced prey availability or prey quality due to large-scale fishing operations
- Climate changes in the 1970s that may have affected the availability of quality of prey
- Non-fatal diseases that inhibit sea lions' ability to forage for food
- Impairment (reduced fecundity) caused by the consumption of contaminated prey
- Predation by killer whales
- Incidental mortality caused by fishing operations
- Illegal harvest
- Subsistence harvesting
- Fatal diseases caused by contagious pathogens or increased exposure to pollutants

While there may not be consensus on a single causative factor for the decline of sea lion abundance in Alaskan waters, nutritional stress is probably the leading hypothesis (Fritz and Hinckley 2005; Porter 1997; Trites and Donnelly 2003). Sea lion declines in abundance have coincided with the declines of other Alaskan pinniped stocks (harbor seal and northern fur seal) and some seabird breeding colonies. Over the same period of these declines, there has been a rapid growth in groundfish fisheries in Alaska, which suggests that competition by fisheries and reduced prey availability may be limiting the growth and reducing the fitness of sea lions (Porter 1997). Pollock make up over 50 percent of the prey consumed by sea lions; the removal of large quantities of Pollock, and other groundfish that could provide alternative prey, by commercial fisheries may have caused increased nutritional stress and reduced the fitness of sea lions, resulting in increased mortality rates.

5.6 Essential Fish Habitat in Project Area

An EFH assessment is applied to the defined EFH for all species managed under a federal Fisheries Management Plan (FMP). The following FMPs have fisheries resources that might be affected by the action:

- The FMP for Groundfish of the Gulf of Alaska.
- The FMP for Scallop Fishery off Alaska.
- The FMP for the Salmon Fisheries in the EEZ off the coast of Alaska.

The NMFS has recently updated an Environmental Impact Statement (EIS) defining EFH for the Alaskan region affected by these and other FMPs (NMFS 2010c). The definition NOAA Fisheries uses for a species' EFH is based on the subset of the species' population and is 95 percent of the population for a particular life stage, if life history data are available for the species. Where information is insufficient and a suitable proxy cannot be inferred, EFH is not described for that species life stage.

The EFH species and life stages present in the Gulf of Alaska are shown for groundfish, weathervane scallops, and salmon in Tables 5-2, 5-3, and 5-4, respectively. EFH species in Cook Inlet is mapped in Figure 6.

Table 5-2. Gulf of Alaska Groundfish EFH Species Life Stages Present in the Project Area

Gulf of Alaska species	Eggs	Larvae	Early juvenile	Late juvenile	Adult
Walleye pollock	1	1	-	1	1
Pacific cod	2	1	-	1	1
Yellowfin sole	2	2	-	2	2
Arrowtooth flounder	-	1	-	1	1
Rock sole	-	1	-	1	1
Alaska plaice	1	2	-	2	2
Rex sole	1	1	-	1	1
Dover sole	1	1	-	1	1
Flathead sole	1	1	-	1	1
Sablefish	2	1	-	1	1
Shortraker/rougheye rockfish	-	1	-	2	2
Northern rockfish	-	-	-	-	2
Thornyhead rockfish	-	1	-	2	2
Yelloweye rockfish	-	1	-	2	2
Dusky rockfish	-	1	-	-	2
Atka mackerel	2	2	-	-	2
Sculpins	-	-	-	1	1
Skates	-	-	-	-	1
Sharks	-	-	-	-	-
Forage fish complex	-	-	-	-	-
Squid	-	-	-	1	1
Octopus	-	-	-	-	-

- = no information is available to define EFH in the Gulf of Alaska.
1 = life stage with defined EFH in the project area.
2 = life stage with defined EFH, but none in the project area. Source: NMFS 2005c.

Table 5-3. Alaska Scallops' EFH Life Stages Present in the Project Area					
Scallop species	**Egg**	**Larvae**	**Early juvenile**	**Late juvenile**	**Adult**
Weathervane	-	-	-	1	1

- = no information is available to define EFH in the Gulf of Alaska.
1 = life stage with defined EFH in the project area.
2 = life stage with defined EFH, but none in the project area. Source: NMFS 2005c.

Table 5-4. Salmon Species' EFH Life Stages Present in the Project Area						
Salmon species	**Freshwater eggs**	**Freshwater larvae and juveniles**	**Estuarine juveniles**	**Marine juveniles**	**Marine immature and maturing**	**Freshwater adults**
Pink Chum Sockeye Chinook Coho	2	2	1	1	1	2
	2	2	1	1	1	2
	2	2	1	1	1	2
	2	2	1	1	1	2
	2	2	1	1	1	2

- = no information is available to define EFH in the Gulf of Alaska.
1 = life stage with defined EFH in the project area.
2 = life stage with defined EFH, but none in the project area. Source: NMFS 2005c.

5.7 SPECIES ESSENTIAL FISH HABITAT DESCRIPTIONS

This section presents information on EFH characteristics and general life history for only species with defined EFH in the project area. Species without defined EFH in the project area are not discussed. With the exception of EFH for salmon species, all other defined EFH in the project area is limited to the outer third of Cook Inlet, with most near or just outside the Cook Inlet entrance. (See Appendix D of NMFS 2005c and NMFS 2010c)

5.7.1 Walleye Pollock

The egg, larval, late juvenile, and adult life stages of walleye pollock have EFH in the project area. With the exception of the adult life stage, which extends into Kachemak Bay, all others are restricted to extending slightly inside the Cook Inlet entrance. Eggs, which are pelagic, are found at depths from 0 to 1,000 meters. The epipelagic larvae have a similar distribution. Juveniles and adults are most often in the lower and middle portions of the water column, at depths less than 200 meters (656 feet) for juveniles and between approximately 10 to 1,000 meters (3.3 to 3,280 feet) for adults. These life stages have no substrate preference. Seasonal migrations occur from the OCS to shallow waters (90 to 140 meters, or 295 to 459 feet) for spawning. Spawning takes place in early spring; the eggs hatch in about 10 to 20 days, depending on water temperature, and larvae spend 20 to 30 days in the surface waters.

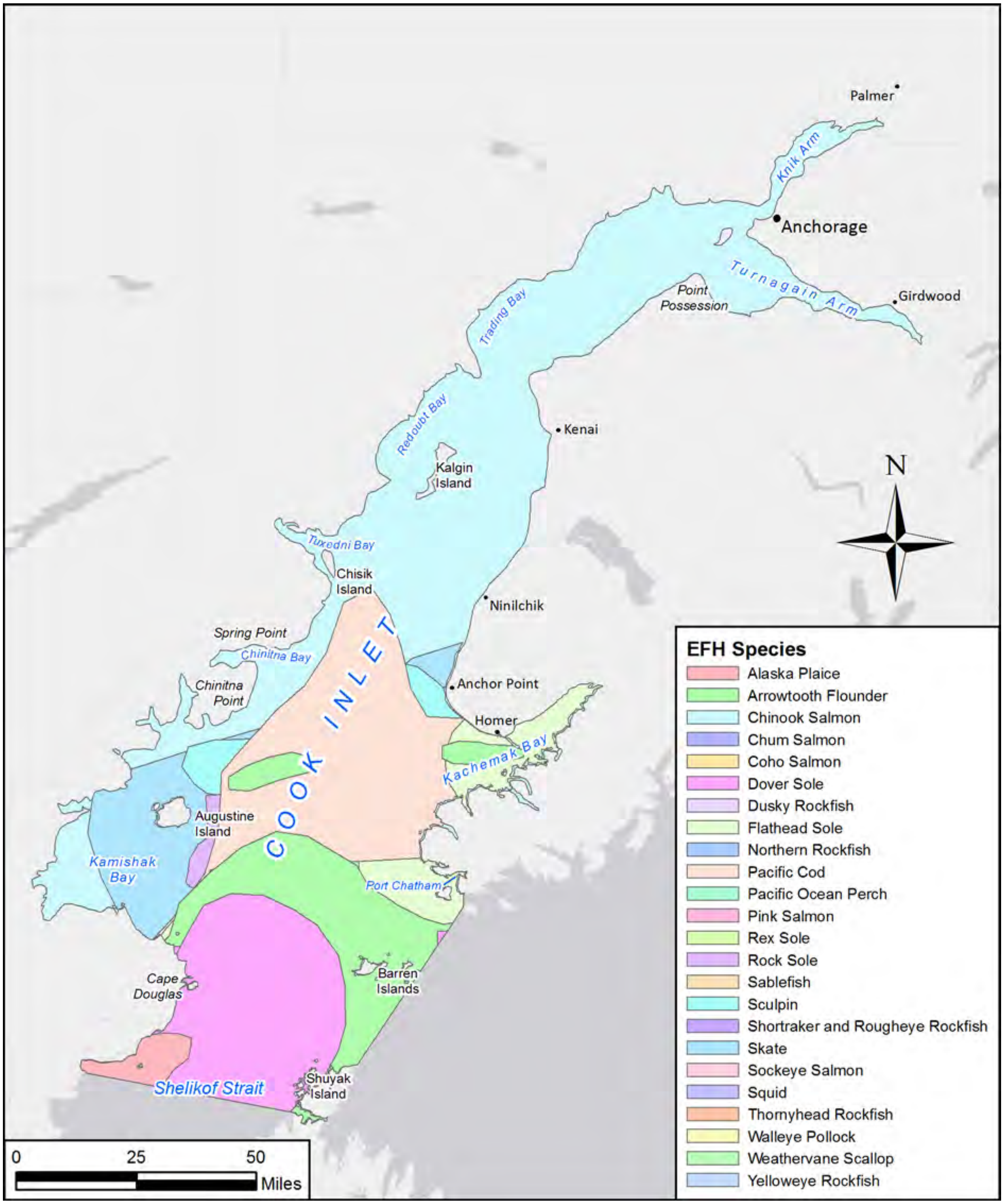


Figure 7: Essential Fish Habitat in Cook Inlet

5.7.2 Pacific Cod

EFH for larvae, late juveniles, and adults is present in the Permit coverage area; however, only the adult stage EFH extend well into Cook Inlet, while others are restricted to near the entrance. Pacific cod is generally a demersal species that occurs on the continental shelf and upper continental slope (NMFS 2010c). Spawning habitat occurs along the continental shelf and slope from about 40 to 290 meters (131 to 951 feet); spawning typically occurs from January to April. The optimal conditions for embryo development are water temperatures between 3 ˚C and 6 ˚C (37 °F and 43 °F) and dissolved oxygen concentrations from 2 to 3 parts per million (ppm) saturation. The larvae are epipelagic, occurring primarily in the upper 45 meters (148 feet) of the water column shortly after hatching, and they move downward in the water column as they grow. The larvae occur primarily in waters less than 100 meters (328 feet) deep over soft substrate. Juvenile and adult EFH occurs in the lower portion of the water column in the inner, middle, and outer continental shelf from 0 to 200 meters (656 feet), where their preferred substrate is soft sediment primarily from mud to gravel (NMFS 2005c).

5.7.3 Arrowtooth Flounder

EFH in the project area includes larvae, near the Cook Inlet entrance, and juveniles and adults, extending into Cook Inlet as far as Kachemak Bay. All life stages of Arrowtooth flounder occur along the entire continental shelf region with water depths ranging from 0 to 3000 meters. Spawning is thought to occur from September through March. Larvae are planktonic for at least 2 to 3 months until metamorphosis occurs; juveniles usually inhabit shallow areas until reaching 10 to 15 centimeters in length (Martin and Clausen 1995). Adults are found in continental shelf waters until age 4, and they occupy both shelf and deeper slope waters at older ages with highest concentrations at 100 to 200 meters (328 to 656 feet) (NMFS 2005c). Both adults and juveniles are often found over soft substrate, typically mud and sand, in the lower portion of the water column.

5.7.4 Rock Sole

Project area EFH for larvae occurs near the Cook Inlet entrance, while juvenile and adult EFH extends beyond the Kachemak Bay entrance. All life stages of rock sole, except the egg stage, occur in the inner continental shelf regions. Spawning takes place during late winter/early spring near the edge of the continental shelf at depths from 125 to 250 meters (410 to 820 feet). The eggs are demersal and adhesive. The larvae are planktonic for at least 2 to 3 months until metamorphosis occurs. The juveniles inhabit shallow waters until at least age 1 (NMFS 2005c). Juveniles and adults occur over moderate to softer substrates of sand, gravel, and cobble, mostly at depths from 0 to 200 meters.

5.7.5 Alaska Plaice

EFH for Alaska plaice in the project area includes eggs, late juveniles, and adults. The EFH for all three life stages is at the outer edge of the project area, outside Cook Inlet. Alaska plaice is considered a deepwater species in the Gulf of Alaska groundfish management area, located generally along the entire continental shelf and the slope (NMFS 2010c). Eggs are present over a range of depths (0 to 500 meters) in the spring. Juvenile and adult EFH is in the lower portion of the water column at depths of 0 to 200 meters, over sand and mud substrate (NMFS 2005c).

5.7.6 Rex Sole

All life stages of Rex sole EFH are present in the project area. All EFH is present only in the area at the entrance of Cook Inlet. Pelagic eggs and larvae are present over a range of depths (0 to 500 meters) from October to June (Abookire 2006). EFH of juveniles and adults is in the lower portion of the water column at depths of 0 to 200 meters, but are most abundant at depths between 100 and 200 meters (NMFS 2010c). Juvenile and adult individuals can be found over gravel, sand, and mud substrate (NMFS 2005c).

5.7.7 Dover Sole

The project area EFH for Dover sole egg, larval, late juvenile, and adult life stages is present only near the Cook Inlet entrance. This fish is considered a deepwater flatfish in the Gulf of Alaska management area. The EFH ranges to great depths (0 to 3,000 meters) for planktonic larvae and eggs, although adult and juvenile EFH is less deep (0 to 500 meters) in the middle and outer shelf and upper slope areas, occurring in the lower portion of the water column over soft substrate of sand and mud (NMFS 2005c).

5.7.8 Flathead Sole

The Flathead sole EFH for eggs and larvae extends inside the Cook Inlet entrance, while late juvenile and adult habitat extends into Kachemak Bay in the project area. The adults are benthic and have separate winter spawning and summer feeding distributions. The fish overwinter near the continental shelf margin and then migrate onto the mid- and outer continental shelf areas in the spring to spawn in deepwater areas near the margin of the continental shelf. The eggs are pelagic, and the larvae are planktonic, and usually inhabit shallow areas. Egg and larval EFH ranges from 0 to 3000 meters, while juveniles' and adults' EFH is shallower (0 to 200 meters) and occurs over sand and mud substrate. Like all flatfish, Flathead sole occur in the lower portion of the water column.

5.7.9 Sablefish

The EFH for larval, juvenile, and adult sablefish is present only at the entrance of the Cook Inlet in the project area. Spawning is pelagic at depths of 300 to 500 meters (984 to 1,640 feet) near the edges of the continental slope. Larvae are oceanic through the spring; by late summer, small juveniles (10 to 15 centimeters [4 to 6 inches]) occur along the outer coasts of southeast Alaska, where they predominantly spend their first winter. First- to second-year juveniles are found primarily in nearshore bays; they move to deeper offshore waters as they age, with EFH habitat at depths of 200 to 1,000 meters (656 to 3,280 feet). Adults are found on the OCS mainly on the slope and in deep gullies at typical depths of 200 to 1,000 meters (656 to 3,280 feet), over varied habitat, usually in soft substrate (NMFS 2005c).

5.7.10 Rockfish

Some 32 rockfish species are present in Alaskan waters, but only 7 rockfish species (Table 5-2) have designated EFH in the Gulf of Alaska (NMFS 2005c). The EFH of larvae for all rockfish species is grouped, not separated by species. Within the project area rockfish larvae are present only near the Cook Inlet entrance. No juvenile or adult EFH for any of the seven rockfish species is present in the project area because all habitat for these life stages is present in deeper water, often near the continental shelf, or in other nearshore areas of the Gulf of Alaska. The EFH for rockfish larvae is characterized as being in the entire shelf (0 to 200 meters [656 feet]) and slope areas (200 to 3000 meters [656 to 9,843 feet]), except the EFH for Pacific Ocean perch, which extends only to a 500-meter (1,640-foot) depth in the upper slope area. In general, rockfish tend to be demersal as late juveniles and adults, although some species are pelagic occupying midwater areas. Many species are associated with rocky substrates. Rockfish have internal fertilization and release live young in the spring (NMFS 2005c).

5.7.11 Sculpins

Though a demersal fish, the EFH for juvenile and adult sculpins in the project area is present only in a narrow band extending from Kachemak Bay in the east to Kamishak Bay, north of Augustine Island, to the west (NMFS 2005c). Both juveniles and adults are present in the lower portion of the water column in the inner, middle, and outer shelf (0 to 200 meters) and also in the upper slope (200 to 500 meters) in the Gulf of Alaska, over varied substrate (mud to rock). Most spawning occurs in the winter, and some species have internal fertilization. Eggs are typically laid in rocks, where males guard them. Larvae often have diel migration (near the surface at night) and might be present year-round.

5.7.12 Skates

The EFH for adult skates extends well into the Cook Inlet project area, beyond Kachemak Bay, and covers most of outer third of the inlet (NMFS 2005c). Adult EFH is found in waters of 0 to 500 meters (1,640 feet) on shelf and upper slope areas. Adult skates are present in the lower portion of the water column over varied substrate from mud to rock. Skates are oviparous, fertilization is internal, and eggs are deposited in a horny case for incubation. After hatching, the juveniles likely remain in shelf and slope waters, but their distribution is unknown. No data on habitat requirements or movement are available (NMFS 2005c).

5.7.13 Squid

The EFH for juvenile and adult squid is present only in the outer portion of the project area, between Cape Douglas and the Barren Islands, outside Cook Inlet. Juveniles and adults use the entire water column over the shelf (0 to 500 meters [1,640 feet]) and all the slope (500 to 1,000 meters [1,640 to 3,280 feet]) regions (NMFS 2005c). Reproduction is poorly known, but fertilization is internal, and squid lay eggs in gelatinous masses in water 200 to 800 meters (656 to 2,625 feet) deep. Young juveniles are often in water less than 100 meters deep, while older juveniles and adults are more often in waters 150 to 500 meters (492 to 1,640 feet) deep. Spawning occurs in the spring, over rocks, shells, and other hard substrate (NMFS 2010c).

5.7.14 Weathervane Scallop

The designated EFH for late juvenile and adult weathervane scallops extends well into the outer half of Cook Inlet to beyond the entrance to Kachemak Bay. The EFH habitat of late juveniles and adults is along the seafloor in the middle (50- to 100-meter [164- to 328-foot]) to outer (100- to 200-meter [328- to 656-foot]) shelf areas. It is generally elongated along the current lines, as is apparent in the EFH in Cook Inlet, which tends to be in an elongated distribution toward the middle of the inlet (NMFS 2005c). The scallops are generally over clay to gravel substrates. Although they are capable of swimming, they usually remain along seafloor depressions. Fertilization is external, and pelagic larvae drift for a month before they settle to the seafloor (NMFS 2005c).

5.7.15 Pink Salmon

The EFH for pink salmon within the project area includes estuarine juvenile, marine juvenile, and marine immature and maturing adults (NMFS 2005c). The estuarine EFH is the mouth areas of streams from the mean high tide line to the salinity transition zone. All other marine life stage EFH includes the entire project area because EFH for this species extends from the mean higher tide line to the 200-nautical-mile limit of the U.S. EEZ. This species is pelagic to a depth of about 200 meters. Pink salmon spawn in small streams within a few miles of the shore, within the intertidal zone, or at the mouths of streams. Eggs are laid in stream gravels. After hatching, salmon fry move downstream to the open ocean. Pink salmon stay close to the shore, moving along beaches during their first summer feeding on plankton, insects, and small fish. At about 1 year of age, pink salmon move offshore to ocean feeding areas.

5.7.16 Chum Salmon

The EFH for chum salmon within the project area includes estuarine juveniles, marine juveniles, and marine immature and maturing adults (NMFS 2005c). The estuarine EFH is the mouth areas of streams from the mean high tide line to the salinity transition zone. All other marine life stage EFH includes the entire project area because EFH for this species extends from the mean high tide line to the 200-nautical-mile limit of the U.S. EEZ. This species is pelagic to a depth of about 200 meters. Most chum salmon spawn in small streams within a few miles of the shore, or within the intertidal zone, but some travel great distances up large rivers. Eggs are laid in stream gravels. After hatching, salmon fry move downstream to the open ocean.

5.7.17 Sockeye Salmon

The EFH for sockeye salmon within the project area includes estuarine juveniles, marine juveniles, and marine immature and maturing adults (NMFS 2005c). The estuarine EFH is the mouth areas of streams from the mean high tide line to the salinity transition zone. All other marine life stage EFH includes the entire project area because EFH for this species extends from the mean high tide line to the 200-nautical-mile limit of the U.S. EEZ. This species is pelagic to a depth of about 200 meters. Sockeye spawn in stream systems with lakes in late summer and autumn. After 1 to 3 years in freshwater lakes, the fry move downstream to the open ocean.

5.7.18 Chinook Salmon

The EFH for chinook salmon within the project area includes estuarine juveniles, marine juveniles, and marine immature and maturing adults (NMFS 2005c). The estuarine EFH is the mouth areas of streams from the mean high tide line to the salinity transition zone. All other marine life stage EFH includes the entire project area because EFH for this species extends from the mean high tide line to the 200-nautical-mile limit of the U.S. EEZ. This species is pelagic to a depth of about 200 meters. Chinook spawn in small and large streams, and the eggs are laid in stream gravels. After hatching, salmon fry move downstream to the open ocean. Freshwater ecosystems in the Pacific Northwest represent EFH for sustaining the diversity and abundance of chinook salmon throughout the Alaska EEZ (NMFS 2010c).

5.7.19 Coho Salmon

The EFH for coho salmon within the project area includes estuarine juveniles, marine juveniles, and marine immature and maturing adults (NMFS 2005c). The estuarine EFH is the mouth areas of streams from the mean high tide line to the salinity transition zone. All other marine life stage EFH includes the entire project area because EFH for this species extends from the mean high tide line to the 200-nautical-mile limit of the U.S. EEZ. This species is pelagic to a depth of about 200 meters. Coho salmon spawn in small streams and the eggs are laid in stream gravels. After 1 to 3 years in freshwater ponds, lakes, and stream pools, the salmon fry move downstream to the open ocean.

6.0 DETERMINATION OF NO UNREASONABLE DEGRADATION

Under the Ocean Discharge Criteria regulations, no NPDES permit may be issued if it is determined to cause unreasonable degradation of the marine environment. EPA considers the 10 Ocean Discharge Criteria and other factors specified in 40 CFR Part 125, Subpart M when evaluating the potential for unreasonable degradation. Unreasonable degradation of the marine environment is defined as:

- Significant adverse changes in ecosystem diversity, productivity, and stability of the biological community in the area of discharge and surrounding biological community;
- Threat to human health through direct exposure to pollutants or through consumption of exposed aquatic organisms; or
- Loss of aesthetic, recreational, scientific, or economic values that are unreasonable in relation to the benefit derived from the discharge.

Neither CWA § 403 nor EPA's implementing regulations require EPA to ensure that there is no degradation before issuing a permit. Nor do the regulations require EPA to have complete knowledge of the potential effects of a discharge before permit issuance. Rather, a determination is made on the basis of available information. In addition, EPA must exercise reasonable judgment when making a determination about unreasonable degradation.

In cases where sufficient information is available to determine whether unreasonable degradation of the marine environment will occur, 40 CFR 125.123(a) and (b) govern EPA's actions. Discharges that cause unreasonable degradation will not be permitted. Other discharges may be authorized with necessary permit conditions to ensure that unreasonable degradation will not occur.

In circumstances where there is insufficient information to determine, before permit issuance, that a discharge will not result in unreasonable degradation, a discharge may be permitted if EPA determines on the basis of available information that:

- Such discharges will not cause irreparable harm to the marine environment during the period in which monitoring is undertaken;
- There are no reasonable alternatives to the on-site disposal of these materials; and
- The discharge will be in compliance with all permit conditions established pursuant to 40 CFR 125.123(d).

6.1 DETERMINATION OF NO UNREASONABLE DEGRADATION

The 2007 Permit established discharge rate and depth limits for drilling fluid and drill cuttings discharges, toxicity triggers for seawater and freshwater discharges to which treatment chemicals have been added as well as discharge prohibitions in several environmentally sensitive areas of Cook Inlet. EPA reviewed these limits and triggers and determined that it is appropriate to retain these requirements in the Permit to ensure waterbody protection.

Based on the information provided in Sections 1-5 and the evaluation provided below, EPA has determined that the discharges authorized by the 2016 Permit will not cause unreasonable degradation of the marine environment, provided that the discharges meet the requirements and conditions specified in the Permit. EPA's ocean discharge criteria evaluation, related findings, and determinations are discussed in this section.

6.1.1 Criterion 1

The quantities, composition, and potential for bioaccumulation or persistence of the pollutants to be discharged:

6.1.1.1 Quantities and Estimated Discharge Volumes

Sediment mass discharge rates, sediment transport, and chemical partitioning on sediment particles are key factors for evaluating the persistence of pollutants proposed to be discharged under the Permit. Chemicals that are expected to persist in the environment typically have an affinity for portioning onto fine-grained sediment. The composition and estimated discharge volumes for all proposed discharges were discussed in Section 3.

The total estimated volume of drilling fluids and drill cuttings for 12 exploration wells considered in this ODCE is 187,200 bbls and 52,200 bbls, respectively. These figures are based on maximum values reported in a recent End of Well Report submitted for a well drilled to 15,298 feet, which included the cumulative discharge of 15,600 bbls of drilling fluids and a calculated volume of 4,350 bbls of drill cuttings. By using the deepest well drilled to date, EPA believes this estimate provides a realistic maximum estimate of volumes that can be expected over the five year permit term to base a determination of no unreasonable degradation. These estimates are less than the volumes noted in the Draft ODCE for the Permit. As discussed previously, drill cuttings are expected to become mixed with natural coarse grained sediment near the vicinity of the discharge while the fine-grained drilling fluids are transported from the site as sediment. On an annual basis, the estimated volume of drilling fluids represents a small fraction of the total sediment load in Cook Inlet (see Section 3.4).

6.1.1.2 Drilling Fluids Composition and Potential for Persistence

The composition of drilling fluids and drill cuttings was presented in Section 3.1.1. Table 3-2 provides a listing of metals that potentially could persist in the environment as a result of discharging drilling fluids and drill cuttings under the Permit. The ELGs recognize cadmium and mercury as surrogate metals for evaluating metals in the discharge of drilling fluids and drill cuttings. Persistence of pollutants in the environment may be indicated by elevated concentrations in fine-grained sediments or in organisms in the vicinity of the discharge. Fish tissue samples collected to date do not suggest there is a concern for bioaccumulation from the discharge of pollutants from oil and gas facilities. Metal tissue concentrations from Cook Inlet species are comparable to tissue concentrations from other locations in Alaska. See Section 6.1.6 for a more detailed discussion on fish tissue sampling results.

Similar to tissue samples, recent analysis of fine grain sediment in Cook Inlet does not indicate metals are accumulating in areas of deposition that could be influenced by discharges from oil and gas. ICIEMAP results indicate the metals typically associated with drilling fluids were at background concentrations at all 55 sites sampled and these concentrations were below effects range-medium (ERM) and effects range-low (ERL) sediment quality guidelines. Furthermore, there was no evidence suggesting metal concentrations in bottom sediments were being impacted from oil and gas discharges. This conclusion appears to be transferrable to discharges proposed under the Permit when considering the potential annual volume input of sediment from the proposed discharge of drilling fluids compared to the natural sediment load entering Cook Inlet from streams.

Using USGS 1999 data for annual sediment load in Cook Inlet (44 million tons) and the annual estimate of drilling fluid from exploration facilities (Table 3-4), the percentage of drilling fluid that could be mixed into the total the sediment being deposited in the lower Cook Inlet is very small, 0.031%. This small percentage of sediment load was reviewed in relation to the metal ELGs for barite, with 3 mg/kg of cadmium and 1 mg/kg of mercury rather than reported barite concentrations which are typically lower (See Table 3-2). The contribution of drilling fluids in the total sediment load was estimated to be 0.00099 mg/kg cadmium and 0.00014 mg/kg mercury. The maximum concentrations observed in Cook Inlet sediment in the Produced Water Study (Kinnetic Laboratories, Inc. 2010) data was 0.30 mg/kg for cadmium and 0.14 mg/kg for mercury, and guidelines for ERL are 1.2 mg/kg and 0.15 mg/kg, respectively (NOAA 1999b). By direct comparison, the potential impact from drilling fluids metals in Cook Inlet sediments that may lead to adverse effects is negligible.

There have been several surveys of the concentrations of metals in tissues of marine animals from the vicinity of offshore water-based drilling fluids and drill cuttings discharges in temperate and cold-water marine environments near drilling operations (Neff 2010). In nearly all cases, these surveys have shown that metals and hydrocarbon concentrations in tissues of marine animals near drilling operations are similar to concentrations in tissues of the same or similar species well away from and out of the influence of the drilling operations.

As described in the PERF (2005) study, most of the metals in drilling fluids and drill cuttings on the sea floor are associated with barite. These metals are relatively immobile and non-bioavailable to bottom-living animals because of the low solubility of barite in seawater and in anoxic marine sediments. The solubility of barite in marine sediments and drill cutting piles is controlled by sulfate concentration in sediment pore water (Monnin et al., 2001 as cited by PERF 2005). Lead appears to be the only metal that is bioavailable in some cuttings piles (PERF 2005).

The metals in cuttings piles are present primarily as insoluble inclusions in barite, clay, and cuttings particles (PERF 2005). Solid metals and metal salts associated with barite, clay, and cuttings particles are not readily bioaccumulated by animals living in close association with the cuttings pile; the metals are not passed efficiently through marine food chains (PERF 2005, citing the following authors: Neff 1987a; Neff et al. 1989b, Neff 1989c; Leuterman et al. 1997; URS 2002). When accumulated, the metals often are not assimilated into the tissues, but remain in the tissues as insoluble, inert concretions, probably of the original barite particles (Jenkins et al. 1989). In a study examining the bioavailability of metals to several species of benthic organisms, PERF (2005), citing Leuterman et al. (1997), determined that lead was the only metal in impure grades of barite that was bioaccumulated to potentially toxic concentrations in tissues of marine animals in the experiments.

Citing Schaanning et al. (1996), PERF (2005) showed that mercury and most other metals, except possibly lead, associated with anoxic sediments of cuttings piles do not dissolve from the barite, leach into sediment pore water, and are not bioavailable to benthic marine animals. Dissolution of barite under reducing conditions when sulfate concentrations are low does not result in dissolution of metal sulfide inclusions in the barite (Trefry et al. 1986 and Trefry 1998, cited in PERF 2005).

In consideration of both high and low current locations, the potential for bioaccumulation or persistence of metal associated with drilling fluids and drill cuttings is not expected. However, there may be localized toxicity effects associated with accumulation of drilling fluids and drill cuttings in areas of low dispersion. Again, the area of coverage is predominantly in high dispersion areas and low dispersion areas are not likely to be encountered.

6.1.1.3 Acute Toxicity Effects

Drilling fluids are complex mixtures, and there appear to be several reasons for their toxicity. Some of the apparent toxicity may be due to physical effects, such as particle size coagulations, abrasions, etc. However, there is some chemical toxicity associated with drilling fluids that produces or contributes in part to the lethality in acute toxicity tests (EPA 2006). Oxygen depletion appears to be strongly correlated with toxicity in laboratory toxicity tests.

Spearman Rank correlations of 96-hour LC_{50} data and 5-day biochemical oxygen demand/ultimate biochemical oxygen demand (BOD_5/BOD_u) data showed a remarkably strong correlation, especially with BOD_5 data derived with artificial seawater and activated seed. These data showed a correlation of 0.97 with toxicity. All BOD_5/BOD_u values showed correlations of 0.87 to 0.97 (BOD_5) and 0.91 to 0.95 (BOD_u), but total organic carbon/chemical oxygen demand (TOC/COD) values gave correlations of 0.64 to 0.67. Given the absence of oxygen demand data, no such correlation could be developed for non-generic fluids. Another indicator of the large inherent oxygen demand of drilling fluids is that dissolved oxygen levels in test environments dropped below normal, despite the continuous aeration of test media that followed pre-aeration of the test material. This was especially noted during the first day of testing, during which dissolved oxygen concentration was depressed dependently by the test fluids (EPA 2000).

The effects of drilling fluids on biological organisms are most commonly assessed by conducting acute laboratory toxicity tests. Unfortunately, in many cases, comparison of toxicity test results obtained in different studies are difficult because different drilling fluids were used, the animals were exposed to different portions of drilling fluid (liquid, suspended particulates, or solids) that may have been prepared in a different manner, or experimental procedures differed between investigators. Nevertheless, results obtained in the majority of studies to date have generally indicated low toxicity (EPA 2006).

Drilling fluid toxicity tests have been performed using whole fluids and various component fractions, such as the suspended particulate phase (SPP) or fluid aqueous fraction. Whole drilling fluids appear to be more toxic than aqueous or particulate fractions. The SPP appears to be more toxic than the other individual phases (EPA 2006).

The variability and complexity in the composition of drilling fluids is reflected in the results and interpretation of toxicity tests. Test results of sample splits of the same fluid performed at two different laboratories have differed by an order of magnitude. In such cases, laboratory procedure or sample handling is a significant factor. Different batches of the same generic fluid have shown significantly different toxicities. In this case, different proportions of major constituents (as allowed by fluid type definition) may be a factor. To improve consistency in toxicity test results, there are required standard procedures for sample handling and testing. The current ELGs require toxicity testing for the SPP. Under the Permit, discharge of fluids with a 96-hour LC_{50} of less than 30,000 ppm SPP is prohibited.

In a summary of over 415 toxicity tests of 68 drilling fluids using 70 species, one to two percent exhibited an LC_{50} ranging from 100 to 999 ppm, six percent exhibited an LC_{50} ranging from 1,000 to 9,999 ppm, 46 percent exhibited an LC_{50} ranging from 10,000 to 99,999 ppm, and 44 percent exhibited an LC_{50} greater than 100,000 ppm (EPA 1985). Two to three percent of the data were not usable. A significant difference was noted between the toxicity of generic drilling fluids, which appear to have acute, lethal toxicity characteristics similar to the distribution of the larger dataset described above, and a series of 11 non-generic drilling fluids that the Petroleum Equipment Supplies Association provided to EPA. These latter drilling fluids, as a group, appear to be substantially more toxic than would be anticipated from the toxicity distribution of either the generic drilling fluids or the larger dataset.

Unlike the WBFs, the SBFs are water insoluble and do not disperse in the water column as do WBFs, but rather sink to the bottom with little dispersion (EPA 2000). Since 1984, the SPP toxicity test, an aqueous-phase toxicity test, has been used to evaluate the toxicity of drilling fluids, including SBFs. Using the SPP toxicity test, SBFs have routinely been found to have low toxicity. However, an inter-laboratory variability study indicated that SPP toxicity results are highly variable when applied to SBFs (EPA 2000). In general, benthic test organisms appear to be more sensitive to the SBFs than water column organisms. The ranking for SBF toxicity from least toxic to most toxic is: esters < internal olefins < linear alpha olefins < polyalphaolefins < paraffins (EPA 2000). The extrapolation of single species toxicity tests to overall effects in the ecosystem still has a large, inherent uncertainty (EPA 2006).

Petrazzuolo (1981), cited in Dalton et al. (1985), has ranked organisms according to their sensitivity to drilling fluids in tests and found the following order of decreasing sensitivity: copepods and other plankton, shrimp, lobsters, mysids and finfish, bivalves, crabs, amphipods, echinoderms, gastropods, polychaetes, and isopods. Larval organisms are more sensitive than adult stages (maximally 20-fold); animals are more susceptible during molting (EPA 2006).

A variety of Alaskan marine organisms have been exposed to drilling fluid in laboratory or field experiments. Most of these studies have addressed short-term acute effects in a relative or screening sense, with little effort directed at separating chemical from physical causes. The majority of Alaskan organisms apparently show high tolerance to acute exposure to drilling fluid. Sublethal effects observed following acute exposure have included alteration of respiration and filtration rates, enzyme activities, and behavior. There are several Alaskan taxa that have not been exposed to drilling fluid but may be relatively sensitive. The temperate copepod, Acartia tonsa, has exhibited one of the lowest LC_{50} concentrations (100 ppm) of any organism in a drilling fluid. Alaskan copepods have not been tested, but there is no reason to believe their tolerances would fall outside variability in tolerances of other marine copepods (EPA 2006).

Seven Arctic polymer drilling fluids were used for toxicity testing of salmon (Houghton et al. 1981). Five of the seven drilling fluids displayed a 96-hour LC_{50} of less than 40,000 ppm for the SPP fraction; the most toxic drilling fluid had a 96-hour LC_{50} of 15,000 ppm, and the least toxic fluid a 96-hour LC_{50} of 190,000 ppm. Clam worms (polychaetes), soft-shelled clams, purple shore crabs, and sand fleas had approximately the same sensitivity to the fluids as did the salmon. These invertebrate 96-hour LC_{50} concentrations ranged from 10,000 to more than 560,000 ppm (Neff 1981).

Houghton et al. (1981) conducted a study on several species of crustaceans, including a shrimp (Pandalus hypsinotus), a mysid (Neomysis integer), an amphipod (Eogammarus confervicolus), an isopod (Gnorimosphaeroma oregonensis), and pink salmon fry (Onchorhyncus gorbuscha). These species were exposed to high-density lignosulfonate in drilling fluid obtained from exploration drilling conducted in lower Cook Inlet. Pink salmon fry were the most sensitive, with a 96-hour LC_{50} of 3,000 ppm for SSP. The lowest crustacean concentration was 10 times higher (Neff 1981).

In general, planktonic and larval forms appear to be the most sensitive of the Alaskan organisms that have been exposed to drilling fluid in acute lethal bioassays. However, not all planktonic organisms are sensitive to short term exposure to drilling fluids. Carls and Rice (1981) found several drilling fluids to have low toxicity to the larvae of six Alaskan species of shrimp and crab. The 96-hour LC_{50} for the SPP of a drilling fluid seawater mixture ranged from 500 to 9,400 ppm. Toxicity was far less when the particulates were removed. At that time, the 96-hour LC_{50} ranged from 5,800 to 119,000 ppm (EPA 2006).

Drilling fluid toxicity data that EPA Region 10 compiled from Alaskan exploration and production wells indicate that the drilling fluids used in all current and recent operations are acutely toxic only to a slight degree for mysid shrimp (*Mysidopsis bahia*). The LC_{50} results for the 91 valid toxicity test data points ranged from 2,704 to 1,000,000 ppm SPP, with a mean of 540,800 ppm. Only 7 of the 91 tests had an LC_{50} less than the 30,000 ppm limit. Some of the records in this database were not included in the above statistics due to quality control issues including pH values outside of range, incomplete reports, and other reasons (EPA 2006).

The COST Well Study conducted in Cook Inlet included in situ water column acute toxicity study. The *in situ* bioassays performed during the COST well did not show acute toxicity (lethal) effects (Dames and Moore, 1978).

Chronic Toxicity Effects

Since drilling discharges are episodic and typically only a few hours in duration, organisms that live in the water column are not likely to have long-term exposures to drilling fluids. Risks to these organisms are best assessed using acute toxicity data. Benthic organisms, particularly sessile species, are more likely to be exposed for longer time periods and risks to these organisms are best assessed with chronic toxicity data (EPA 2006). A few studies have looked at chronic toxicity of heavy metals in drilling fluids and tend to focus on benthic organisms. The lowest reported concentration of drilling fluid producing a significant chronic effect was 50 mg/L for 30 days of continuous exposure with bay mussels, but there was no attempt to separate chemical from physical effects (EPA 1985).

Few studies have evaluated impacts on Alaskan species following chronic exposure to drilling fluids and the species were invertebrates with small sample sizes. Estimating No Observable Effect levels (NOELs) was not possible for much of the reported data (EPA 2006). Laboratory studies on recruitment and development of benthic communities suggest that drilling fluid and barite can affect recruitment and alter benthic communities or depress abundances. These data are corroborated by results from artificial substrate experiments conducted in the Beaufort Sea that showed significantly different colonization rates at drilling fluid test plots and control plots, especially for amphipods and copepods (EPA 2006). However, benthic communities have been observed to rebound within a few years (Menzie et al, 1980).

The dynamic tidal action in Cook Inlet imparts strong currents that disperses pollutants in the water column, transport sediments, and does not promote deposition near the discharge (Dames & Moore 1978). Therefore, chronic toxicity to organisms in the water column or benthic layer is not expected. The Permit also requires WET testing for chemically treated miscellaneous discharges. WET testing results must not exceed toxicity triggers but if this occurs further testing and investigation will identify toxic components and result in less toxic substances being utilized.

6.1.1.4 Toxicity of Mineral and Diesel Oil

In the past, the oil industry added diesel oil to drilling fluid systems to free stuck drilling pipes and for other specialized applications. Diesel oil is highly toxic to aquatic life, and much of the toxicity of drilling fluids was attributed to its presence. Studies found high correlations of toxicity with added diesel and mineral oil to whole fluid (diesel oil r = 0.88; mineral oil r = 0.97). Toxicity did not correlate quite as well with the oil levels determined in a variety of fluid samples (r = 0.81). The available data indicate that this may be partially due to various types of sequestrations within the drilling fluid matrix, as well as the variable presence of toxic constituents in drilling fluids other than diesel or mineral oil (EPA 2006).

The hazard to aquatic life from consuming organisms or inhabiting water contaminated with diesel oils is greater than that for mineral oil because the aromatics in diesel oils tend to be more soluble and biologically active than paraffinic hydrocarbons. Although the PAHs contained in mineral oil have been shown to be highly soluble in adipose tissue and lipids (Sittig 1985), mineral oil differs from diesel oil in that it contains a lower concentration of aromatic hydrocarbons (15 - 20 percent vs. 20 - 61 percent for diesel oil). In addition, saturated aliphatics (paraffinics) generally represent a larger percentage of mineral oil compared to diesel oil. Aromatic hydrocarbons are generally more toxic and resist biodegradation to a greater degree than do paraffinics (Petrazzuolo 1983, cited in Dalton et al. 1985). Research studies indicate that some mineral oils are much less acutely toxic (5 to 30 times less) to certain marine organisms than diesel oil (EPA 2006). Despite the reduced toxicity of some mineral oils as compared to diesel oils, mineral oils do contribute potentially toxic organic pollutants to drilling fluids to which they are added (EPA 2006).

Due to the toxicity of oil, EPA prohibits the discharge of diesel oil but authorizes the use of mineral oil, subject to adherence to stringent permit conditions. EPA authorizes the discharge of mineral oil associated with freeing stuck pipes and the discharge of residual amounts of mineral oil pills, provided that the pill and a buffer of drilling fluid on either side of the pill are removed and not discharged. The residual mineral oil concentration in the discharged fluid should not exceed 2 percent (volume component per total volume [v/v]) and must comply with all permit conditions (EPA 2006). These stipulations help to ensure toxicity of mineral oil is controlled. The hazards associated with residual mineral oil present in discharged fluid covered under the Permit are not expected to be significant (EPA 2006).

6.1.1.5 Effectiveness of Mitigating Measures

A study panel of the US National Research Council (1983) examined all the information available at that time on the environmental fates and effects of WBM and cuttings discharges and concluded: “Based on laboratory and field studies to date, most WBFs used on the US Outer Continental Shelf have low acute and chronic toxicities to marine organisms, (because of) the expected or observed rates of dilution and dispersal of drilling fluids in the ocean after discharge. Their effects are restricted primarily to the ocean floor in the immediate vicinity and for a short distance downcurrent from the discharge. The bioaccumulation of metals from drilling fluids appears to be restricted to barium and chromium and is observed to be small in the field.” More recent laboratory and field studies have confirmed these conclusions. Water column communities are not harmed by drilling fluid and cuttings discharges, because discharges are intermittent and of short duration during drilling and dispersion, and dilution is rapid of dissolved and particulate components of the discharge. Aldredge et al. (1986) could not detect significant biological effects of WBM and WBM chemicals on phytoplankton communities from the Santa Barbara Channel, California.

6.1.1.6 Summary and Determination

This ODCE was developed using best available scientific information including studies assessing Cook Inlet. The amount of drilling fluids and drill cuttings estimated to be discharged under the permit, 187,200 and 52,200 barrels, respectively, represents a very small contributing fraction of total sediment entering Cook Inlet from onshore river systems that result in deposition in lower Cook Inlet. Although not expected to occur within the area of coverage, accumulation of drilling fluids and drill cuttings near the point of discharge will not result in bioaccumulation or persistence in the environment. Based on EPA's evaluation of potential discharges authorized by the Permit, drilling fluids and drill cuttings have the greatest bioaccumulation potential. Other discharges from exploration drilling operations are required to meet permit limits and conditions that prevent toxic effects or bioaccumulation or persistence in the water column or via portioning to sediment. Due to the low contributing volumes and minimal pollutant concentrations of the discharges, the potential for bioaccumulation or persistence of contaminants is low. Sediment sample results from the Produced Water Study (Kinnetic Laboratories, Inc. 2010) data supports this conclusion. Therefore, unreasonable degradation of the marine environment is unlikely to result from oil and gas exploration discharges covered under the Permit.

6.1.2 Criterion 2

The potential transport of such pollutants by biological, physical, or chemical processes:

Factors influencing the transport and persistence of discharged drilling fluids and drill cuttings include oceanographic characteristics of the receiving water, depth of discharge, discharge rate, and method of disposal. Oceanographic influences include tide, wind, freshwater overflow, ice movement, stratification, and current regime. Sediment transport in lower Cook Inlet and Shelikof Strait follows the general counterclockwise circulation pattern of the gyre. The flow of Cook Inlet water generally is to the southwest. Long-term deposition of sediment from drilling fluid and drill cuttings discharged under the Permit is not anticipated to deposit within the vicinity of the discharge. The large grained cuttings are expected to become rapidly mixed and sorted with the natural seafloor material within a few tidal cycles. The fine grained fraction of the drilling fluids and cuttings will be transported out of the coverage area and become mixed with the voluminous riverine sediment load and deposited in lower Cook Inlet (See Section 6.1.1.1).

The bottom currents in lower Cook Inlet are strong enough to prevent the deposition of sand-sized and smaller particles (Hampton 1982; Sharma 1979). Regional sediments indicate sorting by present-day transporting currents (Hampton et al. 1981). Silts and muds are moved southward to outermost Cook Inlet and Shelikof Strait (Carlson et al. 1977; Hampton 1982; MMS 2000).

The density of any drilling fluids discharged into Cook Inlet should range within 1,000 - 2,000 parts per thousand (ppt) wet weight. This is a typical density range used for drilling fluid. For example, Adams (1985) stated a range between 1,080 and 1,800 ppt and the National Research Council (1983) stated a range (for OCS wells) between 1,190 and 2,090 ppt (MMS 2003). It is expected that minimal amounts of solids contained in the drilling fluids and cuttings discharged into Cook Inlet will accumulate on the seafloor near the discharge and only for a short duration. Sediment re-suspension is dominated by strong tidal currents which generate bottom currents of 100 cm/s (40 in/s) (Dames and Moore 1978 as cited in EPA 1994). Discharged substances that are dissolved or remain in suspension generally would be transported out of Cook Inlet and into the Gulf of Alaska within about 10 months (Kinney et al. 1969). In depositional areas (which are predominately excluded by the Permit) Menzie et al. (1980 as cited in EPA 1994) suggested that benthic communities within the initial impact zone are recolonized and commence recovery within a year following cessation of discharge.

The model used to evaluate the transport and persistence of discharged drilling fluids did not include drill cuttings (EPA 1994). Drill cuttings are expected to be of coarser grain size than drilling fluids and will settle rapidly to the seafloor. Jones and Stokes (1989 as cited in EPA 1994) indicated that the majority of drill cuttings will probably be deposited within 100 m (328 ft) from the point of discharge at all depths and current speeds. However, due to the high tidal currents in the area of coverage for the Permit, drill cuttings are expected to be redistributed and well mixed with natural sediments within a few tidal cycles.

Dispersion of dissolved pollutants is expected to occur rapidly in the strong currents of Cook Inlet (National Research Council 1983). Permit limits and conditions control the concentration of pollutants and chemical additives in the discharges.

6.1.2.1 Summary and Determination

Cook Inlet is a high-energy environment. Fast tidal currents and tremendous mixing produce rapid dispersion of soluble and particulate pollutants. Within a distance of between 100 and 200 m (328 to 656 ft) from the discharge point, the turbidity caused by suspended particulate matter in discharged drilling fluids and drill cuttings is expected to be diluted to levels that are within the range associated with the variability of naturally occurring suspended particulate matter concentrations.

In general, the amounts of dissolved pollutants or chemical additives in the other discharges are expected to be relatively small (from 400 to 800 liters per month) due to treatment, best management practices, and pollution prevention requirements of the Permit. Discharges will be diluted rapidly upon being discharged into the receiving waters.

EPA has determined that discharges oil and gas exploration operations will have little effect on the nearfield or far-field water column or result in a long-term zone of deposit on the seafloor. Based on evaluation of transport, EPA has determined that issuance of the Permit will not result in unreasonable degradation of the marine environment within the territorial seas.

6.1.3 Criterion 3

The composition and vulnerability of the biological communities that may be exposed to such pollutants, including the presence of unique species or communities of species, the presence of species identified as endangered or threatened pursuant to the ESA, or the presence of those species critical to the structure or function of the ecosystem, such as those important for the food chain:

As discussed in Section 6.1.1, there is potential for discharges authorized under the Permit to produce either acute or chronic localized effects through exposure either in the water column or in the benthic environment. The following discussion addresses potential effects in the water column and on the seafloor.

6.1.3.1 Water Column Effects

EPA estimates the potential drilling of up to 12 exploration and delineation wells in federal waters during the five year term of the Permit. The total volume of drilling fluids estimated to be discharged during the five-year term is 187,200 bbls and the total volume of drill cuttings estimated to be 52,200 bbls. Based on the currents found in the area of coverage, discharges would disperse rapidly. Subsequently, there would be no effect on planktonic organisms, such as shrimp (National Research Council 1983). This assessment also confirms the conclusion in the water quality section that mixing in the water column would reduce the toxicity of drilling fluids to levels that would not be harmful to organisms in the water column.

Low concentrations of BOD and nutrients in domestic wastewater and graywater discharges could stimulate primary productivity and enhance zooplankton production. This effect is predicted to be negligible as permit coverage is excluded from beluga whale critical habitat areas as well as from key prey species habitat, and within 4,000 meters from shore.

The Permit limits required for the miscellaneous discharges (desalination unit wastes; blowout preventer fluid; boiler blowdown; fire control system test water; non-contact cooling water; uncontaminated ballast water; bilge water; excess cement slurry; and mud, cuttings, and cement at the seafloor) restrict chemical additives and prohibit free oil. These requirements are in place to restrict any potential water column effects.

6.1.3.2 Benthic Habitat Effects

The literature does not suggest that a link occurs between benthic organisms potentially contaminated by drilling fluid discharges and accumulation in higher tropic levels. For the particles that remain on the bottom, most of the organic chemicals in water-based muds (WBMs) are biodegradable under aerobic conditions in 14 - >100 days (Terzaghi et al. 1998). The toxic effects from drilling fluids is strongly correlated with smothering and oxygen depletion. Currents in Cook Inlet tend to disperse drilling fluids and prevent long-term accumulations of WBMs on the sea floor.

Any observed effects from drilling fluids and drill cuttings discharge and possible potential burial of benthic organisms would occur over a relatively small area of benthic habitat. Neff (1981) indicates that during high rates of discharge of drilling fluids to the ocean, dilution of drilling fluids to background concentrations occurs within about 1,000 meters downcurrent from the discharge point and is accomplished in less than two hours. For affected benthic populations, recruitment of new colonists occurs from planktonic larvae and immigration from adjacent undisturbed sediments. Ecological recovery usually begins shortly after completion of drilling and often is well advanced within a year. Full recovery may be delayed until concentrations of biodegradable organic matter decrease through microbial biodegradation to the point where surface layers of sediment are oxygenated (PERF 2005)

6.1.3.3 Threatened and Endangered Species

Threatened and endangered species that could occur in Cook Inlet include short-tailed albatross, Steller’s eider, Kittlitz Murrelet, blue whale, fin whale, humpback whale, northern right whale, sei whale, sperm whale, Steller sea lion, beluga whale, and northern sea otter. Most of these species are not likely to use water close to permitted activities so they are unlikely to be affected by discharges from oil and gas exploration facilities in Cook Inlet.

There is Steller sea lion designated critical habitat within the geographic coverage area for the Permit, but critical habitat restrictions do not allow discharges in the vicinity of Steller sea lion rookeries. In addition, rapid dilution and the low toxicity of drilling fluids discharged to Cook Inlet imply that these discharges would not be likely to adversely affect pollock or other Steller sea lion prey.

Beluga whales have been identified as depleted under the MMPA and endangered under the ESA. Drilling fluid discharges in Cook Inlet could adversely affect prey availability in the immediate vicinity of the discharges because of the burial of benthic organisms, or changes in bottom habitat characteristics, but such effects would be of limited size and duration. In addition, the Permit does not cover discharges to areas that align with the restricted beluga Habitat Area 1 or 2 and the beluga would have limited exposure during migration.

Drilling fluid discharges in Cook Inlet could alter prey available to the northern sea otter in the immediate vicinity of the discharges through burial of benthic organisms or changing bottom habitat characteristics but such effects would be of limited size and duration. Northern sea otters are not expected to be adversely affected by exposure to pollutants discharged water compliance with effluent or WET requirements.

Contaminant levels in marine mammals have been reviewed, focusing on Sea Otters, Stellar Sea Lions, and Beluga Whales. The USFWS Recovery Plan for Sea Otters notes that “heavy metals are unlikely to be casual factor in the decline” in sea otter populations in and around Cook Inlet. Similarly, the NMFS Stellar Sea Lion Recovery Plan (NMFS 2008b) indicates that oil and gas activities and their related discharges are not likely to pose significant health risks to the population. The concentration of contaminants found in Cook Inlet Beluga Whales were lower than in other Alaskan beluga stocks (Becker 2000).

6.1.3.4 Summary and Determination

EPA has reviewed the vulnerability of biological communities found in and near the Permit coverage area. The Permit excludes discharging in key areas and limits the toxicity of the discharges to reduce any potential impact that the permitted discharges may have on these species. The coverage area excludes areas where endangered species may congregate. The EPA has determined that there will be no unreasonable degradation to the biological communities as long as the Permit limitations and requirements are met.

6.1.4 Criterion 4

The importance of the receiving water area to the surrounding biological community, including the presence of spawning sites, nursery/forage areas, migratory pathways, or areas necessary for other functions or critical stages in the life cycle of an organism:

Cook Inlet is an important area for marine mammals including beluga whales, Steller sea lions, and harbor seals. Lower Cook Inlet is one of the most productive areas for seabirds in Alaska, with an estimated 100,000 seabirds; 18 species breed in Cook Inlet. Waterbirds and waterfowl breed in the Cook Inlet region. In spring, large numbers of waterbirds migrate through the area. Large populations of staging waterfowl are found in tidal flats, along river mouths, and in bays on the west side of Cook Inlet, including Redoubt Bay. Redoubt Bay has especially high concentrations of geese and ducks.

Anadromous fish migrate through Cook Inlet toward spawning habitat in rivers and streams, and juveniles travel through Cook Inlet toward marine feeding areas. HPCs within EFH in Cook Inlet are the estuarine and nearshore habitats of Pacific salmon (e.g., eelgrass [Zostera sp.] beds) and herring spawning grounds (e.g., rockweed [Fucus sp.] and eelgrass). Offshore HPCs include areas with substrates that serve as cover for organisms including groundfish. All anadromous streams qualify as HPC. The Susitna River drainage is a primary source of these anadromous fish in Cook Inlet. Eulachon also return to spawn in some of the rivers. Because discharges will be rapidly dispersed, and fish are transient, it is unlikely that they would adversely affect migrating anadromous fish.

6.1.4.1 Fish

Section 5.2 describes fisheries resources (i.e., pelagic finfish, ground finfish, and shellfish) in the lower Cook Inlet area. MMS performed an analysis on population-level impacts where the definition of a population is defined as a group of organisms of one species occupying a defined area (the central Gulf of Alaska encompassing the South Alaska Peninsula, Kodiak Archipelago, Shelikof Strait, Cook Inlet, and Prince William Sound) and usually isolated to some degree from other similar groups. Routine activities associated with this alternative that may adversely affect fisheries resources include permitted drilling discharges. Various effects to fisheries resources, taken together, would not likely result in population-level changes in the central Gulf of Alaska (MMS 2003).

6.1.4.2 Marine Birds

Section 5.4 describes coastal and marine birds species and related habitat information. The potential impacts to birds from oil and gas exploration facilities is associated with free oil on the water surface that can coat the birds. Permitted discharges are not expected to have an effect on marine and coastal birds based on the discharge requirements of no free oil, the high degree of dilution that would occur and the fact that bioaccumulation of associated pollutants is not expected (SAIC 2000). The Permit prohibits the discharge of oil that could affect birds. The evaluation required by 40 CFR 125 focuses on the potential effects of authorized discharges, not activities that may lead to unauthorized or accidental discharges. Furthermore, the risk of an unauthorized discharge, or spill, is significantly reduced through adherence with BMPs and requirements from other agencies.

6.1.4.3 Marine Mammals

Seven species of non-endangered marine mammals numbering in the hundreds to thousands commonly occur year-round or seasonally in a portion of, or throughout, the Cook Inlet region and could be exposed to discharges from some exploration activities in Cook Inlet. These include the harbor seals and northern fur seals; Southcentral Alaska sea otters; killer, minke, and gray whales; and Dall’s and harbor porpoises. Pollution and alteration of habitats could adversely affect these marine mammals found within Cook Inlet. However, the Permit contains limits and conditions to control the discharge of pollutants, and discharges to nearshore habitats are prohibited.

6.1.4.4 Summary and Determination

In summary, the discharges associated with oil and gas facilities in upper Cook Inlet have not had a documented effect on lower trophic-level organisms. The discharges from new exploration facilities would be similar, and no measurable effects on the local populations are expected from these discharges (MMS 2003). No adverse impacts from the discharges from the oil and gas exploration facilities in Cook Inlet are predicted due to the rapid dispersion of waste discharges from oil and gas exploration facilities in Cook Inlet. No adverse impacts on birds are predicted due to prohibiting the discharge of oil and preventative measures to reduce the risk of unauthorized discharges.

6.1.5 Criterion 5

The existence of special aquatic sites including, but not limited to, marine sanctuaries and refuges, parks, national and historic monuments, national seashores, wilderness areas, and coral reefs:

The following special aquatic sites are in proximity to the permit coverage area:

- Kachemak Bay CHA
- Kalgin Island CHA
- Lake Clark National Park
- Susitna Flats SGR
- Clam Gulch CHA
- Trading Bay SGR
- Redoubt Bay CHA
- Port Graham/Nanwalek Area Meriting Special Attention

Facilities operating within these areas and the associated 4,000-meter buffer would not be authorized to discharge wastewater under the Permit.

6.1.5.1 Summary and Determination

Based on the analysis of criteria 1, 2, 3, and 4 (Sections 6.1.1, 6.1.2, 6.1.3, and 6.1.4), these special aquatic sites would not be affected by authorized discharges.

6.1.6 Criterion 6

The potential impacts on human health through direct and indirect pathways:

The ODCE is based on existing, available, and sufficient scientific information and related studies. During the development of the ODCE, EPA reviewed many studies that focused on fish consumption habits and related concerns. There is no known direct exposure pathway (i.e. physical contact) to humans from the discharges associated with oil and gas exploration in Cook Inlet, Alaska. Indirect exposure is primarily from direct consumption of species exposed to discharges. There does not appear to be a discernable difference in contaminant concentrations in Cook Inlet fish compared to fish from other locations in the state. Contaminant concentrations detected in fish in Cook Inlet are similar to those in fish collected throughout Alaska (ATSDR 2009). As described in the ATSDR 2009 health consultation, the concentrations of pesticides, dioxins, and PCBs detected in Cook Inlet skinless Chinook salmon fillets fall within the range of concentrations detected from fish caught throughout Alaska. None of the maximum concentrations in Cook Inlet fish exceeded the maximum concentrations detected in fish elsewhere.

Tribes in the Cook Inlet region have expressed concerns over the last several years regarding the potential impacts of discharges from oil and gas facilities on fish and other subsistence resources. Fish consumption is one of the most important indicators available for determining human exposure to pollutants via subsistence sources. However, this presents challenges as published consumption data is limited. The Alaskan Traditional Knowledge and Native Foods Database (2002) indicates that while harvest data is available for subsistence communities, consumption data is necessary to estimate exposure to individuals. The ADF&G provided additional information regarding subsistence harvests in their 2003 report. Published (e.g., Fall et al. 2004) and unpublished data (e.g., Seldovia Village Tribe, 2013) are available that assess fish consumption in the Cook Inlet communities of Cooper Landing, Hope, Nikolaevsk, Ninilchik, Seldovia, Port Graham, Nanwalek, and Tyonek. More recent studies, like the one completed by the Seldovia Village Tribe, considered consumption habits for the local communities of Seldovia, Port Graham, Nanwalek, and Tyonek. Additional studies are ongoing in both federal and state agencies that may be used to inform future permitting activities.

Fall et al. (2004) report the quantity of fish harvested, received, given away, and used by subsistence users in Cook Inlet (in number of fish and pounds). As estimated in pounds usable weight per person, fish harvests were relatively low to moderate in the four communities on the road system in the 2002–2003 study year: 61.7 pounds per person at Cooper Landing, 62.4 pounds per person at Hope, 73.7 pounds per person at Nikolaevsk, and 81.8 pounds per person at Ninilchik. Fish harvests at Seldovia were higher, at 161.3 pounds per person.

While the data obtained can be informative and aid in creating human health guidelines, users must exercise caution in extrapolating. Ponce et al. (1997) compiled a summary of the studies on trace metals in tissues of Alaskan and other Arctic and sub-Arctic marine mammals from the 1970s to the 1990s. The evaluation cautions that at the time of review, some critical information was not available in sufficient quantity. For example, few published reports were available for any given species, sample sizes were small, and age estimates and sex information was rarely reported. Since age is a significant predictor of trace metal concentrations in organ tissues in these species, age data are needed to help compare study populations over time and by geographic region. Tissue concentrations of methylmercury, particularly for muscle tissue, were lacking and insufficient information is available regarding the ratio of methylmercury to total mercury in marine mammal organ tissues. Further, environmental factors such as naturally occurring trace metals might compound with anthropogenic sources to determine an organism’s total body burden of chemicals. Since this study was published, there have been several subsequent surveys of the concentrations of metals in tissues of marine animals from the vicinity of offshore water based fluids and cuttings discharges in temperate and cold-water marine environments near drilling operations (Neff 2010). In nearly all cases, these surveys have shown that metals and hydrocarbon concentrations in tissues of marine animals near drilling operations are similar to concentrations in tissues of the same or similar species well away from and out of the influence of the drilling operations.

NPRB (2013) summarized the findings of the health condition assessment in Cook Inlet of two species of salmon and two species of shellfish. The study examined arsenic, cadmium, chromium, lead, mercury, nickel, selenium, chlordanes, DDTs, PAHs, and PCBs. The NPRB (2013) study found that for elements warranting US Food and Drug Administration (USFDA) action levels (arsenic, cadmium, chromium, lead, and nickel), the observed tissue concentrations in clams were far below USFDA thresholds, some by more than an order of magnitude. For mobile animals such as the salmon, NPRB (2013) notes that these organisms will spend significant periods of their lives in other habitats; the chemical makeup of those habitats will reflect total body burden of pollutants. Note that adult Pacific salmon are not affected by contaminated food sources in the Cook Inlet because they stop feeding on their spawning migration from the open ocean into coastal estuaries and rivers. Thus, their body burdens are primarily a result of their exposure and diet in the open ocean. For the salmon examined, NPRB (2013) found that muscle tissue levels were below calculated chronic No Adverse Effect levels for cadmium and selenium. Mercury levels are on the same order of magnitude, but still below the EPA chronic level. Liver concentrations are considerably higher than muscle in all cases except arsenic and mercury. There are no consumption standards for liver tissue, and the liver constitutes a much smaller proportion of the mass of the fish compared to the muscle. Mercury does not tend to accumulate in the liver. Most mercury in tissues is converted into methylmercury and remains in the tissues. The levels of organic contaminants in the fish tissues were far below USFDA action levels and EPA chronic no-effect concentrations.

Within Cook Inlet, body burdens of chemicals for some animals may actually be less than in neighboring areas. Becker et al. (2000) found Cook Inlet belugas had much lower concentrations of PCB's and chlorinated pesticides than those reported for belugas from Point Hope and Mackenzie River (eastern Beaufort Sea animals) and Point Lay (eastern Chukchi Sea animals). As compared to the other persistent organic contaminants, chlordane contributed substantially less to the total burden of the compounds in the Cook Inlet belugas than it did to the burden of any of the other belugas. In the case of heavy metals and other elements, cadmium, mercury, and selenium were much lower in the livers of Cook Inlet animals than all other belugas, and vanadium and silver were lower in the Cook Inlet belugas than in the other Arctic Alaska belugas. An initial estimate of the human health risk associated with the consumption of beluga blubber (based on the Allowable Daily Intake that Health Canada recommends) suggested that the principal chemical limiting the recommended consumption rate of Cook Inlet blubber was an insecticide, toxaphene, which is now banned for all uses in the US. This was different from the eastern Beaufort Sea and eastern Chukchi Sea belugas, where the limiting compound was chlordane.

Holen and Fall (2011) reported that salmon (all species) contributed 69 percent of the total harvests of wild resources for subsistence users reported by Tyonek respondents. Further, when considering one of the key contaminants of concern, available data show methylmercury concentrations in the most frequently consumed Alaska fish (e.g., Chinook, Coho, sockeye, chum, and pink salmon) are among the lowest of all fish species (average < 0.05 mg/kg) (EPA 2004).

Between June and August 2002, EPA collected 65 fish, which included Pacific cod, Chinook salmon, pink salmon, chum salmon, red salmon, silver salmon, pollock, and halibut, from lower Cook Inlet. Skinless fillets and halibut roasts from 47 fish were analyzed for heavy metals (arsenic, cadmium, chromium, lead, nickel, selenium, and methylmercury). Fillets from six Chinook salmon were also analyzed for pesticides, dioxins, and polychlorinated biphenyls (PCBs). The average concentrations of metals in fish fillets collected from Cook Inlet were compared to fish fillets collected from marine waters throughout Alaska. There was no clear pattern of higher contaminant concentrations. Most average concentrations of metals in fish from Cook Inlet were similar to the average concentrations in fish collected from marine waters throughout Alaska (http://EPA.alaska.gov/eh/vet/fish.htm as cited in ATSDR 2009).

Based on the qualitative comparisons made between Cook Inlet fish contaminant concentrations and Columbia River or USFDA market basket sample results (EPA 2002; USFDA 2000; USFDA 2003) in EPA's Survey of Chemical Contaminants in Fish, Invertebrates and Plants Collected in the Vicinity of Tyonek, Seldovia, Port Graham and Nanwalek – Cook Inlet, AK (EPA Region 10, 2003), organochlorine pesticide (dieldrin, DDT, chlordane) and PAH concentrations were greater in either or both Columbia River or USFDA market basket samples than in Cook Inlet fish samples. Mercury concentrations were also greater in most Columbia River or USFDA market basket samples except for Cook Inlet chinook and sea bass samples which had concentrations similar to or between the concentrations detected in Columbia River and the USFDA market basket study. Cadmium concentrations were detected at levels less than 30 ppm, which is the high end of the ATSDR range of cadmium concentrations detected in edible meat or marine shellfish (ATSDR 1999). Hexachlorobenzene was one contaminant that was detected in Cook Inlet chinook and sockeye samples in greater concentrations than those detected in the Columbia River. Overall, with the exception of hexachlorobenzene concentrations in Cook Inlet chinook and sockeye samples, contaminants detected in Cook Inlet fish were less than or comparable to contaminants detected in regional or national studies. Note that hexachlorobenzene is not associated with discharges from oil and gas exploration activities.

The 2003 report states that the extent to which concentrations in the samples analyzed in the study were representative of concentrations in other Cook Inlet biota consumed by Alaskan tribal villagers is unknown. Not all fish, invertebrate and plant species consumed in a traditional diet were included in the study. Seven fish species were considered and reported (Chinook, chum, and sockeye salmon; sea bass; cod; flounder; and halibut). The size of the species sampled in the study was intended to be representative of the size of organisms traditionally harvested by Cook Inlet Alaskan tribal villagers for consumption. However, contaminant concentrations in specimens smaller or larger than the sizes analyzed in the study may vary. Size ranges of the specimens analyzed for the study were reported by species in Table 2 (page 8) of the 2003 report.

The contaminant concentrations presented in the 2003 report are based on analyses of uncooked whole-body, un-scaled fish samples. For the purposes of a contaminant survey, whole-body samples are representative of exposures to the fish or predators that consume the whole fish. However, chemical concentrations derived from a whole-body measurement may not be representative of exposures resulting from consumption of individual body parts. For many contaminants, whole-body levels would be expected to exceed those in edible fillets. Other species potentially consumed by humans, such as mussels, clams, chiton, octopus, snails, and three plants were also analyzed in the study.

The 2003 report identified potential uncertainties associated with its study, including sampled species, age/size of specimens, timing of sample collection, sample type, analytes, chemical speciation of inorganic chemicals, concentrations reported as not detected, and the effects of cooking and preparation. The report stated that:

- The biota species which were sampled, the size of the biota and the harvest locations were intended to represent those traditionally used by members of the four Alaskan tribal villages of Tyonek, Seldovia, Port Graham and Nanwalek.
- All possible harvest sites were not evaluated and not all fish, invertebrate and plant species consumed in a traditional diet were included in the survey.
- It is unlikely that the one-time sampling is representative of contaminant concentrations in these species over the entire lifetime of a human who consumes these species.

In July 2009 the Agency for Toxic Substances and Disease Registry (ATSDR) published a Public Health Consultation which evaluated seafood and plant data collected from Cook Inlet near the Native Villages of Port Graham, Nanwalek, Seldovia, and Tyonek. The consultation was issued in response to a specific request by these Native Villages to ATSDR to evaluate whether or not eating traditional subsistence foods could harm their health.

Despite being published more than five years ago, ATSDR 2009 represents one of the most recent reviews of specific contaminants in the Cook Inlet area and one of the most complete reviews of contaminants of concern for subsistence fisheries in Cook Inlet. Environmental data reviewed for the ATSDR publication were based on information available from state and federal agencies that contained contaminant information from key subsistence species including salmon and other saltwater fish, mussels, clams, snail, chiton (badarki), and octopus, kelp, seaweed, and goose tongue. The range of species examined by ATSDR was based on the data available at the time of publication.

The ATSDR health consultation, in general, discussed the concentrations of pesticides, dioxins, and PCBs detected in Cook Inlet skinless Chinook salmon fillets, which fall within the range of concentrations detected from fish caught throughout Alaska. None of the maximum concentrations in Cook Inlet exceeded the maximum concentrations detected elsewhere. Also, most average metals concentrations in fish fillets collected from Cook Inlet were similar to the average concentrations in fish collected throughout Alaska.

ATSDR 2009 reached five important conclusions in the health consultation as provided below.

- Lead found in chiton (badarki) could harm children's health. Preschool and elementary age children should only eat 3 ounces or less of chiton a week to help prevent high blood lead levels. Adults eating chiton are not at risk of high blood lead levels because adults absorb less lead from food than children. Further, ATSDR concluded that the small amount of lead found in other Native foods will not cause elevated blood lead levels in children or adults.
- Other chemicals detected in Native foods from Cook Inlet were at the same levels as other native foods, and were not expected to harm people's health. While metals, pesticides, PCBs, one dioxin compound, and PAHs were detected in Native foods in small amounts, the levels were often at levels found in fish from other parts of Alaska and from grocery store bought fish. ATSDR reached this conclusion because either (a) the exposure from each chemical was below levels of health concern, or (b) in some cases, the chemicals were found occasionally in just a few samples.
- Based on anticipated consumption rates obtained through community surveys, eating fish and other Native food was not expected to cause a noticeable increase in cancer. Several chemicals that are known to cause cancer were infrequently detected or detected at low levels. Due to limited data available, the effects of eating eggs or organs from Cook Inlet fish could not be determined.
- Lastly, ATSDR could not adequately evaluate the effects of several PAHs that were detected in low levels in some seafood samples because very little information is available about their harmful effects.

In 2014, the Alaska Department of Health and Social Services (DHSS) issued Fish Consumption Advice for Alaskans: A Risk Management Strategy to Optimize the Public's Health (DHSS 2014). Due to the numerous well-documented health (and cultural) benefits of fish consumption, teenage boys, adult men, and women who cannot become pregnant were advised to continue unrestricted consumption of all fish from Alaska waters. Women who are or can become pregnant, nursing mothers, and children aged 12 years and under should continue unrestricted consumption of fish from Alaska waters that are low in mercury, which include all five species of Alaska salmon, pacific cod, walleye pollock, black rockfish, pacific ocean perch, halibut under 20 pounds, and lingcod less than 30 inches.

DHSS advised that to protect the nervous systems of developing fetuses and young children, women who are or can become pregnant, nursing mothers, and children aged 12 years and under should limit their consumption of the fish that are known to have elevated mercury levels according to the following categories:

- Category 1: limit consumption of sablefish, rougheye rockfish, medium-sized halibut (20–39.9 pounds), store-bought halibut, and medium-sized lingcod (30 to 39.9" length) to ≤ 4 meals per week (or ≤16 meals per month);
- Category 2: limit consumption of medium-large halibut (40 to 49.9 pounds) to ≤3 meals per week (or ≤12 meals per month);
- Category 3: limit consumption of large lingcod (40–44.9" length), yelloweye rockfish, and large halibut (50–89.9 pounds) to ≤2 meals per week (or ≤8 meals per month); and

- Category 4: limit consumption of salmon shark, spiny dogfish, very large lingcod (45” and longer) and very large halibut (≥90 pounds) to ≤1 meal per week (or ≤4 meals per month).

The fish consumption limitations listed above assume a person eats fish from a single category listed above, and that an adult meal size is 6 ounces. For those who eat multiple fish species, a tool to calculate mixed diet allowances is available at: www.epi.alaska.gov/eh/fish/. Women who are or can become pregnant, nursing mothers, and children aged 12 years and under who consume fish from the categories listed above during a given month may also consume unlimited quantities of fish known to be low in mercury (e.g., salmon) during that month.

Since the average commercially-caught halibut in Alaska weighs only 33 pounds, women who are or can become pregnant, nursing mothers, and children aged 12 years and under may eat up to sixteen meals per month of halibut from Alaska that are sold in stores and restaurants. Alaska DHSS’s recommendations and guidance on fish consumption may change as new data become available.

The Cook Inlet Regional Citizens Advisory Council (CIRCAC) conducted a technical evaluation of the environmental monitoring program (EMP) data collected in Cook Inlet from 1993 through 1997 (Lees et al. 1999). The major objective of the EMP was to determine if oil and gas operations in Cook Inlet, specifically whether hydrocarbon from oil and gas activities, have had an adverse effect on the surrounding ecosystem. While produced water, which contains levels of hydrocarbon, is not authorized to be discharged under the Permit, the following results from the technical evaluation are noteworthy:

- Sediment samples exhibit extremely low levels of PAHs, the sources of which are varied and mixed, but cannot be directly attributed to Cook Inlet oil and gas operations.
- The sediments do not contain adequate concentrations of hydrocarbon to cause mortality or sublethal effects to organisms exposed to them.
- No relationship was observed between toxicity and PAH or metal concentrations in the entire suite of toxicity tests (Kinnetic, 2010).

Lees et al. also recommended that trace metals monitoring in sediment and tissues be discontinued. The discharge plume modeling conducted during the evaluation suggested a very low probability of trace metal accumulation in sediments in Cook Inlet. The data collected did show variable concentrations that were likely due to different geologic regimes in the region, the influence of large natural events, and anthropogenic inputs that likely occurred in Pre-1950 development of the region (Kinnetic, 2010 and Little, 2001). The Permit includes a requirement to submit a Drilling Fluids Plan to assess and limit the toxicity of potential discharges as well as SPP testing.

Additionally, the 2007 Permit (AKG315000) required operators discharging produced water greater than 100,000 gallons per day to conduct a fate and transport study of pollutants in the water column and sediments in the vicinity of the discharges (EPA 2007). Generally, the study, which includes Trading Bay Production Facility and East Foreland Treatment Facility, found there was no evidence of elevated contaminant concentrations in sediments from oil and gas production operations in Cook Inlet. Concentrations of dissolved metals measured at both facilities are below the Alaska WQS criteria for both aquatic life in marine water and for human health for consumption, and that produced water does not cause elevated values of particulate metals (associated with suspended sediments) in samples from Cook Inlet (Kinnetic Laboratories Inc. 2010).

This ODCE was developed using best available scientific information that reasonably demonstrates that human health effects from direct exposure to drilling fluids are unlikely to occur from oil and gas exploration discharges. Ingestion of organisms that have accumulated significant concentrations of heavy metals or other contaminants from drilling fluids is the potential principal source of adverse human health effects caused by offshore oil and gas drilling operations. However, as discussed above, contaminant concentrations detected in fish in Cook Inlet are similar to those in fish collected throughout Alaska (ATSDR 2009). Furthermore, based on existing data, the Alaska Department of Human Health and Safety recommends that the majority of Alaskans (healthy adults) continue unrestricted consumption of all fish from Alaskan waters, including those from Cook Inlet (Alaska DHSS 2014).

6.1.6.1 Summary and Determination

In summary, there is no known direct exposure pathway to humans from the discharges associated with oil and gas activities in Cook Inlet. Indirect exposure is primarily from consumption of species exposed to discharges. Increases in metal body burdens of animals consumed by humans that are attributable to the discharges are expected to be minor. Most contaminants detected in Cook Inlet fish are less than or comparable to contaminants detected in regional or national studies. The metal content of drilling fluids is minimized through the effluent limitations for mercury and cadmium established as surrogate metals in the Permit. Adherence to these limitations will also control the concentrations of other metal constituents discharged to Cook Inlet. Additionally, operators of new exploration facilities discharging drilling fluids and/or drill cuttings must conduct an environmental monitoring study to assess discharge-related impacts, including changes to sediment concentrations and impacts to the benthic community in the vicinity of the discharge. This data will be used to inform future permitting decisions including the evaluation of unreasonable degradation in the next reissuance of the Permit.

Based on the available information, EPA has made the determination there will be no unreasonable degradation to the marine environment in regard to human health concerns and fish consumption.

6.1.7 Criterion 7

Existing or potential recreational and commercial fishing, including finfishing and shellfishing:

The fish of central and lower Cook Inlet have been well studied, due in part to the numerous commercial fisheries in the area. There are commercial and subsistence fisheries in the Cook Inlet, including anadromous species that migrate and benthic species (refer to Section 5.2 for additional information). The permit coverage area excludes waters within 4,000 meters of the special aquatic sites mentioned in Criterion 5 (Section 6.1.5). This exclusion preserves key fish and shellfish habitat and the potential for recreational and commercial fishing in the area.

6.1.7.1 Summary and Determination

The discharges associated with exploration in the area covered by the Permit are predicted to have insignificant impacts on the quantity or quality of the commercial, recreational, or subsistence harvests in Cook Inlet on the basis of the potential effects of disturbance on subsistence resources, the mobility of harvested species, the potential effects of permitted discharges on water quality, and the rapid dispersion of discharges by the strong tidal flux of Cook Inlet. EPA has determined there will be no unreasonable degradation to existing or potential fishing or shellfishing in the area.

6.1.8 Criterion 8

Any applicable requirements of an approved Coastal Zone Management Plan:

NOAA approved the Alaska Coastal Management Program (ACMP) in 1979 as a voluntary state partner in the National Coastal Management Program. The ACMP expired by operation of the Alaska Statute (AS) 44.66.020 and 44.66.030 on June 30, 2011. As a result of its expiration, the ACMP was withdrawn from this program on July 1, 2011, and there is no longer a Coastal Zone Management Act (CZMA) program in Alaska (76 FR 39857). A statewide referendum to reinstate the ACMP failed on August 28, 2012 (Ballot Pedia 2012).

Because a federally approved coastal management program must be administered by a state agency, no other entity can develop or implement a federally approved coastal management program for the state. Accordingly, the CZMA federal consistency provision no longer applies in Alaska. Federal agencies shall no longer provide Alaska with CZMA Consistency Determinations or Negative Determinations pursuant to 16 United States Code (U.S.C.) 1456(c)(1) and (2), and 15 CFR part 930, subpart C.

6.1.8.1 Summary and Determination

The ACMP expired on June 30, 2011, by operation of AS 44.66.020 and 44.66.030. As of July 1, 2011, there is no longer a CZMA program in Alaska. Since a federally approved CZMA program must be administered by a state, NOAA withdrew the ACMP from the National Coastal Management Program. See 76 Fed. Reg. 39,857 (July 7, 2011). As a result, the CZMA consistency provisions at 16 USC 1456(c)(3) and 15 CFR part 930 no longer apply in Alaska. Accordingly, federal agencies are no longer required to provide Alaska with CZMA consistency determinations.

6.1.9 Criterion 9

Such other factors relating to the effects of the discharge as may be appropriate:

The Permit establishes limits based on existing ELGs and conditions to ensure compliance with CWA requirements, including preventing unreasonable degradation of the marine environment. As discussed in this ODCE, EPA has evaluated the potential for significant adverse changes in ecosystem diversity, productivity, and stability of the biological communities within the Area of Coverage.

The ODCE also evaluates the threat to human health through the direct physical exposure to discharged pollutants and indirectly through consumption of exposed aquatic organisms in the food chain (see Criterion 6). As a result of these evaluations, area and depth prohibitions are included in the Permit as precautionary measures to ensure no unreasonable degradation occurs during the anticipated exploration activity. The Permit imposes an environmental monitoring program to gather additional, relevant information about potential effects of the discharges in Cook Inlet. Additionally, EPA has the authority to modify the Permit or revoke coverage if unreasonable degradation could or does result from the wastewater discharges.

The Environmental Monitoring Program is also designed to obtain additional information that can be used during implementation of the Permit and in future permitting decisions.

6.1.9.1 Summary and Determination

In summary, EPA carefully considered the potential impacts related to the authorized discharges in the Permit, especially the potential for disproportionate effects on communities and residents that engage in subsistence activities. That analysis determined that, with respect to the discharges, there will not be adverse human health or environmental effects on residents in the Cook Inlet region near the Area of Coverage.

6.1.10 Criterion 10

Marine water quality criteria developed pursuant to section 304:

The marine water quality criteria developed pursuant to CWA § 304 are recommended criteria adopted by State and Tribes as WQS and are approved by EPA for use in State and Tribal waters. These WQS are not applicable to the federal waters covered by the Permit. This section instead addresses compliance of Cook Inlet oil and gas exploration facility discharges with ELG technology-based effluent limitations (TBELs) developed pursuant to CWA § 307 and reviewed/updated pursuant to CWA § 304 and Ocean Discharge Criteria developed pursuant to CWA § 403.

6.1.10.1 Technology-Based Limits

TBELs required under the ELGs are incorporated into the Permit. The ELGs established BCT, BAT, BPT, and New Source Performance Standards (NSPS) for the Offshore and Coastal Subcategories of the Oil and Gas Extraction Point Source Category (40 CFR 435, Subpart A).

6.1.10.1.1 Drilling Fluids

The following limits and prohibitions are based on the ELGs: (1) no discharge of free oil; (2) no discharge of diesel oil; and (3) a toxicity limit of ≥ 30,000 ppm SPP (3 percent by volume). The Permit limits the discharge of organic contaminants through these free oil and diesel oil prohibitions, and by restricting the use of mineral oil in drilling fluids. Permittees must measure free oil in drilling fluid discharges using the static sheen test method, as described in the Permit. Permittees must measure toxicity using a 96-hour LC_{50} on the SPP using the Mysidopsis bahia species. As a pollution prevention practice, permittees are required to develop and implement a Drilling Fluids Plan (DFP). The DFP identifies chemical additives that may be used and provides an estimate of SPP toxicity using the maximum projected concentrations that may be used. The DFP also describes procedures for substituting or adding new chemicals.

Stock barite, which is added to drilling fluids, contains cadmium and mercury which are the surrogates for the heavy metals in drilling fluid discharges. Per the ELGs, the Permit establishes effluent limits for cadmium and mercury of 3 mg/kg and 1 mg/kg, respectively. The Permit requires permittees to report cadmium and mercury concentrations measured in the stock barite before it is added to the drilling fluids using EPA test methods 245.5 or 7471.

The Permit prohibits discharges of oil-based drilling fluids, inverse emulsion drilling fluids, oil-contaminated drilling fluids, and drilling fluids to which mineral oil has been added. The purpose of these prohibitions is to ensure compliance with the toxicity limit and the prohibition against the discharge of free oil. The Permit allows an exception to those prohibitions for drilling fluids to which mineral oil or nonaqueous-based fluids have been added as a carrier agent, lubricity additive, or pill. Permittees are allowed to discharge nonaqueous-based and synthetic-based drilling fluids that adhere to drill cuttings under the Offshore Category in the ELGs, as amended in 2001.

6.1.10.1.2 Drill Cuttings

Drill cuttings are primarily coarse sediment comprised of native material of the geologic formations being drilled through. The main source of pollutants in drill cutting discharges come from drilling fluids that are used in drilling a well that then adhere to the drill cuttings. Therefore, on the basis of the ELGs for BAT, BCT, BPT, and NSPS, drill cuttings discharges are subject to the same limits that apply to drilling fluid discharges as described above.

As noted previously, the Permit would authorize the discharge of drill cuttings generated using SBF. The use of SBF is considered a type of pollution prevention technology because the drilling fluids are not disposed of through bulk discharge at the end of drilling. Instead, the drilling fluids are brought back to shore and refurbished so they can be reused. In addition, drilling with SBFs allows operators to drill a slimmer well and causes less sloughing of the well during drilling than when WBFs are used. These factors result in a reduction in the volume of drill cuttings discharged. The Permit requires permittees to remove SBF from the drill cuttings and pass the Static Sheen Test prior to discharge. The ELGs also include limits for sediment toxicity and biodegradation for SBF. Although the ELGs do not address specific types of SBF, the ELGs contain toxicity and biodegradation limits that require operators to use less toxic fluids that biodegrade quickly.

The Permit contains limits for SBF at three points. First, for stock synthetic fluids prior to combination with other components of the drilling fluids system, the Permit imposes limits on polynuclear aromatic hydrocarbons sediment toxicity (10-day), and biodegradation rate. Second, combined fluid components are limited for formation oil contamination. Third, drilling fluids that adhere to drill cuttings are limited for sediment toxicity (4-day) and formation oil contamination.

6.1.10.1.3 Deck Drainage

For deck drainage discharges, the Offshore and Coastal Subcategory ELGs for NSPS, BAT, and BCT require a limitation of no discharge of free oil as determined by the presence of film, sheen, or a discoloration of the surface of the receiving water or by conducting a Static Sheen Test. This limit was in the 2007 Permit and EPA has reviewed and determined that it is still applicable and has been retained in the Permit.

6.1.10.1.4 Sanitary Wastewater

For sanitary wastewater discharges, the Offshore Subcategory ELGs for BCT require total residual chlorine (TRC) to be maintained as close to 1 mg/L as possible immediately after the point of chlorination for facilities that are continuously manned by 10 or more persons. The minimum TRC limit is a surrogate for bacteria destruction. For facilities continuously manned by nine (9) or fewer persons or only intermittently manned by any number of persons, BCT requires no discharge of floating solids.

6.1.10.1.5 Domestic Wastewater

For domestic wastewater discharges, the ELGs prohibit the discharge of floating solids, garbage, or foam. The 2007 Permit contained these limits. The EPA determined that the limits are still applicable and have been retained in the Permit.

6.1.10.1.6 Chemically-Treated Seawater and Freshwater Discharges

The Permit uses WET testing triggers to ensure chemically treated seawater and freshwater discharges that are more toxic will be evaluated thoroughly. This approach is preferable to attempting to limit the discharge of specific biocides, scale inhibitors, and corrosion inhibitors. Due to the large number of chemical additives used, it would be very difficult to develop technology-based limits for each individual additive. In addition, if the Permit were to limit specific chemicals, it could potentially halt the development and use of new and potentially more beneficial treatment chemicals.

Many of the chemicals normally added to seawater or freshwater, especially biocides, have manufacturer recommended maximum concentrations or EPA product registration labeling. In addition, information obtained from offshore operators demonstrates that it is unnecessary to use any of the chemical additives or biocides in concentrations greater than 500 mg/L, as the fact sheet describes. Therefore, the Permit limits discharges of seawater or freshwater to the most stringent of the following:

- The maximum concentrations and any other conditions specified in the EPA product registration labeling if the chemical additive is an EPA-registered product.
- The maximum manufacturer's recommended concentration.
- 500 mg/L or less

Compliance with this limitation is calculated on the basis of the amount of treatment chemicals added to the volume of water discharged.

As with other miscellaneous discharges described above, the Permit contains BCT limits prohibiting the discharge of free oil for chemically treated seawater and freshwater discharges. Free oil is a direct measurement of oil contamination and, on the basis of BPJ, the Permit uses it as a surrogate parameter for conventional pollutants in these discharges.

6.1.10.1.7 Free Oil Limitations

The Permit limits the discharge of free oil to help prevent the discharge of toxic pollutants contained in oil. The Ocean Discharge Criteria include 10 factors that must be considered in determining whether a discharge will cause unreasonable degradation of the marine environment (40 CFR 125.122). One of the 10 factors is the potential impact on human health through direct and indirect pathways. 40 CFR 110.3 defines quantities of oil that may be harmful to public health or welfare as a discharge that causes a sheen or discoloration on the receiving water. Therefore, the Permit limits all discharges to no free oil as measured using the visual sheen test method, as described in the Permit.

6.1.10.1.8 All Discharges

The Permit prohibits the discharge of rubbish, trash, and other refuse on the basis of the International Convention for the Prevention of Pollution from Ships (MARPOL). On the basis of CWA 403(c), 33 USC 1343(c), the Permit also requires minimization of the discharge of surfactants, dispersants, and detergents.

6.1.10.2 Ocean Discharge Criteria

Discharges to marine waters in the territorial seas are subject to additional regulatory requirements established under CWA 403. CWA 403 applies to marine discharges under CWA 402 permits and allows for more stringent controls when necessary to protect the environment. These controls need not be restricted by engineering attainability or rigorous cost or economic considerations when determining permit conditions. The evaluation includes sediment and dissolved constituents and seeks to protect aquatic species and places special emphasis on unique, sensitive, or ecologically critical species. The EPA can impose discharge limitations or other conditions needed to attain compliance with CWA 403.

Based on the Ocean Discharge Criteria, the Permit retains discharge rate and depth limits for drilling fluids discharges, as well as discharge prohibitions in and near several environmentally sensitive areas of Cook Inlet. The 2007 Permit established toxicity triggers for seawater and freshwater discharges to which treatment chemicals have been added. EPA has reviewed these triggers and determined that they are applicable and the Permit retains all of these requirements.

6.1.10.3 Summary and Determination

The ODCE was developed with the best available scientific information and incorporated additional information based on public comments received. The EMP baseline studies conducted by new exploration facilities indicate the environmental conditions are representative of net erosional sediment conditions that lack the fine grained benthic substrate to support a diverse and abundant biological community. This information supports the determination that there is no unreasonable degradation and that there is no adverse effects anticipated because the drilling fluids will be adequately dispersed in the receiving water. EPA requires continued environmental monitoring during the next permit cycle to collect data to inform future decisions.

6.2 SUMMARY

EPA has evaluated the 13 discharges in the Permit against the 10 Ocean Discharge Criteria found in 40 CFR 125.122. Based on this evaluation, EPA concludes that the discharges will not cause unreasonable degradation of the marine environment under the conditions, limitations, and requirements of the Permit.

With regard to discharge of drilling fluids and drill cuttings, this ODCE identifies recent studies that show that trace metals commonly associated with water-based drilling fluids and drill cuttings are not readily absorbed by living organisms. Data suggest that bioaccumulation risks are expected to be low because the bioavailability of trace metals in drilling fluid components (i.e., barite) is low. See Section 6.1.2. In addition, while increased sedimentation from drilling fluids and cuttings can affect benthic organisms in the discharge area due to smothering, the effects are limited to a small area (less than 328 ft [100 m]) and have been shown to have few long-term impacts. Several studies document the resilience of affected benthic communities in re-establishing affected areas within months after discharges cease. Also, other studies of former offshore drilling locations show that trace metal concentrations in seafloor sediment are not persistent, and decrease to levels below risk-based sediment guideline concentrations. See Section 6.1.1. These studies demonstrate that discharge of drilling fluids and drill cuttings from exploration facilities will not result in an unreasonable degradation of the marine environment during or after discharge activities. Finally, because discharges from exploration facilities are relatively short in duration and intermittent during drilling operations, long-term widespread impacts are not anticipated. The determination that drilling fluid and drill cuttings will not result in unreasonable degradation of the marine environment is not dependent on whether the discharge is to an erosional or depositional area of

Cook Inlet. However, discharge to an erosional area is preferred and most known depositional areas are not within the coverage area.

Regarding non-contact cooling water discharge, available data show that operators use either large or small volumes of water through their cooling systems, which result in effluent streams with distinct temperature signature: large volumes result in a lower temperature differential as compared with ambient conditions, and small volumes have a higher temperature differential. Under either scenario, the ODCE does not identify any acute or chronic effects of such temperature differences. Thermal effects to receiving water from the discharge of non-contact cooling water will disburse and disappear quickly after the discharges cease.

All other waste streams that will be authorized by the Permit (e.g., domestic wastewater, deck drainage) do not contain pollutants that are bioaccumulative or persistent. The Permit contains effluent limitations and requirements that ensure protection of the marine environment.

Miscellaneous Discharges may contain chemical additives. These discharges are controlled through chemical inventories, adherence to chemical use guidelines, and WET toxicity testing and triggers based on the rate of discharge. The toxicity triggers are established to ensure that more toxic discharges are thoroughly investigated by the Toxic Indentification Evaluation and Toxic Reduction Evaluation requirements. This approach protects water quality and allows flexibility for the operators to substitute less toxic chemicals that may become available during the permit cycle.

The ODCE also addresses subsistence use within the coverage area. As discussed above in sections 6.1.6 and 6.1.9, EPA acknowledges the concerns related to the consumption of subsistence resources and public health. In particular, EPA is mindful of concerns about human exposure to contaminants through consumption of subsistence foods and through other environmental pathways. EPA acknowledges the importance of assessing and clearly articulating the risk related to the discharges, because even the perception of contamination has the potential to produce adverse effects on subsistence hunters and their practices. EPA has evaluated the discharges and does not anticipate a threat to human health through either direct exposure to pollutants or consumption of exposed aquatic organisms. However, as a result of these evaluations, continuation of environmental monitoring is required during exploration activities to inform future permitting decisions.

Importantly, the Permit requires permittees to implement an EMP and imposes other conditions that assess the site-specific impacts of the discharges on water, sediment, and biological quality. The monitoring program includes assessments of pre-, during, and post-drilling conditions and persistent impacts of drilling fluids and drill cuttings discharges on aquatic life. Permittees are required to assess the areal extent of cuttings deposition and conduct ambient measurements in the water column including temperature and turbidity measurements. Permittees are also required to evaluate the characteristics of all discharges.

Finally, in accordance with 40 CFR 125.123(d)(4) the Permit states modification or revocation could happen at any time if, on the basis of any new data, EPA determines that continued discharges may cause unreasonable degradation of the marine environment. Thus, EPA will be able to assess new data that is submitted in the required annual reports for each operator as a means to continually monitor potential effects on the marine environment and to take precautionary actions that ensure no unreasonable degradation occurs during the permit term.

7.0 REFERENCES

15 CFR 930 Subpart C.

35 FR 8491- 8498. Whales. June 2, 1970.

40 CFR 110.

40 CFR 125 Subpart M.

40 CFR 435 Subpart A.

50 CFR 17.

50 CFR 223 and 224.

50 CFR 226.

53 FR 33516. Beluga. August 31, 1988.

55 FR 12645. Steller Sea Lion. April 5, 1990.

55 FR 49204. Steller Sea Lion. November 26, 1990.

56 FR 58619. Snake River Sockeye. November 20, 1991.

57 FR 14653. Snake River Chinook. April 22, 1992.

58 FR 45269. Steller Sea Lion. August 27, 1993.

59 FR 30715. Stellar Sea Lion. June 15, 1994.

59 FR unknown. North Atlantic Right Whale. June 3, 1994.

62 FR 24345. Steller Sea Lion. May 5, 1997.

62 FR 24355. Steller Sea Lion. May 5, 1997.

62 FR 31748. Stellers Eider. June 11, 1997.

65 FR 13262. Stellers Eider. March 13, 2000.

65 FR 34590. Beluga. May 31, 2000.

65 FR 38778. Beluga. June 22, 2000.

65 FR 46643. Shorttailied Albatross. July 31, 2000.

67 FR 7660. North Pacific Right Whale. February 20, 2002

68 FR 17560. North Pacific Right Whale. April 10, 2003.

69 FR 30857. North Pacific Right Whale. June 1, 2004.

70 FR 46366. Sea Otter. August 9, 2005.

73 FR 12024. North Pacific Right Whale. March 6, 2008.

73 FR 62919. Beluga. October 22, 2008.

74 FR 51988. Sea Otter. October 8, 2009.

76 FR 20180. Beluga. April 11, 2011.

76 FR 39857. CZMA. July 7, 2011.

Abookire, A.A., and J.F. Piatt. 2005. Oceanographic conditions structure forage fishes into lipid-rich and lipid-poor communities in Lower Cook Inlet, Alaska, USA. *Marine Ecology Progress Series* 287: 229-240.

Abookire, A.A. 2006. Reproductive biology, spawning season, and growth of female rex sole (*Glyptocephalus zachirus*) in the Gulf of Alaska. *Fisheries Bulletin* 104: 350–359.

Abookire, A.A., J.F. Piatt, and M.D. Robards. 2000. Nearshore fish distributions in an Alaskan estuary in relation to stratification, temperature and salinity. *Estuarine, Coastal and Shelf Science* 51: 45-49.

Abookire, A.A., J.F. Piatt, and B.L. Norcross. 2001. Juvenile groundfish habitat in Kachemak Bay, Alaska, during late summer. *Alaska Fishery Research Bulletin* 8(1): 45-56.

Adams, N. 1985. *Drilling Engineering: A Complete Well Planning Approach*. PennWell Publishing Company, Tulsa, OK.

ADEC (Alaska Department of Environmental Conservation). 2004. *Alaska Fish Tested For Mercury, Get Clean Bill of Health*. <http://www.sitnews.us/0903news/092003/092003_health_ak_fish.html>.

ADEC (Alaska Department of Environmental Conservation). 2013. Spills DB Online Query - Home. Alaska Department of Environmental Conservation, Division of Spill Prevention and Response. <http://dec.alaska.gov/applications/spar/SpillsDBQuery/search.asp > Accessed November 2013.

ADF&G (Alaska Department of Fish and Game). 1986. *Distribution, Abundance, and Human Use of Fish and Wildlife – Alaska Habitat Management Guide, Southcentral Region, Volume II*. Alaska Department of Fish and Game, Habitat Division, Juneau, AK.

ADF&G (Alaska Department of Fish and Game). 1994a. *Blue Whale*. Revised 2008. <http://www.adfg.alaska.gov/static/education/wns/blue_whale.pdf>. Accessed August 2013.

ADF&G (Alaska Department of Fish and Game). 1994b. *Humpback Whale*. Revised 2008. <http://www.adfg.alaska.gov/static/education/wns/humpback_whale.pdf>. Accessed November 2013.

ADF&G (Alaska Department of Fish and Game). 1994c. *Steller's Sea Lion*. <http://www.adfg.alaska.gov/index.cfm?adfg=stellersealion.main>. Accessed November 2013.

ADF&G (Alaska Department of Fish and Game). 1994d. *Sea otter*. <http://www.adfg.alaska.gov/index.cfm?adfg=seaotter.main>. Accessed November 2013.

ADF&G (Alaska Department of Fish and Game). 1994e. *Beluga whale*. <http://www.adfg.alaska.gov/index.cfm?adfg=beluga.main>. Accessed November 2013.

ADF&G (Alaska Department of Fish and Game). 2011. *Final 2010 Sport Halibut Harvest Estimates*. <http://alaskafisheries.noaa.gov/npfmc/pdfdocuments/halibut/area2c3a_final2010adfgdata.pdf> Accessed August 2012.

ADF&G (Alaska Department of Fish and Game). 2013. *Harbor Seal*. <http://www.adfg.alaska.gov/index.cfm?adfg=harborseal.main >. Accessed November 2013.

ADF&G (Alaska Department of Fish and Game). Undated. *Sei Whale*. <http://www.adfg.alaska.gov/static/education/wns/sei_whale.pdf>. Accessed August 2013.

ADNR (Alaska Department of Natural Resources). 1999. *Five-year oil and gas leasing program*. Alaska Department of Natural Resources, Division of Oil and Gas, Anchorage, AK.

ADNR (Alaska Department of Natural Resources). 2009a. *Beaufort Seas Areawide Oil and Gas Lease Sale: Final Finding of the Director, Chapter 4*. Alaska Department of Natural Resources, Division of Oil and Gas, Anchorage, AK.

ADNR (Alaska Department of Natural Resources). 2009b. Chapter Three: Description of the Cook Inlet Lease Sale Area. Chapter 3 in *Cook Inlet Areawide Final Best Interest Finding*, State of Alaska, Department of Oil and Gas.

ADNR (Alaska Department of Natural Resources). 2013. Summary of State Competitive Oil and Gas Lease Sales -- 1959 through 2013.

Agler, B.A., S.J. Kendall, P.E. Seiser, and D.B. Irons. 1995. *Monitoring Seabird Population in Areas of Oil and Gas Development on the Alaskan Continental Shelf: Estimates of Marine Bird and Sea Otter Population Abundance in Lower Cook Inlet, Alaska, During Summer 1993 and Winter 1994*. U.S. Department of the Interior, Fish and Wildlife Service, Anchorage, AK.

AKNHP (Alaska Natural Heritage Program). 2013. *Alaska Species Ranking System Summary Report - Sperm whale, North Pacific*. <http://aknhp.uaa.alaska.edu/wp-content/uploads/2013/05/Physeter_macrocephalus_report.pdf>. Accessed September 2013.

Alaska DHSS. 2014. *Fish Consumption Advice for Alaskans: A Risk Management Strategy to Optimize the Public's Health*. Prepared by Ali K. Hamade, PhD, DABT on behalf of the Alaska Scientific Advisory Committee for Fish Consumption, Section of Epidemiology, Division of Public Health, Department of Health and Social Services, Anchorage, AK.

Alaska Division of Public Health. 2002. *Mercury in Hair Monitoring Program Information for Pregnant Women*. Alaska Department of Health and Social Services, Division of Public Health Section of Epidemiology, Anchorage, AK.

Alaska Volcano Observatory. 2008. *Restless Volcanoes*. U.S. Geological Survey and Geophysical Institute, University of Alaska Fairbanks. <http://www.avo.alaska.edu>. Accessed July 2008.

Alaskool. 2004. *Alaska Regional Profiles: Southcentral Region*. Institute of Social and Economic Research, University of Alaska Anchorage. <http://www.alaskool.org/resources/regional/sc_reg_pro/contents.htm> Accessed June 2008.

Alldredge, A.L., M. Elias, and C.C. Gotschalk. 1986. Effects of drilling muds and mud additives on the primary production of natural assemblages of marine phytoplankton. *Marine Environmental Research* 19:157-176.

Allen, B. M., and R. P. Angliss. 2011a. Alaska marine mammal stock assessments: Beluga Whale (*Delphinapterus leucas*): Bristol Bay Stock. NOAA-TM-AFSC-234. Pp. 79-83.

Allen, B. M., and R. P. Angliss. 2011b. Alaska marine mammal stock assessments, 2010. U.S. Dep. Commer., NOAA Tech. Memo. NMFSAFSC-223, 292 p.

Allen, B. M., and R. P. Angliss. 2013. Alaska marine mammal stock assessments, 2012. U.S. Dep. Commer., NOAA Tech. Memo. NMFS AFSC-245, 282 p.

Allen, S.G., J. Mortenson, and S. Webb. 2011. *Field Guide to Marine Mammals of the Pacific Coast: Baja, California, Oregon, Washington, British Columbia*. University of California Press. Berkeley and Los Angeles, CA.

American Cetacean Society (ACS). Undated. *Sperm Whale. American Cetacean Society Fact Sheet*. < http://acsonline.org/fact-sheets/sperm-whale/ > Last accessed April 2015.

Angliss R.P., and K.L. Lodge. 2002. *Alaska Marine Mammal Stock Assessments, 2002*. NOAA Technical Memorandum NMFS-AFSC-133. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, National Marine Mammal Laboratory, Alaska Fisheries Science Center, Seattle, WA.

Angliss, R.P., and K.L. Lodge. 2004. *Alaska Marine Mammal Stock Assessments 2003*. NOAA Technical Memorandum NMFS-AFSC-144. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, National Marine Mammal Laboratory, Alaska Fisheries Science Center, Seattle, WA.

Angliss, R.P., and R. Outlaw. 2005. *Alaska Marine Mammal Stock Assessments 2005*. NOAA Technical Memorandum NMFS-AFC-161. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, National Marine Mammal Laboratory, Alaska Fisheries Science Center, Seattle, WA.

Apeti, D.A., S.I. Hartwell, S.M. Myers, J. Hetrick, and J. Davenport. 2013. Assessment of contaminant body burdens and histopathology of fish and shellfish species frequently used for subsistence food by Alaskan Native communities. North Pacific Research Board Final Report 63 pp.

ARB, Inc. 2011. Chapter 45: Threatened and Endangered Species and Species of Conservation Concern. ABR, Inc. Environmental Research & Services.

Arneson, P.D. 1980. *Identification, Documentation, and Delineation of Coastal Migratory Bird Habitat in Alaska*. Alaska Department of Fish and Game.

Ashford, J.R., T. Ezer, and C.M. Jones. 2013. River discharge predicts spatial distributions of beluga whales in the Upper Cook Inlet, Alaska, during early summer. *Polar Biology* 2013(36): 1077-1087.

Atlas, R.M., M.I. Venkatesan, I.R. Kaplan, R.A. Feely, R.P. Griffiths, and R.Y. Morita. 1983. Distribution of Hydrocarbons and Microbial Populations Related to Sedimentation Processes in Lower Cook Inlet and Norton Sound, Alaska. *Arctic Institute of North America*. 36(3):251-261.

ATSDR (Agency for Toxic Substances and Disease Registry). 2009. *Evaluation of Seafood and Plant Data Collected from Cook Inlet near the Native Villages of Port Graham, Nanwalke, Seldovia, and Tyonek, Alaska*. U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Division of Health Assessment and Consultation, Atlanta, GA.

Avanti Corporation (Avanti). 1991. *Ocean Discharge Criteria Evaluation for the NPDES General Permit for the Gulf of Mexico OCS Draft*. Prepared for U.S. Environmental Protection Agency Water Management Division Region 6. Avanti Corporation, Vienna, VA.

Ayers, R.C., Jr., T.C. Sauer, Jr. R.P. Meek, and G. Bowers. 1980. *An Environmental Study to Assess the Impact of Drilling Discharges in the Mid-Atlantic. I. Quantity and Fate of Discharges*. Pages 382-418 In: Proceedings of Symposium, Research on Environmental Fate and Effects of Drilling Fluids and Cuttings, Vol. I. January 21-24, 1980, Lake Buena Vista, FL.

Bailey, E.P. 1976. Breeding bird distribution and abundance in the Barren Islands Alaska. *Murrelet* 57:2-12.

Baird, P.H., and R.A. Moe. 1978. Breeding Biology and Feeding Ecology of Marine Birds in the Sitkalidak Strait Area, Kodiak Island. Appendix IV in *Population Dynamics and Trophic Relationships of Marine Birds in the Gulf of Alaska and Southern Bering Sea*, ed. C. Lensink and K. Wohl, pp. 313-524. U.S. Department of Commerce, National Oceanic and Atmospheric Administration and U.S. Department of Interior, Bureau of Land Management, Boulder, CO.

Baird, R.W. 2000. The Killer Whale: Foraging Specializations and Group Hunting. Chapter 5 in *Cetacean Societies: Field Studies of Dolphins and Whales*, ed. J. Mann, R.C. Connor, P.L. Tyack and H. Whitehead, pp. 127-153. University of Chicago Press, Chicago, IL.

Ballot Pedia. 2012. *Results of the Alaska Coastal Management Question (Ballot Measure 2)*. <http://ballotpedia.org/wiki/index.php/Alaska_Coastal_Management_Question,_Ballot_Measure_2_(August_2012)>. Accessed September 2012.

Becker, P.R., M.M. Krahn, E.A. Mackey, R. Demiralp, M.M. Schantz, M.S. Epstein, M.K. Donais, B.J. Porter, D.C.G. Muir, and S.A. Wise. 2000. Concentrations of Polychlorinated Biphenyls (PCB's), Chlorinated Pesticides, and Heavy Metals and Other Elements in Tissues of Belugas, *Delphinapterus leucas*, from Cook Inlet, Alaska. *Marine Review* 62(3):81-98.

Beget, J.E., and Nye, C.J. 1994. Postglacial eruption history of Redoubt Volcano, Alaska. *Journal of Volcanology and Geothermal Research* 62(1994): 31–54.

Berger, B.D., and K.E. Anderson. 1992. *Modern Petroleum -- A Basic Primer of the Industry, Third Edition.* PennWell Publishing Company, Tulsa, OK.

Best, E.A., and W.H. Hardman. 1982. *Juvenile Halibut Surveys, 1973-1980*. Technical Report No. 20. International Pacific Halibut Commission, Seattle, WA.

Bigg, M.A. 1981. Harbour Seal, *Phoca vitulina, Linnaeus*, 1758 and *Phoca largha*, Pallus 1811. , Vol. 2: Seals in *Handbook of Marine Mammals,* ed. S.H. Ridgeway and R.J. Harrison, pp. 1–27. Academic Press, NY.

BLM (Bureau of Land Management) 2006. Ring of Fire: Proposed Resource Management Plan and Final Environmental Impact Statement. U.S. Department of the Interior, Bureau of Land Mangement, Anchorage Field Office. <http://www.blm.gov/ak/st/en/prog/planning/ring_of_fire_plan/ring_of_fire_proposed.html >. Accessed November 2013.

Bodkin, J.L., G.G. Esslinger, and D.H. Monson. 2004. Foraging Depths of Sea Otters and Implication to Coastal Marine Communities. *Marine Mammal Science* 20:305–321.

BOEM (Bureau of Offshore Energy Management). 2012. Final Programmatic Environmental Impact Statement for the Oil and Gas Leasing Program: 2012-2017. (OCS EIS/EA BOEM 2012-030). BOEM Headquarters. Herndon, VA.

Boveng, P.L., J.M. London, R.A. Montgomery, and J.M. Ver Hoef. 2011. Distribution and abundance of harbor seals in Cook Inlet, Alaska. Task I: Aerial surveys of seals ashore, 2003-2007. Final Report. BOEM Report 2011-063. Bureau of Ocean Energy Management, Alaska Outer Continental Shelf Region, Anchorage, Alaska, USA. 46 pp.

Brabets, T.P. and M.S. Whitman 2004. *Water-Quality, Biological, and Physical-Habitat Conditions at Fixed Sites in the Cook Inlet Basin, Alaska, National Water-Quality Assessment Study Unit, October 1998 - September 2001*. Scientific Investigations Report 2004-5021, U.S. Geological Survey. <http://pubs.usgs.gov/sir/2004/5021/pdf/sir20045021.pdf>. Accessed September 2012.

Brabets, T.P., G.L. Nelson, J.M. Dorova, and A.M. Milner. 1999. *Water Quality Assessment of the Cook Inlet Basin, Alaska — Environmental Setting,* Water Resources Investigation Report 99-4025, U.S. Geological Survey, Anchorage, AK.

Bradner, T. 2011, March 9. Revival of oil industry in Cook Inlet? Smaller companies have high hopes, some spurred by state incentives. Morris News Service, <http://homernews.com/stories/030911/business_rooici.shtml>. Accessed August 2012.

Braham, H. 1984. The status of endangered whales: an overview. *Marine Fisheries Review*. 46(4):2-6.

Braun, G.M. 1985. The structure of an Arctic shallow benthic community: Effects of ice gouging. Master's thesis, Oregon State University.

Brower, Jr., W.A., R.G. Baldwin, Jr., C.N. Williams, J.L. Wise, and L.D. Leslie. 1988. *Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska,* Vol. I, Gulf of Alaska. NAVAIR 50-1C-551; MMS 87-0011. U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, and U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Brueggeman, J.J., G.A. Green, K.C. Balcomb, C.E. Bowlby, R.A. Grotefendt, K.T. Briggs, M.L. Bonnell, R.G. Ford, D.H. Varoujean, D. Heinemann, and D.G. Chapman. 1990. *Oregon-Washington Marine Mammal and Seabird Survey: Information Synthesis and Hypothesis Formulation.* U.S. Department of Interior, Outer Continental Shelf Study, Minerals Management Service 89-0030.

Buckland, S.T., K.L. Cattanach, and R.C. Hobbs. 1993. *Abundance Estimates of Pacific White Sided Dolphin, Northern Right-Whale Dolphin, Dall's Porpoise and Northern Fur Seal in the North Pacific, 1987/90*. Pages 387-407 in W. Shaw, R.L. Burgner, and J. Ito (eds.), Biology, Distribution and Stock Assessment of Species Caught in the High Seas Driftnet Fisheries in the North Pacific Ocean. International North Pacific Fisheries Commission Symposium; 4–6 November 1991, Tokyo, Japan.

Burek K.A., and Goertz C. 2010. Morbidity and mortality trends in stranded Cook Inlet beluga whales. <http://www.fakr.noaa.gov/protectedresources/whales/beluga/workshop/presentations/21_burek_cib_strandings.pdf> Accessed November 2013.

Burn, D.M., and A.M Doroff. 2005. Decline in sea otter (Enhydra lutris) populations along the Alaska Peninsula, 1986-2001. *Fishery Bulletin* 103: 270-279.

Burns, J.J., and G.A. Seaman. 1985. *Investigations of Belukha Whales in Coastal Waters of Western and Northern Alaska: II. Biology and Ecology*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Alaska Department of Fish and Game, Anchorage, AK.

Calambokidis, J., E. Falcone, A. Douglas, L. Schlender, and J. Huggins. 2010. *Photographic Identification of Humpback and Blue Whales off the U.S. West Coast: Results and Updated Abundance Estimates from 2008 Field Season*. Final Report for Contract AB133F08SE2786 from Southwest Fisheries Science Center. 18pp.

Calkins, D.G. 1983. *Marine Mammals of Lower Cook Inlet and the Potential For Impact From Outer Continental Shelf Oil and Gas Exploration*, Final Report 20:171-265, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Alaska Department of Fish and Game, Anchorage, AK.

Calkins, D.G. 1986. Marine Mammals. Chapter 17 in *The Gulf of Alaska: Physical Environment and Biological Resources*, ed. D.W. Hood and S.T. Zimmerman, pp. 527-560 U.S. Department of Commerce, U.S. Department of the Interior.

Carls, M.G., and S.D. Rice. 1981. *Toxicity of Oil Well Drilling Muds to Alaskan Larval Shrimp and Crabs*. Final Report for Outer Continental Shelf Energy Assessment Program. U.S. Department of the Interior, Bureau of Land Management, Washington, DC.

Carlson, P.R., B.F. Molnia, S.C. Kittelson, and J.C. Hampson, Jr. 1977. *Map of Distribution of Bottom Sediments on the Continental Shelf, Northern Gulf of Alaska*. U.S. Geological Survey Miscellaneous Field Studies Map MF 876. Menlo Park, CA.

Carollo Engineers. 2009. *Water Desalination Concentrate Management and Piloting*. Prepared by Carollo Engineers, Sunrise, FL, for South Florida Water Management District, FL.

CBD (Center for Biological Diversity). 2000. *Petition to Revise the Critical Habitat Designation for the Northern Right Whale (*Eubalaena glacialis*) Under the Endangered Species Act*. Center for Biological Diversity. Berkeley, CA. <http://www.biologicaldiversity.org/swcbd/species/right/petition.pdf>. Accessed September 2012.

Chenelot, H. 2003. Factors Affecting Estuarine Population of *Nereocystis leutkeana* in Kachemak Bay, Alaska. Master's thesis, University of Alaska Fairbanks.

Combellick, R., and W.E. Long. 1983. *Geologic Hazards in Southeastern Alaska, an Overview: State of Alaska*, Alaska Report of Investigations 83-17, Division of Geological and Geophysical Surveys.

Combellick, R.A., R.D. Reger, and C.J. Nye. 1995. *Geologic hazards in and near proposed State of Alaska oil and gas lease sale 85A (Cook Inlet)*. DGGS Public Data File 95-36.

Compton, R., L. Goodwin, R. Handy, V. Abbott. 2008. A critical examination of worldwide guidelines for minimising the disturbance to marine mammals during seismic surveys. *Marine Policy* 32:255–262.

Consiglieri, L.D., H.W. Braham, M.E. Dalheim, C. Fiscus, P.D. McGuire, C.E. Peterson, and D.A. Pippenger. 1982. Seasonal Distribution and Relative Abundance of Marine Mammals in the Gulf of Alaska, pp. 191-343 in Vol. 61 *Outer Continental Shelf Environmental Assessment Program Final Reports of the Principal Investigators*, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Alaska Department of Fish and Game.

Cooney, R.T. 1986. Zooplankton. Chapter 10 in *The Gulf of Alaska: Physical Environment and Biological Resources*, ed. D.W. Hood and S.T. Zimmerman, pp. 285-304 U.S. Department of Commerce, U.S. Department of the Interior.

Costello, J.A. 1985 *Tsunamis: Hazard Definition and Effects on Facilities*. U.S. Geological Survey Open File Report 85-533.

Dahlheim, M.E., D. Ellifrit, and J. Swenson. 1997. *Killer Whales of Southeast Alaska: A Catalog of Photo-identified Individuals*. Day Moon Press, Seattle, WA.

Dahlheim, M., A. York, R. Towell, J. Waite, and J. Breiwick. 2000. Harbor porpoise (*Phocoena phocoena*) abundance in Alaska: Bristol Bay to southeast Alaska, 1991-1993. *Marine Mammal Science* 16(1):28-45.

Dalton, Dalton, and Newport. 1985. *Assessment of Environmental Fate and Effects of Discharges from Oil and Gas Operations*. March 1985.

Dames and Moore. 1978. Drilling fluid dispersion and biological effects study for the lower Cook Inlet C.O.S.T. well. Prepared for Atlantic Richfield Co.

Dau, C.P., P.L. Flint, and M.R. Petersen. 2000. Distribution of recoveries of Steller's eiders banded on the lower Alaska Peninsula, Alaska. *Journal of Field Ornithology* 71(2):541-548.

Dayton P.K., T. Currie, B.D. Gerrodette, R. Rosenthal, and R. Ven Tresca. 1984. Patch dynamics and stability of some California kelp communities. *Ecological Monographs* 54(3):253-298.

Dayton, P.K., M.J. Tegner, P.B. Edwards, and K.L. Riser. 1999. Temporal and spatial scales of kelp demography: The role of oceanographic climate. *Ecological Society of America* 69(2): 219-250.

DeGange, A.R., and G.A. Sanger. 1986. Marine Birds. Chapter 16 in *The Gulf of Alaska: Physical Environment and Biological Resources*, ed. D.W. Hood and S.T. Zimmerman, pp. 479-526 U.S. Department of Commerce, U.S. Department of the Interior.

Demarchi, M.W., M. Holst, D. Robichaud, M. Waters, and A.O. MacGillivray. 2012. Responses of steller sea lions (eumetopias jubatus) to in-air blast noise from military explosions. *Aquatic Mammals* 38(3):279-289.

Doroff, A.M., J.A. Estes, M.T. Tinker, D.M. Burns, and T.J. Evans. 2003. Sea otter population declines in the Aleutian Archipelago. *American Society of Mammalogists* 84:55–64.

Drew, G.S. 2005. *North Pacific Pelagic Seabird Database: Compiling Datasets and Creating an Archive, Accessible Database, and Pelagic Seabird Atlas. Final Report for the North Pacific Marine Research Institute (NPMRI)*. Anchorage, Alaska. <http://alaska.usgs.gov/science/biology/nppsd/pubs_reports/NPPSD_Final_Report.pdf>. Accessed September 2012.

Dunton, K.H., E. Reimnitz, and S. Schonberg. 1982. An arctic kelp community in the Alaskan Beaufort Sea. *Arctic Institute of North America* 35(4):465-484.

Eagleton, M. 2000. Personal Communication (telephone with C. Perham, LGL Alaska Research Associates, Inc.). December 13, 2000, National Marine Fisheries Service, Anchorage, AK.

Elphick, C.S., and G.L. Hunt, Jr. 1993. Variations in the distributions of marine birds with water mass in the Northern Bering Sea. *The Condor* 95(1):33-44.

Environment Canada. 2004a. *Species at Risk: Sei Whale, Pacific Population*. Environment Canada. <http://www.speciesatrisk.gc.ca/search/speciesDetails_e.cfm?SpeciesID=755.> Accessed November 2004.

Environment Canada. 2004b. *Species at Risk: Blue whale, Pacific Population*. Environment Canada. <http://www.dfo-mpo.gc.ca/speciesespeces/species/species_blueWhale_Pacific_e.asp.> Accessed August 2005.

Eslinger, D.L., R.T. Cooney, C.P. McRoy, A. Ward, Jr., T.C. Kline, P. Simpson E.J. Wang, and J.R. Allen. 2001. Plankton dynamics: Observed and modelled response to physical conditions in Prince William Sound, Alaska. *Fisheries Oceanography* 10(Suppl. 1): 81-96.

Ezer, T., R. Hobbs, and L-Y. Oey. 2008. On the movement of beluga whales in Cook Inlet, Alaska: Simulations of tidal and environmental impacts using a hydrodynamic inundation model. *Oceanography* 21(4): 186-195.

Ezer, T., J.R. Ashford, C.M. Jones, B.A. Mahoney, and R.C. Hobbs. 2013. Physical–biological interactions in a subarctic estuary: How do environmental and physical factors impact the movement and survival of beluga whales in Cook Inlet, Alaska? *Journal of Marine Systems* 111-112(2013): 120-129.

Fall, J.A., R.T. Stanek, B. Davis, L. Williams, and R. Walker. 2004. Cook Inlet Customary and Traditional Subsistence Fisheries Assessment. Federal Subsistence Fishery Monitoring Program, Final Project Report No. FIS03-045. U.S. Fish and Wildlife Service, Office of Subsistence Management, Fishery Information Services Division, Anchorage, AK.

Fechhelm, R.G., W.J. Wilson, W.B. Griffiths, T.B. Stables, and D.A. Marino. 1999. *Forage Fish Assessment in Cook Inlet Oil and Gas Development Areas, 1997-1998*. Report prepared by LGL Alaska Research Associates, Inc., Anchorage, AK, and BioSonics, Inc., Seattle, WA, for USDOI, Minerals Management Service, Anchorage, AK.

Feder, H.M., and S.C. Jewett. 1986. The Subtidal Benthos. Chapter 12 in *The Gulf of Alaska: Physical Environment and Biological Resources*, ed. D.W. Hood and S.T. Zimmerman, pp. 347-389 U.S. Department of Commerce, U.S. Department of the Interior.

Feder, H.M. 1981. Distribution, Abundance, Community Structure, and Trophic Relationships of the Nearshore Benthos of Cook Inlet. pp. 416-676. *Environmental assessment of the Alaskan continental shelf*. Final reports of principal investigators. Vol. 14: Biological studies. National Oceanic and Atmospheric Administration/Bureau of Land Management, Boulder, CO.

Feely, R.A., G.J. Massoth, A.J. Paulson, M.F. Lamb, E.A. Martin. 1981. *Distribution and Elemental Composition of Suspended Matter in Alaskan Coastal Waters*. NOAA Technical Memorandum ERL PMEL-27. National Oceanic and Atmospheric Administration

Ferrero, R.C., and W.A. Walker. 2006. Age, Growth, and Reproductive Patterns of Dall's Porpoise (*Phocoenoides Dalli*) in the Centeral North Pacific Ocean. *Marine Mammal Science* 15(2): 273-313. <http://onlinelibrary.wiley.com/doi/10.1111/j.1748-7692.1999.tb00803.x/abstract?systemMessage=Wiley+Online+Library+will+be+unavailable+17+Dec+from+10-13+GMT+for+IT+maintenance> Accessed September 2012.

Fiedler, P., S. Reilly, R. Hewitt, D. Demer, V. Philbrick, S. Smith, W. Armstrong, D. Croll, B. Tershy, and B. Mate. 1998. Blue whale habitat and prey in the Channel Islands. *Deep Sea Research II* 45(1998): 1781-1801.

Fisheries and Oceans Canada. 2005. *Backgrounder. Sei Whale.* BG-PR-05-015c-e. Fisheries and Oceans Canada. < http://www-comm.pac.dfompo.gc.ca/pages/release/bckgrnd/2005/bg015c_e.htm.> Accessed August 2005.

Flint, P.L., and M. P. Herzog. 1999. Breeding of Steller's eiders, *Polysticta stelleri*, on the Yukon-Kuskokwim Delta, Alaska. *Canadian Field-Naturalist* 113: 306-308.

Flint, P.L., M.R. Petersen, C.P. Dau, J.E. Hines, and J.D. Nichols. 2000. Annual survival and site fidelity of Steller's Eiders molting along the Alaska Peninsula. *The Journal of wildlife management*, 261-268.

Foster, M.S., and D.R. Schiel. 1986. The structure of subtidal algal stands in temperate waters. *Oceanography andMarine Biology Annual Review*. 24:265-307

Foster, N.R, D. Lees, S.C. Lindstrom, and S. Saupe. 2010. *Evaluating a Potential Relict Arctic Invertebrate and Algal Community on the West Side of Cook Inlet*. Minerals Management Service, Department of the Interior, and the School of Fisheries & Ocean Sciences, University of Alaska. Final Report OCS Study MMS 2010-005.

Fox, J., and P. Shields. 2004. *Upper Cook Inlet Commercial Fisheries Annual Management Report, 2003*. Alaska Department of Fish and Game. Anchorage, AK. <http://www.sf.ADF&G.state.ak.us/fedaidpdfs/RIR.2A.2004.18.pdf>. Accessed August 2012.

Fredericksen, M., H. Jensen, F. Daunt, R.A. Mavor, and S. Wanless. 2008. Differential effects of local industrial sand lance fishery on seabird breeding performance. *Ecological Society of America* 18(3): 701-710.

Fritz, L.W., and S. Hinckley. 2005. A critical review of the regime shift – "junk food" – nutritional stress hypothesis for the decline of the western stock of steller sea lion. *Marine Mammal Science* 21(3): 476-518.

Fritz, L.W., and C. Stinchcomb. 2005. *Aerial, Ship and Land-Based Surveys of Steller Sea Lions (*Eumetopias jubatus*) in the Western Stock in Alaska, June and July 2003 and 2004.* Technical Memorandum NMFS-AFSC-153U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Fritz, L., M. Lynn, E. Kunisch, and K. Sweeney. 2008a. *Aerial, Ship and Land-Based Surveys of Steller Sea Lions (*Eumetopias jubatus*) in the Western Stock in Alaska, June and July 2005-2007*. Technical Memorandum NMFS-AFSC-183 U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Fritz, L.W., K. Sweeney, C. Gudmundson, T. Gelatt, M. Lynn, and W. Perryman. 2008b. *Survey of Adult and Juvenile Steller Sea Lions, June-July 2008*. National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle WA. <http://www.afsc.noaa.gov/nmml/pdf/SSLNon-Pups2008memo.pdf> Accessed November 2013.

Funk, D.W., T.M. Markowitz, and R. Rodrigues. 2005. *Baseline Studies of Beluga Whale Habitat Use in Knik Arm, Upper Cook Inlet, Alaska, July 2004-July 2005*. Report by LGL Alaska Research Associates, Inc., Anchorage, AK, in association with HDR Alaska, Inc., Anchorage, AK, for the Knik Arm Bridge and Toll Authority, Anchorage, AK, the Department of Transportation and Public Facilities, Anchorage, AK, and the Federal Highway Administration, Juneau, AK.

Gatto, L.W. 1976. *Baseline Data on the Oceanography of Cook Inlet, Alaska.* CRREL Report 76-25. U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory. Hanover, NH.

GEO Drilling Fluids, Inc., Bakersfield, CA. Weight Up Chart http://www.geodf.com/index.cfm/fuseaction/Pages.Page/id/286 (accessed March 23, 2015)

Gill, R.E., Jr., and T.L. Tibbits. 1999. *Seasonal Shorebird Use of Intertidal Habitats of Cook Inlet, Alaska.* OCS Study, MMS 99-0012. U.S. Department of the Interior, Marine Management Service, Alaska OCS Region, Anchorage, AK.

Goetz, K.T., D.J. Rugh, A.J. Read, and R.C. Hobbs. 2007. Habitat use in a marine ecosystem: beluga whales *Delphinapterus leucas* in Cook Inlet, Alaska. *Marine Ecology Progress Series* 330:247-256.

Gould, P.J., and J.F. Piatt. 1993. Seabirds of the central North Pacific. Pages 27-38 in *The Status, Ecology, and Conservation of Marine Birds of the North Pacific*, ed. K. Vermeer, K.T. Briggs, K.H. Morgan, and D. Siegel-Causey. Canadian Wildlife Service: Ottawa, Canada.

Gregr, E.J., and A.W. Trites. 2001. Predictions of Critical Habitat for Five Whale Species in the Waters of Coastal British Columbia. *Canadian Journal of Fisheries and Aquatic Science* 58: 1265-1285.

Griffiths, W.B., and R. E. Dillinger. 1980. Invertebrates. Part 5 in Vol. 8, Biological Studies, *Environmental Assessment of the Alaskan Continental Shelf, Final Reports of Principal Investigators*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Alaska Department of Fish and Game.

Hampton, M.A. 1982. *Synthesis Report: Environmental Geology of Lower Cook Inlet, Alaska.* Open-File Report 82-197, U.S. Geological Survey, Anchorage, AK.

Hampton, M.A., K.H. Johnson, M.E. Torresan, and W.J. Winters. 1981. *Description of Seafloor Sediment and Preliminary Geo-environmental Report, Shelikof Strait, Alaska*. Open-File Report 81-1113. U.S. Geological Survey, Reston, VA.

Haney, J.C., and P.A. McGillivary. 1985: Midshelf fronts in the South Atlantic Bight and their influence on seabird distribution and seasonal abundance. *Biological Oceanography* 3(4): 401-430.

Hansen D.J., and J.D. Hubbard. 1999. *Distribution of Cook Inlet Beluga Whales (*Delphinapterus leucas*) in Winter*. OCS Study, MMS 99-0024. U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, Anchorage, AK.

Hart, J.L. 1973. Pacific fishes of Canada. *Fisheries Research Board of Canada*. 180: 739.

Hatch, S.A., and J.F. Piatt. 1995. Seabirds in Alaska. Pp. 49-52 in O*ur Living Resources: A report to the Nation*, eds. E.T. Roe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac. U.S. Department of the Interior, National Biological Service, Washington, DC.

Hatch, S.A. 1984. Nestling Diet and Feeding Rates of Rhinoceros Auklets in Alaska. In *Marine Birds: Their Feeding Ecology and Commercial Fisheries Relationships*, ed. G.A. Sanger, D.N. Nettleship, and P.F. Springer, pp. 106-115.. Canadian Wildlife Service Special Publication, Dartmouth, N.S., Canada.

Hill, P.S., and D.P. DeMaster. 1999. *Alaska Marine Mammal Stock Assessments, 1999*. Technical Memorandum MNFS-AFSC-110. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA.

Hill, P.S., D.P. DeMaster, and R.I. Small. 1997. *Alaska Marine Mammal Stock Assessments, 1996*. Technical Memorandum MNFS-AFSC-78. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA.

Holen, D. and Fall, J. 2011. Overview of Subsistence Salmon Fisheries in the Tyonek Subdistrict and Yentna River, Cook Inlet, Alaska. Special Publication No. BOF 2011-01. Alaska Department of Fish and Game, Division of Subsistence, Anchorage, AK.

Houghton, J.P., K.R. Critchlow, D.C. Lees, and R.D. Czlapinski. 1981. *Fate and Effects of Drilling Fluids and Cuttings Discharges in Lower Cook Inlet, Alaska, and on Georges Bank—Final Report.* U.S.

Department of Commerce, National Oceanic and Atmospheric Administration, and the U.S. Department of Interior, Bureau of Land Management, Washington, DC.

Hughes, J.H., and G.A. Sanger. 1999. *Observations of Peale's Peregrine Falcons, Falco peregrinus pealei, on the Northern Gulf of Alaska Coast*. *Exxon Valdez* Oil Spill State/Federal Natural Resource Damage Assessment Final Report. Bird Study No. 5. State of Alaska, Department of Fish and Game, Division of Wildlife Conservation, Anchorage, AK.

Huntington, H.P. 2000. Traditional Knowledge of the Ecology of Belugas, *Delphinapterus leucas*, in Cook Inlet, Alaska. *Marine Fisheries Review* 62: 134- 140.

Incze, L.S., D.W. Siefert, and J.M. Napp. 1996. Mesozooplankton of Shelikof Strait, Alaska: abundance and community composition. *Continental Shelf Research* 17, 287-305.

IPHC (International Pacific Halibut Commission). 1998. *The Pacific Halibut: Biology, Fishery, and Management Technical Report. International Pacific Halibut Commission*. Seattle, WA.

Ivey, S.S., and D. Sweet. 2004. *Recreational Fisheries of Northern Cook Inlet, 2003-2004*: Report to the Alaska Board of Fisheries. Fishery Management Report No. 04-18. Alaska Department of Fish and Game, Divisions of Sport and Commercial Fisheries. Juneau, AK.

Jensen, A.S. and G.K. Silber. 2003. Large Whale Ship Strike Database. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-OPR- , 37 pp

Jepson, S.J. 2001. Cook Inlet Gas Considerations Testimony to Joint Committee on Natural Gas Pipelines. Phillips Alaska, Inc.

Johnson, W.R., T.C. Royer, and J.L. Luick. 1988. On the Seasonal Variability of the Alaska Coastal Current. *Journal of Geophysical Research* 93:12,423-12,437.

Joling, D. 2004, July 28. Rare blue whales spotted in Alaska. Associated Press. <http://www.msnbc.msn.com/id/5538657/>. Accessed August 2013

Jones and Stokes Associates, Inc. 1989b. Fates and effects of exploratory phase oil and gas drilling discharges in the Navarian Planning Area, Lease Sale 124. Prepared for U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Jones, M.L., and S.L. Swartz. 1984. *Demography and Phenology of Gray Whales and Evaluation of Whale-Watching Activities in Laguna San Ignacio, Baja California Sur, Mexico*, pp. 309-374, in *The Gray Whale* Eschrictius robustus, ed. M.L. Jones, S.L. Swartz, and S. Leatherwood. Academic Press, Orlando, FL.

Jones, R.D. 1965. Returns from Steller's eiders banded in Izembek Bay, Alaska. *Wildfowl* 16:83-85.

Kingsley, M.C.S. 2002. Status of the belugas of the St. Lawrence Estuary, Canada. *NAMMCO Scientific Publishings* 4:239-258.

Kinnetic Laboratories, Inc. 2010. *Final Report: Produced Water Fate and Transport in Cook Inlet, 2008 – 2009* (or *Integrated Cook Inlet Environmental Monitoring and Assessment Program* [ICIEMAP]). Prepared for the U.S. Environmental Protection Agency, Region 10, Seattle, WA, for the NPDES General Permit AKG-31-5000.

Kinney, P.J., D.K. Button, and D.M. Schell. 1969. *Kinetics of Dissipation and Biodegradation of Crude Oil in Alaska's Cook Inlet*. In Proceedings of the 1969 Joint Conferences on Prevention and Control of Oil Spills, pp. 333-340, New York, 1969. American Petroleum Institute, Washington, DC.

Kipphut, G.W. 1990. Glacial meltwater input to the Alaska coastal current: Evidence from oxygen isotope measurements. *Journal of Geophysical Research* 95(C4):5177-5181.

Kline, E.R. 1994. Potential Biological Consequences of Submarine Mine-Tailings Disposal: A Literature Synthesis. U.S. Department of the Interior, Bureau of Mines. OFR 36-94.

KPB (Kenai Peninsula Borough) 2007. Kenai Peninsula Borough coastal management program, final plan amendment. April 2007. <http://www.borough.kenai.ak.us/KenaiRiverCenter/Agencies/Coastal/07CoastalPlan/CZM2007.pdf> Accessed November 2013.

KPB (Kenai Peninsula Borough). 2008. *Kenai Peninsula Borough CMP (Coastal Zone Management Plan)*. <http://www.kenairivercenter.org/Agencies/coastal/2008CMP/CZM_content_full.pdf>. Accessed September 2012.

KPB (Kenai Peninsula Borough). 2011. Tsunamis and Seiches. Chapter 6 in *KPB All-Hazard Mitigation Plan.* <http://www.borough.kenai.ak.us/images/KPB/OEM/AHMP/6.0_tsunami_0711.pdf>. Accessed August 2013.

Kyle, R.E. and T.P. Brabets. 2001. *Water Temperature of Streams in the Cook Inlet Basin, Alaska, and Implications of Climate Change*. Water-Resource Investigations Report 01-4109. U.S. Department of the Interior, U.S. Geologic Survey. <http://or.water.usgs.gov/pubs_dir/WRIR01-4109/wrir014109_4.pdf>. Accessed August 2012.

Lalli, C.M. and T.R. Parsons. 1997. *Biological Oceanography, An Introduction.* Oxford, UK: Elsevier Butterworth-Heinemann

Larned, W.W. 2005. *Aerial Survey of Lower Cook Inlet to Locate Moulting Flocks of Steller's Eiders and Mergansers.* U.S. Fish and Wildlife Service, Soldotna, AK. <http://alaska.fws.gov/mbsp/mbm/waterfowl/surveys/pdf/TRIP%20REPORT%2091405.pdf>. Accessed August 2012.

Larned, W. W. 2006. *Winter distribution and abundance of Steller's eiders (*Polysticta stelleri*) in Cook Inlet, Alaska, 2004-2005*. U.S. Fish and Wildlife Service, Waterfowl Management Branch, Anchorage, Alaska. OCS Study, MMS 2006-066.

Larrance, J.D., and A. J. Chester. 1979. *Source, Composition, and Flux of Organic Detritus in Lower Cook Inlet*. U.S. Department Commerce, National Oceanic and Atmospheric Administration. Outer Continental Shelf Environmental Assessment Program.

Larrance, J.D., D.A. Tennant, A.J. Chester, and P.A. Ruffio. 1977. Phytoplankton and Primary Productivity in the Northeast Gulf of Alaska and Lower Cook Inlet. In Vol 10.of *Environmental Assessment of the Alaskan Continental Shelf*. Outer Continental Shelf Environmental Assessment Program, U.S. Department of Commerce and U.S. Department of Interior, Boulder, CO.

Laubhan, M.K., and K.A. Metzner. 1999. Distribution and diurnal behavior of Steller's eiders wintering on the Alaska Peninsula. *The Condor* 101:694-698.

Leatherwood, S. and R.R. Reeves. 1987. *The Sierra Club Handbook of Whales and Dolphins.* Sierra Club, San Francisco, CA.

Leatherwood, S., R.R. Reeves, W.F. Perrin, and W.E. Evans. 1982. *Whales, Dolphins and Porpoises of the Eastern North Pacific and Adjacent Arctic Waters: Guide to Their Identification*. NOAA Technical Report NMFS Circular 444. Juneau, AK.

Lees, D.C., and R.J. Rosenthal. 1977. *An Ecological Assessment of the Littoral Zone along the Outer Coast of the Kenai Peninsula for State of Alaska, Department of Fish & Game*. Dames & Moore.

Lees, D.C., W.B. Driskell, J.R. Payne, and M.O Hayes. 2001. *Final Report for CIRCAC Intertidal Reconnaissance Survey in Upper Cook Inlet*. Cook Inlet Regional Citizens Advisory Council.

Leuterman, A., I. Still, I. Johnson, J. Christie, and N. Butcher. 1997. *A study of trace metals from barites: their concentration, bioavailability, and potential for bioaccumulation*. 13 pp. In: Proceedings of the Offshore Mediterranean Conference and Exhibition (OMC97), Ravenna, Italy, 19-21 March, 1997

Li, X., Li, C., Pichel, W.G., Clemente-Colón, P., & Friedman, K.S. (2005). Synthetic Aperture. IEEE *Journal of Oceanic Engineering* 30(3):543-551.

Lippert, H, R. Brinkmeyer, T. Mulhaupt, and K. Iken. 2003. Antimicrobial activity in sub-Arctic marine invertebrates. *Polar Biology* 2003(26): 591-600.

Loughlin, T.R., and A.E. York. 2000. An accounting of the sources of Steller Sea Lion, *Eumetopias jubatus*, mortality. *Marine Fisheries Review* 62: 40-45.

Loughlin, T.R., A.S. Perlov, and V.A. Vladimirov. 1992. Range-wide survey and estimation of total abundance of Steller Sea Lions in 1989. *Marine Mammal Science* 8: 220-239.

Lowry, L.F., K.J. Frost, and G.A. Seaman. 1986. *Investigations of Belukha Whales in Coastal Waters of Western and Northern Alaska III.* Food Habits. Final Report Outer Continental Shelf Environmental Assessment Program Research Unit 612. Alaska Department of Fish and Game, Fairbanks, AK.

Luick, J.L., T.C. Royer, and W.R. Johnson. 1987. Coastal atmospheric forcing in the Northern Gulf of Alaska. *Journal of Geophysical Research* 92(C4):3841-3848.

Lyons, W.C. and G.J. Plisga. 2005. *Standard handbook of petroleum and natural gas engineering.* Gulf Professional Publishing. 1568 pp.

Lyons, W.C. 2009. *Working Guide to Drilling Equipment and Operations.* Gulf Professional Publishing. 602 pp.

Malme, C.I., P. Miles, P. Tyack, C. Clark, and J. Bird. 1985. *Investigation of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Feeding Humpback Whale Behavior*. OCS Study, MMS 85-0019. Anchorage, AK. Prepared by BBN Laboratories Incorporated, Cambridge, MA for U.S. Department of the Interior, Minerals Management Service, AK OCS Office, Anchorage, AK.

Marine Fisheries Review. 61(1), 1999. *The Blue Whale, Pygmy Blue Whale, and the Antarctic or True Blue Whale*. 61(1).

Markowitz, T.M., D.W. Funk, D.S. Ireland, R. Rodrigues, and M.R. Link. 2005. Use of Knik Arm by Cook Inlet beluga whales. Chapter 8 in *Baseline studies of beluga whale habitat use in Knik Arm, Upper Cook Inlet, Alaska, July 2004-July 2005*, ed. Funk, D.W., T.M. Markowitz, and R. Rodrigues. Rep. from LGL Alaska Research Associates, Inc., Anchorage, AK, in association with HDR Alaska, Inc., Anchorage, AK, for Knik Arm Bridge and Toll Authority, Anchorage, AK, Department of Transportation and Public Facilities, Anchorage, AK, and Federal Highway Administration, Juneau, AK.

Martin, M. H., and D. M. Clausen. 1995. *Data report: 1993 Gulf of Alaska Bottom Trawl Survey*. U.S Deptepartment of Commerce. NOAA Technical Memo. NMFS-AFSC-59. 217 p.

McCauley R. D., J. Fewtrell, and A.N. Popper. 2003. High intensity anthropogenic sound damages fish ears *Journal of the Acoustical Society of America* 113: 638–642. doi: 10.1121/1.1527962

McKinney, F. 1965. Spacing and chasing in breeding ducks. *Wildfowl* 16: 92- 106.

Menzie, C. A., D. Maurer, and W. A. Leathem. 1980. An Environmental Monitoring Study to Assess the Impact of Drilling Discharges in the Mid-Atlantic. IV: The Effects of Drilling Discharges on the Benthic Community. Pp. 499-540 in 1980 Symposium- Research on Environmental Fate and Effects of Drilling Auids and Cuttings. Lake Buena Vista, FL.

Merrick, R. L., T. R. Loughlin and D. G. Calkins. 1987. Decline in abundance of the northern sea lion, Eumetopias jubatus, in 1956–86. *Fishery Bulletin*, U.S. 85:351–365.

Mizroch, S.A., D.W. Rice, and J.M. Breiwick. 1984. The Blue Whale, Balaenoptera musculus. *Marine Fisheries Review*. 46: 15-19.

Mizroch, S. A., D. Rice, D. Zwiefelhofer, J. Waite, and W. Perryman. 2009. Distribution and movements of fin whales in the North Pacific Ocean. *Mammal Review*. 39(3):193-227.

Marine Mammal Commission (MMC). 2002. North Pacific Right Whale (Eubalaena japonica). <http://www.mmc.gov/reports/annual/pdf/2002annualreport.pdf>. Accessed November 2013.

MMS (Minerals Management Service). 1982. *Final Environmental Impact Statement; OCS Proposed Oil & Gas Lease Sale 57; Norton Sound* (BLM-YK-ES-82-012-1792). Bureau of Land Management, Minerals Management Service, Alaska OCS Region, Anchorage, AK.

MMS (Minerals Management Service). 1987a. *Beaufort Sea Sale 97 – Final Environmental Impact Statement* (OCS EIS/EA MMS 87-0069). U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, Anchorage, AK.

MMS (Minerals Management Service). 1987b. *Chukchi Sea Sale 109 Final Environmental Impact Statement* (MMS OCS EIS/EA 87-0110). U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, Anchorage, AK

MMS (Minerals Management Service). 1990. *Beaufort Sea Planning Area Oil and Gas Lease Sale 124. Final Environmental Impact Statement* (MMS OCS EIS/EA 90-0063). U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, Anchorage, AK.

MMS (Minerals Management Service). 1991. *Chukchi Sea Planning Area Oil and Gas Lease Sale 126. Final Environmental Impact Statement* (MMS OCS EIS/EA 90-0095). U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, Anchorage, AK

MMS (Minerals Management Service). 1992. Geologic Report for the Gulf of Alaska Planning Area. R.F. Turner (ed.). (OCS Study MMS 92-0065). Alaska OCS Region. Anchorage, AK.

MMS (Minerals Management Service). 1995. Cook Inlet Planning Area Oil and Gas Lease Sale 149 Final EIS. (OCS EIS/EA MMS 95-0066). Alaska OCS Region. Anchorage, AK.

MMS (Minerals Management Service). 2000. *Sediment Quality in Depositional Areas of Shelikof Strait and Outermost Cook Inlet* (OCS Study MMS 2000-024), Minerals Management Sservice Prepared by Arthur D. Little, Inc., Cambridge, MA for U.S. Department of the Interior, Minerals Management Service, Alaska Outer Continental Shelf, Anchorage, AK.

MMS (Minerals Management Service). 2003. *Cook Inlet Planning Area Oil and Gas Lease Sales 191 and 199, Final Environmental Impact Statement* (OCS EIS/EA MMS 2003-055). U.S. Department of the Interior, Minerals Management Service, Alaska Outer Continental Shelf, Anchorage, AK.

MMS (Minerals Management Service). 2008. *Beaufort Sea and Chukchi Sea Planning Areas Oil and Gas Lease Sales 209, 212, 217, and 221 Draft Environmental Impact Statement* (OCS Report MMS 2008-0055). U.S. Department of the Interior, Minerals Management Service, Alaska Outer Continental Shelf, Anchorage, AK.

Monnin, C., C.G. Dupre, H. Elderfield, and M.M. Mottl. 2001. *Barium Geochemistry in Sediment Pore Waters and Formation Waters of the Oceanic Crust on the Eastern Flank of Juan de Fuca Ridge* (ODP Leg 168)

Montgomery, R.A., J.M. Ver Hoef, and P.L. Boveng. 2007. Spatial modeling of haul-out site use by harbor seals in Cook Inlet, Alaska. *Marine Ecology Progress Series*. 341:257-264.

Moore, S.E., S. K.E.W., L.K. Litzky, B.A. Mahoney, and D.J. Rugh. 2000. Beluga, Delphinapterus leucas, habitat associations in Cook Inlet, Alaska. *Marine Fisheries Review* 62:60-80.

Moore, S. E., J. M. Waite, N. A. Friday and T. Honkalehto. 2002. Cetacean distribution and relative abundance on the central-eastern and southeastern Bering Sea shelf with reference to oceanographic domains. *Progress in Oceanography* 55(2002): 249-261.

Morrow, J.E. 1980. *The Fresh water Fishes of Alaska.* Alaska Northwest Pub. Co., Anchorage, AK.

Moulton, L.L. 1997. Early Marine Residence, Growth, and Feeding by Juvenile Salmon in Northern Cook Inlet, Alaska. *Alaska Fishery Research Bulletin* 4(2); 154-177.

MSB (Matanuska-Susitna Borough). 2006, August 26. MSB flood emergency operations phase summary. News Release.

Mulherin, N. D., W. B. Tucker, III, O. P. Smith and W. J. Lee. 2001. Marine Ice Atlas for Cook Inlet, Alaska (DRDC/CRREL TR-01-10). Prepared byU.S. Army Corps of Engineers, Engineer Research and Development Center, Cold Regions Research and Engineering for U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Response and Restoration.

National Academies. 2002. *Too Few Clues to Solve Mystery of Steller Sea Lions' Decline; Monitoring of Controlled Fishing Areas May Provide Answers*. National Research Council, Division on Earth and Life Studies, Ocean Studies Board, Washington, D.C. Available: < http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12042002>. Accessed September 2012.

National Research Council. 1983. *Drilling Discharges in the Marine Environment*. Panel on Assessment of Fates and Effects of Drilling Fluids and Cuttings in the Marine Environment, National Academy Press, Washington, DC.

NCG (Northern Consulting Group). 2001. *Environmental Information Document, Redoubt Shoal Unit Development Project, Cook Inlet, Alaska*, prepared for Forest Oil Corporation (formerly Forcenergy, Inc.), Anchorage, AK by Northern Consulting Group, Anchorage, AK.

Neal, C.A., T.L. Murray, J.A. Power, J.N. Adleman, P.M. Whitmore, and J.M. Osiensky. 2011. Hazard information management, interagency coordination, and impacts of the 2005-2006 eruption of Augustine Volcano. Chapter 28 in *The 2006 eruption of Augustine Volcano, Alaska*. Eds. J.A. Power, M.L. Coombs, and J.T. Freymueller. U.S. Geological Survey Professional Paper 1769, p. 645-667

Neff, J.M. 1981. *Final Technical Report on Fate and Biological Effects of Oil Well Drilling Fluids in the Marine Environment: A Literature Review*. Prepared for U.S. Environmental Protection Agency Environmental Research Laboratory Gulf Breeze, FL.

Neff, J.M. 1987. Biological Effects of Drilling Fluids, Drill Cuttings and Produced Waters in *Long-Term Effects of Offshore Oil and Gas Development,* ed. D.F. Boesch and N.N. Rabalais, pp. 469-538. Elsevier Applied Science Publishers, London.

Neff, J.M. 2008. Estimation of bioavailability of metals from drilling mud barite. *Integrated Environmental Assessment and Management*, 4 (2): 184-193.

Neff, J.M. 2010. Fates and effects of water based drilling muds and cuttings in cold water environments. Prepared for Shell Exploration and Production Company, Houston, TX by Neff & Associates, LLC., Duxbury, MA.

Neff, J.M., K. Lee, and E.M. DeBlois. 2011. Produced Water: Overview of Composition, Fates, and Effects, in *Produced Water: Environmental Risks and Advances in Mitigation Technologies*, ed. K. Lee and J.M. Neff, pp 3-54. Springer New York, New York, NY.

Nemoto, T. 1970. Feeding Pattern of Baleen Whales in the Oceans. in *Marine Food Chains,* ed. J.H. Steele,pp. 241-252. University of California Press, Berkeley, CA.

NMFS (National Marine Fisheries Service). 1998. *Recovery Plan for the Blue Whale (Balaenoptera Musculus)*. Prepared for National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD by Reeves, R.R., P.J. Clapham, R.L. Brownell, Jr., and G.K. Silber. 42 pp. <http://www.nmfs.noaa.gov/pr/pdfs/recovery/whale_blue.pdf> Accessed September 2012.

NMFS (National Marine Fisheries Service). 2000. *2000 Beluga Whale Tagging.* National Oceanic and Atmospheric Administration, National Marine Fisheries Service, National Marine Mammal Laboratory. <http://www.afsc.noaa.gov/nmml/cetacean/belugatags/belugatags2000.pdf>. Accessed September 2012.

NMFS (National Marine Fisheries Service). 2002. *Right Whale Calf Sighted in Bering Sea.* National Oceanic and Atmospheric Administration, National Marine Fisheries Service, National Marine Mammal Laboratory, Alaska Region, Juneau, AK. <http://www.fakr.noaa.gov/newsreleases/2002/rightwhale.htm>. Accessed November 2013.

NMFS (National Marine Fisheries Service). 2005a. *Right Whales.* National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Region. Juneau, AK <http://www.nmfs.gov/pr/species/mammals/cetaceans/right_whales.doc> Accessed June 2005.

NMFS (National Marine Fisheries Service). 2005b. *Draft Conservation Plan for the Cook Inlet Beluga Whale.* National Oceanic and Atmospheric Administration, National Marine Fisheries Service, National Marine Mammal Laboratory, Protected Resources Division, Alaska Region, Juneau, AK. 149 p.

NMFS (National Marine Fisheries Service). 2005c. *Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska*. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Region.

NMFS (National Marine Fisheries Service) 2006. October 13. Letter from Robert D. Mecum, National Marine Fisheries Service, Acting Administrator, Alaska Region, to Hanh Shaw, US EPA Region 10, Seattle, WA regarding EPA's Revised Biological Evaluation for the Cook Inlet Oil and Gas Exploration, Development, and Production Facilities NPDES General Permit Reissuance and request for concurrence in EPA's determination of not likely to adversely affect listed species or their critical habitat.

NMFS (National Marine Fisheries Service). 2007. *Species of Concern: Beluga whale Delphinapterus leucas Cook Inlet DPS.* National Oceanic and Atmospheric Administration, National Marine Fisheries Service <http://www.nmfs.noaa.gov/pr/pdfs/species/belugawhale_detailed.pdf>. Accessed September 2012.

NMFS (National Marine Fisheries Service). 2008a. *Conservation Plan for the Cook Inlet Beluga Whale (Delphinapterus leucas)*. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Region, Juneau, AK.

NMFS (National Marine Fisheries Service). 2008b. Recovery Plan for the Steller Sea Lion (Eumetopias jubatus). Revision. National Marine Fisheries Service, Silver Spring, MD. 325 pages.

NMFS (National Marine Fisheries Service). 2010a. Final Recovery Plan for the Fin Whale (*Balaenoptera Physalus*). National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD. <http://www.nmfs.noaa.gov/pr/pdfs/recovery/finwhale.pdf>. Accessed September 2012.

NMFS (National Marine Fisheries Service). 2010b . *Endangered Species Act – Section 7 Consultation Biological Opinion. Authorization of Small Takes Under the Marine Mammal Protection Act for Certain Oil and Gas Exploration Activities in the U.S. Beaufort and Chukchi Seas, Alaska for 2010*. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Region.

NMFS (National Marine Fisheries Service). 2010c. *Essential Fish Habitat (EFH) 5-year Review for 2010. Summary Report Final*. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Region. <http://www.fakr.noaa.gov/habitat/efh/review/efh_5yr_review_sumrpt.pdf>. Accessed September 2012.

NMFS (National Marine Fisheries Service) 2010d. *Final Recovery Plan for the Sperm Whale (Physeter macrocephalus)*. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD. <http://www.nmfs.noaa.gov/pr/pdfs/recovery/final_sperm_whale_recovery_plan_21dec.pdf>. Accessed September 2012.

NMFS (National Marine Fisheries Service). 2010e. *Sperm Whale (Physeter macrocephalus): North Pacific Stock*. National Oceanic and Atmospheric Administration, National Marine Fisheries Service. <http://www.nmfs.noaa.gov/pr/pdfs/sars/ak2010whsp-pn.pdf>. Accessed September 2012.

NMFS (National Marine Fisheries Service). 2010f. Blue Whale (*Balaenoptera musculus):* Hawaiian Stock. National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

NMFS (National Marine Fisheries Service). 2011a. *Humpback Whale (megaptera novaeanglis)*. National Oceanic and Atmospheric Administration, National Marine Fisheries Service. <http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whhb-cow.pdf>. Accessed September 2012.

NMFS (National Marine Fisheries Service). 2011b. *North Pacific Right Whale (Eubalaena japonica): Eastern North Pacific Stock*. National Oceanic and Atmospheric Administration, National Marine Fisheries Service. <http://www.nmfs.noaa.gov/pr/pdfs/sars/ak2011whnr-pen.pdf>. Accessed September 2012.

NMFS (National Marine Fisheries Service). 2011c. *Final Recovery Plan for the Sei Whale (Balaenoptera borealis).* <http://www.nmfs.noaa.gov/pr/pdfs/recovery/seiwhale.pdf>. Accessed September 2012.

NMFS (National Marine Fisheries Service). 2011d. Blue Whale (*Balaenoptera musculus musculus*): Eastern North Pacific Stock. National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

NMFS (National Marine Fisheries Service). 2013a. *Pacific Eulachon/Smelt (Thaleichthys pacificus)* National Oceanic and Atmospheric Administration, National Marine Fisheries Service. <http://www.nmfs.noaa.gov/pr/species/fish/pacificeulachon.htm>. Accessed November 2013.

NMFS (National Marine Fisheries Service). 2013b. *Killer Whale* (*Orcinus orca*). National Oceanic and Atmospheric Administration, National Marine Fisheries Service. <http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/killerwhale.htm>. Accessed October 2013.

NMFS (National Marine Fisheries Service). 2013c. *Beluga Whale (Delphiapterus leucas*). National Oceanic and Atmospheric Administration, National Marine Fisheries Service. <http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/belugawhale.htm>. Accessed October 2013.

NMFS (National Marine Fisheries Service) 2013d. *Sperm Whales (Physeter macrocephalus*). National Oceanic and Atmospheric Administration, National Marine Fisheries Service. <http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/spermwhale.htm>. Accessed August 2013.

NMML (National Marine Mammal Laboratory). 2004. *Steller Sea Lion*. Multi-link Web Site to Information on Steller Sea Lion Management and Research. <http://stellersealions.noaa.gov>. Accessed November 2013.

NMML (National Marine Mammal Laboratory). 2013. *Sperm Whales, Marine Mammal Education Web*. <http://www.afsc.noaa.gov/nmml/education/cetaceans/sperm.php>. Accessed November 2013.

NMML (National Marine Mammal Laboratory). Undated. *Harbor Porpoise (*Phocoena phocoena*)*. <http://www.afsc.noaa.gov/nmml/species/species_harporp.php>. Last accessed August 2013.

NOAA (National Oceanic and Atmospheric Administration). 1999a. *Center for Operational Oceanographic Products and Services*. <http//co-ops.nos.noaa.gov> Accessed October 2013.

NOAA 1999b. Sediment Quality Guidelines developed for the National Status and Trends Program http://archive.orr.noaa.gov/book_shelf/121_sedi_qual_guide.pdf last accessed March 23, 2015

NOAA (National Oceanic and Atmospheric Administration). 2006. Tidal station locations and ranges. Retrieved from NOAA website: http://tidesandcurrents.noaa.gov/tides07/tab2wc2b.html#154

NOAA (National Oceanic and Atmospheric Administration). 2011. *Ice Breakup Reconnaissance in Alaska.* <http://aprfc.arh.noaa.gov/resources/docs/brkup.php>. Accessed September 2012.

NUKA (NUKA Research and Planning Group LLC). 2013. Cook Inlet Risk Assessment: Consequence Analysis. NUKA Research and Planning Group LLC, Seldovia, AK.

OBIS (Ocean Biogeographical Information System). 2005. *Balaenoptera physalus (Fin Whale).* <http://seamap.env.duke.edu/species/tsn/180527>. Accessed November 2013.

Ohsumi, S. and S. Wada. 1974. Status of whale stocks in the North Pacific, 1972. *Reports for the International Whaling Commission* 25: 114-126.

Ohsumi, S. 1986. Yearly change in age and body length at sexual maturity of a fin whale stock in the eastern North Pacific. *Scientific Reports of the Whale Research Institute* 37:17-30. Whale Research Institute, Tokyo, Japan.

Okkonen, S.R. 2004. Observations of Hydrography and Currents in Central Cook Inlet, Alaska During Diurnal and Semidiurnal Tidal Cycles (OCS Study MMS 2004-058). Retrieved from University of Alaska website: http://www.arlis.org/docs/vol1/70265562.pdf

Okkonen, S.R. 2005. Observations of hydrography and currents in central Cook, Inlet, Alaska during diurnal and semidiurnal tidal cycles. Institute of Marine Science, University of Alaska Fairbanks.

Okkonen, S., S. Pegau and S. M. Saupe. 2009. *Seasonality of Boundary Conditions for Cook Inlet, Alaska Final Report*. OCS Study MMS 2009-041, University of Alaska Coastal Marine Institute, University of Alaska, Fairbanks and USDOI, MMS, Alaska OCS Region.

O'Neil, Randy. 2014. Furie Operating Alaska, LLC. Personal communication with US EPA, Region 10 regarding average number of days to drill Kitchen Lights Unit wells in Cook Inlet.

Osborne, J., and C. Leeder. 1989. Acute and Chronic Toxicity of Base Oil and Cuttings from Three Wells Drilled in the Beaufort Sea, in *Drilling Wastes*, Proceedings of the 1988 International Conference on Drilling Wastes, Calgary, Alberta, Canada, 5-8 April 1988.

Overland, J.E. and T.R. Hiester. 1980. Development of a synoptic climatology for the Northeast Gulf of Alaska. *Journal of Applied Meteorology* 19(1):1-14.

Pentec Environmental. 2005. *Marine fish and benthos studies in Knik Arm Anchorage, Alaska*. Prepared for Knik Arm Bridge and Toll Authority and HDR Alaska, Inc. 12214-10/12214-12. <http://www.knikarmbridge.com/Tech_Reports/Boiler%20QC/Marine%20Fish%20and%20Benthos%20Studies.pdf> Accessed November 2013.

PERF (Petroleum Environmental Research Forum). 2005. *Composition, Environmental Fates, And Biological Effects Of Water Based Drilling Muds And Cuttings Discharged To The Marine Environment: A Synthesis and Annotated Bibliography*. Prepared for Petroleum Environmental Research Forum (PERF) and American Petroleum Institute, Duxbury, MA.

Perricone, C. 1980. Major drilling fluid additives - 1979. In *Symposium on research on Environmental Fate and Effects of Drilling Fluids and Cuttings*. Pp 15-29. Courtesy Associates, Washington, DC.

Perry, S.L., D.P. DeMaster, and G.K. Silber. 1999. The Great Whales: History and status of six species listed as endangered under the U.S. Endangered Species Act of 1973. *Marine Fisheries Review. Special Issue.* 61(1): 1-74.

Petersen, M. 1980. Observations of wing-feather molt and summer feeding ecology of Steller’s eiders at Nelson Lagoon, Alaska. *Wildfowl* 31:99-106.

Petrazzuolo, G. 1981. *Preliminary Report: An Environmental Assessment of Drilling Fluids and Cuttings Released onto the Outer Continental Shelf*. U.S. Environmental Protection Agency, Ocean Programs Branch, Office of Water and Waste Management and the NPDES Technical Support Branch, Office of Water Enforcement and Permits, Washington, DC.

Petrazzuolo, G. 1983. *A Review of the Potential Environmental Effects of Mineral Oil used in Drilling Fluids*. Draft Report. Technical Resources, Inc., Bethesda, MD.

Piatt, J. F., and Anderson, P. 1996. Response of common murres to the *Exxon Valdez* oil spill and long-term changes in the Gulf of Alaska marine ecosystem. *American Fisheries Society Symposium*. 18: 720-737.

Piatt J.F. and A.M.A. Harding. 2007. Population ecology of seabirds in Cook Inlet. In *Long-term ecological change in the Gulf of Alaska*, ed. R.B. Spies. Elsevier, Amsterdam p. 335–352.

Piatt, J. F., and D.G. Roseneau. 1997. Cook Inlet Seabird and Forage Fish Studies (CISeaFFS). *Sisyphus News* 1997(1):1-8.

Piatt, J.F. 1994. *Oceanic, Shelf and Coastal Seabird Assemblages at the Mouth of a Tidally Mixed Estuary (Cook Inlet, Alaska)*. National Biological Service, Final Report for Minerals Management Service, OCS Study MMS 92-0072. Anchorage, Alaska.

Piatt, J.F. 2002. Response of Seabirds to Fluctuations in Forage Fish Density. Oil Spill Restoration Project 00163J Final Report. Anchorage, AK: *Exxon Valdez* Oil Spill Trustee Council and U.S. Department of the Interior, Mineral Management Service, Alaska OCS Region.

Piatt, J.F., J.L. Wells, A. MacCharles, and B. Fadely. 1991. The distribution of seabirds and their prey in relation to ocean currents in the southeastern Chukchi Sea. *Canadian Wildlife Service Occasional Papers* 68: 21-31.

Piatt, J.F., G. Drew, T. Van Pelt, A. Abookire, A. Nielsen, M. Shultz, and A. Kitaysky. 1999. Biological effects of the 1997/1998 ENSO in Cook Inlet, Alaska. *PICES Scientific Report* 10:93-99.

Pitcher, K.W. and Calkins, D.G. 1981. Reproductive biology of Steller sea lions in the Gulf of Alaska. *Journal of Mammalogy* 62: 599-605.

Ponce, R.A., G.M. Egeland, J.P. Middaugh, and P.R. Becker. 1997. Twenty years of trace metal analyses of marine mammals: Evaluation and Summation of data from Alaska and other Arctic regions. State of Alaska Epidemiology Bulletin 1(3):1-15.

Poole, F.W. and J.L. Hufford. 1982. Meterological and Oceanographic Factors Affecting Sea Ice in Cook Inlet. Journal of Geophysical Research. 87C3:2061-2070.

Popov, V.V., A.Y. Supin, V.V. Rozhnov, D.I. Nechaev, E.V. Sysuyeva, V.O. Klishin, M.G. Pletenko and M.B. Tarakanov. 2013. Hearing threshold shifts and recovery after noise exposure in beluga whales, *Delphinapterus leucas*. *The Journal of Experimental Biology* 216:1587-1596.

Porter, B. 1997. Winter Ecology of Steller Sea Lions (Enmetopias jubatus) In Alaska. Master's thesis. University of British Columbia. 95 pp. Available: < http://www.marinemammal.org/wp-content/pdfs/porter.pdf >. Accessed August 2013.

Post, A., and Mayo, L.R., 1971, Glacier dammed lakes and outburst floods in Alaska: U.S. Geological Survey Hydrologic Investigations Atlas HA-455, 10 p., scale 1: 1,000,000, 3 sheets.

Rappeport, M.L., 1981. Studies of tidally dominated shallow marine bedforms, lower Cook trough, Cook Inlet, Alaska: Stanford University unpublished ph.D. thesis.

Redburn, D.R., K.K. Imamura, and D.C. Toland. 1976. *Environmental Assessment of Lower Cook Inlet for Outer Continental Shelf and Related Development.* Alaska Department of Environmental Conservation.

Reed, R.K., J.D. Schumacher, and L.S. Incze. 1987. Circulation in Shelikof Strait, Alaska. Journal of Physical Oceanography 17:1546-1554.

Reeves, R.R., G.K. Silber, and P.M. Payne. 1998. Draft Recovery Plan for the Fin Whale Balaenoptera physalus and Sei Whale Balaenoptera borealis. Silver Spring, MD: USDOC, NOAA, NMFS, Office of Protected Resources, 65 pp.

Rice, D.W. 1974. Whales and Whale Research in the Eastern North Pacific. In: The Whale Problem: A Status Report, W.E. Schevill, ed. Cambridge, MA: Harvard University Press.

Rice, D.W. 1986. Blue whale. Pp. 4-45 In: D. Haley (ed.) Marine mammals of eastern North Pacific and Arctic waters. Second edition. Pacific Search Press.

Rice, D. 1989. Sperm Whale, Physeter macrocephalus. Pp. 177-233. In S.H. Ridgway and R. Harrision (eds.), Handbook of Marine Mammals. Vol. 4. River Dolphins and the Larger Toothed Whales. Academic Press, New York.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. *Marine Mammals and Noise*, pp. 576. Academic Press Inc., San Diego, CA.

Right Whale Listening Network, The Cornell Lab of Ornithology. Undated. Ship Strikes. Available: < http://www.listenforwhales.org/page.aspx?pid=439>. Accessed September 2012.

Robards, M. D., J. F. Piattt, and G.A. Rose. 1999. Maturation, fecundity, and intertidal spawning of Pacific sand lance in the northern Gulf of Alaska. *Journal of Fish Biology* 54:1050-1068.

Rodrigues, R., M. Nemeth, T. Markowitz, and D. Funk. 2006. Review of literature on fish species and beluga whales in Cook Inlet, Alaska. Final report prepared by LGL Alaska Research Associates, Inc., Anchorage, AK, for DRven Corporation, Anchorage, AK.

Roseneau, D.G., A.B. Kettle, and G.V. Byrd. 2000. Common Murre Population Monitoring at the Barren Islands, Alaska, 1999. Restoration Project 99144 Final Report. <http://www.evostc.state.ak.us/Files.cfm?doc=/Store/FinalReports/1999-99144A-Final.pdf&>. Accessed September 2012.

Rosenthal, R. J., D. C. Lees, and T. M. Rosenthal. 1977. *Ecological Assessment of Sublittoral Plant Communities in the Northern Gulf of Alaska*. Final Report, Outer Continental Shelf Environmental Assessment Program, Research Unit 78.

Royer, T.C. 1982. Coastal Fresh Water Discharge in the Northeast Pacific. *Journal of Geophysical Research* 87:2017-2021.

Rugh, D.J., K.E.W. Shelden, and B.A. Mahoney. 2000. Distribution of belugas, Delphinapterus leucas, in Cook Inlet, Alaska, During June/July 1993-2000. Marine Fisheries Review 62: 6-21.

Ruthrauff, D.R., R.E. Gill, Jr., T.L. Tibbitts. 2013. Coping with the cold: An ecological context for the abundance and distribution of rock sandpipers during winter in Upper Cook Inlet, Alaska. Arctic Institute of America 66(3): 269-278.

Rye, H. M. Reed, and N. Ekrol. 1998. The PARTRACK model for calculation of the spreading and deposition of drilling mud, chemicals and drill cuttings. *Environmental Modelling & Software*. 13(1998): 431-441.

SAIC (Sciences Applications International Corporation). 2000. Biological Assessment for Endangered Species in Outer Continental Shelf Waters of South and Central California for Consultation with the United States Fish and Wildlife Service. Report WA No. IM-5-30. Washington, DC; San Francisco, CA; Reston, VA; and Santa Barbara, CA: USEPA Headquarters and Region 9, 28 pp.

SAIC (Sciences Applications International Corporation). 2001. *Ocean Discharge Criteria Evaluation for the Forest Oil Osprey Platform, Redoubt Shoal Unit Development Project.* Prepared for U.S. Environmental Protection Agency Region 10, by Sciences Applications International Corporation, Bothell, WA.

SAIC (Science Applications International Corporation). 2002. *Environmental Assessment for the New Source NPDES Forest Oil Redoubt Shoal Unit Production Oil and Gas Development Project Cook Inlet, Alaska.* Prepared for U.S. Environmental Protection Agency Region 10 Office of Water, NPDES Permit Unit, Seattle, WA. 452 pp.

Sambrotto, R.N. and Lorenzen, C.J. 1986. Phytoplankton and Primary Production. Chapter 9 in *The Gulf of Alaska: Physical Environment and Biological Resources*, ed. D.W. Hood and S.T. Zimmerman, pp. 249-284. U.S. Department of Commerce, U.S. Department of the Interior.

Sanger, G.A. and R.D. Jones. 1984. Winter Feeding Ecology and Trophic Relationships of Oldsquaws and White-Winged Scoters on Kachemak Bay, Alaska, pp. 20-28, in *Marine Birds: Their Feeding Ecology and Commercial Fisheries Relationships, Proceedings of Pacific Seabird Group Symposium*, G.A. Sanger, A.M. Springer, and D.N. Nettleship, eds. Seattle, Wash., Jan. 6-8, 1982. CW66-65/1984. Dartmouth, N.S. Canada: Canadian Wildlife Service.

Schaanning, M.T., K. Hylland, D. Eriksen, T.D. Bergan, J.S. Gunnarson, and J. Skei. 1996. Interactions between eutrophication and contaminants. II. mobilization and bioaccumulation of hg and cd from marine sediments. *Marine Pollution Bulletin* 33(1-6):71-79.

Scheffer, V.B. and J.W. Slipp. 1944. The Harbor Seal in Washington State. *American Midl. Nat.* 32:373-416.

Schneider, D.C. 1990. Seabirds and fronts: a brief overview. *Polar Research* 8:71-21.

Schneider, D.C., G.L. Hunt, and N.M. Harrison. 1986. Mass and energy transfer to seabirds in the southeastern Bering Sea. *Contin. Shelf Res.* 5: 241-257.

Schneider, D.C., N.M. Harrison, and G.L. Hunt. 1987. Variation in the occurrence of marine birds at fronts in the Bering Sea. *Estuar. Coastal Shelf Sci.* 25: 135-141.

Schoch, G.C., and H. Chenelot. 2004. The role of estuarine hydrodynamics in the distribution of kelp forests in Kachemak Bay, Alaska. *Journal of Coastal Research* 45:179-194.

Schoch, G.C. and H. Chenolet. 2001. The spatial distribution of bull kelp (Nereocystis leutkeana) in the Kachemak Bay Research Reserve. Kachemak Bay Research Reserve, National Estuarine Research Reserve System. http://www.habitat.adfg.state.ak.us/geninfo/kbrr/pdf_files/kelp_report.pdf.

Schumacher, J.D. and R.K. Reed. 1980. Coastal Flow in the Northwest Gulf of Alaska: the Kenai Current. *Journal of Geophysical Research*, 85: 5580-6688.

Schumacher, J.D. and R.K. Reed. 1986. On the Alaska Coastal Current in the Western Gulf of Alaska. *Journal of Geophysical Research* 91:9655-9661.

Schumacher, J.D., P.J. Stabeno, and A.T. Roach. 1989. Volume Transport in the Alaska Coastal Current. *Continental Shelf Research* 9(12):1071-1083.

Scott, W.B., and E.J. Crossman. 1973. Fresh water Fishes of Canada. *Fisheries Research Board of Canada Bulletin 198.*

Sears, R. and J. Calambokidis. 2002. Update COSEWIC status report on the Blue Whale Balaenoptera musculus in Canada, in COSEWIC assessment and update status report on the Blue Whale Balaenoptera musculus in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 32 pp.

Seldovia Village Tribe. 2013. Draft Assessment of Cook Inlet Tribes Subsistence Consumption, Revised 2nd Draft. Unpublished draft (Revised date 05/20/2013). Seldovia Village Tribe, Environmental Department, Seldovia, AK.

Sharma, G.D. and D.C. Burrell. 1970. Sedimentary Environment and Sediments of Cook Inlet, Alaska. *American Association of Petroleum Geologists Bulletin* 54(4):647-654.

Sharma, G.D. 1979. *The Alaskan Shelf: Hydrographic, Sedimentary, and Geochemical Environment*. Springer-Verlag, New York, NY.

Sheath, R.G., M.L. Vis, J.A., Hambrook and K.M. Cole. 1996. Tundra stream macroalgae of North America: Composition, distribution and physiological adaptations. In: Kristiansen, J., ed. Biogeography of freshwater algae. *Hydrobiologia* 336:67 – 82.

Shelden, K.E.W., D.J Rugh,B.A. Mahoney, and M.E. Dahlheim. 2003. Killer whale predation on belugas in Cook Inlet, Alaska: Implications for a depleted population. *Marine Mammal Science* 19(3): 529-544.

Sherburne, J. 1993. Status Report on the Short-tailed Albatross Diomedea albatrus. Unpublished Rep. for the U.S. Fish and Wildlife Service. Alaska Natural Heritage Program. 33pp.

Shields, P., and A. Dupuis. 2013. *Upper Cook Inlet Commercial Fisheries Annual Management Report, 2012*. Alaska Department of Fish and Game, Divisions of Sport Fish and Commercial Fisheries.

Simenstad, C.A., B.S. Miller, C.F. Myblade, K. Thornburgh, and L.J. Bledsoe. 1979. *Food Web Relationships of Northern Puget Sound and the Strait of Juan de Fuca*. Marine Ecosystems Analysis for U.S. Environmental Protection Agency.

Sims, C.L., L. Vate Brattstrom, and K. T. Goetz. 2012. Aerial surveys of belugas in Cook Inlet, Alaska, August 2012. NMFS, NMML Unpublished Field Report. 11p.

Sittig, M. 1985. *Handbook of Toxic and Hazardous Chemicals and Carcinogens.* Second Edition. Noyes Publications, Park Ridge, NJ. 950 pp.

Smith, O.P. 1993. *Deep Draft Navigation Reconnaissance Report Cook Inlet, Alaska*. Department of the Army, U.S. Army Engineer District, Anchorage, AK.

Snyder-Conn, E., D. Densmore, C. Moitoret, and J. Stroebele. 1990. Persistence of trace metals in shallow artic marine sediments contaminated by drilling effluents. *Oil & Chemical Pollution* 7:225-247.

Sowls, A. L., S. A. Hatch, and C. J. Lensink. 1978. Catalog of Alaskan seabird colonies. U.S. Fish and Wildlife Service, Biological Services—Coastal Ecosystem, Anchorage, Alaska. 153 pp.

Speckman, S.G., J.F. Piatt, C.W. Minte-Vera, and J.K. Parrish. 2005. Parallel structure among environmental gradients and three trophic levels in a subarctic estuary. *Progress in Oceanography* 66:25-65.

Spurkland, T., and K. Iken. 2005. Spatial variation in chemical defenses of Kachemak Bay macroalgal communities in correlation to abiotic factors. School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

Spurkland, T., and K. Iken. 2011. Kelp bed dynamics in estuarine environments in Subarctic Alaska. *Journal of Coastal Research* 27(6A): 133-143.

Stewart, B.S. and S. Leatherwood. 1985. Minke Whale, *Balaenoptera acutorostrata,* pp. 91-136 in S.H. Ridgeway and R. Harrison (eds.) *Handbook of Marine Mammals.* Academic Press, London.

Stewart, B. E., and R. E. A. Stewart. 1989. Delphinapterus leucas. *Am. Soc. Mammal*. 336: 1–8.

Stokes, P.J. 2010. Cook Inlet Gas Study - An analysis for meeting the natural gas needs of Cook Inlet Utility customers. Prepared for ENSTAR Natural Gas Company, Chugach Electric Association and Anchorage Municipal Light and Power (Cook Inlet Utilities) by Petrotechnical Resources of Alaska. Anchorage, AK.

Sturm, M., and Benson, C.S., 1988, Jijkulhlaups from Strandline Lake, Alaska, with special attention to the 1982 event: Alaska Division of Geological & Geophysical Surveys Report of Investigations 88-10, 19 p.

Suryan, R.M., K.S. Dietrich, E.F. Melvin, G.R. Balogh, F. Sato, K. Ozaki. 2007. Migratory routes of short-tailed albatrosses: Use of exclusive economic zones of North Pacific Rim countries and spatial overlap with commercial fisheries in Alaska.

Tarbox, K.E. and Thorne, R.E. 1996. Assessment of Adult Salmon in Near-Surface Waters of Cook Inlet, Alaska. Page 53, ICES Journal of Marine Science

Terzaghi, C., M. Buffagni, D. Cantelli, P. Bonfanti, and M. Camatini. 1998. Physical-chemical and ecotoxicological evaluation of water based drilling fluids used in Italian off-shore. *Chemosphere* 37(14-15):2859-2871.Thibodeaux, L.J., and C.S. Fang. 1986. Transport of chemical contaminants in the marine environment originating from offshore drilling bottom deposits – A vignette model. In *Pollutants in a Multimedia Environment,* ed. Y. Cohen. Plenum Press, New York, NY.

Thompson, F.M., S.N. Wick, and B.L. Stratton. 1986. *Adult Salmon Investigations, May – October 1985*. Report No. 13, Volume 1. Alaska Department of Fish and Game, Sustina River Aquatic Studies Program.

Thompson, G.G., T. A’mar, and W.A. Palsson. 2011. Chapter 2: Assessment of the Pacific Cod Stock in the Gulf of Alaska. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. Seattle, WA. <http://www.afsc.noaa.gov/REFM/docs/2011/GOApcod.pdf>. Accessed August 2012.

Thibodeaux, L.J., D.D. Reible, and C.S. Fang. 1986. Transport of Chemical Contaminants in the Marine Environment Originating from Offshore Drilling Bottom Deposits – A Vignette Model.

Tillman, M.F. 1977. Estimates of Population Size for North Pacific Sei Whale. Rept. Int. Whaling Commission, Special Issue 1: 98-106.

Trites, A.W. and C.P. Donnelly. 2003. The decline of Steller sea lions *Eumetopias* in Alaska: a review of the nutritional stress hypothesis. *Mammal Rev*. 33(1):3-28.

Trites, A. and K. Heise. 2005. Marine Mammals. <http://www.fisheries.ubc.ca/Projects/PWSound/AlaskaEco/GYRE/GYRREP15.HTM >. Accessed July 2005.

URS (URS Corporation). 2002. UKOOA Drill Cuttings Initiative Final Report. UKOOA: Oil and Gas for Britain.

URS (URS Corporation). 2006. Knik Arm Crossing Area Shorebird Study; Unpublished report prepared for Knik Arm Bridge and Toll Authority. Prepared by URS Corporation, Anchorage, AK.

URS (URS Corporation). 2010. Chemical exposures for Cook Inlet beluga whales: a literature review and evaluation. Report prepared for NOAA Fisheries, National Marine Fisheries Service, Anchorage, Alaska. NMFS contract no. AB133F-06-BU-0058.

USEPA (U.S. Environmental Protection Agency). 1985. Assessment of Environmental Fate and Effects of Discharges from Offshore Oil and Gas Operations. EPA-440-4-85-002. Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1987. *Management of Wastes from Oil and Gas Exploration, Development, and Production, Report to Congress*. Office of Solid Waste, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1991. *Technical Support Document for Water Quality Based Toxics Control*. EPA/505/2-90-001. Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1993. Final Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Offshore Subcategory of the Oil and Gas Extraction Point Source Category (EPA 821-R-93-003). Office of Water. Washington, DC.

USEPA. 1994. Ocean Discharge Criteria Evaluation for Cook Inlet/Shelikof Straits Lease Sale 149. Prepared for U.S. Environmental Protection Agency Region 10, Seattle, WA, by Tetra Tech, Inc., Redmond, WA.

USEPA (U.S. Environmental Protection Agency). 2000. Environmental Assessment of Final Effluent Limitations Guidelines and Standards for Synthetic-Based Drilling Fluids and other Non-Aqueous Drilling Fluids in the Oil and Gas Extraction Point Source Category (EPA-821-B-00-014). Office of Water. Washington, DC.

USEPA (U.S. Environmental Protection Agency). 2002. Columbia River Basin Fish Contaminant Survey 1996-1998. EPA 910-R-02-006. U.S. Environmental Protection Agency, Region 10, Seattle WA.

USEPA (U.S. Environmental Protection Agency). 2003. Survey of Chemical Contaminants in Fish, Invertebrates and Plants Collected in the Vicinity of Tyonek, Seldovia, Port Graham, and Nanwalek – Cook Inlet, AK. EPA 910-R-01-003. U.S. Environmental Protection Agency, Region 10, Seattle WA.

USEPA (U.S. Environmental Protection Agency). 2006. Ocean Discharge Criteria Evaluation for the NPDES General Permit for Oil and Gas Extraction Facilities in Federal and States Waters in Cook Inlet (NPDES General Permit No. AKG315000). Prepared by Tetra Tech Inc., finalized and revised by EPA Region 10 Office of Water and Watersheds, Seattle, WA.

USFDA (U.S. Food and Drug Administration). 2000. Total Diet Study Statistics on Element Results. Center for Food Safety and Applied Nutrition, Washington DC. April 25, 2000 (available at http://www.cfsan.fda.gov/~comm/tds-toc.html).

USFDA (U.S. Food and Drug Administration). 2003. Total Diet Study, Summary of Residues Found Ordered by Pesticide, Market Baskets 91-3 – 01-4, Center for Food Safety and Applied Nutrition, Washington, DC. June 2003. (available at http://www.cfsan.fda.gov/~comm/tds-toc.html).

USFWS (U.S. Fish and Wildlife Service). 1992. Catalog of Alaskan Seabird Colonies— Computer Archives. U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, AK.

USFWS (U.S. Fish and Wildlife Service). 2000. Endangered and Threatened Wildlife and Plants; Final Rule to List the Short-tailed Albatross as Endangered in the United States. July 31, 2000, Federal Register 65: 46643-46654.

USFWS (U.S. Fish and Wildlife Service). 2001. Endangered and Threatened Wildlife and Plants; Final Determination of Critical Habitat for the Alaska-breeding Population of the Steller's Eider. Federal Register 66 (Feb. 2, 2001): 8850-8884.

USFWS (U.S. Fish and Wildlife Service). 2002. Steller's Eider Recovery Plan. U.S. Fish and Wildlife Service. Region 7. Anchorage, Alaska U.S. Fish and Wildlife Service

USFWS (U.S. Fish and Wildlife Service). 2005. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Southwest Alaska Distinct Population Segment of the Northern Sea Otter (*Enhydra lyutris kenyoni).* August 9, 2005, *Federal Register* 70: 46366-46386.

USFWS (U.S. Fish and Wildlife Service). 2008. Short-tailed Albatross Recovery Plan. Anchorage, AK, 105 pp. Available: <http://alaska.fws.gov/fisheries/endangered/pdf/stal_recovery_plan.pdf>. Accessed September 2012.

USFWS (U.S. Fish and Wildlife Service). 2009. Short-tailed Albatross (Phoebastria albatrus) 5-year Review: Summary and Evaluation. Available: <http://www.fws.gov/carlsbad/SpeciesStatusList/5YR/20090924_5YR_STAL.pdf>. Accessed September 2012. (Includes personal communication from H. Hasegawa, Toho University.)

USFWS (U.S. Fish and Wildlife Service). 2010. Southwest Alaska Distinct Population Segment of the Northern Sea Otter (Enhyra lutris kenyoni) – Draft Recovery Plan. U.S. Fish and Wildlife Service, Region 7, Alaska. 171pp.

USGS (US Geologic Survey). 1968. McGarr, Arthur and Robert C. Vorhis. THE ALASKA EARTHQUAKE, MARCH 27, 1964: EFFECTS ON THE HYDROLOGIC REGIMEN: Seismic Seiches from the March 1964 Alaska Earthquake. *Geological Survey Professional Paper 544-E.*

USGS (U.S. Geological Survey). 1998. Personal communication from Joe Dorava, USGS to Tom Buccerri, DO&G, December 16, 1998. As cited by Chapter Three: Description of the Cook Inlet Lease Sale Area. Available: <http://dog.dnr.alaska.gov/Leasing/Documents%5CBIF%5CCook_Inlet%5CCookInlet_BIF2009_3_Desciption.pdf>. Accessed September 2012

USGS (U.S. Geological Survey). 1999. Brabets, T.P., G.L. Nelson, J.M. Dorova, and A.M. Milner. Water-Quality Assessment of the Cook Inlet Basin, Alaska – Environmental Setting: Water-Resources Investigations Report 99-4025. National Water Quality Assessment Program, Anchorage, AK.

Visser, M.E., C. Both, and M.M. Lambrechts. 2004. Global climate change leads to mistimed avian reproduction. *Advances in Ecological Research* 35:89–110.

Vos, D.J., and K.E.W. Sheldon. 2005. Unusual mortality in the depleted Cook Inlet beluga (*Delphinapterus leucas*) population. Northwestern Naturalist 86: 59-65.

Wang, Z., K. Sassen, D. N. Whiteman, and B. D. Demoz. 2004. Studying altocumulus with ice virga using ground-based active and passive remote sensors. J. Appl. Meteor., 43, 449–460.

Watts, P., and D.E. Gaskin. 1985. Habitat Index Analysis of the Harbor Porpoise (*Phocoena phocoena*) in the Southern Coastal Bay of Fundy. *Canada. J. Mamm.* 66:733-744.

Waythomas, C.F., and R.B. Waitt. 1998. Preliminary Volcano-Hazard Assessment for Augustine Volcano, Alaska. U.S. Geological Survey Open File Report 98-0106.

Waythomas, C.F., J.M. Dorava, T.P. Miller, C.A. Neal, and R.G. McGimsey. 1997. Preliminary Volcano-Hazard Assessment for Redoubt Volcano, Alaska. U.S. Geological Survey Open File Report 97-0857.

WDFW (Washington Department of Fish and Wildlife). 2011. Pacific Herring Information Summary.

Whitney, J. S. 2002. Cook Inlet, Alaska: Oceanographic and Ice Conditions and NOAA's 18-year Oil Spill Response History 1984-2001, (HAZMAT report 2003-01). Anchorage, Alaska: National Ocean Service, Hazardous Materials Response and Assessment Division. TD427.P4 W61 2002.

Willette, T.M., R.T. Cooney, V. Patrick, D.M. Mason, G.L. Thomas, and D. Scheel. 2001. Ecological Process Influencing Mortality of Juvenile Pink Salmon (*Onchorhynchus gorbushcha)* in Prince William Sound, Alaska. *Fish. Oceanogr.* 10(Suppl. 1):14-41.

Wilson, J.G. and J.E. Overland. 1986. Meteorology, pp. 31-56, in The Gulf of Alaska Physical Environment and Biological Resources, D.W. Hood and S.T. Zimmerman, eds. USDOC, NOAA, NOS, OMPA and USDOI, MMS, Alaska OCS Region, Anchorage, AK.

Witherell, D. 1999. *Status Trends of Principal Groundfish and Shellfish Stocks in the Alaska Exclusive Economic Zone,* 1999. North Pacific Fishery Management Council, Anchorage, AK.

Wright, S. 2012. Biologist. National Marine Fisheries Service, Anchorage, Alaska, *in litteris.*

WWF (World Wildlife Fund). 2013. *Sei Whale*. <http://wwf.panda.org/what_we_do/endangered_species/cetaceans/about/sei_whale/>.

Yesner, D.R. 1976. Aleutian Islands albatrosses: a population history. *Auk* 93:263-280.

Yunker, M.B., R.W. Drinnan, and T.A. Smyth. 1990. Dispersion and fate of oiled drill cuttings discharged from two exploration wells near Sable Island, Canada. *Oil & Chemical Pollution* 7:299-316.

Zerbini, A.N., J. M. Waite, J. L. Laake, and P. R. Wade. 2006. Abundance, trends, and distribution of baleen whales off Western Alaska and the central Aleutian Islands. Deep-Sea Res. I 53:1772–1790.

8.0 ACRONYMS AND ABBREVIATIONS

AAC	Alaska Administrative Code
ACC	Alaska Coastal Current
ACMP	Alaska Coastal Management Program
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
AMSA	Area Meriting Special Attention
AOGCC	Alaska Oil and Gas Conservation Commission
API	American Petroleum Institute
AS	Alaska Statute
ATSDR	Agency for Toxic Substances and Disease Registry
BAT	Best Available Technology Economically Achievable
BCT	Best Conventional Pollutant Control Technology
BOD	Biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
BOEM	Bureau of Ocean Energy Management
BPJ	Best Professional Judgment
BPT	Best Practicable Control Technology Currently Available
CFR	Code of Federal Regulations
COD	chemical oxygen demand
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
dB	decibel; a logarithmic unit of measure of the ratio between two numbers
dBF	decibels expressed as a sound pressure level measurement, time-weighted as “Fast”
DHSS	Department of Health and Social Services (DHSS)
EC_{50}	a toxicant concentration triggering an effect in 50 percent of test organisms
EEZ	Exclusive Economic Zone
EFH	Essential fish habitat
E/m^2	Einsteins per square meter
EIS	Environmental Impact Statement
ELG	Effluent limitations guidelines
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
USFDA	U.S. Food and Drug Administration
FMP	Fisheries Management Plan
FR	Federal Register
GC/MS	Gas chromatography/mass spectrometry
HPC	Habitat areas of particular concern
IWC	International Whaling Commission

LC_{50}	Lethal concentration to 50 percent of test organisms
MARPOL	International Convention for the Prevention of Pollution from Ships
MLLW	Mean lower low water
MMPA	Marine Mammal Protection Act of 1972
MMS	Minerals Management Service
MSD	Marine sanitation device
Mw	Moment magnitude
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOEL	No Observable Effect level
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NSPS	New Source Performance Standards
OCS	Outer Continental Shelf
ODCE	Ocean Discharge Criteria Evaluation
PAH	Polynuclear aromatic hydrocarbons
PCE	Primary constituent element
PTS	Permanent threshold shift
RFI	Request for Information
SBF	Synthetic-based drilling fluid
SGR	State Game Refuge
SGS	State Game Sanctuary
SPP	Suspended particulate phase
TOC	Total organic carbon
TSS	Total suspended solids
TTS	Temporary threshold shift
UOD	Ultimate oxygen demand
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WBF	water-based drilling fluid
WQS	Water Quality Standards
WET	Whole Effluent Toxicity
Y-K Delta	Yukon-Kuskokwim River Delta

UNITS

µg/L	micrograms per liter
°C	degrees Celsius
°F	degrees Fahrenheit
ac	acre
bbl/day	barrels per day
bbl/hour	barrels per hour
bbl/well	barrels per well
cm/s	centimeters per second
cm^3	cubic centimeters
ft^3	cubic feet
gpd	gallons per day
ha	hectare
in/s	inches per second
kg	kilograms
km^2	square kilometer
L	liters
lb	pounds
lb/bbl	pounds per barrel
lb/gal	pounds per gallon
m^2	square meters
m^3	cubic meters
m^3/s	cubic meters per second
mgd	million gallons per day
mg/kg	milligram per kilogram
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
mi^2	square mile
m/s	meters per second
ppm	parts per million
ppt	parts per thousand
v/v	volume component per total volume