APPENDIX A

Accidental Oil Spills and Gas Releases;

Information, Models, and Estimates;

and Supporting Figures, Tables, and Maps

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APPENDIX A OIL SPILL RISK ANALYSIS

A-1 Accidental Large Oil Spills

A-1.1 Large Spill Size, Source, and Oil-Type Assumptions

Table A-1-1 shows the general size categories, source of a large spill(s), type of oil, size of spill(s) in barrels, and the total volume Bureau of Ocean Energy Management (BOEM) assumes in the analysis of oil spill effects in Sections 4.2 through 4.4 and 4.7 of this Final Environmental Impact Statement (FEIS) for the Liberty Development and Production Plan (DPP).

A-1.1.1 OCS Large Oil Spill Sizes

Large Outer Continental Shelf (OCS) spills have a minimum size, or threshold value, of 1,000 barrels (bbl), but the spill size could be larger. Table A-1-1 shows the assumed large spill sizes used in the effects analysis of a large spill for the proposed action.

The large OCS spill size assumptions BOEM uses for a spill from the island and an offshore pipeline leak are based on reported spills in the Gulf of Mexico (GOM) and Pacific (PAC) OCS because no large spills (greater than or equal to 1,000 bbl) have occurred on the Alaska or Atlantic OCS from oil and gas activities. BOEM uses the median OCS spill size as the likely large spill size (Anderson, Mayes, and LaBelle, 2012) because it is the most probable size for that spill size category. The GOM and PAC OCS data show that a large spill most likely would be from a pipeline or a platform. The median size of a crude oil spill greater than or equal to 1,000 bbl from a pipeline on the OCS from 1996 through 2010 is 1,720 bbl, and the average is 2,771 bbl (Anderson, Mayes, and LaBelle, 2012). The median spill size for a platform on the OCS over the entire record from 1964 through 2010, is 5,066 bbl, and the average is 395,500 bbl (Anderson, Mayes, and LaBelle, 2012). Outliers such as the Deepwater Horizon (DWH) spill volume skew the average and the average is not a useful statistical measure. For purposes of this analysis, BOEM uses the median spill sizes for OCS pipelines and platforms, rounded to the nearest hundred shown below, as the likely large spill sizes for an offshore pipeline leak and island spill in the proposed action. The large OCS offshore pipeline spill size due to a rupture is based on the operator's estimate of a worst-case discharge from its pipeline, 3,979 bbl (Hilcorp, 2017), and rounded to the nearest hundred, yielding 5,000 bbl.

Table A-1-1 Large OCS Spill Size Assumptions in Barrels

OCS Offshore Pipeline Leak	OCS Offshore Pipeline Rupture	OCS Island Spill
1,700	5,000	5,100

A-1.1.2 Onshore Large Oil Pipeline Spill Size

The U.S. Department of Transportation (USDOT), Office of Pipeline Safety Research and Special Programs Administration keeps information about distribution and transmission accident and incident data online (USDOT, 2015 a, b, c). The Hazardous Liquid Accident Data (2004 through 2013) was analyzed to estimate crude-oil spills greater than or equal to 1,000 bbl for onshore pipelines. The Pipeline and Hazardous Materials Safety Administration (PHMSA) hazardous liquid incident database was filtered by commodity type and spill volume to obtain a subset of data specific to crude oil pipeline systems. Summary statistics were generated for the 74 crude oil spills greater than or equal to 1,000 bbl identified. The median crude oil spill size is 2,540 bbl and the average is 5,325 bbl. For the purpose of this analysis, BOEM used the PHMSA median spill size for analysis of a large onshore pipeline spill for the Proposed Action rounded to the nearest hundred (2500 bbl).

A-1.1.3 Source and Type of Large Oil Spills

The source is considered the place from which a large oil spill could originate. For the Proposed Action, the sources of large spills are divided into the island, offshore pipeline, and onshore pipeline. Island sources include spills from wells or from equipment located on the island such as diesel fuel tanks. Large offshore pipeline spills include spills from the offshore pipeline to the shore. Large onshore pipeline spills include spills from shore to Pump Station 1.

The types of oil spilled from island spills are assumed to be crude oil or diesel oil. Large onshore and offshore pipeline spills are assumed to be crude oil.

The type of crude oil used in this analysis is Liberty crude oil. Hilcorp provided average reservoir fluid property data from a flow test taken at the Liberty #1 well (Hilcorp 2015, DPP Section 4.2.2). The API (American Petroleum Institute) gravity is a measure of how heavy or light the oil is compared to water. The average API gravity of Liberty crude oil is 24° to 27° API (Hilcorp 2015, DPP Section 4.2.2). SL Ross Environmental Research, Ltd. (S.L. Ross) performed simulated weathering experiments and physical property analyses of Liberty crude oil (SL Ross 1998). This laboratory data was used in the weathering calculations detailed in Table A-1-2 through Table A-1-4. SL Ross (2000) provides a preliminary assessment of the spill behavior of Liberty crude oil if released into the environment.

The type of diesel oil used in this analysis is ultra low sulfur diesel (ULSD) as Hilcorp states that it will be using ULSD during operations (Hilcorp 2015, DPP Table 8-2). A comparable ULSD from Norway's Esso Slagen Refinery is used in BOEM's oil weathering analysis (SEA Consulting Group and SINTEF 2015). The ULSD sample taken from the Esso Slagen Refinery has an API gravity of 38° and an EN 590 specification. It was chosen to be representative for the diesel oil weathering simulations used in this analysis shown in Table A-2-6 though Table A-2-8. Further, a product specification sheet by Petro Star Inc., an Alaska refinery and fuel marketing company, has information on Arctic Grade ULSD (Petrostar, 2016).

A-1.1.4 Historical Loss of Well-Control Incidents on the OCS and North Sea

The loss of well control (LOWC) incidents on the OCS and/or North Sea, and discussion of the analysis of their frequencies is detailed by U.S. Department of the Interior (USDOI, BOEMRE, 2011; Appendix B; Table B-1); USDOI, BOEM, (2012a; Figure 4.3.3-1); BLM (2012; Appendix G); International Association of Oil & Gas Producers (IAOGP) (2010); Bercha Group, Inc. (2014a); and Ji, Johnson, and Wikel (2014). The LOWC occurrence frequencies per well are on the order of 10^{-3} to 10^{-6}. The occurrence frequencies depend upon the operation or activity, if the LOWC was a blowout or well release, and if there was oil spilled.

In general, historical data show that LOWC events escalating into blowouts and resulting in oil spills are infrequent and those resulting in large oil spills are even rarer (Anderson, Mayes, and LaBelle, 2012; Bercha Group, Inc., 2014; Izon et al. 2007; Ji, Johnson, and Wikel, 2014; Robertson et al., 2013; USDOI, BOEMRE, 2011; and USDOI, BOEM, 2016). From 1964 to 2010 there were 283 well control incidents, 61 of which resulted in crude or condensate spills (USDOI, BOEM, 2012a; Table 4.3.3.1). From 1971 to 2010, fewer than 50 well control incidents occurred. Excluding the volume from the DWH spill, the total spilled volume was less than 2,000 bbl of crude or condensate. The largest of the 1971 to 2010 spills (other than the DWH event) was 350 bbl. The DWH event was the only VLOS to occur between 1971 to 2010 (USDOI, BOEM, 2012) and over the same time period, more than 41,800 wells were drilled on the OCS and almost 16 billion barrels (Bbbl) of oil were produced.

From 1971 through 2010, a total of 15,491 exploration wells were drilled: 223 in the PAC OCS, 46 in the Atlantic OCS, 15,138 in the GOM OCS, and 84 in the Alaska OCS. During this period, there were 77 well control incidents associated with exploration drilling. Of those 77 incidents, 14 (18 percent) resulted in oil spills ranging from 0.5 bbl to 200 bbl, for a total 354 bbl, excluding the estimated volume from the DWH spill. These statistics show that while approximately 15,000 exploration wells were drilled, there were a total of 15 LOWC events that resulted in a spill of any size. Fourteen were small spills and one was a large/very large spill (greater than or equal to 1,000 bbl) that resulted in a blowout (the DWH spill).

From 1980 through 2011, industry drilled 745 development wells in the PAC OCS, 19,275 in the GOM OCS, and 9,174 in the North Sea. There were a total of 61 LOWC events during the drilling of these 29,194 development wells. From 1980 through 2011, industry operated 7,674 producing wells in the PAC OCS, 197,721 in the GOM OCS, and 59,137 in the North Sea. There were a total of 111 LOWC events during production and well intervention activities from these 264,532 wells (Bercha Group, Inc. 2014).

The risk of an unlikely or rare event, such as a LOWC incident, is determined using the best available historical data. The 2012 through 2017 5-Year Program Final Programmatic Environmental Impact Statement (PEIS) (USDOI, BOEM, 2012a) provides a detailed discussion of the OCS well control incidents and risk factors that could contribute to a long duration LOWC event. Risk factors include geologic formation and hazards; water depth and hazards; geographic location (including water depth); well design and integrity; LOWC prevention and intervention; scale and expansion; human error; containment capability; response capability; oil types and weathering/fate; and specific regional geographic considerations, including oceanography and meteorology.

Quantifying the frequency of VLOSs from a LOWC event is challenging as relatively few large oil spills which can serve as benchmarks have occurred on the OCS (Scarlett et al., 2011). Based on an analysis of this historic data from both the 1971 through 2010 (the modern regulatory era) and the 1964 through 1971 time frames, the frequency of a LOWC occurring and resulting in a VLOS of different volumes was determined (USDOI, BOEM, 2016, Figure 3.3-1). This analysis, which is set forth in the 2017 through 2022 5-Year Program FEIS, was used to calculate the frequency (per well) of a spill exceeding 4,610,000 bbl, which is the VLOS volume assumed in this FEIS.

A-1.2 Behavior and Fate of Crude Oils

There are scientific laboratory data and field information from accidental and research oil spills about the behavior and fate of crude oils. BOEM discusses the background information on the fate and behavior of oil in Arctic environments and its behavior and persistence properties along various types of shorelines. BOEM also makes several estimates about environmental parameters to perform modeling simulations of oil weathering that are specific to the large spill scenario for the proposed project.

A-1.2.1 Generalized Processes Affecting the Fate and Behavior of Oil

Several processes alter the chemical and physical characteristics and toxicity of spilled oil. Collectively, these processes are referred to as weathering or aging of the oil. The major oil weathering processes are spreading; evaporation; dispersion; dissolution; emulsification; microbial degradation; photochemical oxidation; and sedimentation to the seafloor or stranding on the shoreline (Payne et al., 1987; Boehm, 1987; Lehr, 2001).

Along with physical oceanography and meteorology, weathering processes determine the oil's fate in the environment. Potter et al. (2012), Dickins (2011), and Lee et al. (2011) reviewed the state of fate and behavior of oil in ice and documented the relevant studies; some of which were detailed in the USDOI, Minerals Management Service (MMS) (2007) Lease Sale 193 FEIS, Appendix A, 2.1. Collectively, 40 years of research underpin the available science on fate and behavior of oil in open water and ice.

A-1.2.1.1 Shoreline Type, Oil Behavior, and Persistence

A new shorezone analysis was completed in 2014 and BOEM compiled the new Environmental Sensitivity Information (ESI) for each of the land segments along the northern coast of Alaska (Harper and Morris, 2014). For each land segment, the percentage of each ESI type by length is shown in Table A-2-5. In general, the higher the ESI number, the longer the oil is estimated to persist in that type of substrate.

How long an oil spill persists on water or on the shoreline can vary widely depending on the size of the oil spill, the environmental conditions at the time of the spill, and the substrate of the shoreline. In general, very little oil persists after 30 days unless spilled in the presence of sea ice.

A-1.2.2 Assumptions about Oil Spill Weathering

To run the oil weathering model (OWM) using a consistent framework, several assumptions are made regarding the type of oil, the size of the spill, the environmental conditions, and the location of the spill. The following assumptions are used to estimate weathering of a large oil spill:

- The weathering of crude oil is based on laboratory weathering data of a Liberty crude oil sample (SL Ross, 1998).
- The weathering of diesel oil is based on laboratory weathering data of an ULSD sample from a Norweigen Refinery (SEA and SINTEF, 2015) that serves as a correlative for Arctic Grade ULSD.
- The size of the large diesel fuel spill from the island is 5,100 bbl; see Section A-1.1.
- The sizes of the small diesel fuel spills modeled are 3 bbl and 200 bbl.
- The sizes of the large crude oil spills are 1,700 bbl (pipeline leak), 5,000 bbl (pipeline rupture), and 5,100 (island spill); See Section A-1.1 Large Spill Size, Source, and Oil-Type.
- There is no reduction in the size of spill due to cleanup; instead, cleanup is considered separately as either mitigation or disturbance.
- The wind, wave, water temperature, and ice conditions are as described.
- The spill is a surface spill or a spill from the buried pipeline that reaches the water surface quickly.
- Meltout spills occur in 50 percent ice cover.
- The properties predicted by the OWM are those of the thickest part of the slick.
- The spill occurs as an instantaneous spill over a short period of time.
- The oil spill persists for up to 30 days in open water or in ice.
- The fate and behavior are as modeled (Table A-2-2 through Table A-2-8).

Uncertainties exist, such as:

- The actual size of an oil spill or spills, should they occur.
- The location of the spill.
- Wind, current, wave, and ice conditions at the time of a possible oil spill.
- The crude or diesel properties at the time of a possible spill.

A-1.2.3 Modeling Simulations of Oil Weathering

To judge the effects of a large oil spill, BOEM estimates information regarding how much oil evaporates, how much is dispersed, and how much remains after a certain time period. BOEM derives the weathering estimates of Liberty crude oil and diesel fuel from modeling results using the SINTEF OWM Version 4.0 (Reed et al., 2005) for up to 30 days.

BOEM simulates two general scenarios: one in which the oil spills into open water, and one in which the oil freezes into the ice and melts out into 50 percent ice cover. BOEM assumes that open water conditions can exist within the proposed action area between July and October (see 2017 Liberty DEIS, Section 3.1.2.4), and that meltout can occur from June through July (see 2017 Liberty DEIS Section 3.1.2.1). BOEM models both the open water and meltout spills as instantaneous. Although different amounts of oil could melt out at different times, BOEM took the conservative approach, which was to assume all the oil was released at the same time.

A-1.3 Estimates of Where a Large Offshore Oil Spill May Go

BOEM studies how and where large offshore spills move by using an oil spill trajectory model known as the Oil Spill Risk Analysis (OSRA) model (Smith et al., 1982; Ji, Johnson, and Li, 2011) which has the capability of assessing the probability of oil spill contact to resource areas. The “Large” oil spill means spills with a threshold size of greater than or equal to 1,000 bbl. This model analyzes the likely paths of over tens of thousands of simulated oil spill trajectories in relation to biological, physical, and sociocultural resources. The trajectory is driven by the wind, sea ice, and current data from a coupled ocean-ice model. The locations of resource areas, including sociocultural resource areas, barrier islands, and the coast within the model study area, are used by OSRA to tabulate the percent chance of oil spill contact to these areas. A full report was completed by BOEM in 2017.

A-1.3.1 Inputs to the Oil Spill Trajectory Model

There are several inputs necessary to run the oil spill trajectory model and to assess the probability of oil spill contact to environmental resource areas, boundary segments, land segments, and grouped land segments including:

- Study area;
- Arctic seasons;
- Location of the coastline;
- Location of environmental resource areas;
- Location of land segments and grouped land segments;
- Location of boundary segments;
- Location of facility;
- Location of pipelines and transportation assumptions;
- Current and ice information from a general circulation model; and
- Wind information.

A-1.3.1.1 Study Area and Boundary Segments

Map A-2a (Maps are found in Section A-3, Supporting Maps) shows the study area used in the oil spill trajectory analysis. It extends from 174ºE to 130ºW and 66ºN to 75ºN. The OSRA model has a resolution of 1,970 feet by 1,970 feet and a total of 6 million grid cells in the study area. The study area is formed by 40 offshore boundary segments and the Beaufort (United States and Canada) and Chukchi seas (United States and Russia) coastline. The boundary segments are vulnerable to spills in both Arctic summer and winter. The study area is chosen to be large enough to allow most trajectories of hypothetical oil spills to develop without contacting the boundary segments through as long as 360 days.

A-1.3.1.2 Trajectory Analysis Periods

The OSRA model launches a hypothetical oil spill trajectory from a hypothetical location called a launch point (described in detail in Section 3.1.5) starting on Day 1 in 1986, and it continuously launches the trajectory every other day for a total of 18 years (1986 through 2004). Therefore, a total of 3,240 trajectories are launched over this time period. The trajectories are driven by the 3-hour historical wind, current, and ice data from a coupled ocean ice model with 20 years (1985 through 2005) of simulation (described in detail in Section 3.1.6; Curchitser et al., 2013), and are computed on an hourly basis. Note that data from 1985 are not used in the trajectory analysis because they do not start on January 1.

BOEM defines three time periods for the trajectory analysis of large oil spills. These periods are the months when trajectories are started and the chance of contact is tabulated. BOEM calls these three periods annual, summer, and winter. Shown below are the three time periods that trajectories were started and the months that make them up.

Project Area	Annual	Summer	Winter
Proposed Action Area	January-December	July 1-September 30	October 1-June 30

The annual period is from January 1 to December 31. The summer period is from July 1 through September 30 and generally represents open water or Arctic summer. The winter period is from October 1 through June 30 and represents ice cover or Arctic winter. The choice of this seasonal division was based on meteorological, climatological, and biological cycles and consultation with Alaska OCS Region analysts.

A-1.3.1.3 Locations of Environmental Resource Areas

Environmental Resource Areas (ERAs) represent spatial and temporal areas of social, economic, or biological resources or resource areas. BOEM, Alaska OCS Region analysts designate these ERAs. The analysts work with specialists in other federal and state agencies, academia, and various stakeholders who provide information about these resources. The analysts also designate in which months these ERAs are vulnerable to spills, meaning the time period those resources occupy or use that spatial location. For example, birds migrate and may be there only from May to October.

There are 124 ERAs. Map A-2a through Map A-2h show the location of the 124 ERAs. These resource areas represent concentrations of wildlife, habitat, subsistence hunting areas, and subsurface habitats within the OSRA study area. The names or abbreviations of the ERAs and the general resource they represent are shown in Table A-1-1. Information regarding the general and specific ERAs for lower trophic resources, fish, birds, marine mammals, whales, and subsistence resources is found in Table A-2-2 through Table A-2-8, respectively. Terrestrial mammals are not represented by ERAs but are represented by Grouped Land Segments (GLSs) shown in Table A-2-20 and discussed below. BOEM also includes Land as an additional ERA. Land is the entire study area coastline and is made up of all the individual land segments (LSs) 1 through 146, which are described below.

A-1.3.1.4 Location of Land Segments and Grouped Land Segments

The coastline was further analyzed by dividing the Chukchi (United States and Russia) and Beaufort (United States and Canada) seas coastline into 146 LSs. Some LSs were added together to form larger geographic areas called GLSs.

The LS identification numbers (IDs) and the geographic place names within the LS are shown in Table A-2-19. Maps A-3a, A-3b, and A-3c show the location of these 146 LSs. Land segments are vulnerable to spills in both Arctic summer and winter. The GLSs, their names, and the individual LSs that make them up are shown in Table A-2-20. Maps A-4a, A-4b, and A-4c show the location of these 53 GLSs. Grouped land segments are vulnerable to spills based on the time periods shown in Table A-2-20.

A-1.3.1.5 Location of Proposed Hypothetical Launch Areas

Map A-5 shows the locations of the hypothetical island launch area (LA) and the hypothetical offshore pipeline LA where a large oil spill could originate from if it were to occur. BOEM used operator submitted GIS information for the pipeline route and island to estimate launch points from the launch areas. The LDPI consists of 4 launch points representing the approximated midpoints of the four sides of the island. The pipeline LA, herein referred to as "PL", consists of 6 equally spaced launch points along the offshore pipeline route from the island to the shore. Map A-6 shows a zoomed in view of Map A-5 along with the launch points that make up the LDPI and PL launch areas.

A total of 3,240 trajectories were simulated from each of 10 launch points over the 18 years of wind, current, and ice data for a total of 32,400 trajectories. The results of the trajectory simulations from the 4 island launch points were averaged and are labeled as LDPI in the conditional and combined probability tables (Table A-2-1 through Table A-4-11). The results of the trajectory simulations from the 6 pipeline launch points were averaged and are labeled as PL in the conditional and combined probability tables (Table A-2-1 through Table A-4-11).

A-1.3.1.6 Ocean Current and Ice Information from a General Circulation Model

BOEM uses the results from a new coupled ice ocean general circulation model to simulate oil spill trajectories. The wind-driven and density-induced ocean flow fields and the ice motion fields are simulated using a three-dimensional, coupled, ice ocean hydrodynamic model (Curchitser et al., 2013). The model is based on the Regional Ocean Modeling System (ROMS) (Shcheptkin and McWilliams, 2005). The ROMS has been coupled to a sea ice model (Budgell, 2005), which consists of elastic-viscous-plastic rheology (Hunke and Dukowics, 1997; Hunke, 2001) and the Mellor and Kantha (1989) thermodynamics. This model simulates flow properties and sea ice evolution for the Arctic with enhanced resolution (3+ miles) in the Chukchi and Beaufort seas during the years 1985-2005. The sea ice model was adapted to represent landfast ice, which occurs on the Chukchi Sea coast. The coupled ocean ice model uses 6-hour CORE2 forcing files (Large and Yeager, 2009), including winds, air temperature, air pressure and humidity, plus daily solar radiation to compute the momentum, heat, and salt fluxes. Comparison of model results with observation shows significant skill in the model capability to reproduce observed circulation and sea ice patterns in the Beaufort and Chukchi seas (Curchitser et al., 2013). BOEM down-scaled the model results to an approximately 1.5-mile resolution in the north-south direction.

A-1.3.1.7 Wind Information

BOEM uses the reanalysis (1986 through 2004) wind fields provided by Curchitser et al. (2013). The wind data are from CORE2 (Large and Yeager, 2009) and was interpolated to the coupled ocean model grid at 3-hour intervals. BOEM down-scaled the model results to an approximately 1.5-mile resolution in the north-south direction.

A-1.3.1.8 Large Oil Spill Release Scenario

For purposes of this trajectory simulation, all spills occur instantaneously. For each trajectory simulation, the start time for the first trajectory was the first day of the season (winter or summer) of the first year of wind data (1986) at 6 a.m. Greenwich Mean Time (GMT). The summer season consists of July 1 through September 30, and the winter season is October 1 through June 30. Each subsequent trajectory was started every 2 days at 6 a.m. GMT.

A-1.3.2 Oil Spill Trajectory Model Assumptions

The oil spill trajectory model assumptions are as follows:

- Large oil spills occur at the gravel island or along the pipeline route.
- Produced oil is transported through the pipeline.

- A large oil spill reaches the water surface.
- Large oil spills persist long enough for trajectory modeling for up to 360 days if they are encapsulated in ice and melt out.
- A large oil spill encapsulated in the landfast ice does not move until the ice moves or it melts out.
- Large oil spills occur and move without consideration of weathering. The oil spills are simulated each as a point with no mass or volume. The weathering of the oil is estimated separately in the stand-alone SINTEF OWM model.
- Large oil spills occur and move without any cleanup. The model does not simulate cleanup scenarios. The oil-spill trajectories move assuming booms and skimmers are not used and no other response action is taken. Large oil spills stop when they contact the mainland coastline, but not the offshore barrier islands in Stefansson Sound.

Uncertainties exist, such as:

- The actual size of the large oil spill or spills, should they occur.
- Whether the large spill reaches the water.
- Whether the large spill is instantaneous or a long-term leak.
- The wind, current, and ice conditions at the time of a possible large oil spill.
- How effective response or cleanup is.
- The characteristics of crude or diesel oil at the time of the large spill.
- How Liberty crude or ultra low-sulfur diesel oil will spread.
- Whether or not development and production occurs.

A-1.3.3 Oil Spill Trajectory Simulation

The trajectory simulation portion of the OSRA model consists of many hypothetical oil spill trajectories that collectively represent the mean surface transport and the variability of the surface transport as a function of time and space. The trajectories represent the Lagrangian motion that a particle on the surface might take under given wind, ice, and ocean current conditions. Thousands of trajectories are simulated to give a statistical representation, over time and space, of possible transport under the range of wind, ice, and ocean current conditions that exist in the OSRA study area.

Trajectories are constructed to produce an oil transport vector. For cases where the ice concentration is below 80 percent, each trajectory is constructed using vector addition of the ocean current field and 3.5 percent of the instantaneous wind field—a method based on work done by Huang and Monastero (1982), Smith et al. (1982), and Stolzenbach et al. (1977). For cases where the ice concentration is 80 percent or greater, the model ice velocity is used to transport the oil. Equations 1 and 2 below show the components of motion that are simulated and used to describe the oil transport for each trajectory:

1) $U_{oil} = U_{current} + 0.035\ U_{wind}$

or

2) $U_{oil} = U_{ice}$

Where:

U_{oil} = oil drift vector

$U_{current}$ = current vector (when ice concentration is less than 80 percent)

U_{wind} = wind speed at 33 feet above the sea surface

U_{ice} = ice vector (when ice concentration is greater than or equal to 80 percent)

The wind drift factor was estimated to be 0.035, with a variable drift angle ranging from 0º to 25º clockwise. The drift angle was computed as a function of wind speed according to the formula in Samuels, Huang, and Amstutz (1982). The drift angle is inversely related to wind speed.

The trajectories age while they are in the water and/or on the ice. For each day that the hypothetical spill is in the water, the spill ages—up to a total of 360 days. While the spill is in the ice (greater than or equal to 80 percent concentration), the aging process is suspended. The maximum time allowed for the transport of oil in the ice is 360 days, after which the trajectory is terminated. After coming out of the ice that is melting into open water, the trajectory ages to a maximum of 30 days.

A-1.3.4 Results of the Oil Spill Trajectory Model

A-1.3.4.1 Conditional Probabilities: Definition and Application

The chance that a large oil spill will contact a specific ERA, LS, GLS, or BS within a given time of travel from a certain location (LDPI or PL) is termed a conditional probability. The condition is that BOEM assumes a large spill occurs. Conditional probabilities assume a large spill has occurred and the transport of the spilled oil depends only on the winds, ice, and ocean currents in the study area. Conditional probabilities are reported for three seasons (annual, summer, and winter) and six time periods (1, 3, 10, 30, 90, and 360 days). Conditional probabilities are expressed as a percent chance. This means that the probability (a fractional number between 0 and 1) is multiplied by 100 and expressed as a percentage.

For the Proposed Action, annual, summer, and winter periods are shown in Section 3.1.2 of Appendix A, Contact, tabulated from a trajectory that began before the end of summer season, is considered a summer contact. BOEM also estimates the conditional probability of contact from spills that start in winter, freeze into the sea ice, and melt out in spring or summer. Winter contacts are from spills that begin in winter. Therefore, if any contact an ERA, LS, GLS or BS is made by a trajectory that began by the end of winter, it is considered a winter contact. BOEM also estimates annual conditional probabilities of contact within 1, 3, 10, 30, 90, and 360 days. Annual contact is for a trajectory that began in any month throughout the entire year.

A-1.3.4.2 Conditional Probabilities: Results

The conditional probability results for the oil spill trajectory model are summarized generally below and are listed in Table A-2-1 through Table A-4-11 for the Proposed Action. The Maps referenced in this discussion are as follows:

- Boundary Segments (BSs) are shown in Map A-1,
- Environmental Resource Areas (ERAs) are shown in Maps A-2a through A-2h,
- Land Segments (LSs) are shown in Maps A-3a through A-3c, and
- Grouped Land Segments (GLSs) are shown in Maps A-4a through 4c.

For specific analysis of conditional probabilities in regard to specific resources, please see Chapter 4. The following section provides comparisons for an overall generalized view. Probabilities in the following discussions, unless otherwise noted, are conditional probabilities estimated by the OSRA model (expressed as percent chance) of a spill greater than or equal to1,000 bbl in size contacting ERAs, GLS, and LSs within the days and seasons as specified below.

A-1.4 Oil Spill Risk Analysis

A measure of oil spill risk is determined by looking at the potential for one or more large spills occurring as a result of development or production from the Proposed Action and then of a large spill contacting a shoreline segment, resource, or resource area of concern (called an environmental resource area [ERA]). If spilled crude oil contacts any portion of a shoreline segment or ERA, it is called a contact. The OSRA helps determine the relative risk of occurrence and contact of one or more large spills in and adjacent to the Project Area.

Combined probabilities are the chance of one or more large spills occurring and of those spills contacting over the life of the project. They are estimated using the conditional probabilities, the large oil spill rates, the resource estimates, and the assumed transportation scenarios. These are combined through matrix multiplication to estimate the mean number of one or more large spills from operations in and adjacent to the Project Area occurring and of any of these spills making a contact.

A-1.4.1 Chance of One or More Large Spills Occurring

The chance of one or more large spills occurring is derived from two components: 1) the large spill rate, and 2) the resource-volume estimate. The spill rate is multiplied by the resource volume to estimate the mean number of spills. Oil spills are treated statistically as a Poisson process, meaning that they occur independently of one another. If BOEM constructed a histogram of the chance of exactly 0 spills occurring during some period, the chance of exactly 1 spill, or exactly 2 spills, and so on, the histogram would have a shape known as a Poisson distribution. An important and interesting feature of this distribution is that it is entirely described by a single parameter, the mean number of large spills. Given the mean number of large spills, you can calculate the entire histogram and estimate the chance of one or more large spills occurring.

A-1.4.1.1 Large Spill Rates

BOEM derives the large oil spill rates for the Arctic OCS from a fault-tree modeling study conducted by Bercha Group, Inc. (2016). Using fault trees, oil spill data from the GOM and PAC OCS (Bercha Group, Inc., 2013) were modified and incremented to represent expected Arctic performance and included both Arctic and non-Arctic variability.

Fault tree analysis is a method for estimating the spill rate resulting from the interactions of other events. Fault trees are logical structures that describe the causal relationship between the basic system components and events resulting in system failure. Two general fault trees are constructed, one for large pipeline spills and one for large platform/well (island) spills. In the 2006 and 2008 Bercha Group, Inc. studies, fault trees were used to transform historical spill statistics for non-Arctic regions to predictive spill occurrence estimates for the Beaufort and Chukchi seas' sale areas. The Bercha Group, Inc. (2008) fault tree analysis focused on Arctic effects as well as the variance in non-Arctic effects, such as spill size and spill frequency. Arctic effects were treated as a modification of existing spill causes as well as unique spill causes. Modification of existing spill causes included those that also occur in other OCS regions but at a different frequency, such as trawling accidents. Unique spill causes for pipeline spills included events that occur only in the Arctic, such as ice gouging, strudel scour, upheaval buckling, thaw settlement, and other causes. For platforms, unique spill causes included ice force, low temperature, and other causes. The measures of uncertainty calculated were expanded beyond Arctic effects in each fault tree event to include the non-Arctic variability in spill size, spill frequency, and facility parameters, including wells drilled, number of platforms, number of subsea wells and subsea pipeline length. The inclusion of these types of variability—Arctic effects, non-Arctic data, and facility parameters—is intended to provide a realistic estimate of spill occurrence indicators on the Arctic OCS and their resultant variability.

The Bercha Group, Inc. (2016) fault tree analysis includes updated spill information from the GOM and the PAC OCS (Bercha Group, Inc., 2013). It also included refined information about LOWC frequencies used in the fault tree by incorporating information from a recently completed LOWC study (Bercha Group Inc., 2014a). The LOWC study updated offshore LOWC frequency information through 2011 for both the GOM and the PAC OCS and the North Sea using information from both the SINTEF worldwide database and the U.S. GOM and PAC OCS. Previous fault tree studies (2006 and 2008) used all LOWC events and their resultant frequencies regardless of whether or not they spilled crude or condensate oil. To this extent, previous fault tree results were conservative. In addition, platform spills, which occurred from a LOWC event, were previously double counted as both a platform/well spill and a LOWC event.

Recent studies (Bercha Group, Inc., 2014a; Ji, Johnson, and Wikel, 2014; USDOI, BOEM, 2016) have continued to refine data and information about LOWC. Until recently, a consolidated dataset of multiple variables was not readily available to analyze the volumes of oil associated with LOWC with other applicable variables. Of the approximately 192 GOM LOWC events from 1980 through 2011, 9 escalated into blowouts and spilled crude or condensate greater than or equal to 50 bbl (Bercha Group, Inc., 2014a) all of which were small spills except the DWH. The new information reveals that compared to the total number of LOWC events, there are few crude and condensate spills resulting from a LOWC escalating into a blowout.

A-1.4.1.2 Results for OCS Large Spill Rates

For purposes of fault tree analysis, BOEM uses the the reserve estimates provided by the operator that supplement Figure 4-10 in the 2015 Hilcorp DPP; it is assumed that 0.11779 Bbbl is produced and transported. The annual rates were weighted either by the annual production divided by the total production or the year divided by the total years, and the prorated rates were summed to determine the large spill rates over the life of the development and production of the Proposed Action. For the Proposed Action, the life of development and crude oil production is approximately 25.5 years. This is inclusive of an oil production period of approximately 22 years. Bercha Group, Inc. (2016) calculated the mean spill rate for Island/Wells, Pipelines, and the total, as well as the 95 percent confidence intervals on the total large spill rate per Bbbl as shown in Table A-1-2.

Table A-1-2 Mean Spill Rate by Type per Billion Barrels Produced

Type	Mean
Island/Wells	0.037 spills per Bbbl produced
Pipelines	0.020 spills per Bbbl produced
Total	0.058 spills per Bbbl produced
95% Confidence Interval	0.021 -0.105 spills per Bbbl produced

A-1.4.1.3 Results for the Chance of One or More Large Spills Occurring

In BOEM's estimate of the possibility that one or more large spills will occur, we assume the development will occur and 0.11779 Bbbl of crude oil will be produced. The volume is based on estimates provided by the operator and verified by BOEM.

Additionally, the chance of one or more large spills occurring as a result of operations in and adjacent to the proposed development is estimated over the life of the development; approximately 22 years. In estimates of one or more large spills occurring, annual chances for a large spill from both pipeline and gravel island/wells over the entire estimated life of the development are added together.

The large spill rates used in this section are all based on the mean number of large spills per Bbbl of hydrocarbon produced. Using the above mean spill rates for large spills, Table A-1-2 shows the estimated mean number of large oil spills for the Proposed Action. BOEM estimates 0.0024 pipeline spills and 0.0044 gravel island (including wells) spills would occur, for a total (over the life of the Project) of 0.0068 spills.

BOEM uses the above mean spill number to determine the Poisson distribution. Figure A-1-1 shows the chance of no large spills occurring is 99.32 percent, and the chance of one or more large spills occurring is 0.68 percent.

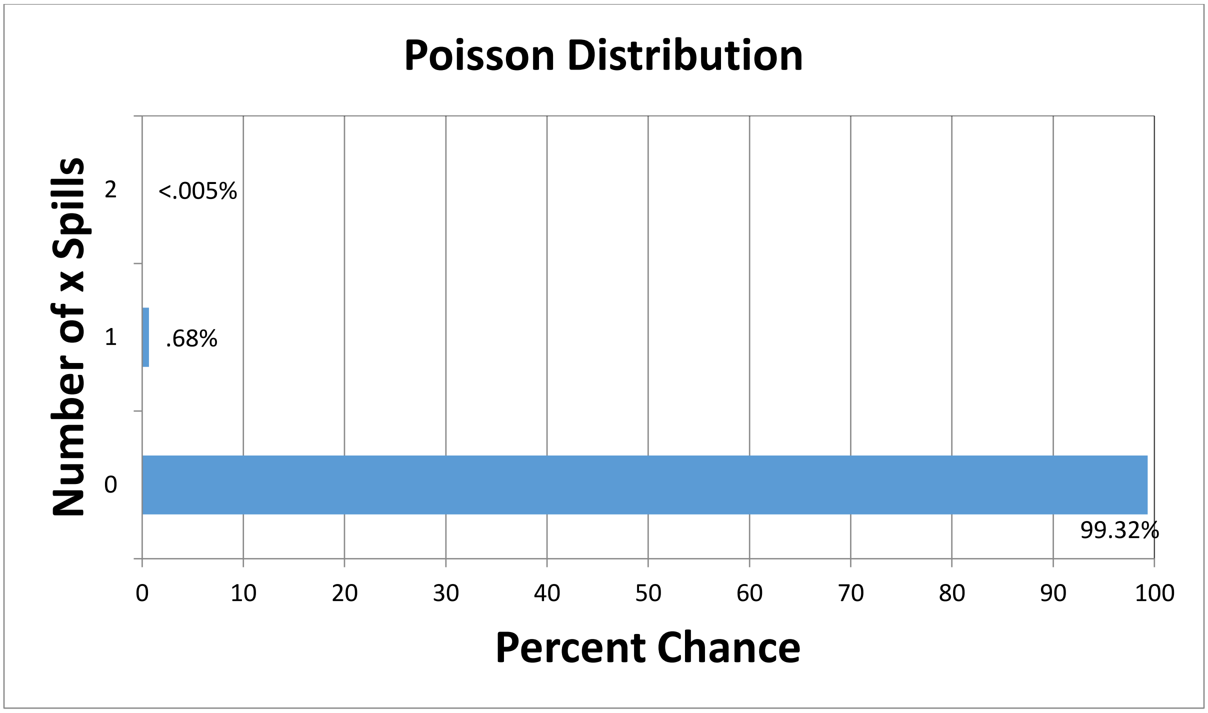


Figure A-1-1 Proposed Action Poisson Distribution over the Project Life

A large spill is a statistically unlikely event. Based on the OSRA data summarized in this Appendix, the mean spill number of large spills over the entire life of the Proposed Action is much less than one (0.0068 [about 0.007 of a large spill]) and the most likely number is zero. There is a 99.32 percent chance of no large spills occurring and a 0.68 percent chance of one or more large spills occurring over the life of the Proposed Action. The statistical distribution of large spills shows that it is much more likely that no large spill occurs than one or more over the life of the Proposed Action. However, because large spills are an important concern, and no one can estimate the future, BOEM assumes a large spill will occur and conducts a large oil spill analysis for development and production activities. This conservative analysis addresses whether such spills could cause serious environmental harm and informs the decision maker of potential impacts should an unlikely large spill occur. Assuming more large spills than the most likely number of spills helps to ensure that this Final EIS does not underestimate potential environmental effects.

A-1.4.2 Chance of a Large Spill Contacting: Conditional Probabilities

During the Proposed Action, the chance of a large spill from operations contacting shoreline sections or ERAs is taken from the oil spill trajectory model results, called Conditional Probabilities. These are summarized in Section 4.1.2.2 of the FEIS and are listed in Table A-2-1 through Table A-2-20.

A-1.4.3 Results of the Oil Spill Risk Analysis: Combined Probabilities

Table A-4-10 through Table A-4-11 show the annual combined probabilities for the DPP. The combined probabilities reflect the chance of one or more large spills occurring and contacting resources over the scenario life.

In summary, the chance of one or more large spills from operations in or adjacent to the Project Area occurring and contacting GLSs or ERAs is 1 percent within 30 days, or 1 percent within 360 days. The ERAs that had a 1 percent chance of contact are the Boulder Patch Area and the Shaviovik River. The GLS that had a 1 percent chance of contact is the U.S. Beaufort Sea Coast.

A-1.5 Accidental Small Oil Spills

Small spills are those less than 1,000 bbl. Table A-1-3 shows the small spills BOEM analyzed for the effects of the Proposed Action in Chapter 4. BOEM considers two oil types for small spills: crude and refined oil.

Small spills have occurred with general routine frequency and are considered likely to occur from development, production, or decommissioning activities The majority of small spills would be contained on the gravel island or landfast ice (during winter), and refined spills that reach the open water would evaporate and disperse within hours to a few days. Further, those spills reaching the water may be contained by booms or absorbent pads. BOEM estimates small spills are likely to occur over the life of the exploration and development activities.

A-1.5.1 Small Spill Assumptions Summary

In order to estimate the number and volume of small crude and refined spills that could occur as a result of the Liberty project, BOEM applied results from *Oil Spill Occurrence Rates for Alaska North Slope Crude and Refined Oil Spills* published by Nuka Research and Planning Group, LLC in October 2013 (Robertson et al., 2013). Nuka's analysis of onshore Alaska North Slope (ANS) crude and refined spills greater than 1 bbl and less than 1,000 bbl is performed collectively for all facilities, pipelines, and flowlines (Robertson et al., 2013).

Nuka used data for the years 1980 through 2010 from three oil fields (Kuparuk River, Milne Point, and Prudhoe Bay) on the ANS to develop regression models for estimating oil spill occurrence. The model used for this analysis is a mixed effects regression that estimates the total number of spills (both refined and crude) based on a given field's oil production volume and pipeline length (Robertson et al., 2013). The model developed by Nuka to estimate total yearly spills from a hypothetical field is provided by Equation 3 below (Robertson et al., 2013).

3) $\mathrm{N_{tot}} = 2.778 + 0.054 * (\mathrm{ProdOil}) + 0.026 * (\mathrm{TotLength})$

Where:
$\mathrm{N_{tot}} = \text{total spills per year}$
$\mathrm{ProdOil} = \text{production of oil per year (millions of bbls)}$
$\mathrm{TotLength} = \text{pipeline length in service (ten} - \text{thousands of linear ft)}$

Diagnostic tests performed by Nuka indicate that the model has a reasonably strong predictive value for annual number of spills. The 95 percent confidence intervals were: Intercept (-0.0003, 5.5570); ProdOil (0.0438, 0.0650); Tot Length (0.0002, 0.0496) (Robertson et al., 2013).

Using yearly production and pipeline length estimates provided by Hilcorp together with Equation 3, BOEM estimates a total of 70 small crude and refined oil spills (less than 1,000 bbl) during the life of the field. Applying the 95 percent confidence interval provides a range of 5 to 134 spills over the life of the field.

Nuka also totaled the number of small spills in three volume categories for the entire ANS spill database, which includes spills from Badami, Colville River (Alpine), Endicott, Kuparuk River, Milne Point, Nikaitchuq, North Star, Ooogururk, Prudhoe Bay, and spills from unknown ANS fields. These totals, together with the percentage of small spills in each category, are shown in Table A-1-3.

Table A-1-3 Breakdown of ANS Spills in the database by Spill Size Class

Spills in Class	Class B 200 < Volume ≤ 1000	Class C 10 < Volume ≤ 200	Class D 1 < Volume ≤ 10
Number	25	250	1,300
Percentage	1.59 %	15.87 %	82.54 %

Note: Nuka table 3.2.
Source: Robertson et al., 2013

BOEM uses these percentages to prorate the estimated number of total small spills at Liberty. The total number of spills, 70, is multiplied by the percentage of spills in each class shown in Table A-1-3. Results of this proration are shown in Table A-1-4.

Table A-1-4 Estimated Small Spills at Liberty by Size Class

Spill Class	Class B 200< Volume ≤1000	Class C 10< Volume ≤200	Class D 1< Volume ≤10	Total Spills
Number of Spills	1	11	58	70

Nuka also provides the number of crude and refined spills (679 and 898, respectively) that have occurred on the entire ANS. BOEM divides ANS crude and refined spill numbers by the total ANS spills in the database (1,577) to yield 43.06 percent crude spills and 56.94 percent refined spills occurring in the ANS. BOEM then prorates the total number of small spills estimated to occur at Liberty by the percentages of crude and refined spills. Out of the 70 small spills BOEM estimates to occur as a result of the Proposed Action, 30 are crude oil spills, and 40 are refined oil spills.

To estimate the total volume of oil spilled from small spills, BOEM first multiplies the median small spill volume of refined oil spills on the ANS (2.39 bbl) by the estimated number of refined spills at Liberty (40) to yield approximately 96 bbl and multiplies the median small spill volume for crude oil spills on the ANS (3.33 bbl) by the number of crude oil spills estimated to occur at Liberty (30) to yield approximately 100 bbl. BOEM then added the small refined spill volume (96 bbl) to the small crude spill volume (100 bbl) to yield 196 bbl that are spilled as a result of the proposed action (Robertson et. al; BOEM, 2016).

To estimate the number of small spills per year for the entire life of the field, BOEM divided the estimated number of small spills (70) by the estimated summation of the number of years of development (approximately 2 years), production life (approximately 22 years), and decommissioning (1.5 years) to yield approximately 3 bbl per year. To estimate the number of small spills per year solely for the production period, BOEM divided the number of small spills (70) by the estimated number of years of production (22 years) which yields approximately 3 spills per year.

As discussed by Robertson et al. (2013) and in Table A-1.5, spill data from 1980 through 2010 from Kuparuk River, Milne Point, and Prudhoe Bay were used to develop Nuka's model (Equation 3). During the years 1980 through 2010, development in addition to production continued to occur at Kuparuk River, Milne Point, and Prudhoe Bay. For example, from the years 2005 to 2009, 8, 5, and 13 new development wells were drilled at Kuparuk River Unit (AOGC Kuparuk Info, 2016), Milne Point (AOGC Milne Point Info, 2016), and Prudhoe Bay (AOGC Prudhoe Bay Info, 2016), respectively. The plugging and abandoning of wells has also occurred in Prudhoe Bay (Oil and Gas Journal, 2000). While the Prudhoe Bay field is not being decommissioned, the plugging and abandoning of wells is an activity that is part of a field's general decommissioning process (30 CFR 250.1703). BOEM assumes that the estimated 70 small spills derived from Nuka's model represents spills that occur during the development, production, and decommissioning activities of the Proposed Action. Further, BOEM includes the 95 percent confidence interval to provide a range for the small spill number accounting for the uncertainty in the model variables.

A-2 Supporting Tables

Table A-2-1 Large (≥1,000 bbl) and Small (<1,000 bbl) Oil Spill Descriptions for Analysis[1,2]

Phase	Size	Source	Type of Oil	Estimated Number	Estimated Size (in bbl)
Development or Production	Large	OCS Island	Crude or Diesel	None[3]	5100 bbl[3,4]
		Offshore Pipeline	Crude		1,700 bbl (leak) or 4000 bbl (rupture)[3,4]
		Onshore Pipeline			2,500 bbl spill[3,4]
Any phase	Small	Island, Roads, Onshore, Offshore	Total	~70 spills	<1,000 bbl
Development and Production	Small	Operational Spills All Sources	Crude	~30 spills	<1,000 bbl
Any	Small	Operational Spills All Sources	Refined	~40 spills	<1,000 bbl

Notes:

[1] Large and small oil spill sizes are described in terms of: source of spill, phase of proposed action it could occur in, type of oil, and number and size of spill type.

[2] The receiving environment for small or large spills can be: open water, on top of or under sea ice, broken ice, shoreline, tundra, snow, or the spills could be contained on the LDPI. Additionally, small spills could occur on ice or traditional roads both onshore and offshore throughout the Proposed Action Area.

[3] No large spills are estimated to occur; one large spill from any of the large spill sources (island, offshore pipeline, or onshore pipeline) is assumed to occur for purposes of analysis;

[4] The estimated size of a large spill that is assumed to occur for purposes of analysis.

Sources: USDOI, BOEM, Alaska OCS Region (2016).

Table A-2-2 Fate and Behavior of a 5100 bbl Diesel Oil spill from the Proposed LDPI

Days Elapsed	Summer Spill[1]				Meltout Spill[2]			
Time After Spill (days)	1	3	10	30	1	3	10	30
Oil Remaining (%)	53	4.4	0	na	84.9	61.6	20.4	0
Oil Dispersed (%)	28.1	65.2	68.5	na	1.2	6.3	28.6	41.5
Oil Evaporated (%)	18.9	30.4	31.5	na	13.9	32.1	51	58.5

Source: USDOI, BOEM, ALASKA OCS Region (2016)
Note: The description following Table A.2-8 applies.

Table A-2-3 Fate and Behavior of a 5100 bbl Crude Oil Spill from the Proposed LDPI

Oil Status	Summer Spill[1]				Meltout Spill[2]			
Time After Spill (days)	1	3	10	30	1	3	10	30
Oil Remaining (%)	86.3	76.3	55.6	26.7	90.3	87.7	84.5	80.2
Oil Dispersed (%)	3.2	10.7	29.2	56.1	0.1	0.4	1.2	3.3
Oil Evaporated (%)	10.5	13	15.2	17.2	9.6	11.9	14.3	16.5
Discontinuous Area(km^2) 3	8.43	34.99	166.43	690.71	10.07	41.81	198.90	825.44
Oiled Coastline(km)4	80.16				75.31			

Source: USDOI, BOEM, ALASKA OCS Region (2016)
Note: The description following Table A.2-8 applies.

Table A-2-4 Fate and Behavior of a 5,000 bbl Crude Oil Rupture from the Pipeline

Oil Status	Summer Spill[1]				Meltout Spill[2]			
Time After Spill (days)	1	3	10	30	1	3	10	30
Oil Remaining (%)	86.3	76.2	55.6	26.7	90.3	87.7	84.5	80.2
Oil Dispersed (%)	3.2	10.8	29.2	56.1	0.1	0.4	1.2	3.3
Oil Evaporated (%)	10.5	13	15.2	17.2	9.6	11.9	14.3	16.5
Discontinuous Area (km^2) 3	8.35	34.63	164.76	683.77	9.97	41.39	196.90	817.15
Oiled Coastline (km)4	79.41				74.61			

Source: USDOI, BOEM, ALASKA OCS Region (2016)
Note: The description following Table A.2-8 applies.

Table A-2-5 Fate and Behavior of a 1,700-bbl Crude Oil Pipeline Leak

Oil Status	Summer Spill[1]				Meltout Spill[2]			
Time After Spill (days)	1	3	10	30	1	3	10	30
Oil Remaining (%)	85	75.5	55.2	26.4	90	87.6	84.4	80.2
Oil Dispersed (%)	4	11.4	29.6	56.3	0.1	0.4	1.3	3.3
Oil Evaporated (%)	11	13.1	15.2	17.3	9.9	12	14.3	16.5
Discontinuous Area(km^2) 3	4.82	19.98	95.06	394.51	5.75	23.88	113.6	471.47
Oiled Coastline(km) 4	47.74				44.85			

Source: USDOI, BOEM, ALASKA OCS Region (2016)
Note: The description following Table A.2-8 applies.

Table A-2-6 Fate and Behavior of a 200-bbl Diesel Oil Spill during Summer

Oil Status	Summer Spill[1]					
Time After Spill (Hours)	1	6	12	24	48	72
Oil Remaining (%)	95.9	77.7	51.8	16.6	0.5	0
Oil Dispersed (%)	0.8	11.7	29	55.6	68.1	68.5
Oil Evaporated (%)	3.3	10.6	19.2	27.8	31.4	31.5

Source: USDOI, BOEM, ALASKA OCS Region (2016)
Note: The description following Table A.2-8 applies.

Table A-2-7 Fate and Behavior of a 200 bbl Diesel Oil Spill during Meltout

Oil Status	Meltout Spill[2]			
Time After Spill (days)	1	3	10	30
Oil Remaining (%)	71.2	39.1	1.3	0
Oil Dispersed (%)	3.6	16.8	40.8	41.5
Oil Evaporated (%)	25.2	44.1	57.9	58.5

Source: USDOI, BOEM, ALASKA OCS Region (2016)
Note: The description following Table A.2-8 applies.

Table A-2-8 Fate and Behavior of a 3 bbl Diesel Oil Spill during Summer

Oil Status	Summer Spill[1]					
Time After Spill (Hours)	1	6	12	24	48	72
Oil Remaining (%)	91.1	39.3	6.6	0	NA	NA
Oil Dispersed (%)	3.4	38.3	63.7	68.6	NA	NA
Oil Evaporated (%)	5.5	22.4	29.7	31.4	NA	NA

Notes: Calculated with the SINTEF oil-weathering model Version 4.0 of Johanson et al. (2010) and assuming a Liberty Crude Oil (SL Ross 1998) or Ultra Low Sulfur Diesel (SEA and SINTEF 2015).

[1] Summer or Open Water (July to October), Wind Speed 6.0 m/s, surface water temperature 5.0°C

[2] Meltout (June to July), Spill is assumed to melt out into 50% ice cover with surface water temperature of 2.0°C and wind Speed of 5.0 m/s.

[3] Equation 6 of Table 2 in Ford (1985) is used to estimate the discontinuous area of a continuing spill or the area swept by an instantaneous spill of a given volume.

[4] Oiled coastline is calculated from Equation 17 of Table 4 in Ford (1985) and is the result of stepwise multiple regressions for length of historical coastline affected

NA = not applicable

Summer surface water temperature is based on CTD Casts collected by cruises/surveys during July, August, and September between 1985-2006 (Arctic Nearshore Impact Monitoring in Development Area (ANIMIDA) (Boehm, 2001) and Endicott Environmental Monitoring Program). The Endicott Environmental Monitoring Program water temperatures were recorded using CTD instruments from 1985-1987 across a series of transect lines during open-water season (Envirosphere 1987, 1990, and 1992). Summer wind speeds are based on average wind speeds measured at Endicott during July, August, September, and October from the years 2001-2006.

Meltout surface water temperature is based on NASA JPL's ROM (Regional Ocean Modeling System) (NASA 2016) and NOAA's Biweekly Sea Ice Analysis (National Ice Center 2016) for the years 2011 to 2015. Wind speeds during meltout are based on average wind speeds measured at Endicott during June and July from the years 2001-2006.

Table A-2-9 Land Segment (LS) ID and the Percent Type of Environmental Sensitivity Index Shoreline Closest to the Ocean for United States, Alaska Shoreline

LS ID	Geographic Place Names	1			3			4	5	6			7	8				9		10			U
		A	B	C	A	B	C			A	B	C		A	B	C	E	A	B	A	B	E	
40	Lopp Lagoon, Mint River	-	-	-	21	-	3	1	23	-	-	-	6	-	-	-	21	7	1	2	-	15	-
41	Ikpek, Ikpek Lagoon	-	-	-	16	-	6	-	-	-	-	-	12	-	-	-	21	7	2	16	-	19	2
42	Arctic Lagoon, Nuluk River	-	-	-	1	-	3	1	7	-	-	-	1	-	-	-	30	6	14	2	-	34	1
43	Sarichef Island	-	-	-	-	-	13	4	1	-	-	-	12	-	-	-	27	7	1	4	-	32	-
44	Cape Lowenstern, Shishmaref	-	-	-	6	-	8	-	-	-	-	1	7	-	-	-	32	6	4	6	-	31	-
45	LS45	-	-	-	17	-	-	-	-	-	-	-	1	-	-	-	25	7	9	-	-	40	2
46	Kalik & Singeakpuk River	-	-	-	13	-	2	-	-	-	-	-	4	-	-	-	38	7	12	-	-	24	-
47	Kitluk River	-	-	-	13	-	1	-	-	-	-	-	32	-	-	-	20	2	24	-	-	-	7
48	Cape Espenberg	-	-	-	13	-	1	-	10	-	-	-	2	-	-	-	7	8	-	25	-	20	14
49	Pish River	-	-	-	19	-	-	-	15	-	-	-	-	-	-	-	14	5	3	20	-	24	-
50	Goodhope Bay & River	1	-	3	4	-	-	4	22	4	12	-	-	-	-	-	12	-	-	4	-	35	-
51	Deering	1	-	11	15	-	-	-	23	6	4	-	-	-	-	-	12	2	1	24	-	-	1
52	Willow Bay	2	5	4	9	-	-	-	35	1	1	-	-	-	1	-	1	-	-	32	-	7	-
53	Kiwalik	-	-	-	3	-	-	-	18	-	-	-	-	2	1	-	-	3	-	13	-	43	15
54	Baldwin Peninsula	-	-	-	15	-	8	-	68	-	-	-	-	1	-	-	2	-	-	-	-	6	-
55	Cape Blossom, Pipe Spit	-	-	-	1	-	6	-	78	1	1	-	-	-	-	-	4	-	-	7	-	1	-
56	Kotzebue, Noatak River	-	1	-	-	-	3	-	13	-	-	1	-	-	-	-	8	9	1	5	-	23	38
57	Aukulak Lagoon	-	-	-	4	-	2	-	18	-	-	-	-	-	-	-	19	7	3	5	-	28	14
58	Cape Krusenstern	-	-	-	-	-	1	-	32	-	1	-	-	-	-	-	17	-	1	22	-	26	-
59	Imik, Ipiavik & Kotlik Lagoon	-	-	-	1	-	-	-	48	4	-	-	-	-	-	-	6	4	-	35	-	2	-
60	Kivalina, Kivalina & Wulik River	-	-	-	-	-	2	1	46	3	-	1	-	-	-	1	19	5	7	9	-	6	-
61	Cape Seppings	-	-	-	-	-	-	-	54	-	-	-	-	-	-	-	9	-	11	6	-	19	-
62	Atosik Lagoon	-	-	-	-	-	-	-	76	-	-	-	-	-	-	-	1	-	17	5	-	1	-
63	Asikpak Lag., Cape Seppings	-	-	1	5	-	1	1	46	11	-	-	19	-	-	-	10	3	1	1	-	-	-
64	Kukpuk River, Point Hope	1	-	2	8	-	1	2	42	4	-	-	12	-	-	-	16	4	6	-	-	1	-
65	Buckland, Cape Lisburne	13	-	2	-	-	-	-	71	10	3	-	-	-	-	-	-	-	-	1	-	-	-
66	Ayugatak Lagoon	54	-	-	-	-	-	-	32	1	-	-	-	-	-	-	-	-	-	12	-	-	-
67	Cape Sabine, Pitmegea River	38	-	3	-	-	15	-	22	1	-	-	-	-	-	-	-	-	-	19	-	-	-
68	Agiak Lagoon, Punuk Lagoon	-	-	-	-	-	11	-	76	11	-	-	-	-	-	-	-	-	-	1	-	-	-
69	Cape Beaufort, Omalik Lagoon	-	-	-	-	-	-	-	44	47	-	-	-	-	-	-	-	-	-	2	-	6	-

LS ID	Geographic Place Names	1			3			4	5	6			7	8				9		10			U
		A	B	C	A	B	C			A	B	C		A	B	C	E	A	B	A	B	E	
70	Kuchaurak and Kuchiak Creek	-	-	-	-	-	-	-	20	-	-	-	20	-	-	-	14	1	21	2	-	19	2
71	Kukpowruk River, Sitkok Point	-	-	-	4	-	9	-	35	-	-	-	21	-	-	-	5	19	4	-	-	2	1
72	Point Lay, Siksrikpak Point	-	-	-	4	-	2	-	49	-	-	-	8	-	-	-	12	15	-	5	-	3	-
73	Tungaich Point, Tungak Creek	-	-	-	-	-	8	-	52	-	-	-	-	-	-	1	4	15	5	10	-	4	-
74	Kasegaluk Lagoon, Solivik Isl.	-	-	-	15	-	-	-	28	1	-	-	1	-	-	-	5	41	2	5	-	-	1
75	Akeonik, Icy Cape	-	-	-	13	-	4	1	34	-	-	-	2	-	-	-	14	14	11	5	1	1	-
76	Avak Inlet, Tunalik River	-	-	-	2	-	8	3	40	-	-	-	1	-	-	-	13	11	8	1	-	13	-
77	Nivat Point, Nokotlek Point	-	-	-	13	-	3	6	42	-	-	-	9	-	-	-	12	9	4	-	-	1	-
78	Point Collie, Sigeakruk Point	-	-	-	15	-	5	-	38	-	-	-	19	-	-	-	-	4	7	-	-	5	8
79	Point Belcher, Wainwright	-	-	-	22	-	1	-	33	2	1	-	32	-	-	-	2	-	-	1	-	5	-
80	Eluksingiak Point, Kugrua Bay	-	-	-	13	-	35	-	10	-	-	-	12	-	-	-	14	9	-	1	-	5	1
81	Peard Bay, Point Franklin	-	-	-	3	-	21	-	37	1	-	-	25	-	-	-	3	9	-	-	-	-	-
82	Skull Cliff	-	-	-	-	-	76	2	12	9	-	-	1	-	-	-	-	-	1	-	-	-	-
83	Nulavik, Loran Radio Station	-	-	-	-	-	73	-	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-
84	Will Rogers & Wiley Post Mem.	-	-	-	1	-	8	-	82	-	-	-	-	-	-	-	-	-	8	-	-	-	-
85	Barrow, Browerville, Elson Lag.	-	-	-	11	-	14	-	37	-	-	-	1	-	-	-	17	2	2	3	-	7	7
86	Dease Inlet, Plover Islands	-	-	-	30	3	5	-	3	-	-	-	2	-	-	-	19	15	3	11	-	9	-
87	Igalik & Kulgurak Island	-	-	-	17	-	4	-	3	-	-	-	-	-	-	-	25	7	-	9	-	34	1
88	Cape Simpson, Piasuk River	-	-	-	6	-	5	6	-	-	-	-	-	-	-	-	14	-	-	-	-	25	44
89	Ikpikpuk River Point Poleakoon	-	-	-	2	-	4	-	-	-	-	-	-	-	-	-	4	57	-	-	-	13	20
90	Drew & McLeod Point, Kolovik	-	-	-	5	-	19	7	-	-	-	-	-	-	-	-	14	16	-	11	-	27	-
91	Lonely, Pitt Pt., Pogik Bay, Smith R	-	-	-	-	-	4	9	7	-	-	-	-	-	-	-	12	5	-	6	-	38	18
92	Cape Halkett, Garry Creek	-	-	-	1	-	20	3	-	-	-	-	-	-	-	-	26	2	-	-	-	31	18
93	Atigaru Pt, Eskimo Isl., Kogru R.	-	-	-	9	-	30	2	1	-	-	-	-	-	-	-	20	1	3	1	-	34	-
94	Tingmeachsiovik River	-	-	-	7	-	20	-	6	-	-	-	-	-	-	-	8	-	-	-	-	59	1
95	Fish Creek, Nechelik Channel	-	-	-	0	-	0	-	-	-	-	-	-	-	-	-	5	42	-	1	-	33	19
96	Tolaktovut Point, Colville River	-	-	-	1	1	0	-	-	-	-	-	-	-	-	-	8	27	-	6	-	10	46
97	Kupigruak Channel, Colville River	-	-	-	6	-	1	-	-	-	-	-	-	-	-	-	10	32	-		-	1	51
98	Kalubik Creek	-	-	-	6	-	16	13	2	-	-	-	-	-	-	-	5	19	-	15	-	25	1
99	Oliktok Point, Ugnuravik River	-	-	-	2	-		10	18	7	-	-	-	-	-	-	17	-	-	2	-	42	1
100	Milne Point, Simpson Lagoon	-	-	-	7	-	1	23	20	-	-	-	-	-	-	-	29	2	3	2	-	11	2
101	Beechy & Back Pt., Sakonowyak R.	-	-	-	6	-	3	52	17	1	-	-	-	-	-	-	3		6	5	-	5	2
102	Kuparuk River, Point Storkersen	-	-	-	1	-		-	28	-	-	-	-	-	-	-	6	30	3	1	-	13	18
103	Point McIntyre, West Dock, Putuligayuk R.	-	-	-	2	-	2	-	49	-	-	-	-	4	1	-	8	7	4	2	-	21	-
104	Prudhoe Bay, Heald Pt.	-	-	-	5	-	7	1	3	-	-	-	-	-	1	-	5	65	-	-	-	6	6
105	Point Brower, Sagavanirktok R., Duck I.	-	-	-	2	-	5	0	1	-	-	-	-	-	-	-	15	51	-	15	-	8	4
106	Foggy Island Bay, Kadleroshilik R.	-	-	-	4	-	2	8	9	-	-	-	-	-	-	-	5	37	-	8	-	21	8
107	Tigvariak Island, Shaviovik R.	-	-	-	7	-	6	0	20	3	-	-	-	-	-	-	10	27	-	3	-	23	0
108	Mikkelsen Bay, Badami Airport	-	-	-	3	-	3	4	39		-	-	-	-	-	-	4	6	-	5	-	29	7
109	Bullen, Gordon & Reliance Points	-	-	-	11	-	5	2	48		-	-	-	-	-	-	-	-	-	18	-	17	-
110	Pt. Hopson & Sweeney, Thomson	-	-	-	3	-	0	3	52	6	-	-	-	-	-	-	9		-	3	-	23	-
111	Staines R., Lion Bay	-	-	-	1	-	6	18	24	-	-	-	6	-	-	-	19	9	-	4	-	13	-
112	Brownlow Point, West Canning River	-	-	-	16	-	8	6	15	-	-	-	-	-	-	-	4	28	-	-	-	8	15
113	Canning & Tamayariak River	-	-	-	24	-	3	-	0	-	-	-	-	-	-	-	6	56	-	-	-	8	1
114	Konganevik Point	-	-	-	30	-	16	-	11	-	-	-	3	-	-	-	15	6	9	-	-	8	-
115	Collinson Point, Simpson Cove	-	-	-	3	-	8	-	39	-	-	-	2	-	-	-	1	21	-	-	-	27	-
116	Marsh and Carter Creek	-	-	-	-	-		-	63	-	-	-	5	-	-	-	-	-	-	1	-	31	-
117	Anderson Point, Sadlerochit River	-	-	-	23	-	3	-	14	-	-	-	26	-	-	-	1	17	5	1	-	10	-
118	Nataroarok Ck., Hulahula and Okpilak R.	-	-	-	15	-		-	3	-	-	-	-	-	-	-	3	74	-	-	-	5	-
119	Arey Island, Barter Island,	-	-	-	6	-	8	2	29	-	-	-	-	-	-	-	18	4	1	-	-	28	2
120	Kaktovik, Jago Lagoon, Bernard Spit	-	-	-	-	-	15	4	60	-	-	1	-	-	2	-	5	9	2	-	-	2	-
121	Jago Spit & R., Tapkaurak Spit & Lagoon	-	-	-	-	-	6	2	34	-	-	-	1	-	-	-	9	24	0	-	-	5	19
122	Griffin Point, Oruktalik Lagoon	-	-	-	-	-	20	2	43	-	-	-	-	-	-	-	13	2	2	1	-	16	-
123	Angun Point, Beaufort Lagoon	-	-	-	-	-	18	30	23	-	-	-	-	-	-	-	14	4	1	-	-	7	3
124	Icy Reef, Kongakut River, Siku Lagoon	-	-	-	-	-		3	26	-	-	-	-	-	-	-	2	28	1	-	-	38	3
125	Demarcation Bay & Point	-	-	-	1	-	15	3	54	-	-	-	-	-	-	-	6	7	3	-	-	5	5

KEY: ID = identification (number). Number Description

1A Exposed rocky shores; exposed rocky banks	**8A** Sheltered scarps in bedrock, mud, or clay; sheltered rocky shores (impermeable) *
1B Exposed, solid man-made structures	
1C Exposed rocky cliffs with boulder talus base	**8B** Sheltered, solid man-made structures; sheltered rocky shores (permeable) *
3A Fine- to medium-grained sand beaches	
3B Scarps and steep slopes in sand	**8C** Sheltered rip rap
3C Tundra cliffs	**8D** Sheltered rocky rubble shores

LS ID	Geographic Place Names	1			3			4	5	6			7	8				9		10			U
		A	B	C	A	B	C			A	B	C		A	B	C	E	A	B	A	B	E	

4 Coarse-grained sand beaches
5 Mixed sand and gravel beaches
6A Gravel beaches; Gravel beaches (granules and pebbles) *
6B Gravel beaches (cobbles and boulders) *
6C Rip rap (man-made) *
7 Exposed tidal flats
8E Peat shorelines
9A Sheltered tidal flats
9B Vegetated low banks
10A Salt and brackish water marshes
10B Freshwater marshes
10E Inundated low-lying tundra
U Unknown

Source: USDOI, BOEM (2016) from Harper and Morris (2014)

Table A-2-10 Identification Number (ID) and Name of Environmental Resource Areas, Represented in the Oil Spill Trajectory Model and Their Location on Environmental Resource Area Maps and Tables

ID	Name	General Resource	Map A-
1	Kasegaluk Lagoon Area	Birds, Barrier Island, Marine Mammals	A-2d
2	Point Barrow, Plover Islands	Birds, Barrier Island	A-2c
3	SUA: Enurmino-Neshkan/Russia	Subsistence	A-2g
4	SUA:Inchoun-Uelen/Russia	Subsistence	A-2f
5	Beaufort Sea Shelf Edge IBA	Birds	A-2d
6	Hanna Shoal	Lower Trophics, Seals	A-2g
7	Krill Trap	Lower Trophics	A-2c
8	Maguire and Flaxman Islands	Birds, Barrier Island	A-2a-2
9	Stockton and McClure Islands	Birds, Barrier Island	A-2a-1
10	Ledyard Bay SPEI Critical Habitat Unit	Birds	A-2f
11	Wrangel Island 12 nmi & Offshore	Marine Mammals	A-2g
12	SUA: Nuiqsut - Colville River Delta	Subsistence	A-2c
13	SUA: Kivalina-Noatak	Subsistence, Whales	A-2g
14	Cape Thompson Seabird Colony Area	Birds	A-2g
15	Cape Lisburne Seabird Colony Area	Birds, Marine Mammals	A-2f
16	Barrow Canyon	Lower Trophics	A-2c
17	Angun and Beaufort Lagoons	Birds, Barrier Island	A-2a-1
18	Murre Rearing and Molting Area	Birds	A-2g
19	Chukchi Spring Lead System	Birds	A-2d
20	East Chukchi Offshore	Whales	A-2f
21	AK BFT Bowhead FM 1	Whales	A-2b
22	AK BFT Bowhead FM 2	Whales, Marine Mammals	A-2b
23	Polar Bear Offshore	Marine Mammals	A-2g
24	AK BFT Bowhead FM 3	Whales	A-2b
25	AK BFT Bowhead FM 4	Whales, Fish	A-2b
26	AK BFT Bowhead FM 5	Whales	A-2b
27	AK BFT Bowhead FM 6	Whales	A-2b
28	AK BFT Bowhead FM 7	Whales, Marine Mammals	A-2b
29	AK BFT Bowhead FM 8	Whales, Marine Mammals	A-2b
30	Beaufort Spring Lead 1	Whales	A-2c
31	Beaufort Spring Lead 2	Whales, Marine Mammals, Fish	A-2c
32	Beaufort Spring Lead 3	Whales	A-2c
33	Beaufort Spring Lead 4	Whales	A-2c
34	Beaufort Spring Lead 5	Whales	A-2c
35	Beaufort Spring Lead 6	Whales	A-2c
36	Beaufort Spring Lead 7	Whales	A-2c
37	Beaufort Spring Lead 8	Whales, Fish	A-2c
38	SUA: Pt. Hope-Cape Lisburne	Subsistence, Marine Mammals, Fish	A-2d
39	SUA: Pt. Lay-Kasegaluk Lagoon	Subsistence, Marin Mammals, Fish	A-2e
40	SUA: Icy Cape-Wainwright	Subsistence, Fish	A-2g
41	SUA: Barrow-Chukchi	Subsistence, Fish	A-2e
42	SUA: Barrow-East Arch	Subsistence, Fish	A-2d
43	SUA: Nuiqsut-Cross Island	Subsistence, Fish	A-2c
44	SUA: Kaktovik	Subsistence, Fish	A-2c

ID	Name	General Resource	Map A-
45	Beaufort Spring Lead 9	Whales	A-2c
46	Wrangel Island 12 nmi Buffer 2	Marine Mammals	A-2g
47	Hanna Shoal Walrus Use Area	Marine Mammals, Fish	A-2e
48	Chukchi Lead System 4	Marine Mammals	A-2e
49	Chukchi Spring Lead 1	Whales, Fish	A-2g
50	Pt Lay Walrus Offshore	Marine Mammals	A-2d
51	Pt Lay Walrus Nearshore	Marine Mammals, Fish	A-2g
52	Russian Coast Walrus Offshore	Marine Mammals	A-2f
53	Chukchi Spring Lead 2	Whales, Fish	A-2d
54	Chukchi Spring Lead 3	Whales, Fish	A-2d
55	Point Barrow, Plover Islands	Marine Mammals, Barrier Islands, Fish	A-2b
56	Hanna Shoal Area	Whales, Fish	A-2g
57	Skull Cliffs	Lower Trophics, Fish	A-2b
58	Russian Coast Walrus Nearshore	Marine Mammals, Fish	A-2f
59	Ostrov Kolyuchin	Marine Mammals, Fish	A-2f
60	SUA: King Point.-Shallow Bay (Canada)	Subsistence, Whales, Fish	A-2b
61	Point Lay-Barrow BH GW SFF	Whales	A-2f
62	Herald Shoal Polynya 2	Marine Mammals	A-2g
63	North Chukchi	Whales	A-2g
64	Peard Bay Area	Birds, Marine Mammals, Fish	A-2d
65	Smith Bay	Birds, Marine Mammals, Whales	A-2c
66	Herald Island	Marine Mammals	A-2g
67	Herschel Island (Canada)	Birds, Fish,	A-2c
68	Harrison Bay	Birds, Marine Mammals	A-2a-1
69	Harrison Bay/Colville Delta	Birds, Marine Mammals	A-2a-2
70	North Central Chukchi	Whales, Fish	A-2g
71	Simpson Lagoon, Thetis and Jones Island	Birds, Fish	A-2c
72	Gwyder Bay, West Dock, Cottle and Return Islands	Birds, Fish	A-2a-2
73	Prudhoe Bay	Birds	A-2a-1
74	Herschel Island (Canada)	Polar Bear, Fish	A-2c
75	Boulder Patch Area	Lower Trophics, Marine Mammals	A-2a-2
76	Kendall Island Bird Sanctuary (Canada)	Birds	A-2c
77	Sagavanirktok River Delta/Foggy Island Bay	Birds	A-2a-2
78	Mikkelsen Bay	Birds	A-2a-2
79	Demarcation Bay Offshore	Birds	A-2c
80	Beaufort Outer Shelf 1	Lower Trophics, Fish	A-2c
81	Simpson Cove	Birds	A-2a-1
82	North Chukotka Nearshore 2	Whales	A-2g
83	North Chukotka Nearshore 3	Whales	A-2g
84	Canning River Delta	Fish	A-2a-2
85	Sagavanirktok River Delta	Fish, Marine Mammals	A-2e
86	Harrison Bay	Fish	A-2a-1
87	Colville River Delta	Fish	A-2e
88	Simpson Lagoon	Fish	A-2a-1
89	Mackenzie River Delta	Fish	A-b
90	SUA: Gary and Kendall Islands (Canada)	Subsistence	A-2b
91	Bowhead Whale Summer (Canada)	Whales	A-2c
92	Thetis, Jones, Cottle & Return Islands	Marine Mammals, Barrier Islands	A-2a-1
93	Cross and No Name Islands	Marine Mammals, Barrier Islands, Fish	A-2a-2
94	Maguire Flaxman & Barrier Islands	Marine Mammals, Barrier Islands	A-2a-1
95	Arey and Barter Islands and Bernard Spit	Marine Mammals, Barrier Islands, Fish	A-2a-2
96	Midway, Cross and Bartlett Islands	Birds, Fish	A-2a-1
97	SUA: Tigvariak Island	Subsistence, Fish	A-2a-1
98	Anderson Point Barrier Islands	Birds, Barrier Island, Fish	A-2a-1
99	Arey and Barter Islands, Bernard Spit	Birds, Barrier Island, Fish	A-2a-1
100	Jago and Tapkaurak Spits	Birds, Barrier Island, Fish	A-2a-1

ID	Name	General Resource	Map A-
101	Beaufort Outer Shelf 2	Lower Trophics, Fish	A-2c
102	Opilio Crab EFH	Opilio Crab Habitat (EFH) , Fish	A-2f
103	Saffron Cod EFH	Saffron Cod Habitat (EFH) , Fish	A-2e
104	Ledyard Bay-Icy Cape IBA	Birds, Fish	A-2e
105	Fish Creek	Fish	A-2a-1
106	Shaviovik River	Fish	A-2c
107	Point Hope Offshore	Whales, Fish	A-2f
108	Barrow Feeding Aggregation	Whales, Fish	A-2f
109	AK BFT Shelf Edge	Whales, Fish	A-2c
110	AK BFT Outer Shelf&Slope 1	Whales, Fish	A-2b
111	AK BFT Outer Shelf&Slope 2	Whales, Fish	A-2b
112	AK BFT Outer Shelf&Slope 3	Whales, Fish	A-2b
113	AK BFT Outer Shelf&Slope 4	Whales, Fish	A-2b
114	AK BFT Outer Shelf&Slope 5	Whales	A-2b
115	AK BFT Outer Shelf&Slope 6	Whales, Fish	A-2b
116	AK BFT Outer Shelf&Slope 7	Whales, Fish	A-2b
117	AK BFT Outer Shelf&Slope 8	Whales	A-2b
118	AK BFT Outer Shelf&Slope 9	Whales, Fish	A-2b
119	AK BFT Outer Shelf&Slope 10	Whales, Fish	A-2b
120	Chukchi Gray Whale Fall (Russia)	Whales	A-2e
121	Cape Lisburne - Pt Hope	Whales, Fish	A-2e
122	Bowhead Fall (Canada)	Whales, Fish	A-2c
123	Offshore Herald Island/Hope Sea Valley	Whales, Fish	A-2g
124	Chukchi Sea Nearshore IBA	Birds, Fish	A-2f

Table A-2-11 Environmental Resource Areas Used in the Analysis of Large or Very Large Oil Spill Effects on Lower Trophic Level Organisms in Sections 4.3 and A-7

ERA ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
6	Hanna Shoal	A-2g	January-December	Lower Trophic Level Organisms	Invertebrates	Dunton, Grebmeier and Trefry, 2014; Grebemier, 2012; Moore and Grebmeier, 2013.
7	Krill Trap	A-2c	May-October	Lower Trophic Level Organisms	Invertebrates	Ashijan et al., 2010 (Figures 8 and 14, pp.187–189); Okkonen et al., 2011.
16	Barrow Canyon	A-2c	January-December	Lower Trophic Level Organisms	Invertebrates	Moore and Grebmeier, 2013.
57	Skull Cliffs	A-2b	January-December	Lower Trophic Level Organisms	Kelp/Invertebrates	Phillips et al., 1984. (pp. 13-14 and 16-19).
75	Boulder Patch Area	A-2a-2	January-December	Lower Trophic Level Organisms	Kelp/Invertebrates	Dunton and Schonberg, 2000 (p. 383, Fig 4. pp.388-392, Table 5. p. 393, Figure 6); Dunton et. al., 2009 (p. 17, Figure 1.3. p. 27, Table 2.1).
80	Beaufort Outer Shelf 1	A-2c	January-December	Lower Trophic Level Organisms	Invertebrates	Norcross, 2013 (Ongoing and unpublished Canada/USA Transboundary survey quarterly/annual reports); Norcross and Edenfield, 2013 (Ongoing and unpublished Canada/USA Transboundary survey quarterly/annual reports).
101	Beaufort Outer Shelf 2	A-2c	January-December	Lower Trophic Level Organisms	Invertebrates	Norcross, 2013; Norcross and Edenfield, 2013.

Source: USDOI, BOEM, Alaska OCS Region (2016).

Table A-2-12 Environmental Resource Areas and Land Segments Used in the Analysis of Large or Very Large Oil Spill Effects on Fish in Sections 4.3 and A-7

ERA GLS or LS ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
ERAs Marine Waters						
84	Canning River Delta	A-2a-2	January - December	Anadromous and Marine Nearshore Fish	Pp, DVpr, CHp, Wp, Arctic cod, capelin, Arctic cisco, stickleback, sculpin spp.	Jarvela and Thorsteinson, 1998; Johnson and Litchfield, 2015.
85	Sagavanirktok River Delta	A-2e	January - December	Anadromous and Marine Nearshore Fish	CHp, Pp, DVpr, Wp Arctic char, Arctic cod, capelin, Arctic cisco, stickleback, sculpin spp.	Craig, 1984; Jarvela and Thorsteinson, 1998; Johnson and Litchfield, 2015.
86	Harrison Bay	A-2a-1	January - December	Marine Fish – nearshore	Arctic cod, Capelin, OM, Saffron cod, Fourhorn sculpin, Wp	Craig, 1984; Jarvela and Thorsteinson, 1998; Johnson and Litchfield, 2015.
87	Colville River Delta	A-2a-1	January - December	Anadromous and Marine Nearshore Fish	CHp, Pp, DVp, Wp, Arctic cod, Capelin, OM, Saffron cod, Fourhorn sculpin, Arctic cisco, Arctic char	Craig, 1984; Jarvela and Thorsteinson, 1998; Johnson and Litchfield, 2015; MBC Applied Environmental Sciences, 2004.
88	Simpson Lagoon	A-2a-1	January- December	Marine Fish – nearshore	Arctic cod, Capelin, OM, Saffron cod, Fourhorn sculpin, Wp, Arctic char	Craig, 1984; Jarvela and Thorsteinson, 1998; Johnson and Litchfield, 2015.
89	Mackenzie River Delta	A-2b	January - December	Anadromous and Marine Nearshore Fish	CHp, OMp, Wp, Sheefish, Saffron cod, Arctic cod, Arctic char, Arctic Cisco, Pacific herring, prickleback spp., sculpin spp.	Craig, 1984; MBC Applied Environmental Sciences, 2004; Sawatzky et.al, 2007; Wong et al., 2013.
102	Opilio Crab EFH	A-2f	January-December	Opilio Crab Habitat (EFH)	Opilio Crab	NMFS, 2009.
103	Saffron Cod EFH	A-2e	January-December	Saffron Cod Habitat (EFH)	Saffron Cod	NMFS, 2009.
105	Fish Creek	A-2e	January-December	Anadromous Fish	CHp, Kp, Pp,DVp, HWp, Wp	Johnson and Litchfield, 2015.
106	Shaviovik River	A-2c	January-December	Anadromous and Marine Nearshore Fish	Ps, DVp, Arctic char, Arctic cod, capelin, Arctic cisco, stickleback, sculpin spp.	Craig and Poulin, 1975; Jarvela and Thorsteinson, 1998; Johnson and Litchfield, 2015.
GLSs Marine Waters						
153	Noatak River	A-4c	January-December	Anadromous and Marine Nearshore Fish	CHs,Kp,Pp,COp,Sp,DVp, Wp, SF	Johnson and Litchfield, 2015.
154	Cape Krusenstern	A-4a	January-December	Anadromous and Marine Nearshore Fish	CHp.Sp,Pp,COp,Sp,DVp,Wp	Johnson and Litchfield, 2015.
155	Wulik and Kivalina Rivers	A-4a	January-December	Anadromous and Marine Nearshore Fish	CHs,COp,Ks,Pp,Ss,DVs,Wp	Johnson and Litchfield, 2015.
166	KuK River	A-4b	January-December	Anadromous and Marine Nearshore Fish	CHp,Pp,BWp,LCp, OMp	Johnson and Litchfield, 2015.

ERA GLS or LS ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
181	Arctic National Wildlife Refuge	A.-4c	January-December	Anadromous and Marine Nearshore Fish	CHp,Pp,DVr,Wp,Kp,COp,OMp, Arctic char, least cisco, herring, capelin, Arctic cod, saffron cod, sculpin species, eelpout species, Arctic flounder, starry flounder, sand lance	Johnson and Litchfield, 2015; U.S. Fish and Wildlife Service, 2013.
LSs Russia						
25	Amguema River	A-3a	May - October	Anadromous Fish	CHs, Ps, ALp, DVs, ACs, Kp, Sp, COp, Ws, OMp	Andreev, 2001.
31	Kolyuchinskaya Bay	A-3a	May - October	Anadromous Fish	Ps, Ks, DVs, ACs, Wp, OMp	Andreev, 2001.
37	Chegitun River	A-3a	May - October	Anadromous Fish	Bering Cisco, ACs, DVs, Ps, Ks, CHs, Ss, OMp	Andreev, 2001.
38	Inchoun Lagoon	A-3a	May - October	Anadromous Fish	CHp, Pp, Kp, COp, Sp, Bering Cisco, Least Cisco	Andreev, 2001.
39	Uelen Lagoon	A-3a	May - October	Anadromous Fish	CHp, Pp, Kp, COp, Sp, Bering Cisco, Least Cisco	Andreev, 2001.
LSs United States						
40	Mint River	A-3b	May - October	Anadromous Fish	CHs, Ps, Sp, DVpr	Johnson and Litchfield, 2015.
41	Pinguk River	A-3b	May - October	Anadromous Fish	CHs, Pp, DVp, Wp	Johnson and Litchfield, 2015.
42	Upkuarok Creek, Nuluk River, Kugrupaga River, Trout Creek	A-3b	May - October	Anadromous Fish	DVpr, CHs, Ps, DVp, Wp, DVp, DVpr, Wp	Johnson and Litchfield, 2015.
43	Shishmaref Airport	A-3b	May - October	Anadromous Fish	DVp	Johnson and Litchfield, 2015.
44	Shishmaref Inlet, Arctic River, Sanaguich River, Serpentine River	A-3b	May - October	Anadromous Fish	DVp, SFp, Wp, CHp	Johnson and Litchfield, 2015.
47	Kitluk River	A-3b	May - October	Anadromous Fish	Pp	Johnson and Litchfield, 2015.
49	Kougachuk Creek	A-3b	May - October	Anadromous Fish	Pp	Johnson and Litchfield, 2015.
51	Inmachuk River, Kugruk River	A-3b	May - October	Anadromous Fish	CHs, Ps, DVp, CHp, Pp, DVp	Johnson and Litchfield, 2015.
53	Kiwalik River, Buckland River	A-3b	May - October	Anadromous Fish	CHp, Pp, DVp, CHp, COp, Kp, Pp, DVp, Wp	Johnson and Litchfield, 2015.
54	Baldwin Penn Kobuk River, & Channels	A-3b	May - October	Anadromous Fish	DVp, DVs, CHp, Kp, Pp, DVs, SFp, Wp	Johnson and Litchfield, 2015.
55	Hotham Inlet Ogriveg River	A-3b	May - October	Anadromous Fish	CHp, Pp, DVs, Wp CHp, Pp, DVp	Johnson and Litchfield, 2015.
56	Noatak River	A-3b	May - October	Anadromous Fish	CHp, COp, Kp, Pp, Sp, DVp, SFp, Wpr	Johnson and Litchfield, 2015.
57	Aukulak Lagoon	A-3b	May - October	Anadromous Fish	Wp	Johnson and Litchfield, 2015.
58	Tasaychek Lagoon	A-3b	May - October	Anadromous Fish	Pp	Johnson and Litchfield, 2015.
59	Kiligmak Inlet Jade Creek, Rabbit Creek, Imik Lagoon New Heart Creek, Omikviorok River	A-3b	May - October	Anadromous Fish	DVp, Wp DVp CHp, Sp, DVp Wp DVr DVp, Wp	Johnson and Litchfield, 2015.
60	Imikruk Lagoon Wulik River, Kivalina River	A-3b	May - October	Anadromous Fish	Wp, CHp, COp, Kp, Pp, Sp, DVs, Wp CHp, CHs, Pp, DVp	Johnson and Litchfield, 2015.
64	Sulupoaktak Chnl	A-3b	May - October	Anadromous Fish	Pp, DVp	Johnson and Litchfield, 2015.
67	Pitmegea River	A-3b	May - October	Anadromous Fish	CHp, Pp, DVp	Johnson and Litchfield, 2015.
70	Kuchiak Creek	A-3b	May - October	Anadromous Fish	CHs, COs	Johnson and Litchfield, 2015.
71	Kukpowruk River	A-3b	May - October	Anadromous Fish	CHp, Pp, DVp	Johnson and Litchfield, 2015.
72	Pt Lay, Kokolik River	A-3b	June - October	Anadromous Fish	CHp, Pp, DVp	Johnson and Litchfield, 2015.
74	Utukok River	A-3b	June - October	Anadromous Fish	CHp, Pp, DVp	Johnson and Litchfield, 2015.
80	Kugrua River	A-3b	June - October	Anadromous Fish	CHs,Ps	Johnson and Litchfield, 2015.
87	Inaru River, Meade River, Topagoruk River, Chipp River	A-3c	June - October	Anadromous Fish	Wsr CHs,Wp Wsr Ps,Wsr	Johnson and Litchfield, 2015.
89	Ikpikpuk River	A-3c	June - October	Anadromous Fish	Psr,Wsr	Johnson and Litchfield, 2015.
91	Smith River	A-3c	June - October	Anadromous Fish	DVp,Wp	Johnson and Litchfield, 2015.
93	Kalikpik River	A-3c	June - October	Anadromous Fish	Wp	Johnson and Litchfield, 2015.
95	Fish Creek, Nechelik Channel	A-3c	June - October	Anadromous Fish	CHp,Kp,Pp,DVp,Wp Wp	Johnson and Litchfield, 2015
96	Colville River & Delta	A-3c	June - October	Anadromous Fish	CHp,Pp,DVp,Wp	Johnson and Litchfield, 2015.
97	Colville River & Delta	A-3c	June - October	Anadromous Fish	CHp,Pp,DVp,Wp	Johnson and Litchfield, 2015.

ERA GLS or LS ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
98	Kalubik River	A-3c	June - October	Anadromous Fish	DVp,Wp Wr	Johnson and Litchfield, 2015.
99	Ugnuravik River	A-3c	June - October	Anadromous Fish		Johnson and Litchfield, 2015.
100	Oogrukpuk River,	A-3c	June - October	Anadromous Fish	Wpr Wr	Johnson and Litchfield, 2015.
101	Sakonowyak River	A-3c	June - October	Anadromous Fish	Wpr Wr	Johnson and Litchfield, 2015.
102	Kuparuk River, Fawn Creek, Unnamed 10435	A-3c	June - October	Anadromous Fish	Wr, Wp	Johnson and Litchfield, 2015.
103	Putuligayuk River	A-3c	June - October	Anadromous Fish	DVr,DVp,Wp,OMp,Wr	Johnson and Litchfield, 2015.
104	West Channel Sagavanirktok River	A-3c	June - October	Anadromous Fish		Johnson and Litchfield, 2015.
105	Sagavanirktok River, E. Sagavanirktok Creek	A-3c	June - October	Anadromous Fish	ACp,Chp,Pp,DVr,Wp DVr	Johnson and Litchfield, 2015.
106	E. Sagavanirktok Creek, Kadleroshilik River	A-3c	June - October	Anadromous Fish		Johnson and Litchfield, 2015.
107	Kavik River, Shaviovik River, 10300 (AWC#)	A-3c	June - October	Anadromous Fish	DVr, DVp, Ps	Johnson and Litchfield, 2015.
108	E Badami Creek, 10300 (AWC#)	A-3c	June - October	Anadromous Fish	DVr	Johnson and Litchfield, 2015.
109	10280 (AWC#)	A-3c	June - October	Anadromous Fish	DVr	Johnson and Litchfield, 2015.
110	10246 (AWC#)	A-3c	June - October	Anadromous Fish	DVr	Johnson and Litchfield, 2015.
111	10238 (AWC#) 10234 (AWC#) Staines River	A-3c	June - October	Anadromous Fish	DVr DVr DVr Pp,DVp,Wp	Johnson and Litchfield, 2015.
112	W. Canning River, Canning River	A-3c	June - October	Anadromous Fish	Pp,DVp,Wp CHp,Pp,DVp,Wp DVr	Johnson and Litchfield, 2015.
113	Canning River, Tamayariak River	A-3c	June - October	Anadromous Fish	DVs,DVp,Pp,Wp,CHp,DVr	Johnson and Litchfield, 2015.
115	Katakturik River, 10193 (AWC#)	A-3c	June - October	Anadromous Fish	DVp DVr	Johnson and Litchfield, 2015.
116	Marsh Creek, Carter Creek	A-3c	June - October	Anadromous Fish	DVr DVr	Johnson and Litchfield, 2015.
118	Nataroarok Creek, Hulahula River, Okpilak River	A-3c	June - October	Anadromous Fish	DVr DVp DVp DVr	Johnson and Litchfield, 2015.
119	10173 (AWC#)	A-3c	June - October	Anadromous Fish	DVr	Johnson and Litchfield, 2015.
121	Jago River	A-3c	June - October	Anadromous Fish	DVp	Johnson and Litchfield, 2015.
122	Kimikpaurauk River	A-3c	June - October	Anadromous Fish	DVr	Johnson and Litchfield, 2015.
123	Siksik River, Sikrelurak River, Angun River, 10150-2004 (AWC#) Kogotpak 10140-2006 (AWC#)	A-3c	June - October	Anadromous Fish	DVr DVr DVr DVr DVp DVr	Johnson and Litchfield, 2015.
124	Aichilik River, Egaksrak River, Kongakut River	A-3c	June – October	Anadromous Fish	DVp DVp DVp	Johnson and Litchfield, 2015.
LSs Canada						
126	Fish River	A-3c	June - October	Anadromous Fish	ACp, Wp	Craig, 1984; Kendel et al., 1974.
127	Malcolm River	A-3c	June - October	Anadromous Fish	ACp, OMp	Craig, 1984.
128	Firth River	A-3c	June - October	Anadromous Fish	ACp,OMp	Craig, 1984.
130	Spring River	A-3c	June - October	Anadromous Fish	ACp, Wp, SFp, OMp, sculpin spp.	Craig, 1984; Majewski et al, 2013.
131	Babbage River	A-3c	June - October	Anadromous Fish	ACp, Wp	Craig, 1984.
133	Blow River	A-3c	June - October	Anadromous Fish	ACp, Wp, SFp	Craig, 1984.
136-140	Mackenzie River	A-3c	June - October	Anadromous Fish	ACp, Wp, CHp, OMp, SFp	Craig, 1984.
141-146	Kugmallit Bay Tuktoyaktuk Peninsula	A-3c	June - October	Anadromous and Marine Nearshore Fish	AC, DV, OM, Arctic cisco, Least Cisco, Whitefish spp., Arctic cod, Saffron cod, Pacific herring, Arctic flounder, Starry flounder, Sculpin spp.	Niemi, et al., 2012

Key:	AC=Arctic Char	DV=Dolly Varden	W=Whitefish (undifferentiated)	AL=Arctic lamprey	P=Pink salmon	s=spawning	K=Chinook salmon
OM=Rainbow smelt	p=present	CH=Chum salmon	S=Sockeye salmon	r=rearing	CO=Coho salmon	SF=Sheefish	

Source: USDOI, BOEM, Alaska OCS Region (2016).

Table A-2-13 Environmental Resource Areas and Grouped Land Segments Used in the Analysis of Large or Very Large Oil Spill Effects on Birds in Sections 4.3 and A-7

ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
ERA						
1	Kasegaluk Lagoon Area	A-2d	May-October	Birds, Barrier Island, Seals, Whales	Birds: BLBR, LTDU, eiders (STEI, COEI), loons (all 3 species)	Dau and Bollinger, 2009, 2012; Johnson, 1993; Johnson, Wiggins, and Wainwright, 1993; Laing and Platte, 1994; Lehnhausen and Quinlan, 1981; Morgan, Day, and Gall, 2012; Seabird Information Network, 2015.
2	Point Barrow, Plover Islands	A-2c	May-October	Birds, Barrier Island	Birds: SPEI, LTDU, BLBR, BLGU	Dau and Bollinger, 2009; Fischer and Larned, 2004; Ritchie et al, 2013; Seabird Information Network, 2015; Troy, 2003.
5	Beaufort Sea Shelf Edge IBA	A-2d	May-October	Birds		Audubon, 2015.
8	Maguire and Flaxman Islands	A-2a-2	May-October	Birds, Barrier Island	Birds: nesting COEI, molting LTDU, PALO	Dau and Bollinger, 2009, 2012, Fischer and Larned, 2004; Flint et al., 2004; Johnson, 2000; Johnson et al., 2005; Noel et al., 2005; Seabird Information Network, 2015.
9	Stockton and McClure Islands	A-2a-1	May-October	Birds, barrier island	Birds: nesting COEI, molting LTDU, staging SPEI	Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Flint et al., 2004; Johnson, 2000, (Table 2); Johnson et al., 2005; Noel et al., 2005; Seabird Information Network, 2015; Troy, 2003.
10	Ledyard Bay SPEI Critical Habitat Unit	A-2f	July-November	Birds	Birds: seabirds, molting/staging SPEI, staging YBLO	66 FR 9146-9185; Laing and Platte, 1994; Morgan, Day, and Gall, 2012; Petersen, Larned, and Douglas, 1999; Piatt and Springer, 2003.
14	Cape Thompson Seabird Colony Area	A-2g	May-October	Birds	Birds: seabirds, gulls, shorebirds, waterfowl, staging YBLO	Morgan, Day, and Gall, 2012; Piatt et al., 1991; Piatt and Springer, 2003; Seabird Information Network, 2015; Springer et al., 1984; Stephenson and Irons, 2003.
15	Cape Lisburne Seabird Colony Area	A-2f	May-October	Birds, Marine Mammals	Birds: seabird breeding colony, staging YBLO	Dragoo and Balland, 2014; Morgan, Day, and Gall, 2012; Oppel, Dickson and Powell, 2009; Piatt et al., 1991; Piatt and Springer, 2003; Roseneau et al., 2000; Seabird Information Network, 2015; Springer et al., 1984; Stephenson and Irons, 2003.
17	Angun and Beaufort Lagoons	A-2a-1	May-October	Birds, Barrier Island	Birds: molting LTDU, scoters, staging shorebirds	Dau and Bollinger, 2009, 2012; Johnson and Herter, 1989.
18	Murre Rearing and Molting Area	A-2g	May-October	Birds	Birds: murre foraging, rearing, and molting area	Piatt and Springer, 2003; Springer et al., 1984.
19	Chukchi Sea Spring Lead System	A-2d	April-June	Birds, Whales	Birds: seabird foraging area; spring migration area for LTDU, eiders (KIEI, COEI), loons	Connors, Myers, and Pitelka, 1979; Oppel, Dickson, and Powell, 2009; Piatt et al., 1991; Piatt and Springer, 2003; Sexson, Pearce, and Petersen, 2014.
64	Peard Bay Area	A-2d	May-October	Birds, Marine Mammals	Birds: eiders (all 4 species), loons (all 3 species)	Fischer and Larned, 2004; Gill, Handel, and Connors, 1985; Laing and Platte, 1994.
65	Smith Bay	A-2c	May-October	Birds, Marine Mammals, Whales	Birds: eiders (SPEI, KIEI), YBLO	Dau and Bollinger, 2009, 2012; Earnst et al., 2005; Powell et al., 2005; Ritchie, Burgess, and Suydam, 2000; Ritchie et al., 2004; Troy, 2003.
67	Herschel Island (Canada)	A-2c	May-October	Birds	Birds: LTDU, BLBR, scoters, eiders, loons, shorebirds	Johnson and Richardson, 1982; Richardson and Johnson, 1981.
68	Harrison Bay	A-2a-1	May-October	Birds, Marine Mammals	Birds: eiders (KIEI, COEI), scoters (BLSC, SUSC), geese (BLBR, CANG, GWFG), loons, shorebirds	Connors, Connors, and Smith, 1984; Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004.
69	Harrison Bay/Colville Delta	A-2a-2	May-October	Birds, Marine Mammals	Birds: geese (BLBR), eiders (KIEI, COEI), LTDU, scoters (BLSC, SUSC), loons (all 3 species)	Bergman et al., 1977; Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Johnson and Herter, 1989.
71	Simpson Lagoon, Thetis and Jones Islands	A-2c	May-October	Birds	Birds: geese (BLBR, LSGO, GWFG), eiders (COEI, KIEI), LTDU, scoters (SUSC, WWSC), shorebirds, loons (all 3 species)	Dau and Bollinger, 2009, 2012; Connors, Connors, and Smith, 1984; Divoky, 1984; Johnson, 2000; Johnson, Herter, and Bradstreet, 1987; Johnson and Herter, 1989; Noel and Johnson, 1997; Richardson and Johnson, 1981; Stickney and Ritchie, 1996; Truett, Miller, and Kertell, 1997.
72	Gwyder Bay, West Dock, Cottle and Return Islands	A-2a-2	May-October	Birds	Birds: geese (BLBR, LSGO, GWFG), eiders (COEI, KIEI), LTDU, scoters (SUSC, WWSC), shorebirds, loons (all 3 species)	Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Johnson, 2000; Noel et al., 2005; Noel and Johnson, 1997; Powell et al., 2005; Truett, Miller, and Kertell, 1997; Stickney and Ritchie, 1996; Troy, 2003.
73	Prudhoe Bay	A-2a-1	May-October	Birds	Birds: geese (BLBR, LSGO, GWFG), eiders (COEI, KIEI), LTDU, scoters (SUSC, WWSC), shorebirds, loons (all 3 species)	Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Johnson and Richardson, 1982; Noel and Johnson, 1997; Noel et al., 2005; Powell et al., 2005; Richardson and Johnson, 1981; Stickney and Ritchie, 1996; Troy, 2003; Truett, Miller, and Kertell, 1997.
76	Kendall Island Bird Sanctuary (Canada)	A-2c	May-October	Birds	Birds: eiders (KIEI, COEI), LTDU, scoters (all 3 species), loons (all 3 species)	Alexander, Dickson, and Westover, 1997; Dickson et al., 1997; Divoky, 1984; Johnson and Richardson, 1982; Richardson and Johnson, 1981.

ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
77	Sagavanirktok River Delta/Foggy Island Bay	A-2a-2	May-October	Birds	Birds: eiders (SPEI, COE)I, LTDU, scoters (all 3 species), loons (all 3 species)	Dau and Bollinger, 2009, 2012; Divoky, 1984; Fischer and Larned, 2004; Johnson, 2000; Johnson, Wiggins, and Wainwright, 1993; Sexson, Pearce, and Petersen, 2014; Troy, 2003.
78	Mikkelsen Bay	A-2a-2	May-October	Birds	Birds: eiders (KIEI, COEI), LTDU, scoters, loons (PALO, RTLO)	Dau and Bollinger, 2009, 2012; Divoky, 1984; Fischer and Larned, 2004; Flint et al., 2004; Johnson, 2000; Noel et al., 2005.
79	Demarcation Bay Offshore	A-2c	May-October	Birds	Birds: eiders (KIEI, COEI), LTDU, scoters (SUSC, WWSC), loons, molting LTDU, staging shorebirds	Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Johnson and Richardson, 1982; Johnson and Herter, 1989; Richardson and Johnson, 1981.
81	Simpson Cove	A-2a-1	May-October	Birds	Birds: COEI, LTDU, PALO, scoters (SUSC, WWSC)	Dau and Bollinger, 2009, 2012; Fischer and Larned, 2004; Johnson and Herter, 1989.
96	Midway, Cross and Bartlett Islands	A-2a-1	May-October	Birds, Barrier Islands	Birds: eiders (SPEI,COEI), LTDU, scoters (all 3 species), loons (all 3 species)	Dau and Bollinger, 2009, 2012; Divoky, 1984; Fischer and Larned, 2004; Johnson, 2000; Troy, 2003, (Figure 3).
98	Anderson Point Barrier Islands	A-2a-1	May-October	Birds, Barrier Islands	Birds: eiders (SPEI,COEI), LTDU, scoters (all 3 species), loons (all 3 species)	Same as ERA96
99	Arey and Barter Islands, Bernard Spit	A-2a-1	May-October	Birds, Barrier Islands	Birds: eiders (SPEI,COEI), LTDU, scoters (all 3 species), loons (all 3 species)	Same as ERA96
100	Jago and Tapkaurak Spits	A-2a-1	May-October	Birds, Barrier Islands	Birds: eiders (SPEI,COEI), LTDU, scoters (all 3 species), loons (all 3 species)	Same as ERA96
104	Ledyard Bay-Icy Cape IBA	A-2e	May-October	Birds		Audubon, 2015
124	Chukchi Sea Nearshore IBA	A-2f	May-October	Birds		Audubon, 2015
GLS						
161	Kasegaluk Lagoon Area IBA	A-4b	May-October	Birds		Audubon, 2015
170	Teshekpuk Lake Special Area (NPR-) IBA	A-4c	May-October	Birds		Audubon, 2015
171	Colville River Delta IBA	A-4a	May-October	Birds		Audubon, 2015, Brown et al., 2007.
182	Northeast Arctic Coastal Plain IBA	A-4c	May-October	Birds		Audubon, 2015
193	Kendall Island Bird Sanctuary (Canada)	A-4b	May-October	Birds		

Notes: Yellow-billed Loon (YBLO), Red-throated Loon (RTLO), Pacific Loon (PALO), COEI (Common Eider), KIEI (King Eider), SPEI (Spectacled Eider), STEI (Steller's Eider), LTDU (Long-tailed Duck), Black Scoter (BLSC), Surf Scoter (SUSC), White-winged Scoter (WWSC), Black Brant (BLBR), Greater White-fronted Goose (GWFG), Canada Goose (CANG), Lesser Snow Goose (LSGO): http://www.birdpop.org/DownloadDocuments/Alpha_codes_eng.pdf

Source: USDOI, BOEM, Alaska OCS Region (2016).

Table A-2-14 Environmental Resource Areas and Boundary Segments Used in the Analysis of Large or Very Large Oil Spill Effects on Whales in Sections 4.3 and A-7

ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference[1]
ERA						
1	Kasegaluk Lagoon Area	A-2d	May-October	Birds, Barrier Island, Seals, Whales	Beluga Whales	Frost and Lowry, 1990; Frost, Lowry, and Carroll, 1993; Suydam et al., 2001; Suydam, Lowry, and Frost, 2005; Citta et al., 2013.
13	SUA: Kivalina-Noatak	A-2g	January-December	Subsistence, Whales	Beluga Whales	Suydam et al., 2001; Suydam, Lowry, and Frost, 2005.
20	East Chukchi Offshore	A-2f	September-October	Whales	Bowhead Whales, Beluga Whales-fall migration, feeding	Clarke et al., 2013, 2014; Fraker, Sergeant, and Hoek, 1978; Harwood and Smith, 2002; Hauser et al., 2014; Ljungblad et al., 1988; Martell, Dickinson, and Casselman, 1984; Melnikov and Bobkov. 1993; Monnett and Treacy, 2005; Quakenbush and Citta, 2013; Quakenbush, Small and Citta. 2013; Treacy, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2001, 2002.
21	AK BFT Bowhead FM 1	A-2b	September-October	Whales	Bowhead Whales, Beluga Whales-fall migration	Clarke et al., 2013, 2014; Hauser et al., 2014; Ljungblad et al., 1988; Monnett and Treacy, 2005; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Shelden and Mocklin, 2013; Treacy, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2001, 2002.

ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference[1]
22	AK BFT Bowhead FM 2	A-2b	September-October	Whales	Bowhead Whales-fall migration	Clarke et al., 2013, 2014; Ljungblad et al., 1988; Monnett and Treacy, 2005; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Shelden and Mocklin, 2013; Treacy, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2001, 2002.
24	AK BFT Bowhead FM 3	A-2b	September-October	Whales	Bowhead Whales-fall migration	Same as ERA22.
25	AK BFT Bowhead FM 4	A-2b	September-October	Whales	Bowhead Whales-fall migration	Same as ERA22.
26	AK BFT Bowhead FM 5	A-2b	September-October	Whales	Bowhead Whales-fall migration	Same as ERA22.
27	AK BFT Bowhead FM 6	A-2b	September-October	Whales	Bowhead Whales-fall migration	Same as ERA22.
28	AK BFT Bowhead FM 7	A-2b	September-October	Whales	Bowhead Whales-fall migration	Same as ERA22.
29	AK BFT Bowhead FM 8	A-2b	September-October	Whales	Bowhead Whales-fall migration	Same as ERA22.
30	Beaufort Spring Lead 1	A-2c	April-June	Whales	Bowhead Whales, Beluga Whales- spring migration	Clarke et al., 2013; Ljungblad et al., 1988; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Shelden and Mocklin, 2013.
31	Beaufort Spring Lead 2	A-2c	April-June	Whales	Bowhead Whales, Beluga Whales- spring migration	Same as ERA30.
32	Beaufort Spring Lead 3	A-2c	April-June	Whales	Bowhead Whales, Beluga Whales- spring migration	Same as ERA30.
33	Beaufort Spring Lead 4	A-2c	April-June	Whales	Bowhead Whales, Beluga Whales; spring migration	Same as ERA30.
34	Beaufort Spring Lead 5	A-2c	April-June	Whales	Bowhead Whales, Beluga Whales- spring migration	Same as ERA30.
35	Beaufort Spring Lead 6	A-2c	April-June	Whales	Bowhead Whales, Beluga Whales- spring migration	Same as ERA30.
36	Beaufort Spring Lead 7	A-2c	April-June	Whales	Bowhead Whales, Beluga Whales- spring migration	Same as ERA30.
37	Beaufort Spring Lead 8	A-2c	April-June	Whales	Bowhead Whales, Beluga Whales- spring migration	Same as ERA30.
45	Beaufort Spring Lead 9	A-2c	April-June	Whales	Bowhead Whales, Beluga Whales- spring migration	Same as ERA30.
49	Chukchi Spring Lead 1	A-2g	April-June	Whales	Bowhead Whales, Gray Whales, Beluga Whales – spring migration- spring leads-Chukchi	Bogoslovskaya, Votrogov, and Krupnik, 1982; Clarke et al., 2013; Doroshenko, and Kolesnikov, 1984; George et al., 2012; Ljungblad et al., 1986, 1988; Miller, Rugh, and Johnson,1986; Melnikov, Zelensky, and Ainana,1997; Melnikov et al., 2004; Melnikov and Zeh, 2007; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Stringer and Groves, 1991.
53	Chukchi Spring Lead 2	A-2d	April-June	Whales	Bowhead Whales, Gray Whales, Beluga Whales – spring migration- spring leads-Chukchi	Same as ERA49.
54	Chukchi Spring Lead 3	A-2d	April-June	Whales	Bowhead Whales, Gray Whales, Beluga Whales – spring migration- spring leads-Chukchi	Same as ERA49.
56	Hanna Shoal Area	A-2g	August-October	Whales	Bowhead Whales, historically Gray Whales (Hanna Shoal)	Clarke et al., 2013; Ljungblad et al., 1986; Moore, DeMaster and Dayton. 2000; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.
60	King Point-Shallow Bay (Canada)	A-2b	April-Sept	Whales, Subsistence	Beluga Whales	Fraker, Sergeant, and Hoek, 1978; Harwood and Smith, 2002; Harwood et al., 1996, 2010; Martell, Dickinson, and Casselman, 1984.
61	Pont Lay–Barrow BH GW SFF	A-2f	July-October	Whales	Bowhead Whales, Gray Whales; summer-fall feeding, Gray and Bowhead Whale cow/calf aggregations and bowhead fall migration	Bogoslovskaya, Votrogov, and Krupnik, 1982; Clarke et al., 2013, 2014; George et al., 2012; Ljungblad et al., 1988; Melnikov and Bobkov, 1993; Melnikov, Zelensky, and Ainana, 1997; Miller, Rugh, and Johnson, 1986; Moore and DeMaster, 1997; Moore et al., 1995; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Shelden and Mocklin, 2013.

ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference[1]
63	North Chukchi	A-2g	October-December	Whales	Bowhead Whales	Martell, Dickinson, and Casselman, 1984; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.
65	Smith Bay	A-2c	May-October	Whales, Birds, Marine Mammals	Bowhead Whales	Clarke et al., 2015a,b.
70	North Central Chukchi	A-2g	October-December	Whales	Bowhead Whales	Ainana, Zelenski, and Bychkov, 2001; Bogoslovskaya, Votrogov, and Krupnik, 1982; Melnikov, 2000; Melnikov and Bobkov, 1993; Melnikov, Zelensky, and Ainana, 1997; Miller, Rugh, and Johnson, 1986; Mizroch, Rice, and Breiwick, 1984; Mizroch et al., 2009; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.
82	North Chukotka Nearshore 2	A-2g	July-October	Whales	Bowhead Whales, Gray Whales; summer-fall feeding and bowhead fall migration	Bogoslovskaya, Votrogov, and Krupnik, 1982; George et al., 2012; Heide-Jorgensen et al., 2012; Ljungblad et al., 1988; Melnikov and Bobkov, 1993; Melnikov, Zelensky, and Ainana, 1997; Miller, Rugh, and Johnson, 1986; Moore and DeMaster, 1997; Moore et al., 1995; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.
83	North Chukotka Nearshore 3	A-2g	July-December	Whales	Bowhead Whales, Gray Whales; summer-fall feeding and bowhead fall migration	Same as ERA82.
91	Bowhead Whale Summer (Canada)	A-2c	July-October	Whales	Bowhead Whale-summer concentration	Braham, Fraker, and Krogman. 1980; Fraker, Sergeant, and Hoek, 1978; Harwood and Smith, 2002; Harwood, Auld and Moore, 2010; Martell, Dickinson, and Casselman, 1984; Quakenbush and Citta, 2013; Quakenbush, Small and Citta. 2013;
107	Point Hope Offshore	A-2f	June-September	Whales	Gray Whales, Fin Whales, Humpback Whales summer fall aggregation	Clarke et al., 2013 (Maps 6, 13); Friday et al., 2014; George et al., 2012; Miller, Johnson, and Doroshenko, 1985.
108	Barrow Feeding Aggregation	A-2f	September-October	Whales	Bowhead Whales, Gray Whales-feeding aggregation- fall	Clarke et al., 2012, 2013; Ljungblad et al., 1988; Monnett and Treacy, 2005; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013; Shelden and Mocklin, 2013.
109	AK BFT Shelf Edge	A-2c	July, August	Whales	Bowhead Whales-cow/calf and feeding aggregation	Christman et al., 2013; Clarke et al., 2012, 2013.
110	AK BFT Outer Shelf & Slope 1	A-2b	July-October	Whales	Beluga Whales –summer- fall feeding concentration and movement corridor	Clarke et al., 2013, 2014; Richard, Martin and Orr, 1998, 2001.
111	AK BFT Outer Shelf & Slope 2	A-2b	July-October	Whales	Beluga Whales –summer- fall feeding concentration and movement corridor	Same as ERA110.
112	AK BFT Outer Shelf & Slope 3	A-2b	July-October	Whales	Beluga Whales –summer- fall feeding concentration and movement corridor	Same as ERA110.
113	AK BFT Outer Shelf & Slope 4	A-2b	July-October	Whales	Beluga Whales –summer- fall feeding concentration and movement corridor	Same as ERA10.
114	AK BFT Outer Shelf & Slope 5	A-2b	July-October	Whales	Beluga Whales –summer- fall feeding concentration and movement corridor	Same as ERA110.
115	AK BFT Outer Shelf & Slope 6	A-2b	July-October	Whales	Beluga Whales –summer- fall feeding concentration and movement corridor	Same as ERA110.
116	AK BFT Outer Shelf & Slope 7	A-2b	July-October	Whales	Beluga Whales –summer- fall feeding concentration and movement corridor	Same as ERA110.
117	AK BFT Outer Shelf & Slope 8	A-2b	July-October	Whales	Beluga Whales –summer- fall feeding concentration and movement corridor	Same as ERA110.
118	AK BFT Outer Shelf & Slope 9	A-2b	July-October	Whales	Beluga Whales –summer- fall feeding concentration and movement corridor	Same as ERA110.
119	AK BFT Outer Shelf & Slope 10	A-2b	July-October	Whales	Beluga Whales –summer- fall feeding concentration and movement corridor	Same as ERA110.
120	Chukchi Gray Whale Fall (Russia)	A-2e	September-October	Whales	Gray Whales-fall feeding aggregation	Bogoslovskaya, Votrogov, and Krupnik, 1982; Doroshenko and Kolesnikov, 1983; George et al., 2012; Miller, Johnson, and Doroshenko, 1985.
121	Cape Lisburne–Pt Hope	A-2e	June-September	Whales	Gray Whale-cow/calf aggregation	Ljungblad et al., 1988.
122	Bowhead Fall (Canada)	A-2c	October-December	Whales	Bowhead Whale- fall migration & feeding	Fraker, Sergeant, and Hoek, 1978; Harwood and Smith, 2002; Martell, Dickinson, and Casselman, 1984; Quakenbush and Citta, 2013; Quakenbush, Small and Citta. 2013;
123	Offshore Herald Island/Hope Sea Valley	A-2g	October - December	Whales	Bowhead Whales	Bogoslovskaya, Votrogov, and Krupnik, 1982; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.

ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference[1]
BSs						
2	RusCh C Dezhnev	A-1	May-October	Whales	Gray Whales, Beluga Whales, Humpback Whales, Bowhead Whales	Clarke et al., 2013 (Maps 6, 13); George et al., 2012; Miller, Johnson, and Doroshenko, 1985.
39-40	Amundsen Gulf BH Spring	A-1	May-July	Whales	Bowhead Whale-spring aggregation	Braham, Fraker, and Krogman, 1980; Fraker, Sergeant, and Hoek, 1978; Harwood and Smith, 2002; Martell, Dickinson, and Casselman, 1984; Quakenbush and Citta, 2013; Quakenbush, Small, and Citta, 2013.

Source: USDOI, BOEM, Alaska OCS Region (2016).

Notes: [1] Clarke et al. (2015a, b) and Kuletz et al.(2015) were used to help define and refine all cetacean ERAs and BSs in U.S. waters; Cita et al. (2015) was used to help define and refine all bowhead ERAs and BSs; Hauser et al. (2014) were used to help define and refine all beluga ERAs and BSs.

Table A-2-15 Environmental Resource Areas, Grouped Land Segments and Land Segments Used in the Analysis of Large or Very Large Oil Spill Effects on Marine Mammals (Polar Bears and Walrus) in Sections 4.3 and A-7

ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
ERAs						
11	Wrangel Island 12 nmi & Offshore	A-2g	January-December	Marine Mammals	Polar Bears, Polar Bear denning (October-April), Walrus (July-November)	Belikov, 1993; Belikov, Boltunov, and Gorbunov, 1996; Boltunov,Nikiforov, and Semenova, 2012; Durner et al., 2006; Fay, 1982; Fay et al., 1984; Federal State Budget Institution, 2014; Fedoseev, 1981; Gilbert et al., 1992; Kochnev, 2004 a,b; Kochnev, 2006; Ovsyanikov, 2012, 2013; Solovyev et al., 2012; Stishov, 1991; Upenski and Kistchinski, 1972; Wilson et al., 2014.
15	Cape Lisburne Seabird Colony Area	A-2f	May-October	Marine Mammals	Walrus	Alaska Clean Seas (ACS), 2015; Christman, 2013; Fay, 1982; Huntington and Quakenbush, 2013; Robards, 2013.
23	Polar Bear Offshore	A-2g	November-June	Marine Mammals	Polar Bears	Durner et al., 2006; USFWS, 2013a; Wilson et al., 2014.
47	Hanna Shoal Walrus Use Area	A-2e	May-October	Marine Mammals	Walrus	Jay, Fischbach, and Kochnev, 2012, Figures 4 & 5, pp. 8-9; Kuletz et al., 2015.
50	Pt Lay Walrus Offshore	A-2d	May-October	Marine Mammals	Walrus	Fay et al., 1984; Jay, Fischbach, and Kochnev, 2012, Figures 4 & 5, pp. 8-9; Kuletz et al., 2015.
51	Pt Lay Walrus Nearshore	A-2g	May-October	Marine Mammals	Walrus	ACS, 2015; Huntington, Nelson, and Quakenbush, 2012; Jay, Fischbach, and Kochnev, 2012, Figures 4 & 5, pp. 8-9; Kuletz et al., 2015.
52	Russian Coast Walrus Offshore	A-2f	May-November	Marine Mammals	Walrus	Jay, Fischbach, and Kochnev, 2012, Figures 4 & 5, pp. 8-9.
55	Point Barrow, Plover Islands	A-2b	January-December	Marine Mammals	Polar Bears	ACS, 2015; Kalxdorff et al., 2002.
58	Russian Coast Walrus Nearshore	A-2f	May-November	Marine Mammals	Walrus	Fay et al., 1984; Jay, Fischbach, and Kochnev, 2012, Figures 4 & 5, pp. 8-9.
59	Ostrov Kolyuchin	A-2f	July - November	Marine Mammals	Polar Bears, Walrus	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Fay et al., 1984; Gilbert et al., 1992; Kavry, Boltunov, and Nikiforov, 2008; Kochnev, 2006, 2013a, 2013b; Kochnev and Kozlov, 2012; Kochnev et al., 2003; Pereverez and Kochnev, 2012.
66	Herald Island	A-2g	January-December	Marine Mammals	Polar Bears, Polar Bear denning (October-April), Walrus (July-November)	Amstrup and Gardner, 1994; Belikov, 1993; Belikov, Boltunov, and Gorbunov, 1996; Durner et al., 2006; Fay, 1982; Federal State Budget Institution, 2014; Fedoseev, 1981; Gilbert et al., 1992; Ovsyanikov, 1998; Ovsyanikov and Menyushina, 2012; Rode et al., 2015; Stishov, 1991.
74	Hershel Island	A-2c	January-December	Marine Mammals	Polar Bears, Polar Bear denning (October-April)	Durner et al., 2004; Stirling and Andriashek, 1992.
92	Thetis, Jones, Cottle & Return Isl.	A-2a-1	January-December	Marine Mammals	Polar Bears, Polar Bear denning (October-April)	ACS, 2015; Durner, Amstrup, and Fischbach, 2003; Durner et al., 2004; Kalxdorff et al., 2002.
93	Cross and No Name Islands	A-2a-2	January-December	Marine Mammals	Polar Bears, Polar Bear denning (October-April)	ACS, 2015; Durner et al., 2004; Kalxdorff et al., 2002; Miller, Schliebe, and Proffitt, 2006.
94	Maguire, Flaxman & Barrier Isl.	A-2a-1	January-December	Marine Mammals	Polar Bears, Polar Bear denning (October-April)	ACS, 2015; Amstrup and Gardner, 1994; Durner, 2005; Durner, Amstrup, and Fischbach, 2003; Durner et al., 2004; Kalxdorff et al., 2002.
95	Arey & Barter Islands,and Bernard Spit	A-2a-2	January-December	Marine Mammals	Polar Bears, Polar Bear denning (October-April)	ACS, 2015; Amstrup and Gardner, 1994; Durner et al., 2004; Kalxdorff et al., 2002; Miller, Schliebe, and Proffitt, 2006.
LSs						

ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
22	Mys Shmidta (Cape Schmidt), Cape Kozhevnikov, Ryrkaipii	A-2a	January-December	Marine Mammal	Walrus (July-November)	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Gilbert et al., 1992; Kavry, Boltunov, and Nikiforov, 2008; Kochnev, 2013a, 2013b; Robards, 2013.
28	Ostrov Karkarpko, Mys Vankarem (Cape Vankarem)	A-2a	January-December	Marine Mammals	Walrus (July-November)	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Kavry, Boltunov, and Nikiforov, 2008; Kochnev, 2004 a,b, 2013a, 2013b; Kryukova and Kochnev, 2012.
29	Mys Onmyn (Cape Onmyn)	A-2a	January-December	Marine Mammals	Walrus (July-November)	Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Kochnev, 2004 a,b; Kryukova and Kochnev, 2012.
31	Kosa Belyaka (Belyaka Spit)	A-2A	January-December	Marine Mammals	Walrus (July-November)	Robards, 2013
38	Mys Unikin (Cape Unikyn)	A-2a	January-December	Marine Mammals	Walrus (July-November)	Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Fay et al., 1984; Kochnev, 2004 a,b, 2013a.
39	Mys Dezhnev, Mys Peek (Cape Dehznev, Cape Peek)	A-2a	January-December	Marine Mammals	Walrus (July-November)	Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Fay et al., 1984; Fedoseev, 1981; Kochnev, 2004 a,b, 2013a.
65	Buckland, Cape Dyer, Cape Lewis, Cape Lisburne	A-2c	January-December	Marine Mammals	Polar Bear denning (October-April)	ACS, 2015; Voorhees and Sparks, 2012.
75	Icy Cape		January-December	Marine Mammals	Walrus (July – November)	Christman, 2013; Fischbach, Monson, and Jay, 2009; Huntington, Nelson, and Quakenbush, 2012; Robards, 2013.
85	Barrow, Browerville, Elson Lagoon	A-2b	January-December	Marine Mammals	Polar Bears (August-November)	ACS, 2015; Durner et al., 2006; Kalxdorff et al., 2002.
GLSs						
147	Bukhta Somnitel'naya (Somnitel'naya Spit), Davidova Spit	A-4c	January-December	Marine Mammals	Polar Bears, Polar Bear denning (October-April), Walrus (July-November)	Belikov, 1993; Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, Semenova, 2012; Durner et al., 2006; Fay, 1982; Gilbert et al., 1992; Kochnev, 2004; Kochnev, 2006, 2013b; Ovsyanikov, 2003, 2012, 2013; Ovsyanikov, Menyushina, and Bezrukov, 2008; Rode et al., 2015; Solovyev et al., 2012.
149	Ostrov Idlidlya (Ididlya Island)	A-4c	July-November	Marine Mammals	Walrus	Boltunov, Nikiforov, and Semenova, 2012; Fay, 1982; Fedoseev, 1981; Gilbert et al., 1992; Kochnev, 2004.
150	Mys Serditse Kamen (Cape Serdtse-Kamen)	A-4c	July-November	Marine Mammals	Walrus	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Chakilev, Dondua, and Kochnev, 2012; Fay, 1982; Fay et al., 1984; Fedoseev, 1981; Gilbert et al., 1992; Kochnev, 2004, 2013a.
151	Chukotka Coast Haulout	A-4c	July-November	Marine Mammals	Walrus	Belikov, Boltunov, and Gorbunov, 1996; Boltunov, Nikiforov, and Semenova, 2012; Fay et al., 1984; Fedoseev, 1981; Gilbert et al., 1992; Jay, Fischbach, and Kochnev, 2012, Figures 4 & 5, pp. 8-9; Kochnev, 2013a.
159	Cape Lisburne	A-4b	January-December	Marine Mammals	Polar Bear denning (October-April), Walrus (August-November)	ACS, 2015; Christman, 2013; Fay, 1982; Fay et al., 1984; Huntington and Quakenbush, 2013; Robards, 2013.
162	Point Lay Haulout	A-4a	July-November	Marine Mammals	Walrus	Christman, 2013; Fischbach, Monson, and Jay, 2009; Huntington, Nelson, and Quakenbush, 2012; Robards, 2013.
172	Colville River Delta	A-4a	October-April	Marine Mammals	Polar Bears denning	ACS, 2015; Blank, 2013.
176	98 -129 Summer	A-4a	June-August	Marine Mammals	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59), Durner et al., 2004.
178	104-129 Fall	A-4b	September-November	Marine Mammals	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59) Durner et al., 2004.
179	Foggy Island Bay	A-4a	January-December	Marine Mammals	Polar Bears, Polar Bear denning (October-April)	Durner, 2005; Hilcorp Alaska, LLC, 2015, Figure 3.12.1-1; Schliebe et al., 2008; Streever and Bishop, 2014.
180	110-124 Winter	A-4b	October-April	Marine Mammals	Polar Bear denning	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59); Durner, 2005; Durner, Amstrup, and Ambrosius, 2005; Durner, Amstrup, and Fischbach, 2003.
187	126-133 Spring	A-4b	March - May	Marine Mammals	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59); Durner et al., 2004; Pilford, 2014.
188	126-135 Winter	A-4a	December-February	Marine Mammals	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59); Durner et al., 2004.
191	136-146 Spring	A-4a	March - May	Marine Mammals	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59); Durner et al., 2004; Pilford, 2014.

ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
192	136-146 Winter	A-4a	December-February	Marine Mammals	Polar Bears	Amstrup and Gardner, 1994; Derocher et al, 2013, (Figure 13, p. 59); Durner et al., 2004.
195	Russia Chukchi Coast Marine Mammals	A-4c	July-November	Marine Mammals	Polar Bears, Walrus	Belikov, Boltunov, and Gorbunov, 1996; Boltunov,Nikiforov, and Semenova, 2012; Durner et al., 2006; Fay et al., 1984; Fedoseev, 1981; Gilbert et al., 1992; Kochnev, 2006, 2013b; Ovsyanikov, 2013; Stishov, 1991.

Source: USDOI, BOEM, Alaska OCS Region (2016).

Table A-2-16 Environmental Resource Areas, Grouped Land Segments and Land Segments Used in the Analysis of Large or Very Large Oil Spill Effects on Marine Mammals (Ice Seals) in Sections 4.3 and 4.4

ERA ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
1	Kasegaluk Lagoon Area	A-2d	May-October	Birds, Barrier Island,Seals, Whales	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
46	Wrangel Island 12 nmi Buffer 2	A-2g	December-May	Marine Mammals	Bearded Seals Ringed Seals	Cameron et al., 2010; Kelly et al., 2010.
48	Chukchi Lead System 4	A-2e	December-May	Marine Mammals	Bearded Seals Ringed Seals	Cameron et al., 2010; Kelly et al., 2010.
62	Herald Shoal Polynya 2	A-2g	December-May	Marine Mammals	Ringed Seals Bearded Seals	Cameron et al., 2010; Kelly et al., 2010.
64	Peard Bay Area/Franklin Spit Area	A-2d	May-October	Marine Mammals	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
65	Smith Bay: Spotted Seal Haulout	A-2d	May-October	Marine Mammals	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
68	Harrison Bay	A-2a-1	May-October	Marine Mammals	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
69	Harrison Bay/Colville Delta	A-2a-2	May-October	Marine Mammals	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
GLS ID						
148	Kolyuchin Bay	A-4c	June-November	Marine Mammals	Spotted Seals Ringed Seals	Boveng et al., 2009; Heptner et al., 1996; Kelly et al., 2010.
169	Smith Bay Spotted Seal Haulout	A-4b	May-October	Marine Mammals	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.
173	Harrison Bay Spotted Seal Haulout	A-4b	June-September	Marine Mammals	Spotted Seals	ADF&G, 2001; Boveng et al., 2009.

Source: USDOI, BOEM, Alaska OCS Region (2016).

Table A-2-17 Grouped Land Segments Used in the Analysis of Large or Very Large Oil Spill Effects on Terrestrial Mammals in Sections 4.3 and 4.4

GLS ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
156	WAH Insect Relief	A-4c	July-August	Terrestrial Mammals	Caribou	ADF&G, 2001; Person et al., 2007.
160	Ledyard Brown Bears	A-4b	June-October	Terrestrial Mammals	Brown Bears	ADF&G, 1986; ADF&G, 2001.
163	Kasegaluk Brown Bears	A-4b	June-October	Terrestrial Mammals	Brown Bears	ADF&G, 1986; ADF&G, 2001.
167	TCH Insect Relief/Calving	A-4b	May-August	Terrestrial Mammals	Caribou	ADF&G, 1986; ADF&G, 2001; Carroll et al., 2011; Person et al., 2007.
174	CAH Insect Relief/Calving	A-4b	May-August	Terrestrial Mammals	Caribou	ADF&G, 1986; ADF&G, 2001; Arthur and Del Vecchio, 2009; Cameron et al., 2002; 2005; Lawhead and Prichard, 2007; Wolfe, 2000.
177	Beaufort Muskox	A-4b	November-May	Terrestrial Mammals	Muskox	ADF&G, 2001; Environment Yukon, 2009; Lawhead and Prichard, 2007; Reynolds, Wilson, and Klein, 2002.
183	PCH Insect Relief	A-4b	July-August	Terrestrial Mammals	Caribou	ADF&G, 2001; Environment Yukon, 2009; Nixon and Russell, 1990.
184	PCH Calving	A-4a	May-June	Terrestrial Mammals	Caribou	ADF&G, 2001; Environment Yukon, 2009; Fancy et al., 1989; Griffith et al., 2002.
185	Yukon Muskox Wintering	A-4a	November-April	Terrestrial Mammals	Muskox	Environment Yukon, 2009.
189	Yukon Moose	A-4b	January-December	Terrestrial Mammals	Caribou	Environment Yukon, 2009.
194	Tuktoyaktuk & Cape Bathurst Caribou Insect Relief	A-4c	July-August	Terrestrial Mammals	Caribou	Gunn, Russell, and Eamer, 2011; Nagy et al., 2005.

Source: USDOI, BOEM, Alaska OCS Region (2016).
Notes: CAH–Central Arctic Herd; PCH–Porcupine Caribou Herd; TCH–Teshekpuk Caribou Herd; WAH–Western Arctic Herd.

Table A-2-18 Environmental Resource Areas and Grouped Land Segments Used in the Analysis of Large or Very Large Oil Spill Effects on Subsistence Resources in Sections 4.4 and A-7

ID	Name	Map	Vulnerable	General Resource	Specific Resource	Reference
ERA						
3	SUA: Enurmino-Neshkan/Russia	A-2g	January-December	Subsistence	Bowhead Whales, Grey Whales, Walrus, Polar Bears, Ocean Fish, Birds	Ainana, Zelensky, and Bychkov, 2001; Melnikov and Bobkov, 1993; Kochnev et al., 2003; Zdor, Zdor, and Ainana, 2010.
4	SUA:Inchoun-Uelen/ Russia	A-2f	January-December	Subsistence	Bowhead Whales, Grey Whales, Walrus, Beluga, Polar Bears, Ocean Fish, Birds	Ainana, Zelensky, and Bychkov, 2001; Huntington and Mymrin, 1996; Kochnev et al., 2003; Melnikov and Bobkov, 1993; Mymrin et al., 1999; Zdor, Zdor, and Ainana, 2010.
12	SUA: Nuiqsut-Colville River Delta	A-2c	April-October	Subsistence	Whales, Seals, Waterfowl, Ocean Fish, Moose, Caribou	Galganaitis, 2009; 2014a, 2014b; S.R. Braund and Assoc., 2010; USDOI, BLM and MMS, 2003.
13	SUA:Kivalina-Noatak	A-2g	January-December	Subsistence, Whales	Walrus, Seals, Bowhead Whales, Beluga Whales, Polar Bears, Ocean Fish, King Crabs	Burch, 1985; Magdanz et al., 2010.
38	SUA: Point. Hope-Cape Lisburne	A-2d	January-December	Subsistence	Beluga Whales, Bowhead Whales, Walrus, Seals	Braund and Burnham, 1984; Frost and Suydam, 2010.
39	SUA: Point. Lay-Kasegaluk Lagoon	A-2e	January-December	Subsistence	Ocean Fish, Seals, Waterfowl, Beluga Whales	Braund and Burnham, 1984; Frost and Suydam, 2010; Galginaitis and Impact Assessment, 1989; Huntington and Mymrin, 1996; S.R. Braund and Assoc., 2013, 2014; USDOI, BLM and MMS, 2003.
40	SUA: Icy Cape-Wainwright	A-2g	January-December	Subsistence	Bowhead Whales, Beluga Whales	Braund and Burnham, 1984; Frost and Suydam, 2010; Kassam and Wainwright Traditional Council, 2001; USDOI, BLM and USDOI, MMS, 2003; S.R. Braund and Assoc. and University of Alaska Anchorage, ISER, 1993a; S.R. Braund and Assoc., 2013.
41	SUA: Barrow-Chukchi	A-2e	April-May	Subsistence	Bowhead Whales, Beluga Whales, Walrus, Waterfowl, Seals, Ocean Fish	Braund and Burnham, 1984; Frost and Suydam, 2010; Pedersen, 1979; S.R. Braund and Assoc., 2010; S.R. Braund and Assoc. and University of Alaska Anchorage, ISER, 1993b; USDOI, BLM and USDOI, MMS, 2003.
42	SUA: Barrow-East Arch	A-2d	August-October	Subsistence	Bowhead Whales, Beluga Whales, Walrus, Waterfowl, Seals, Ocean Fish	Braund and Burnham, 1984; Frost and Suydam, 2010; Pedersen, 1979; S.R. Braund and Assoc., 2010; S.R. Braund and Assoc. and University of Alaska Anchorage, ISER, 1993b; USDOI, BLM and USDOI, MMS, 2003.
43	SUA: Nuiqsut-Cross Island	A-2c	August-October	Subsistence	Bowhead Whales, Seals, Waterfowl, Ocean Fish	Galganitis, 2009; Galganitis, 2014a; 2014b; Impact Assessment, 1990a; S.R Braund and Assoc., 2010.
44	SUA: Kaktovik	A-2c	August-October	Subsistence	Bowhead Whales, Seals, Walrus, Beluga Whales, Waterfowl, Ocean Fish	Frost and Suydam, 2010; Impact Assessment, 1990b; North Slope Borough, 2001; S.R. Braund and Assoc., 2010.
60	SUA: King Pt.-Shallow Bay (Canada)	A-2b	April-September	Subsistence, Whales	Polar Bears, Seals, Fish, Bowhead Whales, Beluga Whales	Fisheries and Oceans Canada 2002, 2009; Environment Canada, 2000; Harwood et al., 2002, 2014.
90	SUA: Garry and Kendall Islands/ Canada	A-2b	July-August	Subsistence	Beluga Whales	Fisheries and Oeceans Canada 2002, 2009; Environment Canada, 2000: Harwood et al., 2002, 2014.
97	SUA: Tigvariak Island	A-2a-1	May-October	Subsistence	Traditional Whaling Area	Pedersen, 1979; S.R. Braund and Assoc., 2010.
GLS						
157	SUA: Point Lay, Point Hope	A-4a	June-September	Subsistence	Caribou	S.R. Braund and Assoc., 2014; Wolfe, 2013.
168	SUA: Barrow, Nuiqsut	A-4b	July-August	Subsistence	Caribou	S.R. Braund and Assoc., 2010.
175	SUA: Kaktovik, Nuiqsut	A-4b	July-August	Subsistence	Caribou	S.R. Braund and Assoc., 2010.
183	PCH Insect Relief/SUA: Kaktovik	A-4b	July-August	Subsistence	Caribou	Galginatis, 2014b; Jacobson and Wentworth, 1982: S.R. Braund and Assoc., 2010.

USDOI, BOEM, Alaska OCS Region (2016). Notes: SUA=Subsistence Use Area.

Table A-2-19 Land Segment ID and the Geographic Place Names within the Land Segment

ID	Geographic Place Names	ID	Geographic Place Names
1	Mys Blossom, Mys Fomy, Khishchnikov, Neozhidannaya, Laguna Vaygan	46	Cowpack Inlet, Cowpack River, Kalik River, Kividlo, Singeak, Singeakpuk River, White Fish Lake
2	Mys Gil'der, Ushakovskiy, Mys Zapadnyy	47	Kitluk River, Northwest Corner Light, West Fork Espenberg River
3	Mys Florens, Gusinaya	48	Cape Espenberg, Espenberg, Espenberg River
4	Mys Ushakova, Laguna Drem-Khed	49	Kungealoruk Creek, Kougachuk Creek, Pish River
5	Mys Evans, Neizvestnaya, Bukhta Pestsonaya	50	Clifford Point, Cripple River, Goodhope Bay, Goodhope River, Rex Point, Sullivan Bluffs
6	Ostrov Mushtakova	51	Cape Deceit, Deering, Kugruk Lagoon, Kugruk River, Sullivan Lake, Toawlevic Point
7	Kosa Bruch	52	Motherwood Point, Ninemile Point, Willow Bay
8	Klark, Mys Litke, Mys Pillar, Skeletov, Mys Uering	53	Kiwalik, Kiwalik Lagoon, Middle Channel Kiwalk River, Minnehaha Creek, Mud Channel Creek, Mud Creek
9	Nasha, Mys Proletarskiy, Bukhta Rodzhers	54	Baldwin Peninsula, Lewis Rich Channel
10	Reka Berri, Bukhta Davidova, , Khishchnika, Reka Khishchniki	55	Cape Blossom, Pipe Spit
11	Bukhta Somnitel'naya	56	Kinuk Island, Kotzebue, Noatak River
12	Zaliv Krasika, Mamontovaya, Bukhta Predatel'skaya	57	Aukulak Lagoon, Igisukruk Mountain, Noak, Mount, Sheshalik, Sheshalik Spit
13	Mys Kanayen, Mys Kekurnyy, Mys Shalaurova, Veyeman	58	Cape Krusenstern, Eigaloruk, Evelukpalik River, Kasik Lagoon, Krusenstern Lagoon,
14	Innukay, Laguna Innukay, Umkuveyem, Mys Veuman	59	Imik Lagoon, Ipiavik Lagoon, Kotlik Lagoon, Omikviorok River
15	Laguna Adtaynung, Mys Billingsa, Ettam, Gytkhelen, Laguna Uvargina	60	Imikruk Lagoon, Imnakuk Bluff, Kivalina, Kivalina Lagoon, Singigrak Spit, Kivalina River, Wulik River
16	Mys Emmatagen, Mys Enmytagyn, Uvargin	61	Asikpak Lagoon,Cape Seppings,Kavrorak Lagoon,Pusaluk Lagoon,Seppings Lagoon
17	Enmaat'khyr, Kenmankautir, Mys Olennyy, Mys Yakan, Yakanvaam, Yakan	62	Atosik Lagoon,Chariot,Ikaknak Pond,Kisimilok Mountain,Kuropak Creek,Mad Hill
18	Mys Enmykay, Laguna Olennaya, Pil'khikay, Ren, Rovaam, Laguna Rypil'khin	63	Akoviknak Lagoon, Cape Thompson, Crowbill Point, Igilerak Hill, Kemegrak Lagoon
19	Laguna Kuepil'khin, Leningradskiy	64	Aiautak Lagoon, Ipiutak Lagoon, Kowtuk Point, Kukpuk River, Pingu Bluff, Point Hope, Sinigrok Point, Sinuk
20	Polyarnyy, Kuekvun', Notakatryn, Pil'gyn, Tynupytku	65	Buckland, Cape Dyer, Cape Lewis, Cape Lisburne
21	Laguna Kinmanyakicha, Laguna Pil'khikay, Amen, Pil'khikay, Bukhta Severnaya, Val'korkey	66	Ayugatak Lagoon
22	Ekiatan', Laguna Ekiatan, Kelyun'ya, Mys Shmidta, Rypkarpyy	67	Cape Sabine, Pitmegea River
23	Emuem, Kemuem, Koyvel'khveyergin, Laguna Tengergin, Tenkergin	68	Agiak Lagoon, Punuk Lagoon
24	No place names	69	Cape Beaufort, Omalik Lagoon
25	Laguna Amguema, Ostrov Leny, Yulinu	70	Kuchaurak Creek, Kuchiak Creek
26	Ekugvaam, Reka Ekugvam, Kepin, Pil'khin	71	Kukpowruk River, Naokok, Naokok Pass, Sitkok Point
27	Laguna Nut, Rigol'	72	Epizetka River, Kokolik River, Point Lay, Siksrikpak Point
28	Kamynga, Ostrov Kardkarpko, Kovlyuneskin, Mys Vankarem, Vankarema, Laguna Vankarem	73	Akunik Pass, Tungaich Point, Tungak Creek
29	Akanatkhyrgyn, Nutpel'men, Mys Onman, Vel'may	74	Kasegaluk Lagoon, , Solivik Island, Utukok River
30	Laguna Kunergin, Nutepynmyn, Pyngopil'khin, Laguna Pyngopil'khin	75	Akeonik, Icy Cape, Icy Cape Pass
31	Alyatki, Zaliv Tasytkhin, Kolyuchin Bay	76	Akoliakatat Pass, Avak Inlet, Tunalik River
32	Mys Dzhenretlen, Eynenekvyk, Lit'khekay-Polar Station	77	Mitliktavik, Nivat Point, Nokotlek Point, Ongorakvik River
33	Neskan, Laguna Neskan, Mys Neskan	78	Kilmantavi, Kuk River, Point Collie, Sigeakruk Point,
34	Emelin, Ostrov Idlidlya, I, Memino, Tepken,	79	Point Belcher, Wainwright, Wainwright Inlet
35	Enurmino, Mys Keylu, Netakeniskhvin, Mys Neten,	80	Eluksingiak Point, Igklo River, Kugrua Bay
36	Mys Chechan, Mys Ikigur, Keniskhvik, Mys Serditse Kamen	81	Peard Bay, Point Franklin, Seahorse Islands, Tachinisok Inlet
37	Chegitun, Utkan, Mys Volnistyy	82	Skull Cliff
38	Enmytagyn, Inchoun, Inchoun, Laguna Inchoun, Mitkulino, Uellen, Mys Unikyn	83	Nulavik, Loran Radio Station
39	Cape Dezhnev, Mys Inchoun, Naukan, Mys Peek, Uelen, Laguna Uelen, Mys Uelen	84	Walakpa River, Will Rogers and Wiley Post Memorial
40	Ah-Gude-Le-Rock, Dry Creek, Lopp Lagoon, Mint River	85	Barrow, Browerville, Elson Lagoon
41	Ikpek, Ikpek Lagoon, Pinguk River, Yankee River	86	Dease Inlet, Plover Islands, Sanigaruak Island
42	Arctic Lagoon, Kugrupaga Inlet, Nuluk River	87	Igalik Island, Kulgurak Island, Kurgorak Bay, Tangent Point
43	Sarichef Island, Shishmaref Airport	88	Cape Simpson, Piasuk River, Sinclair River, Tulimanik Island
44	Cape Lowenstern, Egg Island, Shishmaref, Shishmaref Inlet	89	Ikpikpuk River, Point Poleakoon, Smith Bay
45	No place names	90	Drew Point, Kolovik, McLeod Point,
91	Lonely AFS Airport, Pitt Point, Pogik Bay, Smith River	119	Arey & Barter Island
92	Cape Halkett, Esook Trading Post, Garry Creek	120	Kaktovik, Jago Lagoon, Bernard Spit
93	Atigaru Point, Eskimo Islands, Harrison Bay, Kalikpik River, Saktuina Point	121	Jago Spit & River, Tapkaurak Spit & Lagoon
94	Tingmeachsiovik River	122	Griffin Point, Oruktalik Lagoon

ID	Geographic Place Names	ID	Geographic Place Names
95	Fish Creek, Nechelik Channel, Colville River Delta	123	Angun Point, Beaufort Lagoon
96	Tolaktovut Point, Colville River	124	Icy Reef, Kongakut River, Siku Lagoon
97	Kupigruak Channel, Colville River	125	Demarcation Bay & Point
98	Kalubik Creek	126	Clarence Lagoon, Backhouse River
99	Oliktok Point, Ugnuravik River	127	Komakuk Beach, Fish Creek
100	Milne Point, Simpson Lagoon	128	Nunaluk Spit, Firth River
101	Beechy & Back Pt., Sakonowyak R.	129	Herschel Island
102	Kuparuk River, Point Storkersen	130	Ptarmagin Bay
103	Point McIntyre, West Dock, Putuligayuk R.	131	Stokes and Kay Pt., Phillips Bay
104	Prudhoe Bay, Heald Pt.	132	Sabine Point
105	Point Brower, Sagavanirktok R., Duck I.	133	Shingle Point, Escape Reef
106	Foggy Island Bay, Kadleroshilik R.	134	Tent Island & Shoalwater Bay
107	Tigvariak Island, Shaviovik R.	135	Shallow Bay, West Channel
108	Mikkelsen Bay, Badami Airport	136	Tiktalik Channel
109	Bullen, Gordon & Reliance Points	137	Outer Shallow Bay, Olivier Islands
110	Pt. Hopson & Sweeney, Thomson	138	Middle Channel, Gary Island
111	Staines R., Lion Bay	139	Kendall Island
112	Brownlow Point, West Canning River	140	North Point, Pullen Island
113	Canning & Tamayariak River	141	Hendrickson Island, Kugmallit Bay
114	Collinson Point, Konganevik Point	142	Tuktoyaktuk, Tuktoyaktuk Harbour
115	Collinson Point, Konganevik Point	143	Warren Point
116	Marsh and Carter Creek	144	Hutchison Bay
117	Anderson Point, Sadlerochit River	145	McKinley Bay, Atkinson Point
118	Sabine Point	146	Kidney Lake, Nuvorak Point

Key: ID = identification (number).
Source: USDOI, BOEM, Alaska OCS Region (2016).

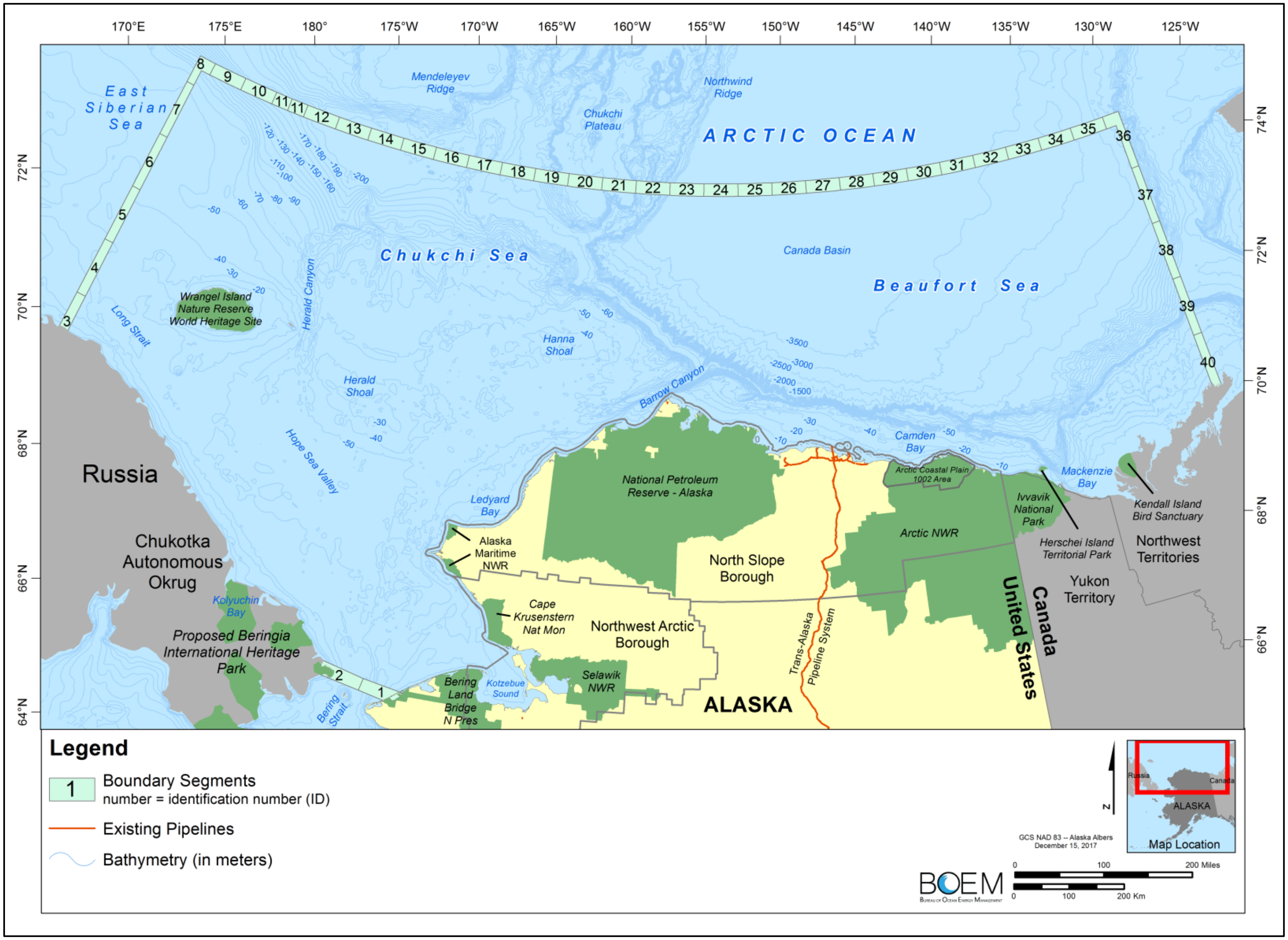
Table A-2-20 Grouped Land Segment ID, Geographic Names, and Land Segments IDs that make up the Grouped Land Segment and Vulnerability

GLS ID	Grouped Land Segment Name	Land Segment IDs	Vunerable	MAP
147	Bukhta Somnitel'naya (Somnitel’naya Spit), Davidova Spit	10-11	January-December	A-4c
148	Kolyuchin Bay	30-31, 33-34	June-November	A-4c
149	Ostrov Idlidlya (Ididlya Island)	33-34	July-November	A-4c
150	Mys Serditse Kamen (Cape Serdtse-Kamen)	35-36	July-November	A-4c
151	Chukotka Coast Haulout	35-39	July-November	A-4c
152	Bering Land Bridge National Preserve	41-42, 45-50	January-December	A-4c
153	Noatak River	54-57	January-December	A-4c
154	Cape Krusenstern National Monument	57-59	January-December	A-4a
155	Wulik and Kivilina Rivers	60-61	January-December	A-4a
156	WAH Insect Relief	61-71	July - August	A-4c
157	SUA: Point Lay-Point Hope	61-71	June-September	A-4a
158	Alaska Maritime National Wildlife Refuge	62-63, 65	January-December	A-4a
159	Cape Lisburne	65-66, 67	January-December	A-4b
160	Ledyard Brown Bears	65-70	June-October	A-4b
161	Kadegaluk Lagoon Area IBA	70-78	May-October	A-4b
162	Point Lay Haulout	71-74	July-November	A-4a
163	Kasegaluk Brown Bears	73-77	June-October	A-4b
164	National Petroleum Reserve Alaska	76-77, 80-83, 86-93	January-December	A-4c
165	Kasegaluk Lagoon Special Area (NPR-A)	76-77	January-December	A-4c
166	Kuk River	78-79	January-December	A-4b
167	TCH Insect Relief/Calving	85-96	May-August	A-4b
168	SUA: Barrow-Nuiqsut	85-96	July-August	A-4b
169	Smith Bay Spotted Seal Haulout	88-89	May-October	A-4b
170	Teshekpuk Lake Special Area (NPR-A)/IBA	86-93	May-October	A-4c
171	Colville River Delta IBA	93-98	May-October	A-4a
172	Colville River Delta	94-97	October-April	A-4a
173	Harrison Bay Spotted Seal Haulout	96-99	June–September	A-4b
174	CAH Insect Relief/ Calving	98-113	May-August	A-4b
175	SUA: Kaktovik-Nuiqsut	98-113	July-August	A-4b
176	98-129 Summer	98-129	June-August	A-4a
177	Beaufort Muskox Habitat	100-103	November-May	A-4b
178	104-129 Fall	104-129	September-November	A-4b
179	Foggy Island Bay	105-107	January-December	A-4a
180	110-124 Winter	110-124	October-April	A-4a
181	Arctic National Wildlife Refuge	112-125	January-December	A-4b
182	Northeast Arctic Coastal Plain IBA	112-125	May-October	A-4b
183	PCH Insect Relief/SUA Kaktovik	112-125	July-August	A-4b
184	PCH Calving	118-123, 126-131	May-June	A-4a
185	Yukon Musk Ox Wintering	125-129	November-April	A-4b
186	Ivvavik National Park (Canada)	126-131	January-December	A-4b
187	126-133 Spring	126-133	March-May	A-4b
188	126-135 Winter	126-135	December-February	A-4b
189	Yukon Moose	130-132	January-December	A-4b
190	Tarium Nirutait Marine Protected Area	122-136,,138, 141	January-December	A-4b
191	136-146 Spring	136-146	March-May	A-4a
192	136-146 Winter	136-146	December-February	A-4a
193	Kendall Island Bird Sanctuary (Canada)	138-139	May-October	A-4b
194	Tuktoyaktuk/Cape Bathurst Caribou Insect Relief	140-146	July-August	A-4a
195	Russia Chukchi Coast Marine Mammals	1-39	July-November	A-4c
196	Russia Chukchi Coast	1-39	January-December	A-4c
197	United States Chukchi Coast	40-84	January-December	A-4c
198	United States Beaufort Coast	85-125	January-December	A-4a
199	Canada Beaufort Coast	126-146	January-December	A-4a

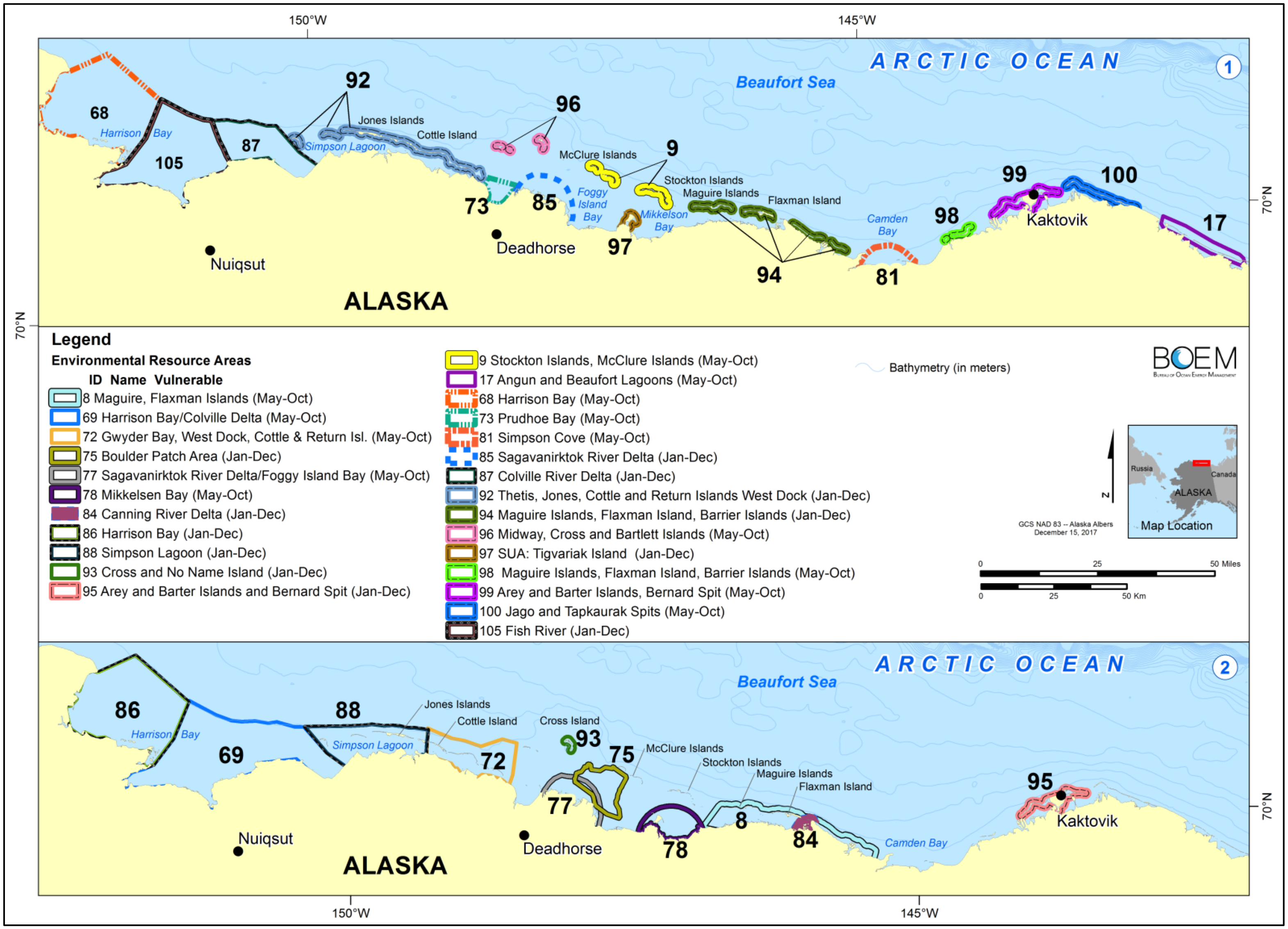
Source: USDOI, BOEM, Alaska OCS Region (2016).

Notes: CAH = Central Arctic Herd IBS = Important Bird Area NPR-A = National Petroleum Reserve-Alaska PCH = Porcupine Caribou Herd
SUA = Subsistence Use Area TCH = Teshekpuk Caribou Herd WAH = Western Arctic Herd

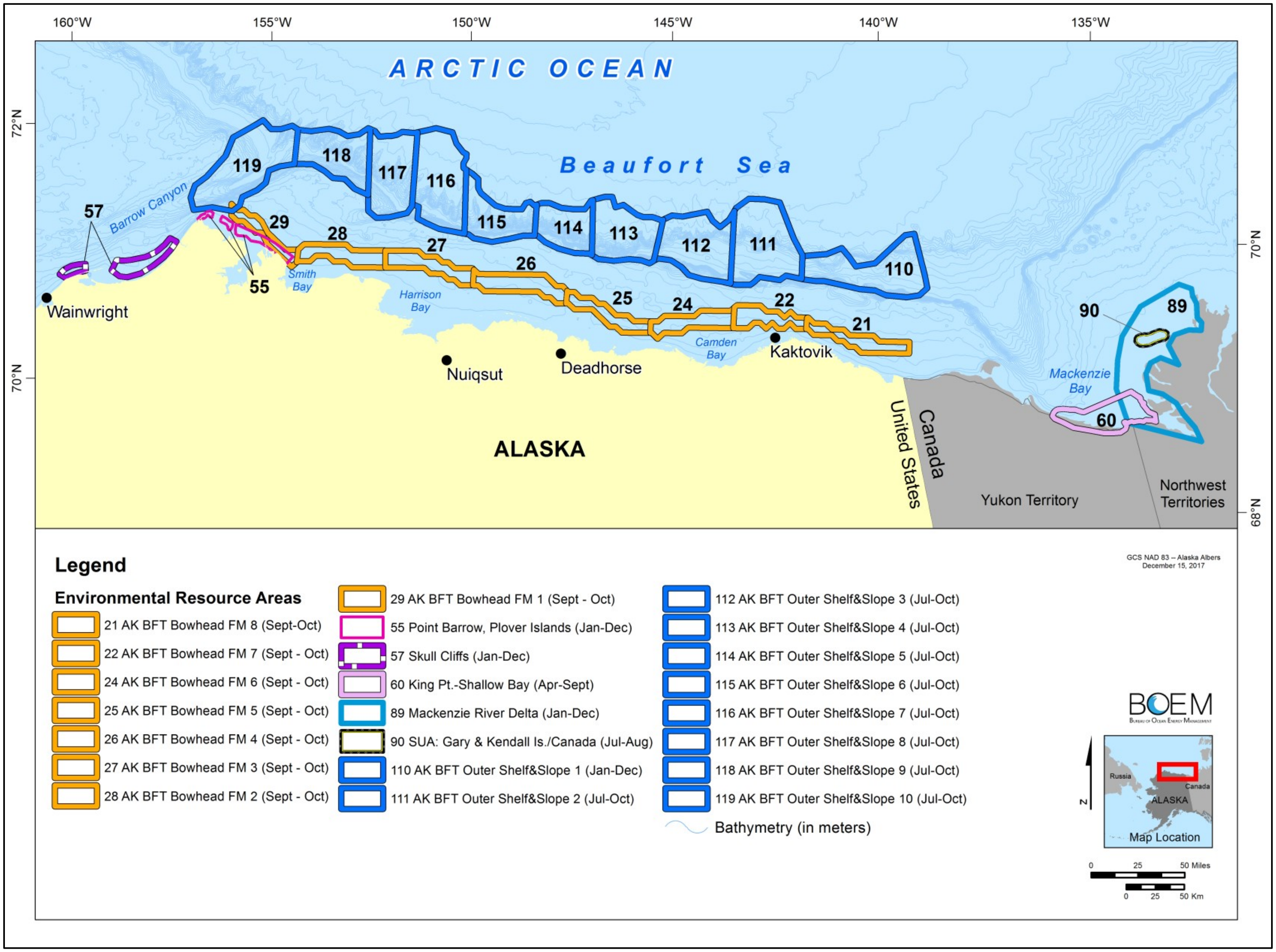
A-3 Supporting Maps



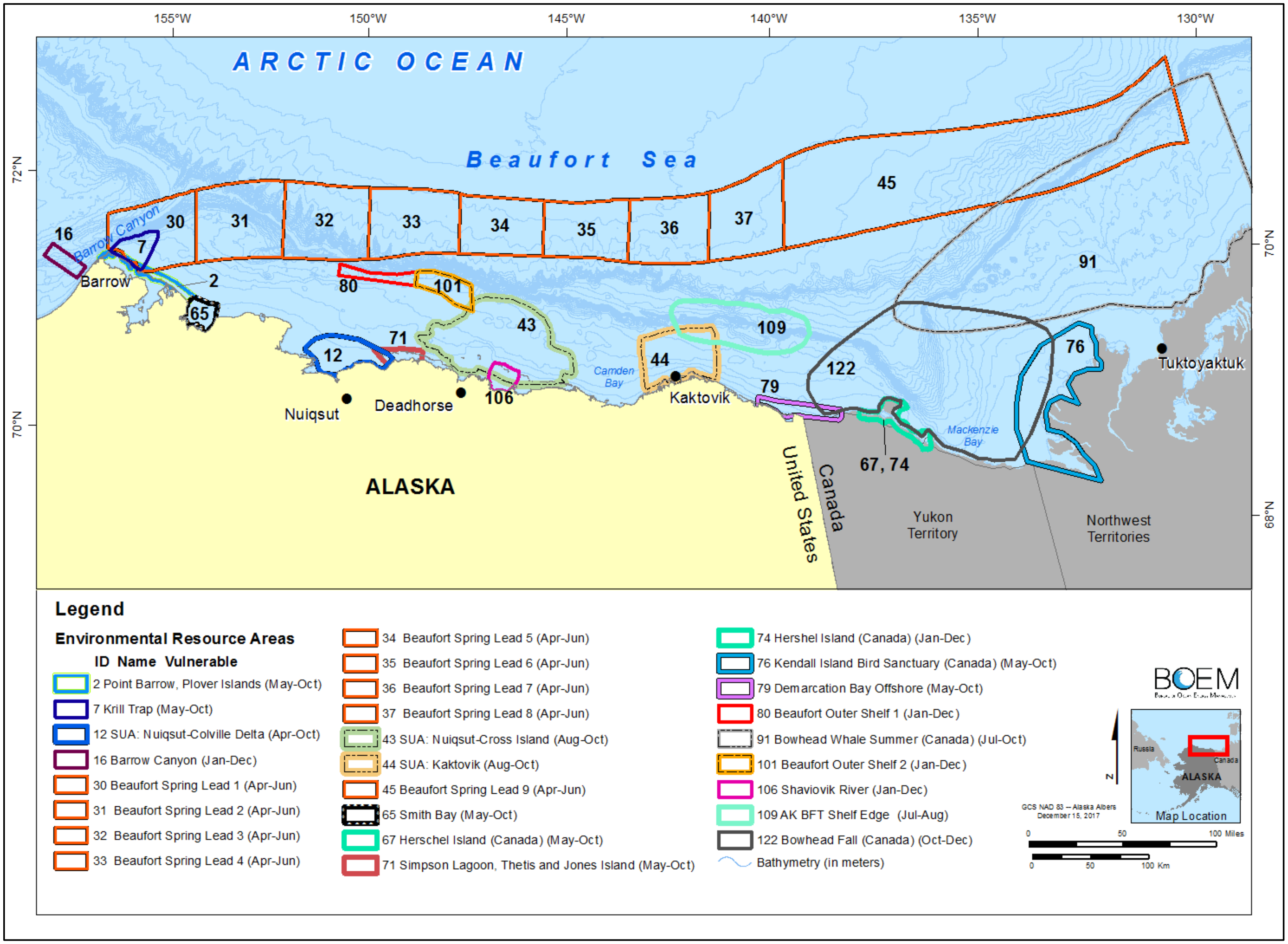
Map A-2b Study Area Used in the Oil-Spill Trajectory Analysis



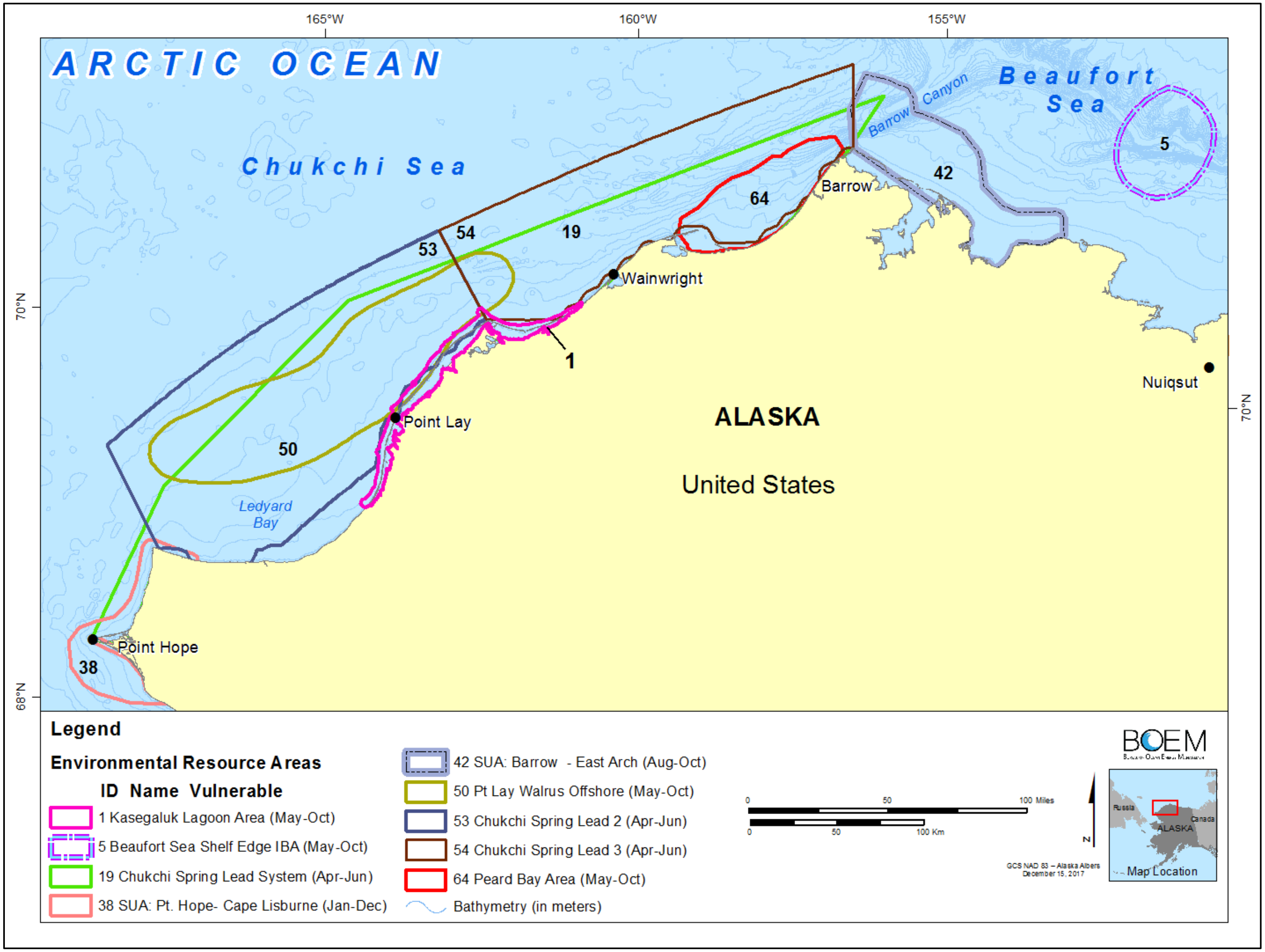
Map A-2c Environmental Resource Areas Used in the Oil-Spill Trajectory Analysis



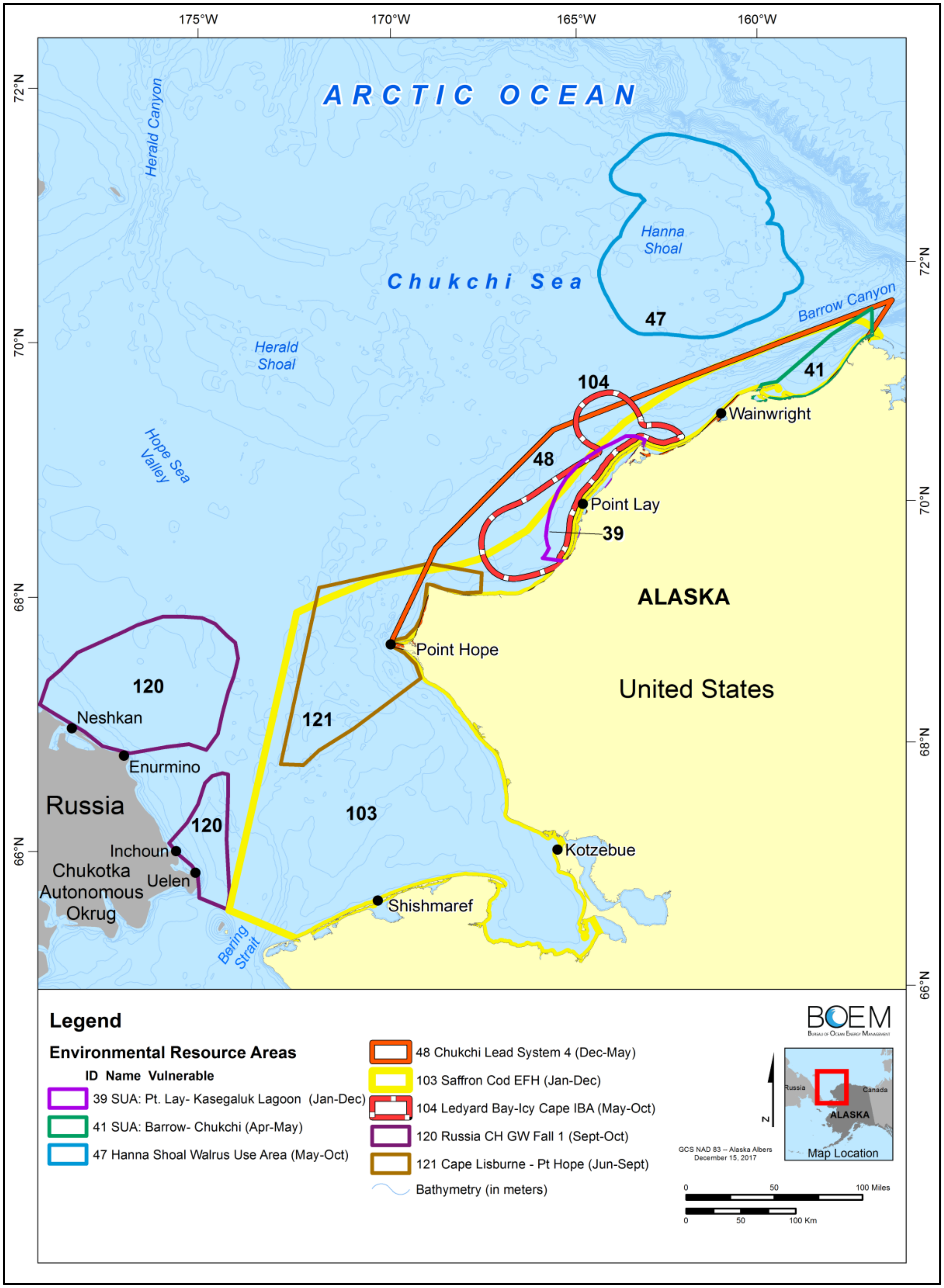
Map A-2d Environmental Resource Areas Used in the Oil-Spill Trajectory Analysis



Map A-2e Environmental Resource Areas Used in the Oil-Spill Trajectory Analysis

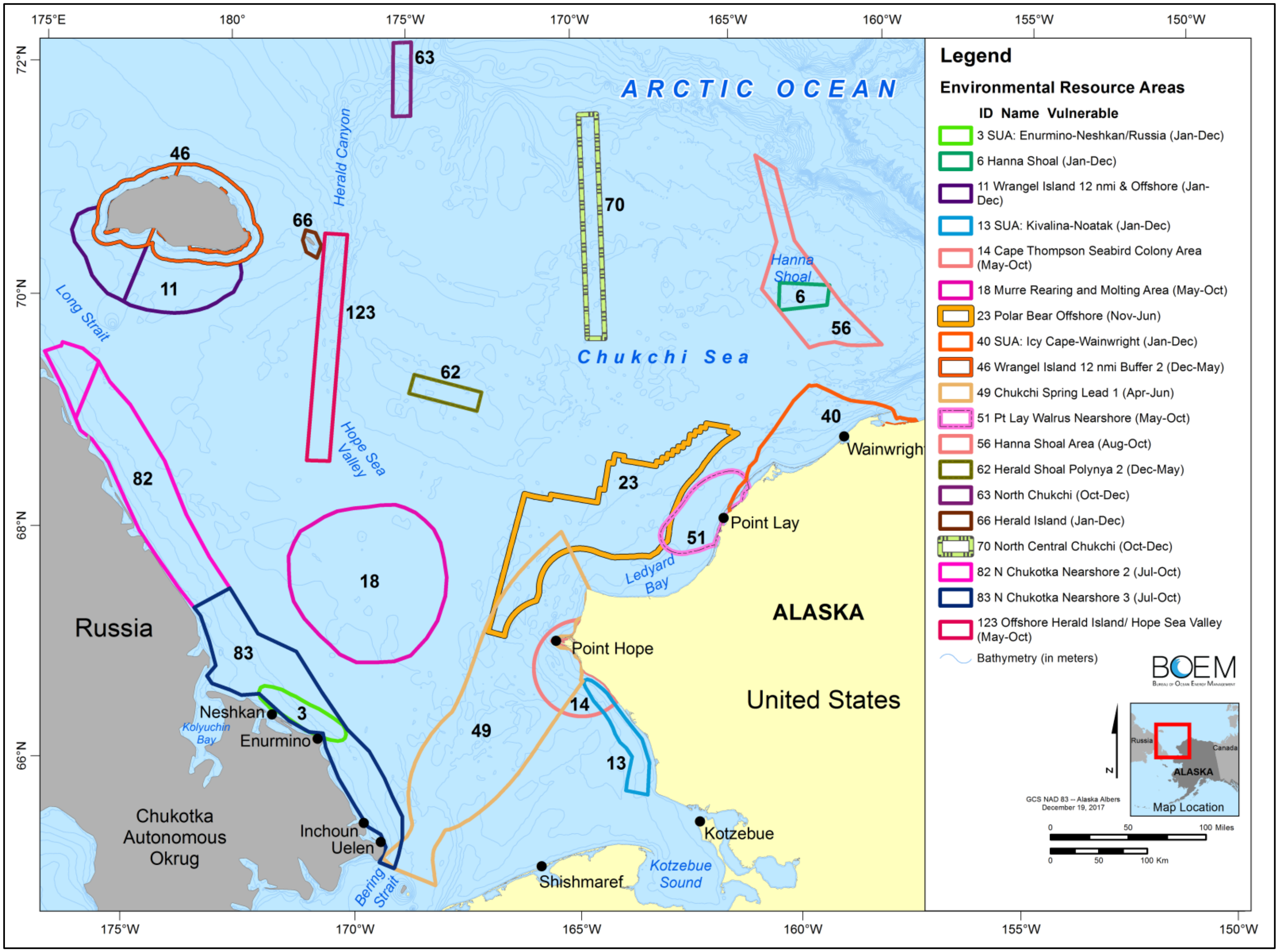


Map A-2f Environmental Resource Areas Used in the Oil-Spill Trajectory Analysis



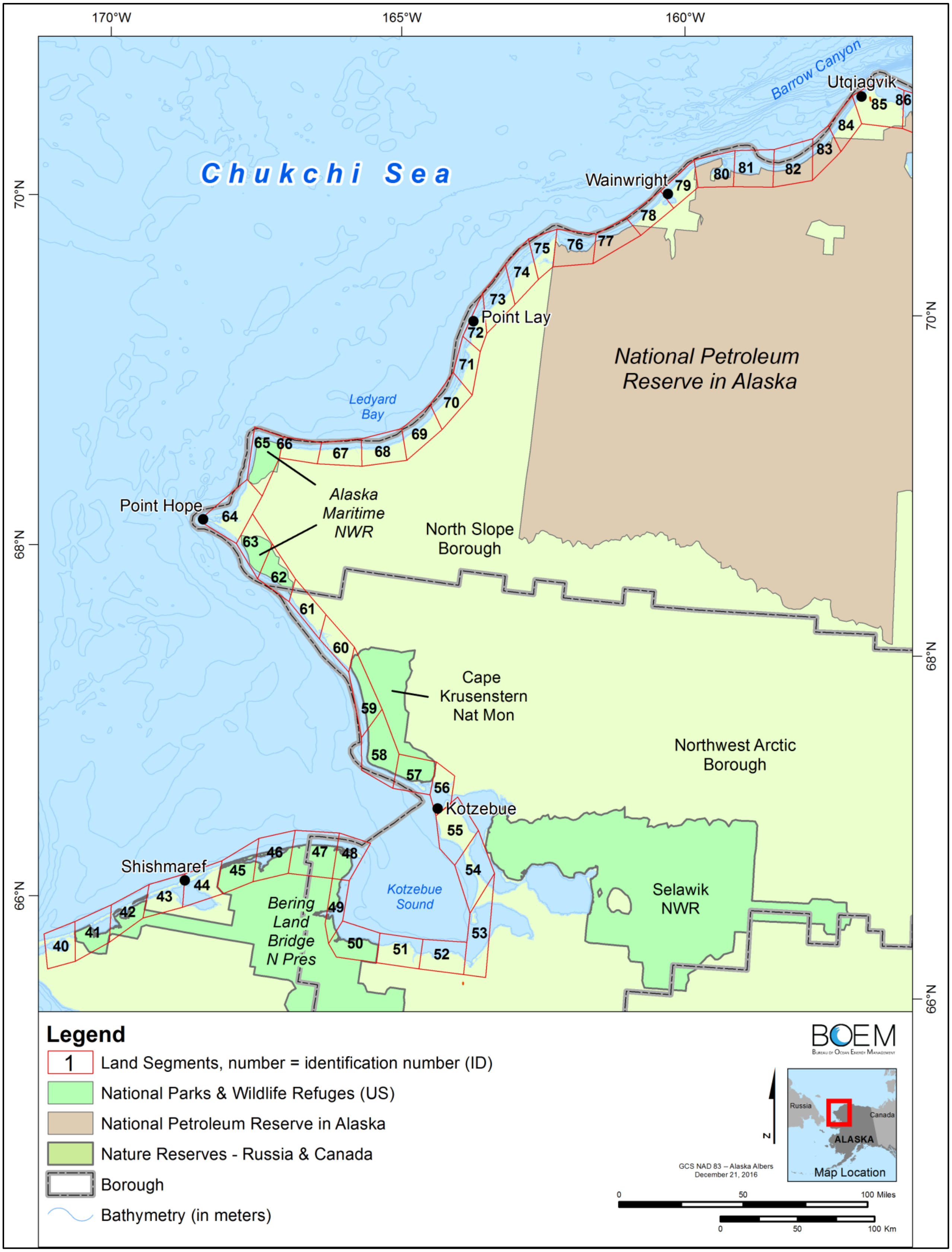
Map A-2g Environmental Resource Areas Used in the Oil-Spill Trajectory Analysis

Map A-2h Environmental Resource Areas Used in the Oil-Spill Trajectory Analysis

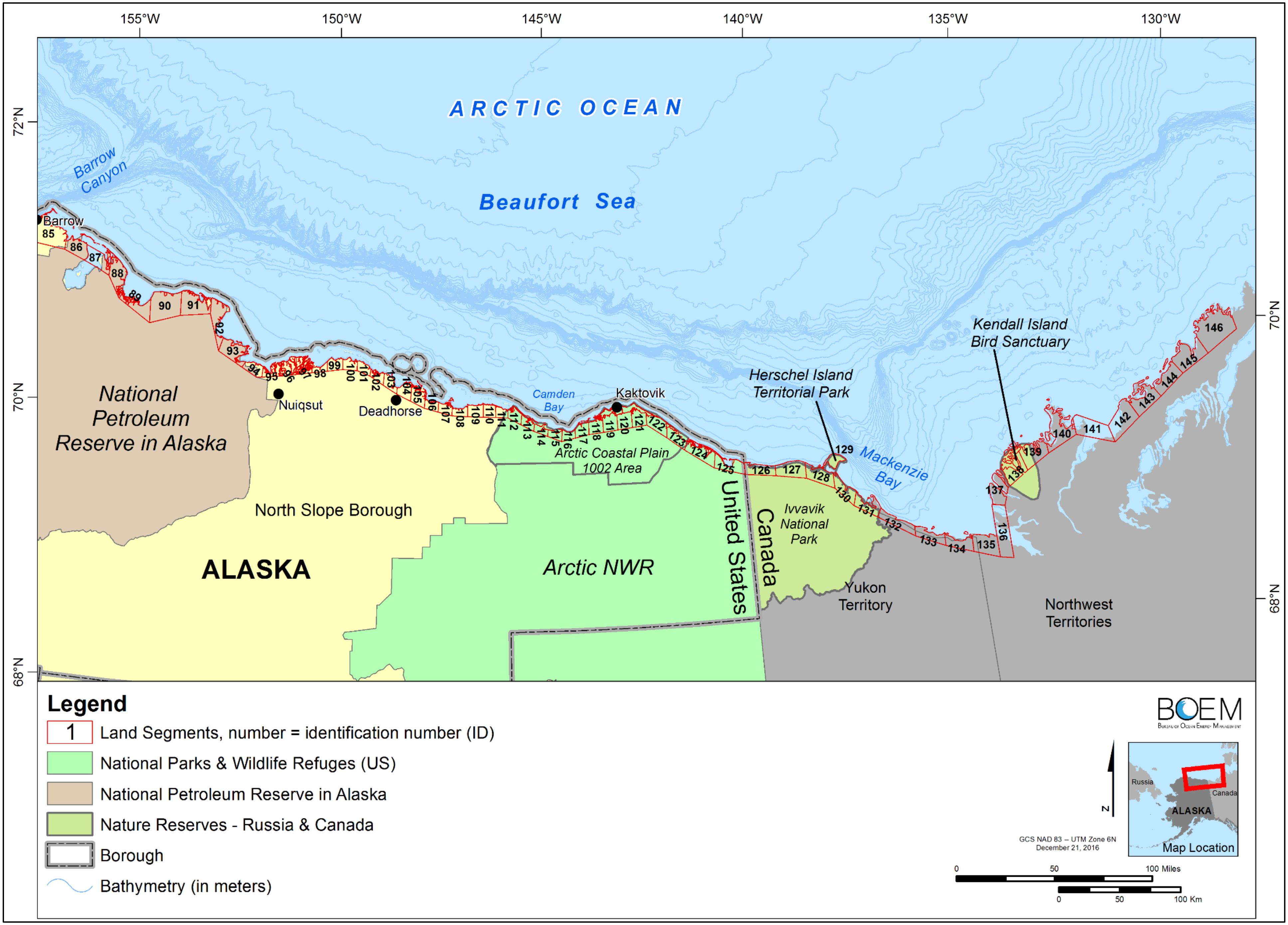


Map A-2i Environmental Resource Areas Used in the Oil-Spill Trajectory Analysis

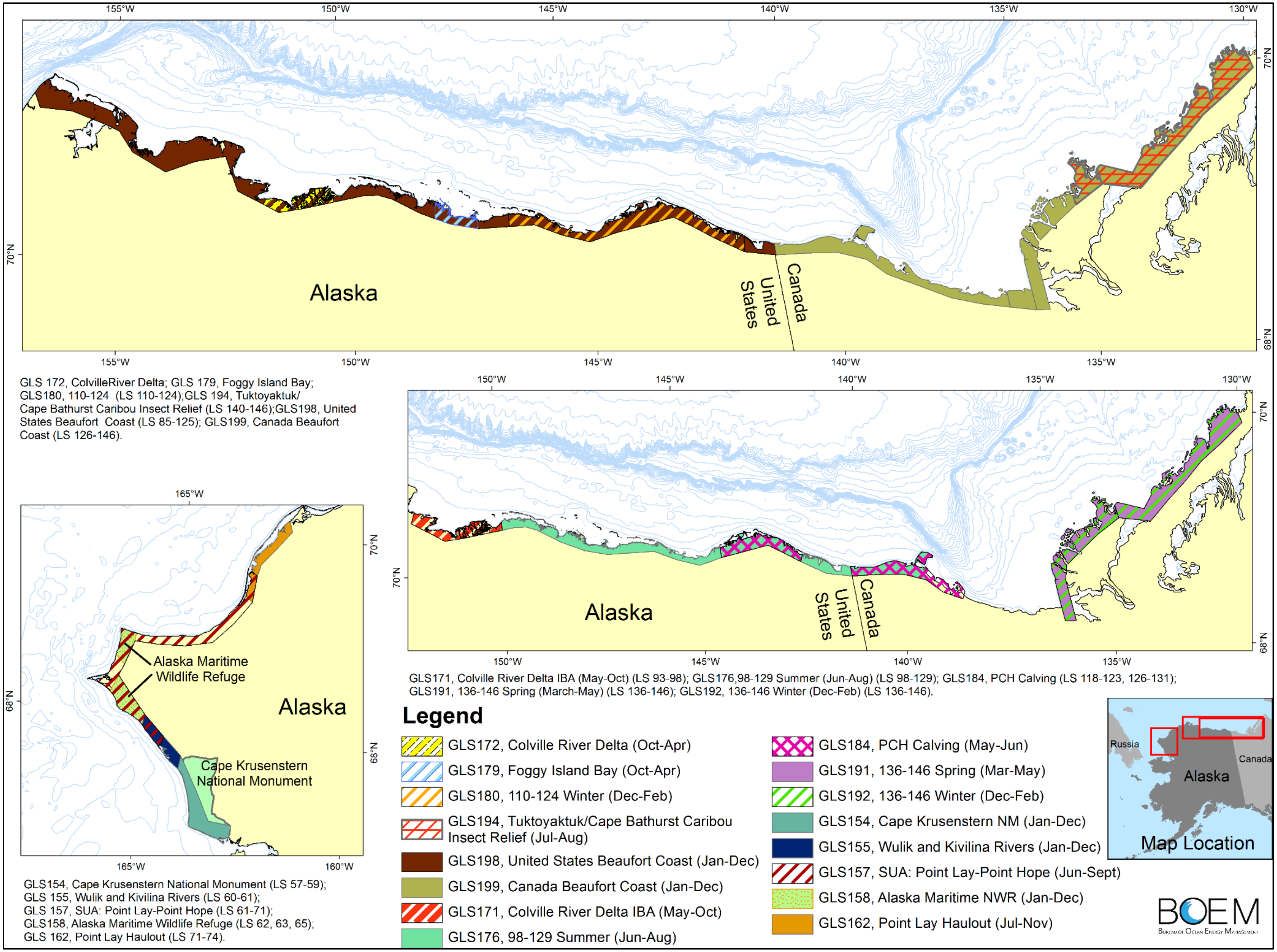
Map A-3a Land Segments 1-39 Used in the Oil-Spill Trajectory Analysis



Map A-3b Land Segments 40-86 Used in the Oil-Spill Trajectory Analysis



Map A-3c Land Segments 85-146 Used in the Oil-Spill Trajectory Analysis

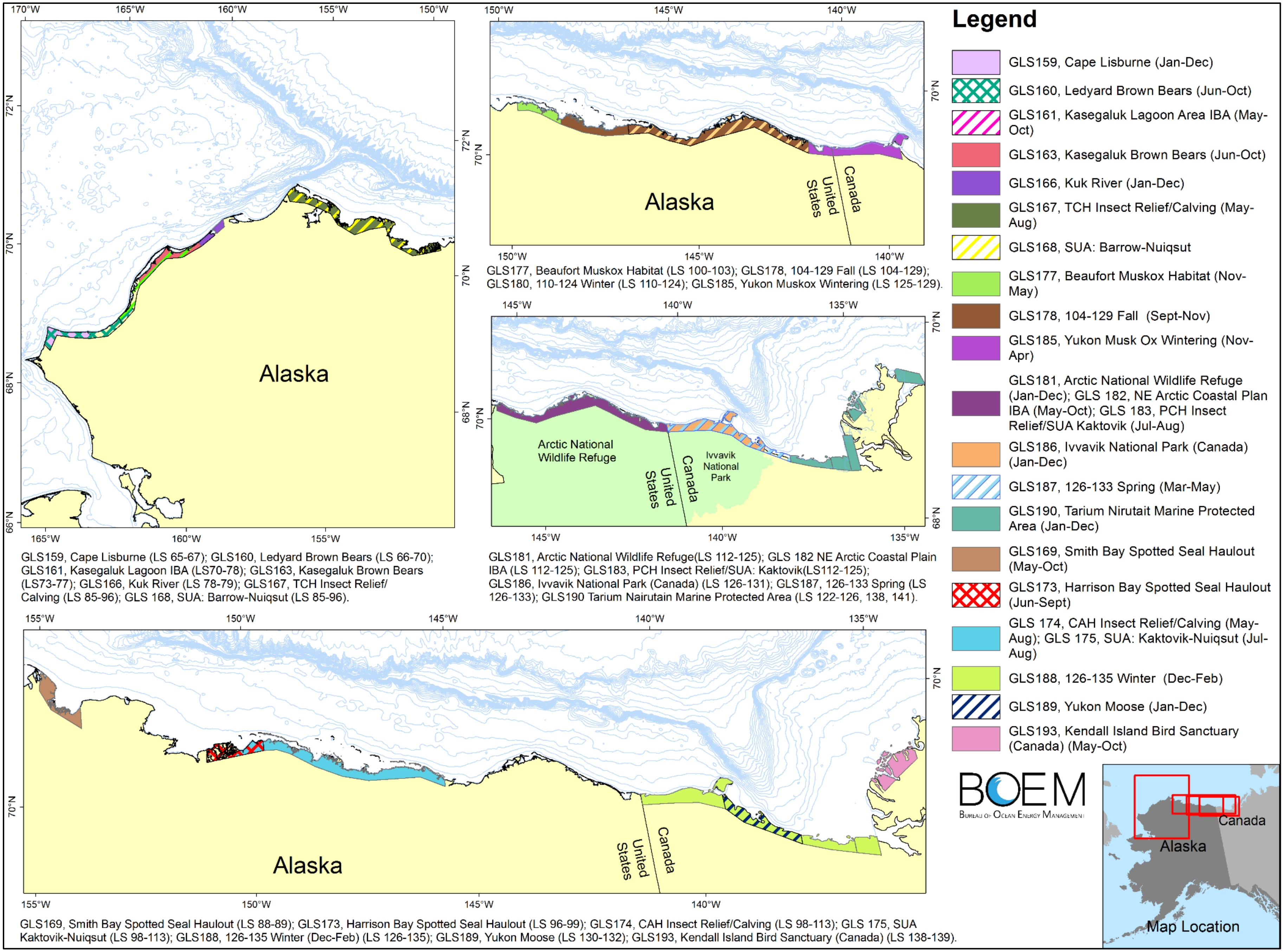


GLS 172, ColvilleRiver Delta; GLS 179, Foggy Island Bay; GLS180, 110-124 (LS 110-124);GLS 194, Tuktoyaktuk/ Cape Bathurst Caribou Insect Relief (LS 140-146);GLS198, United States Beaufort Coast (LS 85-125); GLS199, Canada Beaufort Coast (LS 126-146).

GLS171, Colville River Delta IBA (May-Oct) (LS 93-98); GLS176,98-129 Summer (Jun-Aug) (LS 98-129); GLS184, PCH Calving (LS 118-123, 126-131); GLS191, 136-146 Spring (March-May) (LS 136-146); GLS192, 136-146 Winter (Dec-Feb) (LS 136-146).

GLS154, Cape Krusenstern National Monument (LS 57-59);
GLS 155, Wulik and Kivilina Rivers (LS 60-61);
GLS 157, SUA: Point Lay-Point Hope (LS 61-71);
GLS158, Alaska Maritime Wildlife Refuge (LS 62, 63, 65);
GLS 162, Point Lay Haulout (LS 71-74).

Map A-4a Grouped Land Segments Used in the Oil-Spill Trajectory Analysis



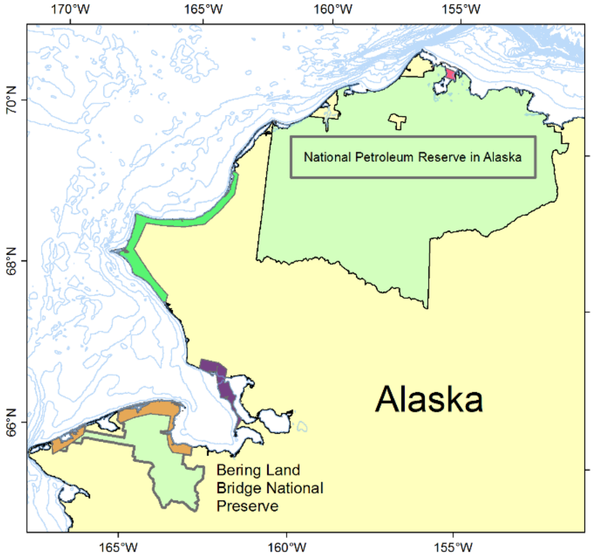
GLS159, Cape Lisburne (LS 65-67); GLS160, Ledyard Brown Bears (LS 66-70); GLS161, Kasegaluk Lagoon IBA (LS70-78); GLS163, Kasegaluk Brown Bears (LS73-77); GLS166, Kuk River (LS 78-79); GLS167, TCH Insect Relief/ Calving (LS 85-96); GLS 168, SUA: Barrow-Nuiqsut (LS 85-96).

GLS177, Beaufort Muskox Habitat (LS 100-103); GLS178, 104-129 Fall (LS 104-129); GLS180, 110-124 Winter (LS 110-124); GLS185, Yukon Muskox Wintering (LS 125-129).

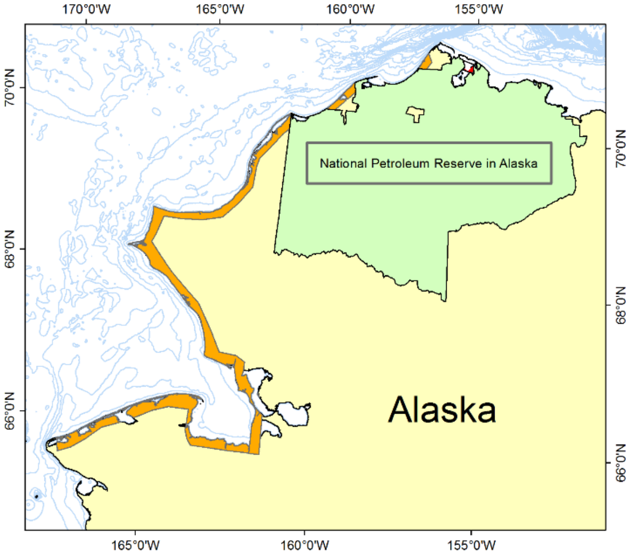
GLS181, Arctic National Wildlife Refuge(LS 112-125); GLS 182 NE Arctic Coastal Plain IBA (LS 112-125); GLS183, PCH Insect Relief/SUA: Kaktovik(LS112-125); GLS186, Ivvavik National Park (Canada) (LS 126-131); GLS187, 126-133 Spring (LS 126-133); GLS190 Tarium Nairutain Marine Protected Area (LS 122-126, 138, 141).

GLS169, Smith Bay Spotted Seal Haulout (LS 88-89); GLS173, Harrison Bay Spotted Seal Haulout (LS 96-99); GLS174, CAH Insect Relief/Calving (LS 98-113); GLS 175, SUA Kaktovik-Nuiqsut (LS 98-113); GLS188, 126-135 Winter (Dec-Feb) (LS 126-135); GLS189, Yukon Moose (LS 130-132); GLS193, Kendall Island Bird Sanctuary (Canada) (LS 138-139).

Map A-4b Grouped Land Segments Used in the Oil-Spill Trajectory Analysis

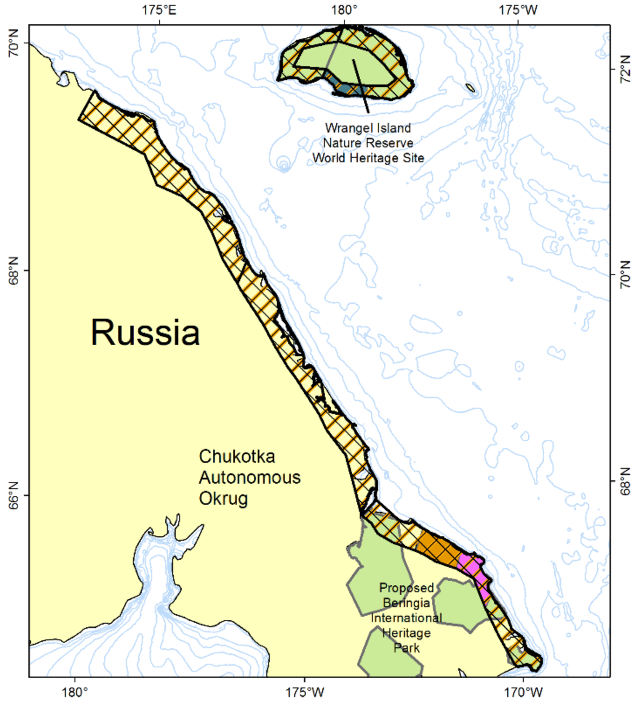


GLS152, Bering Land Bridge National Preserve (LS 41-42, 45-50); GLS 153, Noatak River (LS41-42, 45-50); GLS156, WAH Insect Relief (LS 61-71); GLS165, Kasegaluk Lagoon Special Use Area (LS 76-77); GLS170, Teshekpuk Lake Special Use Area (LS 86-93).



GLS164, National Petroleum Reserve Alaska (LS 76-77, 80-83, 86-93); GLS197, United States Chukchi Coast (LS 40-84).

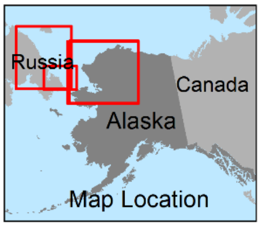
GLS148, Kolyuchin Bay (Jun-Nov); GLS151, Chukotka Coast Haulout (Jul-Nov).



GLS147, Bukhta Somnitel'naya (LS 10-11); GLS149, Ostrov Idlidlya (LS 33-34); GLS150, Mys Serditse Kamen (LS 35-36); GLS195, Russia Chukchi Coast Marine Mammals (LS 1-39); GLS196, Russia Chukchi Coast (LS 1-39).

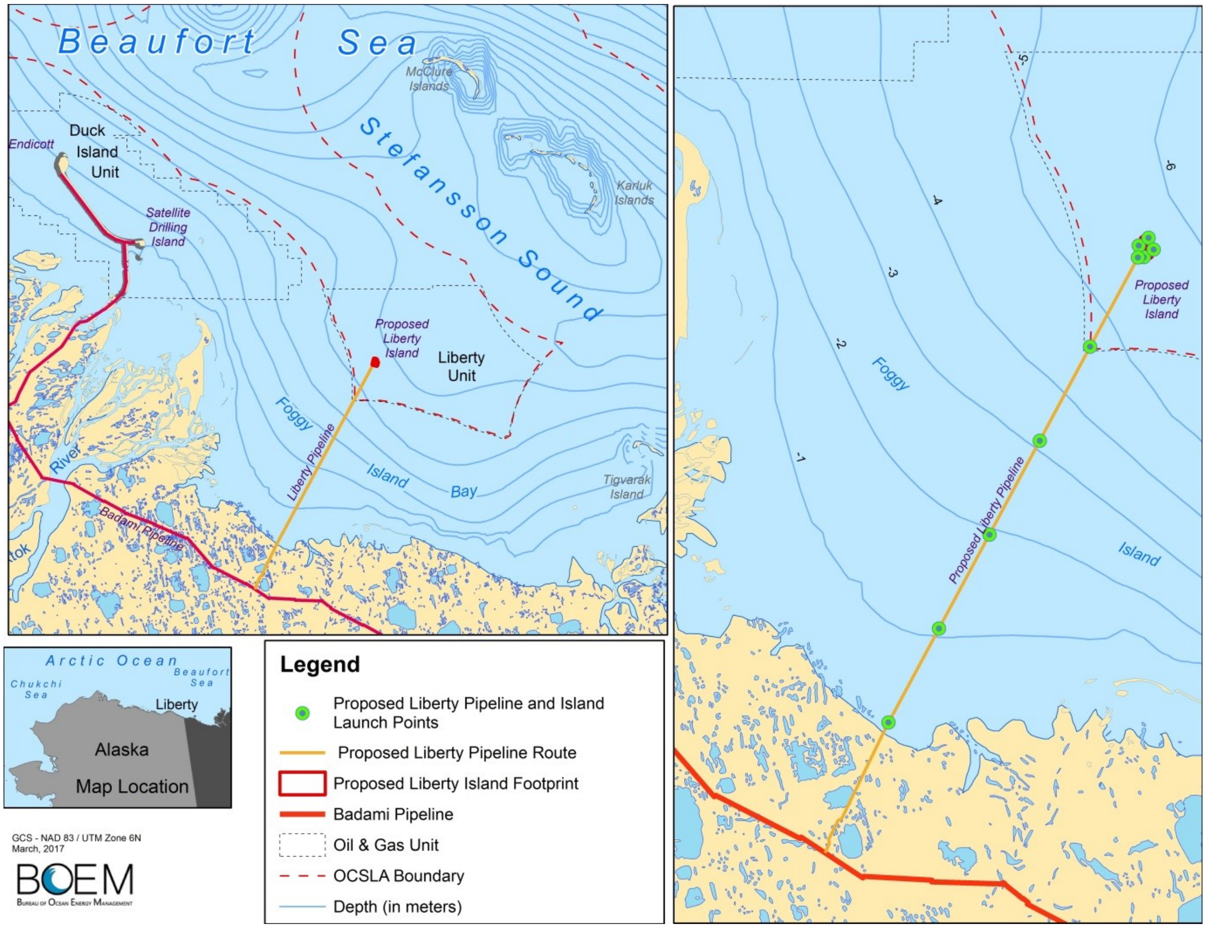
Legend

- 🟧 GLS152, Bering Land Bridge National Preserve (Jan-Dec)
- 🟪 GLS153, Noatak River (Jan-Dec)
- 🟩 GLS156, WAH Insect Relief (Jul-Aug)
- 🟪 GLS165, Kasegaluk Lagoon Special Area (NPR-A) (Jan-Dec)
- 🟥 GLS170, Teshekpuk Lake Special Area (NPR-A)/IBA (May-
- ▨ GLS164, National Petroleum Reserve Alaska (Jan-Dec)
- 🟧 GLS197, United States Chukchi Coast (Jan-Dec)
- 🟦 GLS148, Kolyuchin Bay (Jun-Nov)
- 🟩 GLS151, Chukotka Coast Haulout (Jul-Nov)
- 🟦 GLS147, Bukhta Somnitel'naya (Somnitel'naya Spit) Davidova Spit (Jan-Dec)
- 🟧 GLS149, Ostrov Idlidlya (Ididlya Island) (Jul-Nov)
- 🟪 GLS150, Mys Serditse Kamen (Cape Serdtse-Kamen) (Jul-Nov)
- ▨ GLS195, Russia Chukchi Coast Marine Mammals (Jul-Nov)
- ▨ GLS196, Russia Chukchi Coast (Jan-Dec)



Map A-4c Grouped Land Segments Used in the Oil-Spill Trajectory Analysis

Map A-5 Launch Areas Used in the Oil-Spill Trajectory Analysis



Map A-6 Launch Points Used in the Oil-Spill Trajectory Analysis (zoomed in from Map A-5)

A-4 OSRA Conditional and Combined Probability Tables

Table A-4-1 through Table A-4-9 represent conditional probabilities (expressed as percent chance) that a large oil spill starting at a particular location (Liberty Island [LI] or pipeline [PL]) will contact a certain location (environmental resource area, land segment, boundary segment, or grouped land segment). The tables are further organized as annual or seasonal (winter, summer). Table A-4-1 through Table A-4-3 represent annual conditional probabilities while Table A-4-4 through Table A-4-9 represent seasonal conditional probabilities. Table A-4-10 and Table A-4-11 represent combined probabilities (expressed as percent chance) of one or more large spills, and the estimated number of spills (mean), occurring and contacting a resource over the assumed life of the project.

If the chance of contacting a given resource area is greater than 99.5 percent, it is shown with a double asterisk (**). If the chance of a large spill contacting a resource area is less than 0.5 percent, it is shown with a dash (-). Resource areas with a less than 0.5 percent chance of contact from the LI and PL are not shown.

Table A-4-1 represents the annual conditional probabilities (expressed as percent chance) that a large oil spill starting at the proposed LDPI or pipeline will contact a certain environmental resource area (ERA) within 1, 3, 10, 30, 90, or 360 days:

Table A-4-1 Annual Environmental Resource Area

ID	Environmental Resource Name	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
0	Land	22	51	52	72	72	84	84	90	88	93	88	93
2	Point Barrow Plover Islands	-	-	-	-	-	-	-	-	1	-	1	-
5	Beaufort Sea Shelf Edge IBA	-	-	-	-	-	-	1	1	2	1	2	1
7	Krill Trap	-	-	-	-	-	-	-	-	1	-	1	-
8	Maguire and Flaxman Islands	-	-	1	-	2	1	2	1	2	1	2	1
9	Stockton and McClure Islands	-	-	3	2	6	4	6	4	6	4	6	4
12	SUA: Nuiqsut 0 Colville River Delta	-	-	-	-	1	-	2	1	3	1	3	1
24	AK BFT Bowhead FM 3	-	-	-	-	-	-	1	1	1	1	1	1
25	AK BFT Bowhead FM 4	-	-	-	-	2	1	2	1	2	1	2	1
26	AK BFT Bowhead FM 5	-	-	-	-	1	1	2	1	2	1	2	1
27	AK BFT Bowhead FM 6	-	-	-	-	-	-	1	1	1	1	1	1
28	AK BFT Bowhead FM 7	-	-	-	-	-	-	1	-	1	1	1	1
30	Beaufort Spring Lead 1	-	-	-	-	-	-	-	-	1	-	1	-
31	Beaufort Spring Lead 2	-	-	-	-	-	-	-	-	1	-	1	-
32	Beaufort Spring Lead 3	-	-	-	-	-	-	-	-	1	-	1	-
42	SUA: Barrow-East Arch	-	-	-	-	-	-	1	-	1	1	1	1
43	SUA: Nuiqsut-Cross Island	4	1	8	4	10	5	10	5	11	5	11	5
55	Point Barrow -Plover Islands	-	-	-	-	-	-	1	-	2	1	2	1
61	Point Lay-Barrow BH GW SFF	-	-	-	-	-	-	-	-	1	-	1	-
65	Smith Bay	-	-	-	-	-	-	-	-	1	-	1	-
68	Harrison Bay	-	-	-	-	1	-	2	1	3	1	3	1
69	Harrison Bay/Colville Delta	-	-	-	-	-	-	1	1	2	1	2	1
71	Simpson Lagoon Thetis and Jones Island	-	-	-	-	2	1	3	1	3	2	3	2
72	Gwyder Bay West Dock Cottle and Return Islands	-	-	3	1	6	2	7	3	7	3	7	3
73	Prudhoe Bay	-	-	1	-	2	1	2	1	2	1	2	1
75	Boulder Patch Area	**	55	**	57	**	57	**	57	**	57	**	57
77	Sagavanirktok River Delta/Foggy Island Bay	20	20	28	26	32	28	33	28	33	28	33	28
78	Mikkelsen Bay	1	1	5	4	6	4	6	5	6	5	6	5
80	Beaufort Outer Shelf 1	-	-	-	-	-	-	3	2	4	3	4	3

Note: The following applies to all tables in A-4, OSRA Conditional and Combined Probability Tables:
** = Greater than 99.5 percent
- = less than 0.5 percent
LDPI = Liberty Development and Production Island
PL = Pipeline.
Rows with all values less than 0.5 percent are not shown.

ID	Environmental Resource Name	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
84	Canning River Delta	-	-	-	-	1	1	1	1	1	1	1	1
85	Sagavanirktok River Delta	38	39	55	49	61	54	62	54	63	54	63	54
86	Harrison Bay	-	-	-	-	1	-	3	1	4	2	4	2
87	Colville River Delta	-	-	-	-	1	-	1	1	2	1	2	1
88	Simpson Lagoon	-	-	-	-	3	1	5	2	6	3	6	3
92	Thetis, Jones, Cottle & Return Islands	-	-	2	1	7	3	10	4	10	4	10	4
93	Cross and No Name Island	-	-	1	-	3	2	4	2	4	2	4	2
94	Maguire Flaxman & Barrier Islands	-	-	1	-	2	1	3	2	3	2	3	2
96	Midway Cross and Bartlett Islands	-	-	1	-	3	1	4	2	4	2	4	2
97	SUA: Tigvariak Island	1	1	5	5	7	6	8	6	8	6	8	6
101	Beaufort Outer Shelf 2	-	-	-	-	1	-	3	2	6	3	6	3
103	Saffron Cod EFH	-	-	-	-	-	-	-	-	1	-	1	-
105	Fish Creek	-	-	-	-	-	-	2	1	3	1	3	1
106	Shaviovik River	**	**	**	**	**	**	**	**	**	**	**	**
108	Barrow Feeding Aggregation	-	-	-	-	-	-	1	-	1	1	1	1
111	AK BFT Outer Shelf & Slope 2	-	-	-	-	-	-	-	-	1	-	1	-
112	AK BFT Outer Shelf & Slope 3	-	-	-	-	-	-	1	1	1	1	1	1
113	AK BFT Outer Shelf & Slope 4	-	-	-	-	-	-	1	1	2	1	2	1
114	AK BFT Outer Shelf & Slope 5	-	-	-	-	-	-	1	1	2	1	2	1
115	AK BFT Outer Shelf & Slope 6	-	-	-	-	-	-	1	1	2	1	2	1
116	AK BFT Outer Shelf & Slope 7	-	-	-	-	-	-	-	-	1	1	1	1
117	AK BFT Outer Shelf & Slope 8	-	-	-	-	-	-	-	-	1	1	1	1
118	AK BFT Outer Shelf & Slope 9	-	-	-	-	-	-	-	-	1	-	1	-
119	AK BFT Outer Shelf & Slope 10	-	-	-	-	-	-	-	-	1	-	1	-
124	Chukchi Sea Nearshore IBA	-	-	-	-	-	-	-	-	1	-	1	-

Table A-4-2 represents the annual conditional probabilities (expressed as percent chance) that a large oil spill starting at the proposed LDPI or pipeline will contact a certain land segment (LS) within 1, 3, 10, 30, 90, or 360 days:

Table A-4-2 Annual Land Segment

ID	Land Segment	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
85	Barrow, Browerville, Elson Lag.	-	-	-	-	-	-	-	-	1	-	1	-
88	Cape Simpson, Piasuk River	-	-	-	-	-	-	-	-	1	1	1	1
92	Cape Halkett, Garry Creek	-	-	-	-	-	-	2	1	3	1	3	1
93	Atigaru Pt., Eskimo Isl., Kogru R.	-	-	-	-	-	-	1	-	1	1	1	1
100	Milne Point, Simpson Lagoon	-	-	-	-	-	-	1	-	1	-	1	-
101	Beechy & Back Pt., Sakonowyak R.	-	-	-	-	1	-	2	1	2	1	2	1
102	Kuparuk River, Point Storkersen	-	-	-	-	1	-	2	1	2	1	2	1
103	Point McIntyre, West Dock, Putuligayuk R.	-	-	-	-	2	1	3	1	3	1	3	1
104	Prudhoe Bay, Heald Pt.	1	-	3	1	4	2	5	2	5	2	5	2
105	Point Brower, Sagavanirktok R., Duck I.	14	13	24	19	28	21	29	21	29	22	29	22
106	Foggy Island Bay, Kadleroshilik R.	6	37	17	47	21	50	21	50	21	50	21	50
107	Tigvariak Island, Shaviovik R.	1	1	5	4	7	5	7	6	7	6	7	6
108	Mikkelsen Bay, Badami Airport	-	-	1	1	3	2	3	2	3	2	3	2
109	Bullen, Gordon & Reliance Points	-	-	1	-	2	1	3	1	3	1	3	1
110	Pt. Hopson & Sweeney, Thomson	-	-	-	-	1	-	1	1	1	1	1	1
111	Staines R., Lion Bay	-	-	-	-	-	-	-	-	1	-	1	-
112	Brownlow Point, West Canning River	-	-	-	-	-	-	-	-	1	-	1	-

Note: The following applies to all tables in A-4, OSRA Conditional and Combined Probability Tables:
** = Greater than 99.5 percent
LDPI = Liberty Development and Production Island
- = less than 0.5 percent
PL = Pipeline.
Rows with all values less than 0.5 percent are not shown.

Table A-4-3 represents the annual conditional probabilities (expressed as percent chance) that a large oil spill starting at the proposed LDPI or pipeline will contact a certain group of land segments (GLS) within 1, 3, 10, 30, 90, or 360 days:

Table A-4-3 Annual Grouped Land Segment

ID	Grouped Land Segment	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
164	National Petroleum Reserve Alaska	-	-	-	-	-	-	4	2	7	3	7	3
167	TCH Insect Relief/Calving	-	-	-	-	-	-	2	1	3	2	3	2
168	SUA: Barrow-Nuiqsut	-	-	-	-	-	-	1	1	2	1	2	1
169	Smith Bay Spotted Seal Haulout	-	-	-	-	-	-	-	-	1	-	1	-
170	Teshekpuk Lake Special Area (NPR-A)/IBA	-	-	-	-	-	-	2	1	4	2	4	2
171	Colville River Delta IBA	-	-	-	-	-	-	1	1	2	1	2	1
174	CAH Insect Relief/ Calving	7	16	17	24	25	28	27	30	27	30	27	30
175	SUA: Kaktovik-Nuiqsut	4	8	8	12	12	14	13	14	13	14	13	14
176	98-129 Summer	6	14	14	20	21	24	23	25	24	25	24	25
177	Beaufort Muskox Habitat	-	-	-	-	3	1	4	2	4	2	4	2
178	104-129 Fall	6	15	13	20	17	23	18	23	18	23	18	23
179	Foggy Island Bay	22	51	46	70	56	76	57	77	57	77	57	77
180	110-124 Winter	-	-	-	-	1	1	2	1	2	2	2	2
181	Arctic National Wildlife Refuge	-	-	-	-	1	1	2	1	2	2	2	2
182	Northeast Arctic Coastal Plain IBA	-	-	-	-	-	-	1	1	1	1	1	1
198	United States Beaufort Coast	22	51	52	72	72	84	84	90	88	93	88	93

Table A-4-4 represents the annual conditional probabilities (expressed as percent chance) that a large oil spill starting at the proposed LDPI or pipeline will contact a certain Environmental Resource Area (ERA) within 1, 3, 10, 30, 90, or 360 days:

Table A-4-4 Summer Environmental Resource Area

ID	Environmental Resource Area	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
0	Land	25	53	54	74	74	85	85	91	88	93	88	93
2	Point Barrow Plover Islands	-	-	-	-	-	-	1	-	2	1	2	1
5	Beaufort Sea Shelf Edge IBA	-	-	-	-	-	-	3	2	4	2	4	2
7	Krill Trap	-	-	-	-	-	-	-	-	1	1	1	1
8	Maguire and Flaxman Islands	-	-	2	1	3	2	4	2	4	2	4	2
9	Stockton and McClure Islands	-	-	6	3	9	6	10	6	10	6	10	6
12	SUA: Nuiqsut - Colville River Delta	-	-	-	-	2	1	6	3	6	3	6	3
20	East Chukchi Offshore	-	-	-	-	-	-	-	-	1	-	1	-
22	AK BFT Bowhead FM 2	-	-	-	-	-	-	1	-	1	1	1	1
24	AK BFT Bowhead FM 3	-	-	-	-	1	-	2	2	2	2	2	2
25	AK BFT Bowhead FM 4	-	-	1	-	4	2	5	3	5	3	5	3
26	AK BFT Bowhead FM 5	-	-	-	-	3	1	5	3	6	3	6	3
27	AK BFT Bowhead FM 6	-	-	-	-	1	-	3	2	4	2	4	2
28	AK BFT Bowhead FM 7	-	-	-	-	-	-	2	1	3	1	3	1
29	AK BFT Bowhead FM 8	-	-	-	-	-	-	-	-	1	1	1	1
42	SUA: Barrow East Arch	-	-	-	-	-	-	2	1	4	2	4	2
43	SUA: Nuiqsut Cross Island	10	3	21	10	25	13	26	13	26	14	26	14
44	SUA: Kaktovik	-	-	-	-	-	-	1	-	1	1	1	1
55	Point Barrow -Plover Islands	-	-	-	-	-	-	1	-	2	1	2	1
61	Point Lay-Barrow BH GW SFF	-	-	-	-	-	-	-	-	2	1	2	1
65	Smith Bay	-	-	-	-	-	-	1	1	1	1	1	1
68	Harrison Bay	-	-	-	-	1	-	5	3	6	3	6	3
69	Harrison Bay/Colville Delta	-	-	-	-	1	-	4	2	5	3	5	3
71	Simpson Lagoon Thetis and Jones Island	-	-	-	-	3	1	6	3	6	4	6	4

Note: The following applies to all tables in A-4, OSRA Conditional and Combined Probability Tables:

** = Greater than 99.5 percent	LDPI = Liberty Development and Production Island
- = less than 0.5 percent	PL = Pipeline.

Rows with all values less than 0.5 percent are not shown.

ID	Environmental Resource Area	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
72	Gwyder Bay West Dock Cottle and Return Islands	-	-	5	1	12	5	14	6	14	6	14	6
73	Prudhoe Bay	-	-	1	-	4	2	5	2	5	2	5	2
75	Boulder Patch Area	**	54	**	56	**	56	**	56	**	56	**	56
77	Sagavanirktok River Delta/Foggy Island Bay	42	43	60	55	67	59	68	59	68	59	68	59
78	Mikkelsen Bay	2	2	8	6	10	8	10	8	10	8	10	8
80	Beaufort Outer Shelf 1	-	-	-	-	-	-	2	1	3	2	3	2
84	Canning River Delta	-	-	-	-	1	-	1	-	1	-	1	-
85	Sagavanirktok River Delta	42	43	60	55	67	59	68	59	68	59	68	59
86	Harrison Bay	-	-	-	-	1	-	5	3	6	3	6	3
87	Colville River Delta	-	-	-	-	1	-	2	1	3	2	3	2
88	Simpson Lagoon	-	-	-	-	3	1	6	3	6	4	6	4
92	Thetis, Jones, Cottle & Return Islands	-	-	2	1	8	3	10	4	11	5	11	5
93	Cross and No Name Island	-	-	1	-	3	2	4	2	4	2	4	2
94	Maguire Flaxman & Barrier Islands	-	-	-	-	2	1	2	1	2	1	2	1
96	Midway Cross and Bartlett Islands	-	-	3	1	7	3	8	4	8	4	8	4
97	SUA: Tigvariak Island	1	1	4	4	6	5	6	5	6	5	6	5
101	Beaufort Outer Shelf 2	-	-	-	-	1	-	4	3	6	4	6	4
103	Saffron Cod EFH	-	-	-	-	-	-	-	-	1	-	1	-
105	Fish Creek	-	-	-	-	-	-	3	2	4	2	4	2
106	Shaviovik River	**	**	**	**	**	**	**	**	**	**	**	**
108	Barrow Feeding Aggregation	-	-	-	-	-	-	1	-	4	2	4	2
110	AK BFT Outer Shelf & Slope 1	-	-	-	-	-	-	-	-	1	-	1	-
111	AK BFT Outer Shelf & Slope 2	-	-	-	-	-	-	1	1	1	1	1	1
112	AK BFT Outer Shelf & Slope 3	-	-	-	-	-	-	2	1	2	2	2	2
113	AK BFT Outer Shelf & Slope 4	-	-	-	-	-	-	4	2	4	3	4	3
114	AK BFT Outer Shelf & Slope 5	-	-	-	-	1	-	4	2	4	3	4	3
115	AK BFT Outer Shelf & Slope 6	-	-	-	-	-	-	2	1	3	2	3	2
116	AK BFT Outer Shelf & Slope 7	-	-	-	-	-	-	1	1	2	1	2	1
117	AK BFT Outer Shelf & Slope 8	-	-	-	-	-	-	1	1	2	2	2	2
118	AK BFT Outer Shelf & Slope 9	-	-	-	-	-	-	1	-	2	1	2	1
119	AK BFT Outer Shelf & Slope 10	-	-	-	-	-	-	1	-	2	1	2	1
124	Chukchi Sea Nearshore IBA	-	-	-	-	-	-	-	-	2	1	2	1

Table A-4-5 represents the summer conditional probabilities (expressed as percent chance) that a large oil spill starting at the proposed LDPI or pipeline will contact a certain Land Segment within 1, 3, 10, 30, 90, or 360 days:

Table A-4-5 Summer Land Segment

ID	Land Segment	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
85	Barrow, Browerville, Elson Lag.	-	-	-	-	-	-	-	-	1	-	1	-
88	Cape Simpson, Piasuk River	-	-	-	-	-	-	1	1	2	1	2	1
91	Lonely, Pitt Pt., Pogik Bay, Smith R	-	-	-	-	-	-	-	-	1	-	1	-
92	Cape Halkett, Garry Creek	-	-	-	-	-	-	2	1	3	2	3	2
93	Atigaru Pt., Eskimo Isl., Kogru R.	-	-	-	-	-	-	2	1	3	2	3	2
97	Kupigruak Channel, Colville River	-	-	-	-	-	-	1	-	1	1	1	1
99	Oliktok Point, Ugnuravik River	-	-	-	-	-	-	1	-	1	-	1	-
100	Milne Point, Simpson Lagoon	-	-	-	-	1	-	1	-	1	1	1	1
101	Beechy & Back Pt., Sakonowyak R.	-	-	-	-	1	-	2	1	2	1	2	1
102	Kuparuk River, Point Storkersen	-	-	-	-	1	-	2	1	2	1	2	1
103	Point McIntyre, West Dock, Putuligayuk R.	-	-	1	-	3	1	3	1	3	1	3	1
104	Prudhoe Bay, Heald Pt.	1	-	3	1	5	2	5	2	5	2	5	2
105	Point Brower, Sagavanirktok R., Duck I.	17	15	27	21	32	24	33	24	33	24	33	24

Note: The following applies to all tables in A-4, OSRA Conditional and Combined Probability Tables:
** = Greater than 99.5 percent LDPI = Liberty Development and Production Island
- = less than 0.5 percent PL = Pipeline.
Rows with all values less than 0.5 percent are not shown.

ID	Land Segment	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
106	Foggy Island Bay, Kadleroshilik R.	6	37	17	48	20	49	20	49	20	49	20	49
107	Tigvariak Island, Shaviovik R.	1	1	4	3	5	4	5	4	5	4	5	4
108	Mikkelsen Bay, Badami Airport	-	-	1	1	2	1	2	1	2	1	2	1
109	Bullen, Gordon & Reliance Points	-	-	1	-	1	1	1	1	1	1	1	1
110	Pt. Hopson & Sweeney, Thomson	-	-	-	-	1	-	1	1	1	1	1	1
112	Brownlow Point, West Canning River	-	-	-	-	1	-	1	-	1	-	1	-

Table A-4-6 represents the summer conditional probabilities (expressed as percent chance) that a large oil spill starting at the proposed LDPI or pipeline will contact a certain Grouped Land Segment within 1, 3, 10, 30, 90, or 360 days:

Table A-4-6 Summer Grouped Land Segment

ID	Grouped Land Segment	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
164	National Petroleum Reserve Alaska	-	-	-	-	-	-	6	3	9	5	9	5
167	TCH Insect Relief/Calving	-	-	-	-	-	-	4	2	5	3	5	3
168	SUA: Barrow-Nuiqsut	-	-	-	-	-	-	4	2	5	3	5	3
169	Smith Bay Spotted Seal Haulout	-	-	-	-	-	-	1	1	2	1	2	1
170	Teshekpuk Lake Special Area (NPR-A)/IBA	-	-	-	-	-	-	6	3	8	5	8	5
171	Colville River Delta IBA	-	-	-	-	-	-	3	2	4	3	4	3
173	Harrison Bay Spotted Seal Haulout	-	-	-	-	-	-	1	1	1	1	1	1
174	CAH Insect Relief/ Calving	12	27	28	40	40	46	42	47	42	47	42	47
175	SUA: Kaktovik-Nuiqsut	12	27	28	40	40	46	42	47	42	47	42	47
176	98-129 Summer	12	27	28	40	40	46	43	48	43	48	43	48
178	104-129 Fall	12	26	25	34	30	37	30	37	30	37	30	37
179	Foggy Island Bay	24	53	48	72	57	77	58	78	58	78	58	78
181	Arctic National Wildlife Refuge	-	-	-	-	1	-	1	-	1	-	1	-
182	Northeast Arctic Coastal Plain IBA	-	-	-	-	1	-	1	-	1	-	1	-
183	PCH Insect Relief/SUA Kaktovik	-	-	-	-	-	-	1	-	1	-	1	-
198	United States Beaufort Coast	25	53	54	74	74	85	85	91	88	93	88	93

Table A-4-7 represents the winter conditional probabilities (expressed as percent chance) that a large oil spill starting at the proposed LDPI or pipeline will contact a certain Environmental Resource Area (ERA) within 1, 3, 10, 30, 90, or 360 days

Table A-4-7 Winter Environmental Resource Area

ID	Environmental Resource Area	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
0	Land	22	51	51	72	72	84	84	90	88	93	88	93
2	Point Barrow Plover Islands	-	-	-	-	-	-	-	-	1	-	1	-
5	Beaufort Sea Shelf Edge IBA	-	-	-	-	-	-	-	-	1	1	1	1
8	Maguire and Flaxman Islands	-	-	-	-	2	1	2	1	2	1	2	1
9	Stockton and McClure Islands	-	-	3	1	4	3	5	3	5	3	5	3
12	SUA: Nuiqsut - Colville River Delta	-	-	-	-	1	-	1	-	2	1	2	1
25	AK BFT Bowhead FM 4	-	-	-	-	1	1	1	1	1	1	1	1
26	AK BFT Bowhead FM 5	-	-	-	-	1	-	1	1	1	1	1	1
27	AK BFT Bowhead FM 6	-	-	-	-	-	-	1	-	1	-	1	-
28	AK BFT Bowhead FM 7	-	-	-	-	-	-	1	-	1	-	1	-
30	Beaufort Spring Lead 1	-	-	-	-	-	-	-	-	1	-	1	-
31	Beaufort Spring Lead 2	-	-	-	-	-	-	1	-	1	1	1	1
32	Beaufort Spring Lead 3	-	-	-	-	-	-	1	-	1	-	1	-
34	Beaufort Spring Lead 5	-	-	-	-	-	-	-	-	1	-	1	-
35	Beaufort Spring Lead 6	-	-	-	-	-	-	-	-	1	-	1	-
42	SUA: Barrow-East Arch	-	-	-	-	-	-	-	-	1	-	1	-

Note: The following applies to all tables in A-4, OSRA Conditional and Combined Probability Tables:
** = Greater than 99.5 percent LDPI = Liberty Development and Production Island
- = less than 0.5 percent PL = Pipeline.
Rows with all values less than 0.5 percent are not shown.

ID	Environmental Resource Area	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
43	SUA: Nuiqsut-Cross Island	2	1	4	2	5	2	5	2	5	3	5	3
48	Chukchi Lead System 4	-	-	-	-	-	-	1	-	1	-	1	-
55	Point Barrow -Plover Islands	-	-	-	-	-	-	1	-	1	1	1	1
65	Smith Bay	-	-	-	-	-	-	-	-	1	-	1	-
68	Harrison Bay	-	-	-	-	-	-	1	-	2	1	2	1
69	Harrison Bay/Colville Delta	-	-	-	-	-	-	1	-	1	1	1	1
71	Simpson Lagoon Thetis and Jones Island	-	-	-	-	1	-	2	1	2	1	2	1
72	Gwyder Bay West Dock Cottle and Return Islands	-	-	2	-	4	1	5	2	5	2	5	2
73	Prudhoe Bay	-	-	-	-	1	-	1	1	1	1	1	1
75	Boulder Patch Area	**	55	**	57	**	58	**	58	**	58	**	58
77	Sagavanirktok River Delta/Foggy Island Bay	13	12	18	16	21	17	21	18	21	18	21	18
78	Mikkelsen Bay	1	1	3	3	4	3	4	3	4	3	4	3
80	Beaufort Outer Shelf 1	-	-	-	-	1	-	3	2	5	3	5	3
84	Canning River Delta	-	-	-	-	1	1	1	1	1	1	1	1
85	Sagavanirktok River Delta	37	38	53	47	59	52	61	53	61	53	61	53
86	Harrison Bay	-	-	-	-	1	-	3	1	4	2	4	2
87	Colville River Delta	-	-	-	-	1	-	1	1	2	1	2	1
88	Simpson Lagoon	-	-	-	-	4	1	5	2	6	2	6	2
92	Thetis, Jones, Cottle & Return Islands	-	-	2	1	7	2	10	4	10	4	10	4
93	Cross and No Name Island	-	-	1	-	3	2	4	2	4	2	4	2
94	Maguire Flaxman & Barrier Islands	-	-	1	-	2	2	3	2	4	2	4	2
95	Arey and Barter Islands and Bernard Spit	-	-	-	-	-	-	1	1	1	1	1	1
96	Midway Cross and Bartlett Islands	-	-	1	-	2	1	2	1	2	1	2	1
97	SUA: Tigvariak Island	2	1	6	5	8	6	9	7	9	7	9	7
101	Beaufort Outer Shelf 2	-	-	-	-	1	-	3	2	5	3	5	3
103	Saffron Cod EFH	-	-	-	-	-	-	-	-	1	-	1	-
105	Fish Creek	-	-	-	-	-	-	1	1	2	1	2	1
106	Shaviovik River	**	**	**	**	**	**	**	**	**	**	**	**
112	AK BFT Outer Shelf & Slope 3	-	-	-	-	-	-	-	-	1	1	1	1
113	AK BFT Outer Shelf & Slope 4	-	-	-	-	-	-	-	-	1	1	1	1
114	AK BFT Outer Shelf & Slope 5	-	-	-	-	-	-	1	-	1	1	1	1
115	AK BFT Outer Shelf & Slope 6	-	-	-	-	-	-	-	-	1	1	1	1
116	AK BFT Outer Shelf & Slope 7	-	-	-	-	-	-	-	-	1	1	1	1

Table A-4-8 represents the winter conditional probabilities (expressed as percent chance) that a large oil spill starting at the proposed LDPI or pipeline will contact a certain Land Segment within 1, 3, 10, 30, 90, or 360 days:

Table A-4-8 Winter Land Segment

ID	Land Segment	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
88	Cape Simpson, Piasuk River	-	-	-	-	-	-	-	-	1	-	1	-
92	Cape Halkett, Garry Creek	-	-	-	-	-	-	2	1	3	1	3	1
93	Atigaru Pt., Eskimo Isl., Kogru R.	-	-	-	-	-	-	-	-	1	-	1	-
100	Milne Point, Simpson Lagoon	-	-	-	-	-	-	1	-	1	-	1	-
101	Beechy & Back Pt., Sakonowyak R.	-	-	-	-	2	1	2	1	2	1	2	1
102	Kuparuk River, Point Storkersen	-	-	-	-	1	-	2	1	2	1	2	1
103	Point McIntyre, West Dock, Putuligayuk R.	-	-	-	-	2	1	3	1	3	1	3	1
104	Prudhoe Bay, Heald Pt.	1	-	2	1	4	1	4	2	4	2	4	2
105	Point Brower, Sagavanirktok R., Duck I.	14	13	23	18	27	20	28	21	28	21	28	21
106	Foggy Island Bay, Kadleroshilik R.	6	36	17	47	21	50	22	50	22	50	22	50
107	Tigvariak Island, Shaviovik R.	1	1	5	4	7	6	8	6	8	6	8	6
108	Mikkelsen Bay, Badami Airport	-	-	2	1	3	2	4	2	4	2	4	2

Note: The following applies to all tables in A-4, OSRA Conditional and Combined Probability Tables:

** = Greater than 99.5 percent

- = less than 0.5 percent

LDPI = Liberty Development and Production Island

PL = Pipeline.

Rows with all values less than 0.5 percent are not shown.

ID	Land Segment	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
109	Bullen, Gordon & Reliance Points	-	-	1	-	2	1	3	2	3	2	3	2
110	Pt. Hopson & Sweeney, Thomson	-	-	-	-	1	-	1	1	1	1	1	1
111	Staines R., Lion Bay	-	-	-	-	-	-	-	-	1	1	1	1
112	Brownlow Point, West Canning River	-	-	-	-	-	-	-	-	1	-	1	-

Table A-4-9 represents the winter conditional probabilities (expressed as percent chance) that a large oil spill starting at the proposed LDPI or pipeline will contact a certain Grouped Land Segment within 1, 3, 10, 30, 90, or 360 days:

Table A-4-9 Winter Grouped Land Segment

ID	Grouped Land Segment	1 day		3 days		10 days		30 days		90 days		360 days	
		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
164	National Petroleum Reserve Alaska	-	-	-	-	-	-	3	1	6	3	6	3
167	TCH Insect Relief/Calving	-	-	-	-	-	-	1	-	2	1	2	1
168	SUA: Barrow-Nuiqsut	-	-	-	-	-	-	-	-	1	-	1	-
170	Teshekpuk Lake Special Area (NPR-A)/IBA	-	-	-	-	-	-	1	-	2	1	2	1
171	Colville River Delta IBA	-	-	-	-	-	-	-	-	1	-	1	-
174	CAH Insect Relief/ Calving	6	13	14	19	20	22	22	24	22	24	22	24
175	SUA: Kaktovik0Nuiqsut	1	2	2	3	3	3	3	3	3	3	3	3
176	98-129 Summer	4	9	10	13	14	16	16	17	17	18	17	18
177	Beaufort Muskox Habitat	-	-	1	-	4	1	5	2	5	2	5	2
178	104-129 Fall	4	11	9	16	13	18	14	18	14	19	14	19
179	Foggy Island Bay	21	51	46	69	55	76	57	77	57	77	57	77
180	110-124 Winter	-	-	-	-	1	1	2	2	3	2	3	2
181	Arctic National Wildlife Refuge	-	-	-	-	1	1	2	2	2	2	2	2
182	Northeast Arctic Coastal Plain IBA	-	-	-	-	-	-	1	1	1	1	1	1
190	Tarium Nirutait Marine Protected Area	-	-	-	-	-	-	-	-	1	-	1	-
198	United States Beaufort Coast	22	51	51	72	72	84	84	90	88	92	88	92
199	Canada Beaufort Coast	-	-	-	-	-	-	-	-	1	-	1	-

Table A-4-10 and Table A-4-11 represent combined probabilities (expressed as percent chance), over the assumed life of the Proposed Action of one or more spills ≥1,000 bbl, and the estimated number of spills (mean), occurring and contacting a certain Environmental Resource Area or Grouped Land Segment. All individual land segments had less than a 0.5% chance of contact and are not shown.

Table A-4-10 Environmental Resource Area

ERA ID	Environmental Resource Area Name	1 day		3 days		10 days		30 days		90 days		360 days	
		%	mean	%	mean	%	mean	%	mean	%	mean	%	mean
0	Land	-	-	-	-	1	0.01	1	0.01	1	0.01	1	0.01
75	Boulder Patch Area	1	0.01	1	0.01	1	0.01	1	0.01	1	0.01	1	0.01
106	Shaviovik River	1	0.01	1	0.01	1	0.01	1	0.01	1	0.01	1	0.01

Table A-4-11 Grouped Land Segment

GLS ID	Grouped Land Segment Name	1 day		3 days		10 days		30 days		90 days		360 days	
		%	mean	%	mean	%	mean	%	mean	%	mean	%	mean
198	United States Beaufort Coast	-	-	-	-	1	0.01	1	0.01	1	0.01	1	0.01

Note: The following applies to all tables in A-4, OSRA Conditional and Combined Probability Tables:

** = Greater than 99.5 percent	LDPI = Liberty Development and Production Island
- = less than 0.5 percent	PL = Pipeline.

Rows with all values less than 0.5 percent are not shown.

A-5 Very Large Oil Spill Scenario

A-5.1 Background

The potential environmental effects of a low-probability, high impact event—a hypothetical VLOS in the Proposed Action Area from the proposed LDPI—are analyzed below. This VLOS analysis is comprised of three sections:

- Section A-5 (VLOS Scenario) describes a hypothetical VLOS by providing background information and explaining the specific parameters that characterize the hypothetical VLOS.
- Section A-6 is a summary of recovery and cleanup actions following a hypothetical VLOS.
- Section A-5 analyzes potential environmental impacts that could occur in the very unlikely event of such a hypothetical VLOS in the Beaufort Sea.

A-5.2 OCS Well Control Incidents

A VLOS is not estimated to occur during the life of the development project and would be considered well outside the normal range of probability, despite the inherent hazards of oil development related activities. BOEM (2012) provides a detailed discussion of the OCS well control incidents and risk factors that could contribute to a long duration loss of well control (LOWC). General risk factors include geologic formation and hazards; water depth and geographic location; well design and integrity; LOWC prevention and intervention; scale and expansion; human error; containment capability; response capability; oil types and weathering/fate; and specific regional geographic considerations, including oceanography and meteorology.

A VLOS is a subset of large spills (large spills are defined in FEIS Section 4.1.1.4), which is sometimes also called catastrophic. For the 2017-2022 Five-Year Program Final PEIS (USDOI, BOEM, 2016), BOEM defined a reasonable range of potentially catastrophic OCS spill sizes by applying extreme value statistics to historical OCS spill data (Ji et al., 2014). Extreme value statistical methods and complementary methods (Bercha Group, 2014) were used to quantify the potential frequency of different size spills following LOWC.

BSEE defines a LOWC in the context of its incident reporting requirements (30 CFR 250.187 and 250.188), as uncontrolled flow of formation or other fluids underground (underground blowout) or at the surface (surface blowout) during all types of operational phases (exploration, development, and/or production operations) (USDOI, BOEM, 2016). In combining the estimated per well spill frequency (0.0000246 spills per well) for spills greater than or equal to the VLOS volume (the VLOS volume is assumed in this analysis to be 4,610,000 bbl [4.6 MMbbl] and is explained in greater detail below) with the estimated total number of potential wells that penetrate the reservoir, 14 (6 injector and 8 producer wells (Hilcorp, 2015a, Section 2.2, p. 7), no very large spills are estimated to occur over the life of the development project. The per well frequency of spills caused by a LOWC incident equal to or exceeding the VLOS volume of 4,610,000 bbl is derived using the equation from the 2017-2022 Five-Year Program Final PEIS (USDOI, BOEM, 2016). In applying the per well spill frequency resulting from a loss of well control event (USDOI, BOEM, 2016) to estimate the likelihood of a hypothetical VLOS specifically from the Liberty Development project, it is important to note that the OCS spill database used to derive the per well spill frequency includes spills from exploratory wells, whereas the wells drilled at Liberty are developmental wells. The frequency of a loss of well control event (a potential precursor to a spill) was higher for exploration wells in the US GOM OCS than that of development wells from 1980-2011 in the same region (Bercha Group, 2014); therefore, the application of the per well spill frequency (USDOI, BOEM, 2016) may overstate the likelihood of a hypothetical VLOS.

The hypothetical VLOS volume of 4.6 MMbbl referenced above is based on Hilcorp's estimate of a WCD volume which was independently verified by BOEM (see the following discussion and DPP Section 14.3 for additional information).

As a supplement to the above hypothetical VLOS occurrence estimation, BOEM includes a separate metric for estimating the likelihood of a spill greater than 150,000 bbl (distinguished from a hypothetical VLOS) which is based on developmental wells and does not include exploration well spill data. Bercha Group, Inc., modified the historic LOWC frequency (that lead to spills greater than or equal to 150,000 bbl) for OCS development wells by accounting for Arctic conditions; the LOWC frequency is estimated to be 0.0000044 spills per well (Bercha Group, 2016). In combining this per well spill frequency with the number of potential wells drilled into the reservoir (14 wells), no spills over 150,000 bbl are estimated to occur as a result of the project.

Taking into account the low chance that a development well (production or injector well) would experience a LOWC (see above estimates) which then escalates into a long duration blowout, coupled with the observed low incidence rates for accidental discharges in the course of actual drilling operations, BOEM estimates a very small, but not impossibly small, chance for the occurrence of a VLOS event. But this consideration of probability is not, nor should it be, integrated into the VLOS model. The hypothetical VLOS discharge quantity is "conditioned" upon the assumption that all of the necessary chain of events required to create the VLOS actually occur (appropriate geology, operational failures, escaping confinement measures, the spill reaching the environment, etc.). The hypothetical VLOS discharge quantity is, therefore, not "risked" or reduced by the very low frequency for the occurrence of the event.

A-5.3 Hypothetical VLOS Scenario

As part of the DPP, the operator has submitted an estimation of a WCD volume. The WCD estimation is required by 30 CFR Part 550.213(g) to accompany an EP or a DPP and provide a basis for an OSRP in accordance with 30 CFR Part 254.47. The WCD volume information submitted by the operator and independently verified by BOEM provides the basis for the volume used in the VLOS scenario.

The VLOS scenario is predicated on an unlikely event—a LOWC during developmental drilling that leads to a VLOS. BOEM bases the VLOS volume estimate on Hilcorp's estimated WCD from a LOWC incident during developmental drilling (See DPP Section 14.3). Hilcorp estimates that, in this worst case scenario, 4.6 MMbbl could spill over the course of 90 days (Hilcorp, 2015, Table 14-3) assuming that the hypothetical LOWC was stopped by a relief well rather than other proposed well control methods which have shorter estimated times to stop the spill. In addition to the 90 day oil spill volume, Hilcorp estimated a first day oil spill volume of 91,219 bbl and a first day gas spill volume as 84,538,512 scf (Hilcorp, 2015, Table 14-3). The (American Petroleum Institute [API] gravity of the oil discharged from the well is estimated to be 27° API (Hilcorp, 2015, Appendix I). As stated, the duration of the hypothetical spill resulting from a blowout depends on the time required for successful intervention and response. The spill's duration of 90 days is the total estimated time it could take to mobilize a second rig, drill the relief well, and then kill the blowout. Hilcorp estimates that it could take between 10 and 30 days to mobilize a relief rig and then an additional 30 to 60 days to drill a relief well and kill the blowout. A technique proposed by Hilcorp as a response to controlling a blowout but not considered in this hypothetical VLOS scenario is well capping (discussed in Section A-6.2). Hilcorp states that well capping could regain well control in a total of 10 to 20 days versus this VLOS scenario, which has a duration of 90 days to control the blowout through relief well drilling. Further, Hilcorp's estimated WCD volume and this hypothetical VLOS scenario do not take into account the proposed blowout response technique of well ignition, which could reduce the amount of oil spilled. For example, Hilcorp estimates that 90 percent of oil can be combusted by well ignition (see Hilcorp DPP Sections 14.3.1.1 and 14.3.2.1). For additional information on Hilcorp's blowout prevention and well control procedures, see DPP Appendix H, DPP Section 8, and DPP Section 14.1. The intervention methods not included in this hypothetical VLOS scenario (i.e., well capping and well ignition) are discussed generally below in Section A-6.2.

Hilcorp's WCD estimate is developed based on assumptions summarized in DPP Section 14.3. The volume of WCD is the daily production volume summed over 90 days from an uncontrolled blowout of the highest capacity well that could be drilled into the reservoir. Some of the WCD assumptions that Hilcorp uses are that the blowout preventer systems fail, the wellbore is absent of drilling mud, and the open hole does not collapse. BOEM Office of Resource Evaluation (ORE) completed an independent verification of Hilcorp's WCD model. ORE's verification included constructing a geologic model for the Liberty reservoir using commercially available reservoir simulation software (MERLIN) which when combined with tubing flow curves generated by the interdependent wellbore nodal analysis software (AVALON) estimates the flow of fluids from the reservoir into the well and released at the wellhead.

Hilcorp references the Alaska Clean Seas Technical Manual for the modeling of an uncontrolled surface blowout (Alaska Clean Seas, 2015; Hilcorp, 2015). The blowout from the well causes an oil plume from the wellhead in the direction of the prevailing winds (Hilcorp, 2015). The gas flow rate, plume height, and size of the oil droplets can affect the fallout distribution of oil (Alaska Clean Seas, 2015). Other parameters that can affect the behavior of oil and gas after the initial blowout are turbulence in the atmosphere and oil particle settling velocity (S.L. Ross, 2000). Larger droplets of oil would tend to land closer to the blowout source, while smaller droplets of oil would tend to fall farther downwind from the source (S.L. Ross and D.F. Dickins and Associates, 1998). Literature also provides estimates for the percentage of oil from a hypothetical spill that falls within a specified distance from the blowout source (Belore et al., 1998). Further, some of the oil from the blowout plume could evaporate or become suspended in the atmosphere depending on the size of the droplets (S.L. Ross and D.F. Dickins and Associates, 1998). For a surface blowout at Endicott Island, an existing offshore island development in Alaska, BPXA assumed drops of oil less than a specified threshold size would be held aloft by atmospheric turbulence (BPXA, 2012).

Section A-5.3.1 through Section A-5.3.3 describe the behavior of hypothetical oil spills after the initial blowout during three scenarios: open-water, winter, and break-up and freeze-up.

A-5.3.1 Hypothetical VLOS Scenario for Open-Water or Summer

An open-water or summer spill[1] would begin between approximately July 15 and October 1, based on the operator's proposed periods of reservoir drilling when a blowout could occur and associated seasonal restrictions when a blowout would not likely occur as reservoir drilling restrictions exist (see the 2015 Liberty DPP, Section 8.1 for seasonal drilling restrictions).

The oil from a hypothetical blowout would land on the open water (a similar assumption was made for a hypothetical Liberty surface blowout[2] analysis conducted by S.L. Ross Environmental Research Ltd. [see S.L. Ross, 2000]). Oil from a blowout could also fall on the proposed LDPI, and a percentage of this oil could drain into the open water (USDOI, MMS, 2002). Movement of the oil that falls on the LDPI can potentially be affected by the LDPI grading plan which redirects flow of minor spills to sumps, where separators are located (see Hilcorp, 2015, Section 11.10). A sheet pile wall on the LDPI could provide a degree of containment based on a similar design used in another offshore Alaskan facility, Endicott SDI (see BPXA, 2012; Table 1-17 in Response Action Plan). Oil that reaches the open-water can be affected by wind, currents, and weathering processes (S.L. Ross and

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[1] Another source of a spill during open water is a late season winter blowout. A late season winter blowout could begin around June 1 and flow for 90 days until a relief well is drilled during summer.

[2] The surface blowout size that SL Ross analyzed was 5,500 barrels of oil per day.

D.F. Dickins and Associates, 1998); specific weathering processes are discussed below in Section A-5.4. Both tidal currents and longshore currents may affect the movement of oil (S.L. Ross and D.F. Dickins and Associates, 1998). The direction and velocity of the currents can influence the size of a slick (S.L. Ross, 2000).

During the open-water period, there could be intermittent ice floes (see 2016 Liberty Draft EIS Section 3.1.2.4, Sea Ice), and if oil was present in the water before the ice floes moved into the area of the spill, oil would flow around the ice and accumulate at the water surface (Lee et al., 2015). S.L. Ross predicted that oil from a blowout at Liberty could also fall on transitioning ice floes and would evaporate as opposed to spreading or emulsifying on the ice's surface (S.L. Ross, 2000).

A-5.3.2 Hypothetical VLOS Scenario for Winter

A winter spill would begin between November 15 and June 1 based on the operator's proposed periods of reservoir drilling and associated drilling restrictions (see Hilcorp, 2015, Section 8.1). Another source of a spill during winter is a late season summer blowout. A late season summer blowout could begin around October 1 and last 90 days until a relief well is drilled, which could be during winter.

For a winter blowout, Hilcorp discusses how spill modeling has shown that the majority of oil would settle within 2 miles of the blowout, an area covered by landfast ice in mid-winter (Hilcorp, 2015; Alaska Clean Seas, 2015). Further, the oil from a blowout would have a high viscosity, rapidly spread, and gel (Hilcorp, 2015; S.L. Ross, 2000). A surface blowout during winter where a percentage of oil falls to the ground near the source can coat the surfaces of snow (Nelson and Allen, 1982; Belore et al, 1998; Buist et al., 2013). Some of the oil from the blowout that landed on the proposed LDPI could drain onto frozen ice (USDOI, MMS, 2002). The roughness of the ice surface, wind speed, and volume of snow present are all parameters that can affect the areal extent of oil spilled onto ice (S.L. Ross and D.F. Dickins and Associates, 1998). A snow/oil mulch can form if oil is spilled during snowfall or if snow blows onto an oil pool (McMinn and Golden, 1973). If oil is spilled on snow covered (landfast) ice, it can move below the snow to the ice layer (Lee et al., 2011). If oil spills under ice in late winter, due to the slowed growth rate of new ice at this time, it would most likely not become encapsulated within the ice (TRB and NRC, 2014). An oil spill during mid-winter may be contained on the stable ice cover (Buist et al., 2013); therefore, it may be possible for the spill to be cleaned up using proposed recovery methods (see Section A-6) and thus not contact any resources.

A-5.3.3 Hypothetical VLOS Scenario for Break-Up and Freeze-up

While a LOWC incident during developmental drilling leading to a blowout and a hypothetical VLOS is not estimated to occur in the shoulder seasons (freeze-up or break-up) due to restrictions on reservoir drilling by the operator, the spill resulting from an open-water or winter blowout may persist into the freeze-up or break-up periods.

The behavior of oil in sea ice can vary depending on the concentration of ice present. For example, if spilled oil is present in 30 percent or greater concentration of ice, the oil can drift with the ice (Lee et al., 2011). The behavior of oil in sea ice concentrations less than 30 percent can be similar to that of oil in open-water conditions (Venkatesh et al., 1990; Brandvik et al., 2006). In ice concentrations greater than 50 percent, oil may be restricted to spreading between ice floes, if present (S.L. Ross and D.F. Dickins and Associates, 1998). With respect to oil's potential contact with icy shorelines, it is generally dependent on the time at which it spills. For example, if oil comes in contact with a shoreline before ice formation, it can remain trapped there until the melting season, whereas, if the oil arrives after ice formation, it can be kept off of the shoreline (Fingas, 2015).

If spilled oil is present when new ice is forming during freeze-up, it can become encapsulated within the ice structure and remain trapped until spring (Lee et al., 2011), or it can remain on top of the ice as the ice forms (Lee et al., 2015). The weather conditions during freeze-up can affect the fate and behavior of oil. For example, winds during storms can break up ice that had initially entrained the oil and displace it until the next freezing cycle (the next freezing cycle typically occurring within hours or days) when it can then get re-encapsulated (S.L. Ross and D.F. Dickins and Associates, 1998). The migration of oil through brine channels and the melting of the ice sheet are two common ways in which encapsulated oil can become released during spring (Lee et al., 2011). During spring, encapsulated oil can migrate up through brine channels and form pools on the surface of the ice (Lee et al., 2011). Trapped brine within the sea ice can create vertical channels for oil to migrate through when temperatures rise (Dickins and Buist, 1999).When oil reaches the surface of the ice after it has migrated up through brine channels, it can be absorbed by the overlying snow (if present) before increasing the absorption of solar radiation on the ice to form oil melt pools (NORCOR, 1975). The pour point[3] of Liberty crude oil (37°F) can affect the speed at which migration of the oil through brine channels takes place (S.L. Ross, 2000). The level of solar radiation can also affect the rate at which oil migrates up through brine channels, as demonstrated by observations of oil interactions with fast ice in Cape Parry in the Beaufort Sea (NORCOR, 1975). The migration may also be inhibited by the gelling tendency of the oil and in effect, remain encapsulated until the ice has melted down to its depth to expose it (S.L. Ross, 2000).

During spring break-up, rivers discharge fresh water on top of sea ice and landfast ice breaks off of the shore and melts (see BOEM 2016 Liberty Draft EIS, Section 3.1.2.4). The overflooding of rivers would act to redistribute oil that was spilled on ice (Hearon et al., 2009). In another scenario, if oil is spilled into broken ice during spring break-up, it can coat the ice surfaces or become contained within ice floes (S.L. Ross and D.F. Dickins and Associates, 1998).

Based on laboratory tests and spill observations, waves could move oil present in water to ice surfaces (Fingas and Hollebone, 2003). In leads[4], oil that was initially on the surface of the water could move to the surface of adjacent ice or underneath it, depending on the lead closure rate (MacNeil and Goodman, 1987; Lee et al., 2011); however, analysis of lead pumping (i.e., the redistribution of oil from water to the ice) in the Beaufort Sea has shown that it is rare for oil to get on top of the ice; rather it would likely end up underneath the ice (Fingas, 2015). If oil were to get underneath the ice, it could form reservoirs and subsequently become separated from the ice surface by under-ice currents, if currents were of sufficient velocity (Lee et al., 2011). The surface roughness of the ice can determine the holding capacity of oil; for example, the higher the surface roughness, the more oil that could be contained within cavities (Drozdowski et al., 2011). The under-ice storage capacity of oil underneath landfast ice can vary depending on the time during winter; for example, later season ice can have greater storage capacities than earlier, smoother season ice (Kovacs et al., 1981; Barnes et al., 1979; Dickins and Buist, 1999).

A-5.4 Fate and Behavior of an Oil Spill

The general weathering processes and behavior of oil in Arctic ice-free waters may include spreading, fragmentation into smaller sized slicks, evaporation, dispersion, emulsification, oxidation, sedimentation, biodegradation, and dissolution (Lee et al., 2011). In cold water or when ice is present, the weathering of oil can be slower or non-influential (TRB and NRC, 2014). During freeze up, specific weathering processes that can affect oil are evaporation, dissolution, emulsification, and dispersion (TRB and NRC, 2014). The fate and behavior of oil spilled under ice may include spreading, evaporation, dispersion, emulsification or biodegradation and these processes can be slower or non-influential (Lee et al., 2015).

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[3] The pour point is the temperature in which a fluid becomes semi solid and can no longer flow (Lee et al., 2015).

[4] Leads are vessel navigable passages through sea ice (Fingas, 2015).

Horizontal transport takes place via spreading, advection, dispersion, and entrainment while vertical transport takes place via dispersion, entrainment, Langmuir circulation, sinking, overwashing, partitioning, and sedimentation (USDOI, MMS, 2007b, Appendix A, Figure A.1-1and Figure A-2). The persistence of an oil slick is influenced by the effectiveness of OSR efforts and affects the resources needed for oil recovery (Davis et al., 2004). The persistence of an oil slick may also affect the severity of environmental impacts as a result of the spilled oil.

Key weathering processes that may be relevant to the persistence of an oil spill in an Arctic marine environment are discussed below and are shown in Figure A-5-1 and Figure A-5-2.

A-5.4.1 Spreading

Spreading refers to how oil is affected by a variety of physical properties (including viscosity, buoyancy, and surface tension) as well as how it moves. Oil may coalesce into a denser area known as a slick, and a thinner area known as a sheen that is concentrated along the outer portions of the slick (Lee et al., 2015; Drozdowski et al, 2011). The air and water temperature, wind, and wave state can affect how oil spreads (Lee et al., 2015). Due to the interfacial tension of Liberty crude, sheens are predicted to form on the water when oil is spilled even after considerable weathering (S.L. Ross, 2000). The presence of ice can limit the spreading of oil and concentrate slicks. The spreading of oil in ice depends on the amount and type of ice coverage. The oil film thickness can increase with higher ice coverage (Brandvik et al., 2006). Additional information on the spreading of oil in winter, summer, and freeze-up/break-up are discussed in Section A-5, above.

A-5.4.2 Evaporation

Generally, evaporation causes the loss of the lighter components of the oil and this process can affect its bulk properties (TRB and NRC, 2014). Evaporation of oil on ice during winter is slower compared to oil spilled in open-water (Lee et al., 2011). The evaporation rate of oil is affected by the slick thickness, wind speed, and air temperature (Lee et al., 2011). The evaporation of oil is affected by the surface area in contact with air (S.L. Ross, 2000) and can be inhibited by colder air temperatures (TRB and NRC, 2014). The presence and degree of compaction of snow (if present) can affect the evaporation rate for oil; in field experiments, evaporation was higher when no snow was present, slower in un-compacted snow, and slowest in the densest compacted snow (Belore and Buist, 1988).

At freezing temperatures, the evaporation of Liberty oil (a waxy crude oil) can be affected by the formation of skin around the surface of the slick during weathering. This skin can hinder lighter components within the oil from escaping the slick to the air (S.L. Ross, 2000). Experiments indicate this may occur when the oil has lost 20 percent of its volume by evaporation (S.L. Ross, 2000).

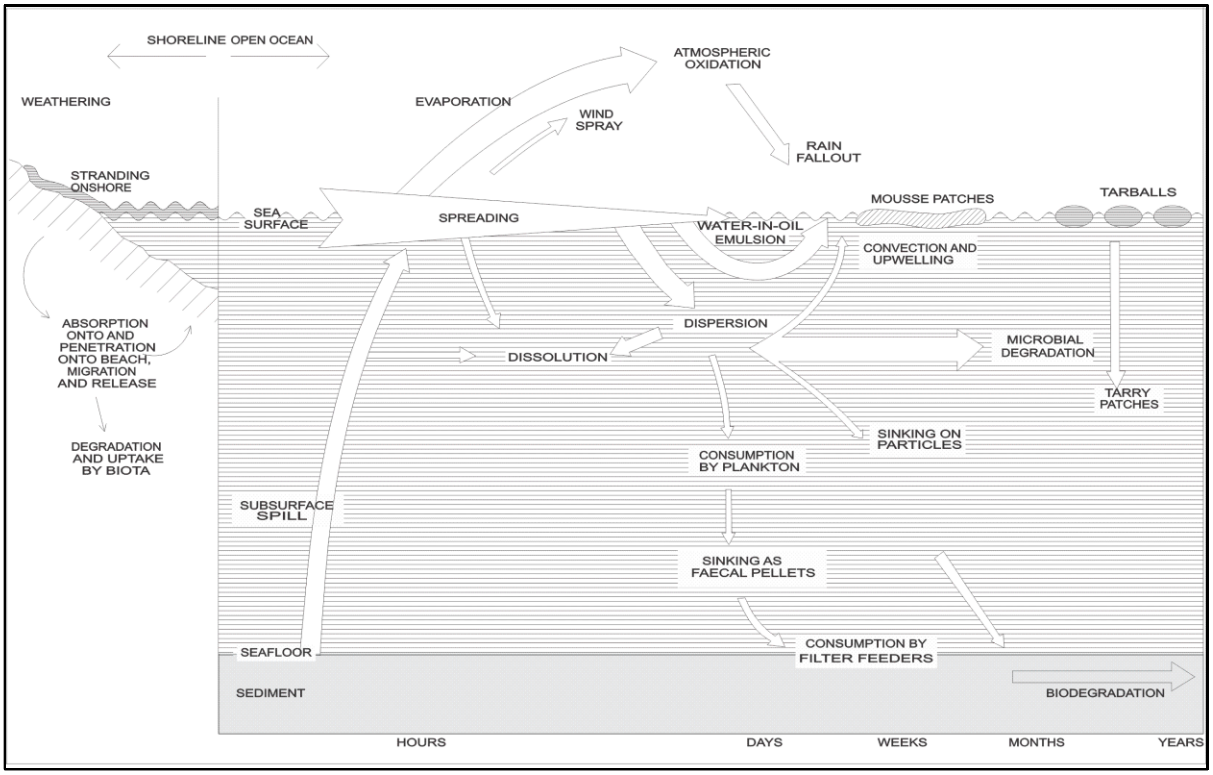

Figure A-5-1 Oil Spill Weathering Processes and Behavior in an Arctic Open Water Environment *(Modified from A. Allen, 1980)*

A-5.4.3 Emulsification

Emulsification occurs when small droplets of one liquid, such as water, are suspended in another liquid, such as oil (Fingas, 2015; ITOPF, 2014). The cause of water-in-oil emulsion formation is thought to be sea energy (Fingas, 2015), or wave action (S.L. Ross, 2000). The viscosity[5] of the oil at ambient temperatures, the availability and amount of mixing energy, and the asphaltene content can influence when an emulsion can form (MAR et al., 2008). Emulsification can increase the bulk volume of the spilled oil through the increased intake of water (S.L. Ross, 1998; Fingas, 2015; Lee et al., 2011). Three types of emulsions that generally form are unstable, mesostable, and stable emulsions (Fingas, 2015). Liberty oil is predicted to form stable emulsions (S.L. Ross, 2000). Both fresh and weathered Liberty crude oil formed stable emulsions in laboratory experiments conducted at 1°C (S.L. Ross, 1998). Stable emulsions are associated with higher viscosity, longer stabilization times, and the formation of mats (Fingas, 2015; S.L. Ross, 2000). The amount of ice present near the oil can affect the extent to which the crude emulsifies; higher ice concentrations can dampen wave activity limiting the emulsifying process (S.L. Ross, 2000). In laboratory weathering experiments of an Endicott crude oil sample, considered an analogue for Liberty crude oil (S.L. Ross, 2000), it was shown that emulsion formation took place in the presence of varying ice concentrations with high wave energy (MAR et al., 2008). Spills of Liberty crude oil directly onto fast ice are predicted not to emulsify (S.L. Ross, 2000).

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[5] The viscosity of the oil slick can affect the amount of small droplets entering it; higher viscosity oil can prevent water from entering the slick (Fingas, 2015). Whether an emulsion forms after water has entered the oil slick is dependent among other factors such as the amount of asphaltenes and resins present (Fingas, 2015).

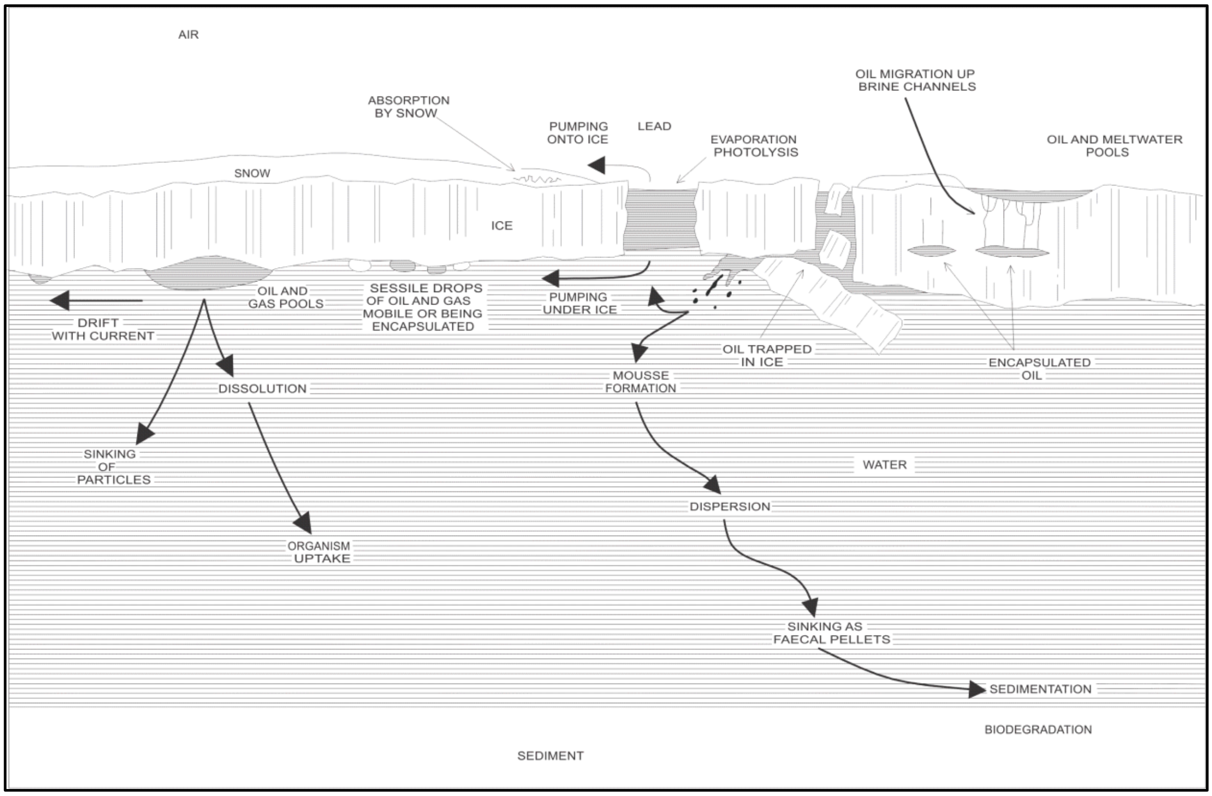

Figure A-5-2 Oil Spill Weathering Processes and Behavior in an Ice-present Arctic Environment *(Modified from A. Allen 1980)*

A-5.4.4 Natural Dispersion

Natural dispersion refers to the process by which waves or turbulence in the water moves oil from the slick into the water column (Lee et al., 2015; Fingas, 2015). Waves can break the oil into droplets of differing sizes which are dispersed into the shallower part of the water column (ITOPF, 2014). The rate of dispersion can depend on the sea state as well as the specific spilled oil properties (Lunel, 1995; Fingas, 2015). Dispersion of oil into the water column can make oil that was originally in the slick available for other weathering processes like dissolution or biodegradation (Brakstad et al., 2015; Prince, 2015; Lee et al., 2015). Spills on winter ice are assumed not to disperse based on predicted characteristics of Liberty crude oil (S.L. Ross, 2000).

A-5.4.5 Dissolution

Dissolution is the process by which water soluble compounds of the oil such as aromatics preferentially dissolve into the water (Faksness and Brandvik, 2008a; Fingas, 2015). Field experiments have been performed demonstrating the dissolution of oil through sea ice (Lee et al., 2011); the temperature of the air can affect the porosity of the ice and thus the rate of dissolution (Faksness and Brandvik, 2008b). Colder air temperatures promote more solid ice (as opposed to warmer temperatures causing higher porosity in ice), slowing the rate at which the water soluble compounds of the oil drop out of the ice (Faksness and Brandvik, 2008(a); Faksness and Brandvik 2008b; Lee et al., 2011).

A-5.4.6 Photooxidation

Photooxidation is the weathering process by which ultraviolet light (Lee et al., 2015) can create new products, such as resins, from the carbon and oxygen present in oil (Fingas, 2015).

A-5.4.7 Biodegradation

Biodegradation is the process by which microorganisms consume oil as a food source. Biodegradation rates are dependent on the type of hydrocarbon; aromatics and asphaltenes are biodegraded slower than saturates (Fingas, 2015).

A-5.4.8 Sedimentation

The sedimentation of oil can occur in the nearshore environment where sediment content is higher. Oil can interact with or attach to sediments in the water column and, as a result, become sequestered on the sea floor (Lee et al., 2011 and Fingas, 2015).

A-5.5 Hypothetical VLOS Conditional Probabilities and Trajectory Modeling

BOEM has conducted OSRA modeling to estimate the percent chance of a large spill contacting a particular resource within a particular time period and season from the Proposed Action Area. A particular resource may be described by ERAs, LSs, or GLSs as shown in Tables A.1-A.11. BOEM uses the conditional probabilities from the large spill analysis to estimate the percentage of trajectories from a VLOS contacting biological, social, and economic resources of concern in and adjacent to the Proposed Action Area. No special OSRA run was conducted to estimate the percentage of trajectories contacting resources from a blowout resulting in a VLOS.

Conditional probabilities resulting from the OSRA refer to the condition (assumption) that a VLOS has occurred. There are some differences between this VLOS analysis and BOEM's earlier analysis of a large oil spill in Section 4.1.1.4 of the Liberty FEIS. A long duration hypothetical VLOS would consist of a spill occurring continuously for up to 90 days (Hilcorp, 2015, Section 14.3). In this case, there would be multiple trajectories over time with each trajectory launched regularly as the well continued to flow. The multiple trajectories representing a hypothetical VLOS change how the conditional probabilities from the large spill analysis are interpreted. In this case, each trajectory models how some fraction of the hypothetical VLOS could spread to a specific resource or location. The conditional probabilities would represent how many trajectories come to that location, described as percent trajectories (number of trajectories contacting a location/total number of trajectories launched). A higher percentage of trajectories contacting a given location could mean more oil reaching the location depending on weathering and environmental factors. The terminology used hereafter is "percentage of trajectories contacting."

The operator proposed confining reservoir drilling to the estimated dates of July 15 through October 1 (open-water time period designation by Hilcorp) and November 15 through June 1 (frozen ice time period designation by Hilcorp). Section 3.1.2.4 describes break-up beginning in late May and lasting through June or early July.; therefore, it is assumed the hypothetical VLOS begins in the open-water or frozen ice periods as opposed to beginning in either the freeze-up period or break-up period when the operator isn't conducting reservoir drilling. However, while the VLOS doesn't begin in the freeze-up or break-up periods, it could still flow during these periods (e.g., late season open-water or winter blowout that lasts during the shoulder seasons). For this reason, BOEM assumes that conditional probabilities for the summer, winter, or annual time periods are applicable for the VLOS analysis. Further, as the operator states that it could take 90 days to drill a relief well, BOEM conservatively assumes that the time period in which to analyze contacts to resources is at least 90 days but can also be up to 360 days. The percentage of trajectories contacting resources within 90 and 360 days from a blowout leading to a VLOS (at Liberty Island) occurring annually, in summer, or in winter are provided in Tables A.2-5, A.2-6, A.2-11, A.2-12, A.2-17, A. 2-18, A.2-23, A.2-24, A.2-29, A. 2-30, A.2-35, A.2-36, A.2-41, A.2-42, A.2-47, A.2-48, A.2-53, and A.2-54. Within these tables, the trajectories contacting resources from Liberty Island (LI) are applicable because the blowout is assumed to occur from a well on the island.

The combined probabilities which are discussed earlier in Chapter 4 for the large spill analysis are not relevant to this VLOS analysis.

A-5.6 Gas Release

The quality and quantity of components in natural gas vary widely by the field, reservoir, or location from which the natural gas is produced. Natural gas is primarily made up of CH_4 and ethane (C_2H_6) which make up 85 percent to 90 percent of the volume of the mixture. BOEM makes general assumptions about a hypothetical gas release as a result of the VLOS in the proposed action. BOEM estimates that 7.26 Bcf of gas could be released over 90 days in the worst case scenario; this estimate is based on Hilcorp's WCD model discussed in Section 14.3 of the DPP.

A-6 Recovery and Cleanup

In the event of a large spill or hypothetical VLOS, response equipment and personnel would be mobilized from locations around the Prudhoe Bay industrial complex, followed by assets being pulled in from locations around Alaska and then other U.S. caches. Personnel would be berthed in available housing at the man-camps and hotels located across the North Slope, temporary man-camps that can be flown or barged in, and possibly airplane hangars at the Deadhorse airport. Camps at Badami and Point Thompson could also be used to house and accommodate workers in the event of a large spill and cleanup operation.

A spill occurring during the open-water season from late June through early November would result in the greatest level of activity. A hundred or more small and medium sized vessels (12 feet to 55 feet) would be employed to respond to the spill due to the shallow water depths near and around the LDPI. The use of an OSRV or ORSB would be required to collect oil that spilled into the open ocean, and to serve as on-water storage for recovered fluids. The OSRB will have an associated tug and high-volume skimmers to recover oil (Hilcorp, 2015). Nearshore skimming vessels would use a boom that directs the oil to a skimmer which is then pumped into mini-barges (Hilcorp, 2015; Alaska Clean Seas, 2015, Tactic R-17). The OSRB, skimming vessels, and mini barges offload collected oil at Endicott SDI or the proposed LDPI.

During the summer months, operations would run around the clock given the long periods of daylight. Responders would utilize several miles of various types and sizes of containment boom to control the spread of the oil on the water surface and to exclude or divert oil from contacting sensitive areas. Several hundred additional personnel would be required to conduct oil spill containment and recovery operations, and to support the responders with maintenance and camp services. A boom, deployed at the Endicott Causeway bridges (approximately 7.3 miles west-northwest from the proposed LDPI location), is used to collect oil in the Harbour buster collection point where these fluids are then pumped into a mini-barge or shoreside storage (Hilcorp, 2015; ACS Tactic R-33). Shoreline and onshore recovery techniques include the use of workboats and airboats which deploy boom and anchors in Foggy Island Bay. Skimmers can then pump oil into temporary tanks (Hilcorp, 2015; Alaska Clean Seas, 2015, Tactic R-16).

During summer, ISB could be employed as a response strategy in which oil at the sea surface is intentionally ignited. The operations can be monitored by air or ground. Oil is collected by boom that is either anchored to shore or towed on the water by tow boats. Once the oil is collected, it is ignited. An igniter boat and hand-held igniter with diesel and road flare are used to burn the oil. The amount of residue after a burn would depend on the environmental conditions and effectiveness of the burn (Hilcorp, 2015). The residue is characterized as being taffy-like and viscous and will either be buoyant, negatively buoyant, or neutral (Hilcorp, 2015). The residue is collected into booms or nets, and then strainers, hand tools, skimmers or sorbents are used for picking up the material (Hilcorp, 2015).

On-water response efforts would continue until formation of ice prevented ready access to the oil. Unless the well was still flowing, response efforts would most likely be suspended until stable solid ice formed in the area. During the shoulder seasons, equipment including hovercraft, amphibious Haagland personnel/small equipment carriers, airboats, an amphibious Ditch Witch trencher, and amphibious backhoes would be used (Hilcorp, 2015). During freeze-up, skimmers would be deployed from bridges at Endicott causeway or from workboats. Skimmers could collect oil in pockets from broken ice (Hilcorp, 2015). During that transition period when vessels and skimmers become ineffective, ISB would be used to reduce the volume of oil in the environment. The oil on the ocean surface and on the shoreline would be encapsulated by the growing ice sheet. The use of tracking equipment such as buoys and ice beacons would be used to track the oil in ice during the winter to facilitate recovery once the ice begins to rot and melt. Response efforts would resume in the late spring as the ice sheet begins to melt and the oil begins to surface through brine channels in the ice sheet and collects in melt pools on the surface of the ice. Response tactics would initially involve ISB of the oil on the melt pools and then resume use of mechanical systems once broken ice conditions allow vessel access. ISB operations may involve helicopter use to assist in the burning of oil in melt pools or oil pockets. During overflood of the rivers, airboats would deploy boom in a U-configuration and conduct ISB operations (Hilcorp, 2015).

In the event of a winter blowout, response methods would be similar to those employed on shore. Instead of using boats and skimmers to mount a response, responders would utilize front-end loaders, bulldozers, vacuum trucks, dump trucks, and front-end mounted ice trimmers to collect and remove the oil-contaminated snow and ice. To facilitate response, ice roads would have to be constructed to adequately support the equipment and maintain safe operating conditions. Another response method includes the use of direct suction in which a vacuum truck with a hose and skimmer head can collect oil from pooled areas such as natural depressions or constructed trenches (Alaska Clean Seas, 2015, ACS Technique R-6). Backhoes, amphibious backhoes, and dump trucks are used to mine the ice when trimming of the ice can’t be performed. (Hilcorp, 2015).An ice miner can grind oiled ice into a pile which a front-end loader can haul to a dump truck (Alaska Clean Seas, 2015, ACS Tactic R-29). In addition to heavy equipment, response operations would also include the use of snow blowers, shovels, and snowmachines/ATVs with sleds to collect and remove the oil. Further, a snow fence can be installed downwind to prevent oiled snow from spreading (Alaska Clean Seas, 2015, ACS Tactic C-19). Manual recovery of lightly oiled snow may involve the use of shovels and brooms. The oiled snow is swept or shoveled into trash cans which are then hauled off by snow machine, loader, or dump truck (Alaska Clean Seas, 2015, ACS Tactic R-2). A high-density polyethylene curtain fabric (plywood or metal can substitute) known as a containment curtain is deployed into an excavated trench in the ice and is used to prevent spreading of oil underneath the ice (Hilcorp, 2015). ISB would also be utilized to remove oil from the ice surface. Propane weed burners are used to ignite smaller oiled areas while hand-held igniters are used on larger oiled areas. Firebreaks are constructed by creating snow berms with front-end loaders or tracked dozers (Hilcorp, 2015) and plowing is used to concentrate oil into piles which can then be ignited and burned (ACS Technique B-5). Trenches in ice can be used to direct oil on the ice surface to a collection point. Through-ice slots can direct oil underneath the ice to a collection point (Alaska Clean Seas, 2015, ACS Tactic C-11). ISB can be used at these collection points. Residue from ISB operations are collected and transported to Endicott SDI or North Slope pads (Hilcorp, 2015). A temporary waste staging area would be used to collect waste material from the recovery operations, which saves time otherwise needed for the spill response vehicles to access North Slope roads (Hilcorp, 2015). The waste material would eventually end up at disposal sites.

An oil release to solid ice conditions is easier to respond to because the oil's dispersal in the environment is drastically limited by the snow and ice as compared to a spill on water. Response operations would be determined by the stability of the ice sheet. Prior to significant response efforts ice thickness would need to be measured to determine what and/or if any response equipment and personnel can access the area. As the ice thickness grows, heavier pieces of equipment can be used to recover oil. In an early winter response, initial efforts may be limited to ISB until the ice is capable of supporting responders and equipment. Response operations can continue around the clock with the use of artificial light but the duration of work can be limited by the winter weather conditions. Wind and frigid temperatures negatively affect both equipment and personnel. Winds can reduce visibility to zero by creating blizzard conditions shutting down operations. At -35°F, hydraulic systems become severely impacted and with wind chills between -25°F and -40°F workers take more breaks, reducing the amount of time that response activity occurs. At -40°F all but emergency work stops.

For a large spill it would require in excess of 150 pieces of large equipment such as front-end loaders, dozers, dump trucks, ice trimmers, vacuum trucks, and rolligons to support on-ice recovery. In addition, there would be 50 or more snowmachines/ATVs, and snow blowers employed to collect smaller and more remote patches of contaminated oil, snow, and ice. Large scale on-ice operations would occur starting in late December and would continue until ice conditions became unsafe due to melting in mid-June. During the transition period from solid ice to broken ice conditions, ISB would occur using a helicopter and helitorch. Any further response operations would revert to vessel-based systems once the ice sheet fractured creating broken ice conditions. Further, the response tactics can vary depending on the spilled oil's location (on ice, under ice, or within ice), oil's condition, and thickness of the ice (Dickins and Buist, 1999).

The conclusion of the response phase to an incident is based on the ability to continue to recover oil from the environment. When there is no remaining recoverable product, the FOSC will end response operations and efforts will shift to remediation of impacted areas.

A-6.1 Scenario Phases and Impact Producing Factors

This section specifically identifies the manners in which the hypothetical VLOS event described above could impact the environment. The intent of this section is to facilitate thorough yet focused impacts analysis in Section A-7.

The events constituting the VLOS scenario are first categorized into three distinct phases. These phases, which range from the initial blowout event to long-term recovery, are presented chronologically. Within each phase are one or more components that may cause impacts to the environment. These components are termed "Impact Producing Factors," or IPFs, and will be used in Section A-7 to guide the environmental impacts analysis. The specific IPFs listed here are intended to inform, rather than limit, the discussion of potential impacts.

A-6.1.1 Well Control Incident, Offshore Spill and Onshore Contact (Phase 1)

Phase 1 of the hypothetical VLOS scenario comprises the blowout and its immediate consequences. Potential IPFs associated with Phase 1 include the following:

- **Explosion.** Gas released during a blowout could accidently ignite, causing an explosion or be released into the atmosphere.
- **Fire.** A blowout could result in a fire that will burn until the fire is extinguished or the well is capped.
- **Psychological/Social Distress.** News and images of an event could cause various forms of distress.

- **Contact with Oil.** Offshore resources (including resources at surface, water column, and sea floor) could be contacted with spilled oil. Onshore resources could come into direct contact with spilled oil.
- **Contamination.** Pollution stemming from an oil spill may contaminate environmental resources, habitat, and/or food sources.
- **Loss of Access.** The presence of oil could prevent or disrupt access to and use of affected areas.

A-6.1.2 Spill Response and Cleanup (Phase 2)

Phase 2 of the scenario encompasses spill response and cleanup efforts in offshore Federal and State waters as well as onshore Federal, SOA, trust, and private lands along the coastline. Potential IPFs associated with Phase 2 include the following and are categorized by season. See Section A-6, Recovery and Cleanup, for further description of responses during all seasons.

A-6.1.2.1 Summer Response

- **Vessels.** Vessels could be used in support of spill response and cleanup activities.
- **Skimmers.** Boats equipped to skim oil from the surface.
- **Booming.** Responders could deploy booms—long rolls of oil absorbent materials that float on the surface and corral oil.
- **In-situ burning.** Remedial efforts may include burning of spilled oil. Operations could be monitored by air.

A-6.1.2.2 Winter Response

- **Vehicles and Equipment.** Bulldozers, dump trucks, and snow machines could be used on ice roads, frozen ice, or snow for supporting spill response and mechanical recovery.
- **In-Situ Burning.** Remedial efforts may include burning of spilled oil.

A-6.1.2.3 Shoulder Season Response

- **Vessels.** Airboats and workboats could be used in support of spill response and cleanup activities.
- **Vehicles and Equipment.** Hovercraft, trenchers, and ATVs could be used in support of spill response and cleanup activities.
- **In-Situ Burning.** Remedial efforts may include burning of spilled oil. A helicopter could be used to support ISB operations.
- **Skimmers.** Boats equipped to skim oil from the surface.
- **Booming.** Responders could deploy booms—long rolls of oil absorbent materials that float on the surface and corral oil.

A-6.1.2.4 All Seasons

- **Animal Rescue.** Animals may be hazed or captured and sent to rehabilitation centers.
- **Drilling of Relief Well.** A drilling rig (either present on LDPI or transported to location in open-water or the frozen ice season) would drill a relief well to control the blowout. The drilling rig cannot be transported during freeze-up or break-up conditions.

A-6.1.3 Post-Spill, Long-Term Recovery (Phase 3)

Phase 3 of the scenario focuses on the long-term. The exact length of time considered during this Phase would vary by resource. Potential IPFs associated with Phase 3 include the following:

- **Unavailability of Environmental Resources.** Environmental resources and food sources may become unavailable or more difficult to access or use.
- **Contamination.** Pollution stemming from an oil spill may contaminate environmental resources, habitat, and/or food sources.
- **Perception of Contamination.** The perception that resources are contaminated may alter human use and subsistence patterns.
- **Co-Opting of Human Resources.** Funds, manpower, equipment, and other resources required to study long-term impacts and facilitate recovery would curtail availability for other purposes.
- **Psychological/Social Distress.** Distress stemming from a VLOS could continue into the long-term.

A-6.2 Opportunities for Prevention, Intervention, and Response

For the purposes of analysis the discharge is assumed to cease within 90 days of the initial event. The use of 90 days corresponds to the longest time period estimated by the operator for a second drilling rig to arrive on site and complete a relief well. This is a conservative estimate as it does not take into consideration the variety of other methods that would likely be employed to halt the spill within this period such as well intervention, wellhead ignition, and well capping. Some other methods are discussed below and include the estimated time each would take to regain well control.

Potential intervention and response methods are analyzed below as a joint response because their concerted application could substantially decrease the duration, volume, and environmental effects of a spill. These methods are not mutually exclusive; several techniques may be employed if necessary as proposed in the DPP. It may also be possible to apply multiple techniques simultaneously. Again, some of these intervention and response methods could be employed prior to drilling a relief well, and are not factored into the estimated spill duration (of 90 days) as described in the hypothetical VLOS scenario above. The availability and effectiveness of these techniques may vary depending on the nature of the blowout, as well as seasonal considerations. Before discussing LOWC intervention and response techniques, some of the prevention methods and protocols are discussed that could prevent a kick or blowout that would have otherwise led to a spill.

The primary well control planning and operational protocols Hilcorp will have in place include selecting the well location to avoid overpressured zones, pore pressure/fracture gradient knowledge, casing design, and pressure control equipment and operational monitoring (Hilcorp, 2015). For a detailed description, see Hilcorp 2015 (Appendix H).

A primary barrier or tool to preventing a blowout is the column of drilling fluid present in the well during drilling (Wild Well Control, 2010; DNV, 2010). The drilling fluid, with a greater hydrostatic pressure than the pore pressure or formation pressure, keeps the formation fluids from entering the wellbore (DNV, 2010; API, 1987; API, 2010). If formation fluids flow into the wellbore, due to insufficient mud weight as an example, a kick can occur (DNV, 2010; Burgess et al., 1990). Kicks can also occur when drill string is pulled from the hole (tripping). In this case, the drilling mud level drops and thus reduces the hydrostatic pressure if not compensated for by increasing the fluid density before the tripping operation or by filling the annulus with drilling fluid before the hydrostatic pressure decreases by 75 psi, or every five stands of drill pipe (30 CFR 250.456(c)) (Burgess et al., 1990; Wild Well Control, 2016a). Further, lost circulation to abnormally low pressured zones or fractured formations can be a precursor to a kick (Burgess et al., 1990). After a kick occurs, if the formation fluid that initially flowed into the wellbore then proceeds to flow to the surface (i.e. the kick is uncontrolled or unrecognized), the kick now becomes a blowout (DNV, 2010; API 1987; Wild Well Control, 2016a).

Secondary barriers to preventing a blowout include the use of blowout preventer (BOP) equipment, kill choke lines, wellhead seals, and casing and cement (DNV, 2010), some of which are discussed below.

Natural bridging or plugging could also occur in which a loss of pressure within the wellbore (in the event of a blowout) causes the surrounding formation to cave in, thereby bridging over or plugging the well. While natural bridging or plugging could render certain forms of operator-initiated well control infeasible, it could also impede or block the release of hydrocarbons from the reservoir from reaching the surface. The majority of Gulf OCS blowouts from 1960 through 1996 were controlled by bridging (either passive or active) (Skalle et al., 1999).

A-6.2.1 Well Intervention

If a kick or blowout occurred, the original drilling rig would initiate well control procedures. The procedures would vary given the specific situation, but could include:

- **BOP Use.** The use of BOP equipment (both ram and annular types) (Hilcorp, 2015). The rams can seal the wellbore (DNV, 2010) and are distinguished by function including shearing blind rams (which can cut the drill pipe) and blind rams (which can seal an empty wellbore without pipe in the hole) (IADC, 2015). The annular, pipe ram, and variable bore ram type preventers can prevent movement of the pipe by closing in on the annulus where drilling fluid is moving towards the surface, and it can seal the open hole and close in on a variety of sizes of pipe (Rigzone, 2016; Wild Well Control, 2016b).
- **Kill Weight Fluids.** Pumping kill weight fluids into the well to control pressures, once the BOP is closed (Hilcorp, 2015). Hilcorp proposes using the “wait and weight” method, driller’s method, and bullhead to regain well control (Hilcorp, 2015). The wait and weight method uses one circulation to circulate out an influx using mud with an appropriately weighted density (Roy et al., 2007; Burgess et al., 1990). The driller’s method uses two circulations to circulate an influx or kick out of the well (Roy et al., 2007). In the first circulation, the drilling mud (with the original mud weight) circulates the influx out through the annulus while the second circulation is employed if the first circulation was not successful in balancing the pore pressure (Roy et. al, 2007; Burgess et al., 1990). The second circulation uses a heavier kill mud than the first circulation and circulates mud from the surface through the drill pipe and out the annulus (Roy et al., 2007; Burgess et al., 1990). The bullheading method involves the use of mud or kill fluid to displace the influx back into the reservoir (API, 2010; Wild Well Control, 2016c)
- **Replace/Repair.** Replacing or repairing any failed equipment to remedy mechanical failures that may have contributed to the LOWC (such as repairing the existing BOP (Exxon Mobil, 2003))

These techniques cure LOWC events the vast majority of the time without any oil being spilled.

A-6.2.2 Well Ignition

Hilcorp proposes the use of well ignition which could combust an estimated 90 percent of the oil (Hilcorp, 2015). Well ignition reduces the volume and environmental impact of the spill (Conroy et al., 2016; ExxonMobil, 2003). Well ignition works by transferring sufficient energy from a flame to oil droplets within the blowout plume so that the oil (and the methane gas vapor cloud [Hilcorp, 2015]) evaporates and burns (Conroy et al., 2016). The volume, type, and temperature of the oil can affect the amount of energy required to burn it (Conroy et al., 2016). How that energy is transferred from the flame to the oil is influenced by the flame temperature and stability, soot production, water in the oil, blowout flow conditions, oil droplet size distribution, and gas oil ratio (Conroy et al., 2016). Burn efficiency which is determined by dividing the volume of oil burned and evaporated by the total oil spilled (Conroy et al., 2016), can affect the spill volume and environmental impacts because the oil that is not burned can settle on the surrounding area (Conroy et al., 2016). Estimated spill volumes with 85 percent, 90 percent, and 95 percent burn efficiencies for a hypothetical blowout at Liberty are presented by Conroy et al. (2016). For a previous oil and gas development project that had a similar response strategy, ExxonMobil considered the surface intervention of well control that is supplemented by well ignition as the best available technology in its Oil Discharge Prevention and Contingency Plan for the Point Thomson project (ExxonMobil, 2003).

A-6.2.3 Well Capping

Well capping is another well control technique that could be used. While the original BOP is used during drilling to prevent a blowout, a capping stack is brought in if the original BOP has failed (Madrid and Matson, 2014). The capping stack includes a separate BOP ram (Madrid and Matson, 2014) and a connector module that connects the capping stack to the wellbore (Wijk, 2014). Capping is the installation of pressure control (or diverter) equipment, known as a capping stack, on the well to regain control of the blowout through post capping kill operations. Post capping kill operations can include direct shut in (BOP or choke shut in blind rams on the BOP are closed or fluid is diverted through a choke and shut in [Abel, 1995]), bullheading, or a bullhead top kill operation in which kill mud and cement can be pumped through the capping stack (Wijk, 2014) when the well is on shut-in or diversion (Abel, 1995), and/or using the volumetric method. The volumetric method bleeds mud from the system to allow for gas expansion (Abel, 1995). The capping stack can shut in and hold pressure on the blowout well using chokes/valves, and it can also provide for further wellbore intervention (Chen et al., 2013). The soft shut in method refers to the chokes progressively limiting the flow (Madrid and Matson, 2014). The capping stack valves can also close and prevent the flow of oil (Chen et al., 2013). Hilcorp states that the most likely method to stop the blowout after failure of the BOP is well capping and is also a primary mechanism for controlling on-land losses of well control (Hilcorp, 2015). Hilcorp estimates the time to attain well control through the use of well capping is 10 to 20 days based on case studies (Hilcorp, 2015, Section 14). Hilcorp considers the use of well capping and relief well drilling the best available and safest technology (Hilcorp, 2015). Before capping could take place, the blow out well rig would be moved off the wellhead to allow access for installation of the capping stack. If the rig moving system is disabled, then bulldozer, block and tackle, and/or crane would be used (Hilcorp, 2015).

A-6.2.4 Relief Well

A relief well is drilled after surface intervention methods have failed (Harvey, 2014). After a relief rig has drilled a relief well down to the appropriate subsurface location to intercept the wellbore of the blowout well, kill fluid is then pumped from the relief well to the blowout well to regain well control (Flores et al., 2014; Wild Well Control, 2010). Typical planning guidelines for drilling a relief well include 1) identifying a surface location that avoids shallow hazards and faults and considers locations of neighboring well bores; 2) analyzing the relief well drilling feasibility by reviewing the well design and kill modeling (kill modeling may include the estimation of hole size needed at target well intercept point, pump rates, and mud volumes [Wild Well Control, 2010]); and 3) determining the well trajectory that could track the blowout well bore and intercept it at the casing shoe above reservoir depth (Halliburton, 2014).

To drill the relief well, the operator proposes using either a company-owned rig or a contract rig. The company-owned rig would be onsite and pre-positioned at the specified relief well surface location on the LDPI while the contracted rig would be mobilized to the LDPI (Hilcorp, 2015, Appendix H). After broken into modules, the relief rig under contract could be mobilized by barge in open water or on ice road during the winter. If either of these forms of transport aren’t available (i.e., if the ice is not thick enough for travel or if the ice concentration is too high during breakup), then the rig would be staged at the closest location to the start of the transport route until conditions are feasible for mobilizing. The total mobilization time for the relief rig is estimated to be 10 to 30 days (Hilcorp, 2015).

As previously mentioned, the availability and/or effectiveness of certain response and intervention techniques can depend on the type of the blowout and time. With respect to the specific discharge point of a blowout, three major distinctions factor into decisions about responses. Possible discharge paths include 1) at the LDPI surface (and the rig is not destroyed) through leak paths on the BOP or wellhead; 2) below the LDPI/seafloor, outside the wellbore; and 3) at the LDPI surface (and the rig is destroyed). Opportunities for operational intervention and response vary in each of these circumstances.

A-6.2.5 Solid Ice Condition

As discussed in Chapter 2, BOEM received several comments which proposed seasonal restrictions on drilling into hydrocarbon zones as a means to reduce the likelihood of a large or very large oil spill contacting the Beaufort Sea and adjacent coastal areas during broken ice or open water conditions.

BOEM considered the following in developing a proposed Solid Ice Condition:

- Historical applications of this type of condition in SOA offshore waters
- Estimated maximum oil spill volumes from Beaufort Sea gravel islands
- Reservoirs accessed from Beaufort Sea gravel islands
- Ice conditions in Foggy Island Bay
- The frequency of well control events during analogous drilling activities
- The recoverability of oil in ice

BOEM found that the SOA has imposed, or the operator has chosen to adopt, a Solid Ice Condition on Northstar Island, Oooguruk Island, and Spy Island (Nikaitchuq) in the Beaufort Sea.

To determine a reasonable reservoir drilling season, BOEM analyzed fall and spring ice conditions of Foggy Island Bay using mooring data and considered information provided in the Liberty EIA. HAK informed BOEM that confining reservoir drilling to late October through June 1 would only increase the drilling timeline by 3 to 15 months; this is within the scope of the 5-year construction and drilling schedule already presented in the DPP and analyzed in this EIS, and was not determined to be a burdensome operational increase by BOEM or HAK.

Using information from three reports – *Loss of Well Control Occurrence and Size Estimators* (Holand et al, 2015), *Oil Spill Occurrence Rates for Alaska North Slope Crude and Refined Oil Spills* (Robertson et al, 2013), and *Oil Spills in the U.S. Arctic Marine Environment* (NRC, 2014) – BOEM determined that uncontrolled surface blowouts that cause “major” pollution are unlikely; oil spills (no matter the source from the facility and associated infrastructure) are typically small (less than 10 bbl); and oil spills are more easily contained and recovered in ice conditions (also discussed in Section A-5).

BOEM applied this Solid Ice Condition to the Proposed Action:

- Reservoir drilling is authorized only during times of solid ice conditions. For the purposes of this condition, "reservoir drilling" is defined to include initial development drilling (as opposed to workovers, recompletions, and other such well operations subsequently conducted on existing wells) beyond the shoe (base) of the last casing string above the Kekiktuk Formation (i.e. drilling that exposes the Kekiktuk Formation to an open, uncased wellbore). 'Solid ice conditions' is defined as at least 18 inches of ice in all areas within 500 ft of the LDPI.

A-7 Effects of a Very Large Oil Spill (VLOS)

A-7.1 Effects of a VLOS on Water Quality

This section assesses the potential water quality effects in the proposed action area from a VLOS from the LDPI. The volume of the VLOS assumed in this analysis is 4,610,000 bbl. Section A-5 describes the hypothetical VLOS scenario. Section A-5.3 describes the fate and behavior of the spill. Section A-6 summarizes oil spill recovery and cleanup. Section A-6.2 discusses opportunities for prevention, intervention, and response for a VLOS from the Proposed Action.

Hydrocarbon concentrations in water have been measured in various major oil spills around the world. Four months into the Ixtoc release (Gulf of Mexico, 1979 to 1980 at approximately 164 feet water depth), liquid hydrocarbons in the spill plume measured greater than 10 ppm within 5 miles of the release, 0.02 ppm at 15 miles from the release, and less than 0.005 ppm at 25 miles from the release (Boehm et al., 1982). Dispersant Corexit 9527 had been applied to surface waters via aerial application to disperse oil in the region of the Ixtoc spill. Similarly, relative decreases were found for specific toxic compounds such as benzene and toluene (NRC, 1985).

At the Ekofisk Bravo release in the North Sea (1977, surface spill) concentrations of volatile liquid hydrocarbons (present mostly as an oil in water emulsion) ranged up to 0.35 ppm within 12 miles of the site, starting 1.5 days into the 7.5-day release (Grahl-Nielsen, 1978). Lesser amounts of oil (less than 0.02 ppm) were detectable in some samples at 35 miles from the site, but not at 55 miles.

In restricted waters during flat calm, a test spill during the Baffin Island Oil Spill Project resulted in maximum hydrocarbon concentrations in the water column of 1 to 3 ppm (Green, Humphrey, and Fowler, 1982). These concentrations were reached within 2 hours of the spill and persisted through 24 hours. No oil was detected deeper than 9.8 feet, and the most oil and highest concentrations were in the top 3 feet (Mackay and Wells, 1983).

The DWH Oil Spill was a seafloor release in deep water in the Gulf of Mexico. Several subsurface studies were conducted in the months following the DWH Oil Spill (e.g., Camilli et al., 2010; Joye et al., 2011; Yvon-Lewis, Hu, and Kessler, 2011; Kessler et al., 2011; Valentine et al., 2010; Hazen et al., 2010; Kujawinski et al., 2011). These studies focused on the distribution, extent, concentration, composition, and degradation of the DWH Oil Spill oil at depth and over time.

The conditions in the waters at the DWH Oil Spill site differ markedly from the conditions present at the Proposed Action Area. The DWH Oil Spill release occurred in at a depth of 4,921 feet; the Proposed Action is to drill from the surface of a gravel island in 19 feet of water. Oil from the hypothetical VLOS would enter the marine environment from the sea surface. This depth difference is important given how gas and liquids behave differently at various pressures, with more gas staying in solution at greater depths. A greater depth may also present a greater likelihood of distinct density layers and currents that could entrain and transport hydrocarbons. Differences between the Gulf of Mexico and the Beaufort Sea in seasonality, weather and wind patterns, sea ice, and surface water temperatures also make extrapolations from the DWH Oil Spill release and a hypothetical release in the Beaufort Sea problematic.

Water temperatures in the shallow Beaufort Sea are similar to the temperatures in the deepwater Gulf of Mexico, suggesting the Beaufort Sea could support similar levels of hydrocarbon (including methane) degradation. Both methane and petroleum hydrocarbon degraders are present and active in the ice, water, and sediment in the Arctic Ocean in general (Gerdes et al., 2005; Damm et al., 2007; Atlas, Horowitz, and Busdosh, 1978; Braddock, Gannon, and Rasley, 2004).

The following subsections describe the types of effects that could occur during each phase of the VLOS scenario.

A-7.1.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

A-7.1.1.1 Well Control Incident

The initial release event could impact water quality via the release of natural gas. When natural gas (primarily methane) is released into the water, it rises through the water column as a function of pressure and temperature. The quality of the water would be altered temporarily as some of the natural gas enters the water as a water-soluble fraction. Upon reaching the surface the gaseous methane would react with air forming water and CO_2, which would then disperse into the atmosphere. The near-surface water quality would have higher concentrations of CO_2 than is natural and could therefore affect processes and reactions in the microlayer at the water-air interface, such as egg and larvae respiration (GESAMP, 1995).

A-7.1.1.2 Offshore Spill

The general weathering processes and behavior of oil in Arctic ice-free waters may include spreading, fragmentation into smaller-sized slicks, evaporation, dispersion, emulsification, oxidation, sedimentation, biodegradation, and dissolution (Lee et al., 2011). In cold water or when ice is present, the weathering of oil can be slower or non-influential (TRB and NRC, 2014). During freeze-up, specific weathering processes that can affect oil are evaporation, dissolution, emulsification, and dispersion (TRB and NRC, 2014). The fate and behavior of oil spilled under ice may include spreading, evaporation, dispersion, emulsification or biodegradation and these processes can be slower or non-influential (Lee et al., 2015).

Horizontal transport takes place via spreading, advection, dispersion, and entrainment while vertical transport takes place via dispersion, entrainment, Langmuir circulation, sinking, overwashing, partitioning, and sedimentation (USDOI, MMS, 2007b, Appendix A, Figure A.1-1, and Figure A-2). The persistence of an oil slick is influenced by the effectiveness of OSR efforts and affects the resources needed for oil recovery (Davis et al., 2004). The persistence of an oil slick may also affect the severity of environmental impacts as a result of the spilled oil.

Key weathering processes that may be relevant to the persistence of an oil spill in an Arctic marine environment are discussed in Section A-5.4.

Oil moves through the water in horizontal and vertical directions. This movement of oil occurs through several processes including spreading, dispersion, advection (tides, current, Langmuir circulation), entrainment, deposition to seafloor sediments, re-suspension from seafloor, uptake and excretion by biota, and stranding on shorelines. Waves and winds can mix oil droplets on the surface into subsurface waters. The various mechanisms by which oil moves in seawater are also influenced by the type and degree of sea ice present and the location of the spilled oil (on the water, under the ice, encapsulated in the ice, or on top of the ice).

The more volatile compounds in an oil slick, particularly aromatic volatiles, are usually the most toxic components of an oil spill. In-situ, cold-water measurements (Paine and Levin, 1981; Payne et al., 1984) have demonstrated that concentrations of individual components in an oil slick decrease substantially over a period of hours to tens of days.

The highest dissolution rates of aromatics from a slick occur in the first few hours of a spill and accumulate in the underlying water (Paine and Levin, 1981). By the time dissolved oil reaches depths of 33 feet in the water column, it becomes diluted and may spread horizontally over about 6.2 miles. The slick would become patchy, with the total area—containing widely separated patches of oil—stretching orders of magnitude larger than the actual amount of surface area covered by oil.

A small portion of the oil from a surface spill would be deposited in the sediments in the immediate vicinity of the spill or along the pathway of the slick. The observed range in deposition of oil in bottom sediments following offshore spills is 0.1 percent to 8 percent of the slick mass (Jarvela, Thorsteinson, and Pelto, 1984). Generally, the higher percentage of deposition occurs in spills nearshore where surf, tidal cycles, and other inshore processes can mix oil into the bottom (Manen and Pelto, 1984).

An offshore spill could create tarballs. Slow photo-oxidation and biological degradation would slowly decrease the residual amount of oil. During the slow process of sinking, sunken tarballs would be widely dispersed in the sediments, resulting in widespread distribution but relatively lower concentrations in any one area of sediment.

Decomposition and weathering processes for oil are much slower in cold waters than in temperate regions. Prudhoe Bay crude remained toxic to zooplankton in freshwater ponds for 7 years after an experimental spill, demonstrating persistence of toxic oil fractions or their weathered and decomposition products (Barsdate et al., 1980). In marine waters, advection and dispersion would reduce the effect of release of toxic oil fractions or their toxic degradation products, including products resulting from photo-oxidation. Isolated waters of embayments, shallow waters under thick ice, or a fresh spill in rapidly freezing ice, however, would not be exposed to this advection and dispersion.

An oil spill that occurs in broken-ice or under pack ice during the deep Arctic winter would freeze into the ice, move with the ice and melt out of the ice the following summer. Spills in first-year ice would melt out in late spring or early summer. Spills in multi-year ice would melt out later in the summer or in subsequent summers. Spills released from the ice would be relatively unweathered and would have the characteristics of fresh oil. Before the oil was released from the ice, the contaminated ice could drift for hundreds of miles.

A-7.1.1.3 Onshore Contact

Oil that contacts the shoreline can be mixed into the nearshore and beach sediments then remobilized and dispersed, causing persistent elevation of hydrocarbon concentrations in nearshore waters. Impacted habitats could include estuaries, embayments, river deltas, and other shoreline environments.

A-7.1.2 Phase 2 (Spill Response and Cleanup)

A-7.1.2.1 Dispersants

Dispersants are a combination of surfactants and solvents that work to break surface oil into smaller droplets which then disperse on the surface and into the water column. Many factors affect the behavior, efficacy, and toxicity of a particular dispersant, including water temperature, surface salinity, wave and wind energy, light regime, water depth, type of oil, concentration of dispersant, how the dispersant is applied (constant or intermittent spikes), and exposure time to organisms. Dispersants are used to degrade an oil spill more quickly through increasing surface area and to curtail oil slicks from reaching shorelines (Word, Pinza, and Gardiner, 2008).

As oil breaks into smaller droplets it can distribute vertically in the water column. If oil droplets adhere to sediment, the oil can be transported to the seafloor and interstitial water in the sediment. In shallow nearshore waters, wind, wave, and current action would more likely mix the dispersant-oil mixture into the water column and down to the seafloor environment. The water toxicity effects of dispersant application in the event of a VLOS would be similar to the effects outlined above under Phase 1 (Section A-7.1.1). Chemically dispersed oil is thought to be more toxic to water column organisms than physically dispersed oil, but the difference is not clear cut, and generally the toxicity is within the same order of magnitude (NRC, 2005). Recent papers also show that some dispersants can inhibit or leave unaffected biodegradation of oil in the water column, while others noted accelerated biodegradation (Fingas, 2014).

A-7.1.2.2 In-Situ Burning

ISB is used to reduce an oil spill more quickly and to curtail oil slicks from reaching shorelines. ISB could increase the surface water temperature in the immediate area, and produce residues. The uppermost layer of water (upper millimeter or less) that interfaces with the air is referred to as the microlayer. Important chemical, physical, and biological processes take place in this layer and it serves as habitat for many sensitive life stages and microorganisms (GESAMP, 1995). Disturbance to this layer through temperature elevation could cause negative effects on biological, chemical, and physical processes.

Residues from ISB can float or sink depending on the temperature and age of the residue. Floating residue can be collected; however, residues that sink could expose the benthic waters and sediment to oil components as the residue degrades on the seafloor.

The NOAA Office of Response and Restoration states, “Overall, these impacts [from open-water in-situ burning] would be expected to be much less severe than those resulting from exposure to a large, uncontained oil spill” (NOAA, 2011). If an oil spill occurred in winter, ISB would be limited by the lack of open water to collect oil and open water in which to burn it. If burning could occur in winter on a limited scale, sea ice would melt in the immediate vicinity of the burn.

A-7.1.2.3 Offshore Vessels and Skimmers

Mechanical recovery of oil would result in more vessel traffic and potential impacts to water quality from potential deck drainage, sanitary and domestic discharges, brine and cooling water discharges, small spills, anchoring in benthic habitat, disturbance of microlayer and potential for introduction of invasive species from foreign or out-of-state vessels. In winter, icebreakers could affect the movement of spilled oil that may be trapped beneath or in the ice. Vessel discharges are permitted by EPA under the Vessel General Permit.

A-7.1.2.4 Drilling of Relief Well

A drilling rig (either present on island or transported to location in open-water or the frozen ice season) would drill a relief well to control the blowout. Muds and cuttings from drilling a relief well would be disposed of in the waste well. There is potential for accidental spills and potential for introduction of invasive species from vessel traffic while drilling a relief well.

A-7.1.2.5 Beach Cleaning and Booming

The cleaning of oiled beaches (and booming and rescue of oiled animals) could entail small boat and aircraft landings on marine and freshwater shorelines and waters; large numbers of people walking and wading through aquatic habitats; collection of oiled sediment and beach wrack; possible booming of coastal waterways; possible hydraulic washing with hot water; possible application of fertilizer to enhance degradation of oil; and possible raking of fine sediments.

These activities could result in effects from suspended sediment in waters and resettlement of sediments elsewhere, possible resuspension of hydrocarbons, runoff of treatment-laden waters that could affect nearshore temperature and nutrient concentrations, removal of beach wrack nutrient sources from intertidal zones, and potential for introduction of invasive species from small boats, waders, and clothing worn by workers from outside of the Alaskan Arctic region.

The coast and barrier islands near the proposed action are vulnerable to contact by a crude oil spill in May through October.

A VLOS would severely affect marine water quality locally for several days by increasing the concentration of hydrocarbons in the water column to levels that greatly exceed background concentrations. Beyond the local area, water quality would be moderately affected. Regional (more than 386 square miles), long-term (more than 1 year) degradation of water quality to levels above

State and Federal criteria because of hydrocarbon contamination is unlikely. Contact with the barrier islands could allow an oil spill to pass through to the Beaufort Sea. The barrier islands closest to the proposed action area are Stockton Islands/McClure Islands (ERA 9); Midway, Cross, and Bartlett Islands (ERA 96); and Tigvariak Island (ERA 97). The excerpts from Appendix A, Tables A.2-1 through A.2-6, represent annual conditional probabilities (expressed as percent chance) that a large oil spill starting at the proposed LDPI or along the proposed PL route would contact the closest barrier islands and reach the Beaufort Sea within the period of days indicated.

A-7.1.3 Conclusion

A VLOS of 4,610,000 bbl of oil released over 90 days could severely affect water quality locally for months to years by increasing the concentration of hydrocarbons in the water column to levels that greatly exceed background concentrations. A VLOS would present sustained degradation of water quality from hydrocarbon contamination that would exceed SOA and Federal water quality criteria. Additional major effects on water quality could occur from response and cleanup vessels, in-situ burning of oil, dispersant use, and activities on shorelines associated with cleanup, booming, beach cleaning, and monitoring. The potential impacts of a VLOS on water quality are therefore deemed to be moderate to major.

A-7.2 Effects of a VLOS on Air Quality

A VLOS event, initiated by a hypothetical blowout, would release potentially harmful emissions into the atmosphere, particularly those pollutants regulated under the Clean Air Act. Pollutants regulated under the Clean Air Act include NO_2, CO, SO_2, PM_{10} and $PM_{2.5}$, and VOCs. Following the initial well control incident, emissions would occur during each phase of the event due to fires (including ISB), evaporative emissions from the oil, and emissions from sources operating during the oil spill recovery and cleanup process. The behavior of emissions released into the atmosphere over the Beaufort Sea, should a VLOS occur there, would be influenced by the Arctic climate as well as the severity of the oil spill and the characteristics of the pollutant sources. The Arctic climate is highly variable by season, influenced by the polar maritime characteristics of the Arctic Ocean, and reflects the polar continental characteristics of the large adjacent Alaskan land mass. Meteorological conditions such as temperature inversions, wind, and precipitation define the atmospheric stability of the area and dictate the amount of turbulence and mixing that can occur. Thus, these parameters affect the buildup of emissions and concentration of harmful pollutants that could threaten human health and wildlife. Therefore, the severity of impacts to air quality from a VLOS would depend largely on whether the spill occurs in the winter or in the summer. As explained in the following subsections, an oil spill or oil spill recovery occurring during the winter would likely result in greater impacts to air quality than a spill occurring during the summer.

A-7.2.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

A-7.2.1.1 Well Control Incident

A LOWC resulting in flames would result in a large black smoke plume containing PM and the other products of combustion, such as NO_x, SO_2, CO, VOC, and CO_2. The fire could also produce PAHs, which are known to be hazardous to human health. In particular, the intense heat of the fire would elevate the level of NO_x emissions, and concentration of PM in the initial smoke plume would have the potential to temporarily degrade visibility in the immediate area and in any affected area designated as a PSD Class II area and other areas where visibility is of significant value. It would be during this initial event when the majority accumulation of black carbon (BC) would occur. The deposits would be more severe if the initial explosion were to occur in the winter when the maximum amount of sea ice and land ice and snow are present.

The heat of the fire would immediately cause the pollutants within the plume to disperse in an upward buoyant flow. The location of high pollutant concentrations due to the smoke depends on the stability of the atmosphere at the time of the explosion. Should the VLOS occur during winter months, the upward transport of the pollutants could be constrained by fumigation conditions limiting dilution with the surrounding air, and restricting transport by wind. In this case, pollutant concentration levels at nearby locations would likely reach levels that exceed the federal and SOA thresholds that define impacts as significant. Otherwise, the rising plume of pollutants would become increasingly diluted with height, and surface concentration levels would not be as high in the immediate vicinity of the fire (Evans et al., 1991). In either case, over time the smoke would be transported by the wind and would eventually affect surface areas at a distance from the fire.

Emissions of VOCs would be high during Phase 1 due to evaporation of freshly surfaced oil. A laboratory analysis of oil spilled during the DWH event showed the first 23 percent of the oil evaporated within the first two hours following the initial explosion. During this time, the emissions of VOCs were confined to a relatively narrow plume as the sea surface transport of oil did not exceed a few miles (de Gouw, Middlebrook, Warneke, Ahmadov, Atlas et al., 2011). Consequently, the VOC impacts would be most severe immediately following the explosion and decrease as the oil slick spreads. With increasing distance from the location of the fire, some of the gaseous pollutants, particularly VOCs, would undergo chemical reactions resulting in the formation of secondary organic aerosols, which are mostly semi-volatile organic material.

Computer modeling conducted to evaluate emissions from a large oil spill considered several different VOCs and other compounds including benzene, ethylbenzene, toluene, and o-xylenes, which are classified by the EPA as hazardous air pollutants (HAP). The results showed that these compounds vaporize almost completely within a few hours following a spill. The ambient concentrations would peak within the first several hours after a spill and would be reduced by two orders of magnitude after about 12 hours. The heavier compounds would take longer to vaporize and may not peak until about 24 hours after spill occurrence. Additional information of air quality impacts from oil spills is included in the 2007 Lease Sale 193 Final EIS (Sections IV.C.1.b; IV.C.2.b; and IV.C.3.b) (USDOI, MMS, 2007b).

A-7.2.1.2 Offshore Spill

Impacts from this phase of the VLOS would continue until the sea is clear of all or most of the oil. As long as there is an oil slick on the sea surface there will be evaporative emissions and some level of air quality degradation until nearly all volatile hydrocarbons are depleted from the oil. As such, impacts from this phase would occur simultaneously and in combination with the impacts occurring during Phase 2 and Phase 3.

Evaporation contributes to weathering of the oil, the natural chemical and physical processes that lead to the disappearance of oil from the sea surface. However, the rate of evaporation differs depending on volatility of the oil and increases with higher temperatures. Higher temperatures also allow an oil slick to spread more quickly, thinning out the layer of oil, and decreasing the emissions of VOC. Evaporation decreases the oil’s toxicity because the lighter more toxic hydrocarbons dissipate. Fifteen to 30 percent of the oil could evaporate within the first 30 days, depending on the season (Polar Research Board, 2003).

During the DWH event, air samples were collected through the inter-agency efforts of British Petroleum (BP), Occupational Safety and Health Administration (OSHA), and the USCG. The samples showed concentration levels of HAPs, such as benzene, toluene, ethyl benzene, and xylene to be below the OSHA Occupational Permissible Exposure Limits (PEL) and the more stringent ACGIH (American Conference of Governmental Industrial Hygienists ®) Threshold Limit Values ® (TLVs) (U.S. Department of Labor, 2010). However, even in low concentrations, some hazardous air pollutant emissions may be hazardous to personnel working in the vicinity of the spill site, which could be reduced by monitoring and using protective gear, including respirators.

Concentrations of pollutants depend largely on the volume of the oil over the sea surface and the type of oil that was spilled. As a general rule, emissions of VOCs would be highest at the source of the spill because the rate of evaporation is influenced by the volume of oil present at the surface. However, with time, the emissions would decrease because even if the oil were not recovered, VOC concentrations would decrease as the surface oil area increases and gets thinner through transport by the current. This phase of the VLOS could continue for weeks so that emissions would eventually disperse in the wind even allowing for frequent temperature inversions during winter when winds are very light. Average wind speeds over the Arctic are sufficient to disperse the evaporated pollutants over such a long period of time. Air quality impacts could be major in the areas where oil is thick over the sea surface, which would likely be at the beginning of Phase 2 and could occur during a winter VLOS. However, minor to moderate levels of effect to air quality are expected as time goes by and the oil volume decreases.

A-7.2.1.3 Onshore Contact

As the spill nears shore, evaporative emissions from the sea surface oil slick would continue to occur as described above. As such, a portion of the most volatile hydrocarbons would have evaporated by the time the oil reaches the shoreline. Therefore, potential for harmful VOC emissions would depend on the remaining volatility of the oil and the volume of oil accumulating on the shore. Combined with the other effects of weathering, such as dissolution and dispersion, further harmful emissions from the oil would likely be limited.

Once the oil is onshore, even minor emissions could cause short-term effects to human health. The emissions may cause temporary eye, nose, or throat irritation, nausea, or headaches, but the doses are not thought to be high enough to cause long-term harm (USEPA, 2010). Conversely, responders could be exposed to levels higher than the PELs established under the OSHA guidelines (USDOL, 2010). During the DWH event, 15,000 air samples collected near shore by BP, OSHA, and the USCG showed most levels of benzene, toluene, ethylbenzene, and xylene were under detection levels. Among the many samples taken by BP, there was only one indicating benzene exceeded the OSHA PEL (BOEMRE, 2011a, Appendix B). All other sample concentrations were below the more stringent ACGIH® TLVs (USDOL, 2010). All measured concentrations of toluene, ethylbenzene, and xylene were within the OSHA PELs and ACGIH TLVs.

The VOC emissions from oil collecting onshore would cause a negligible to minor impact to air quality that is short-term and not expected to cause permanent harm. However, responders are at risk for exposure to harmful levels of benzene and should take safety precautions to avoid exposure.

A-7.2.2 Phase 2 (Spill Response and Cleanup)

The sheer volume of petroleum estimated for release during a VLOS would require an array of spill response and cleanup techniques and strategies. No longer concerned primarily with VOC emissions, efforts during this phase of the VLOS event would engage new sources of emissions, such as dispersants, ISB, and the use of offshore vessels. To support these efforts requires the use of aircraft and surface vehicles, which also produce potentially harmful emissions.

A-7.2.2.1 Dispersants

The use of dispersants and ISB are the two non-mechanical techniques used most commonly in response to an oil spill. Dispersants and ISB focus on changing the characteristics of the oil within the environment rather than using mechanical equipment (physical containment and recovery equipment, such as booms and skimmers) to recover or remove the oil (Ocean Studies Board, 2005). Dispersants, which may be applied by marine vessels or by aircraft, are chemical agents, such as surfactants, solvents, and other compounds, that break up the oil slick by decreasing interfacial tension between water and oil. The result is small oil droplets that will not merge with other oil droplets. The droplets stay suspended in the water column and are transported by waves. The objective of using a dispersant is to transfer oil from the sea surface into the water column (Ocean Studies Board, 2005). While the use of dispersants can decrease the size of the oil slick, toxic emissions are possible from the chemicals and solvents used in dispersants that could be potentially harmful. Following the DWH event, the EPA mobilized the Trace Atmospheric Gas Analyzer (TAGA) buses that are self-contained mobile laboratories that conduct air quality monitoring (EPA, 2015). The EPA conducted monitoring for two chemicals in dispersants that have the greatest potential for air quality impacts: EGBE (2 butoxyethanol) and diproplyene glycol monobutyl ether. The TAGA analysis detected levels of these chemicals in the air along the Gulf Coast that were below the threshold that would likely cause health effects. Consequently, EPA suggests that using dispersants for oil spill cleanup would cause a negligible impact on air quality (EPA, 2015).

A-7.2.2.2 In-Situ Burning

ISB is controlled burning of oil intended to decrease the volume of sea surface oil after an oil spill. The burning of the oil results in emissions of NO_x, SO_2, CO, VOC, and CO_2 within a plume of black smoke. Monitoring studies of controlled oil burning at sea showed levels of NO_x, SO_2, and CO were below detection levels (Fingas, Ackerman, Lambert et al., 1995). The study found that VOC emissions were below levels detected from the unburned oil and PAHs were not at a level considered harmful. Results of smoke-plume modeling showed concentrations of PM did not exceed the health criterion of 150 milligram per square meter (mg/m^3) when measured 3 miles downwind of the burning (USDOI, BOEMRE, 2011a). Considering the low concentrations of pollutants found in monitoring and modeling, and the short-term nature of ISB, there would be a minor impact to air quality. Additional information concerning air quality impacts from ISB is included in the 2007 FEIS (Sections IV.C.1.b; IV.C.2.b; and IV.C.3.b) (USDOI, MMS, 2007a).

A-7.2.2.3 Offshore Vessels

Offshore vessels would be used to remove oil from a spill at sea, apply dispersants during open-water periods, and during parts of break-up and freeze-up periods. The oil-skimming vessels use devices to skim oil off the surface of the water, such as belts, disks, tubes, and suction devices. A VLOS may require up to a hundred or more diesel-powered oil-skimming vessels, and other marine equipment such as icebreakers, over the course of time required confining and removing such a large amount of oil from the surface. It is a time-consuming process that would likely take weeks or months to complete and would result in thousands of tons of emissions, particularly NOx, but also including CO, PM, SO_2, VOC, and CO_2 (Discovery News, 2010; EPA, 1996). Emissions from this number of vessels would likely result in temporary major levels of effect to air quality.

A-7.2.2.4 Aircraft and Surface Vehicles

A portion of dispersants used to decrease the size of the oil slick may be applied using aircraft. During the response and cleanup process other aircraft may be needed for personnel and equipment transport, including helicopters, small piston-powered aircraft, and large commercial jets. Aircraft emissions depend partly on the physical characteristics and performance parameters of each unique aircraft type. These include the airframe type, the type and number of engines, takeoff weight, and approach angle. In addition to the physical characteristics of the aircraft operating at the site, emissions further depend on the time that each aircraft type operates in the various modes that define a landing and takeoff cycle. A landing and takeoff cycle consists of the approach, landing roll, taxi to and from the parking area, idle time, takeoff, and climb out. In addition to aircraft, surface-based vehicles are necessary. Aircraft emissions are likely to cause a negligible to minor impact to air quality.

A-7.2.3 Phase 3 (Post Spill and Long-Term Recovery)

Following the removal or other disposition of the oil by burning, evaporation, or weathering, few, if any, additional recovery efforts would be required that would affect local air quality. However, during the long-term recovery process, there would be continued evidence of the VLOS and the affected areas onshore. In order for this recovery effort to proceed on a long-term basis, the continued use of marine vessels, small boats, aircraft, and surface vehicles would be required. Emissions from these sources would be far below the levels experiences during any of the previous phases of the VLOS. Considering the decrease in pollution sources and the meteorological conditions existing over the Arctic, particularly the potential for Arctic winds to disperse air pollutants, minor levels of effect to air quality would be expected.

A-7.2.4 Oil Spill Trajectory Analysis

The types of impacts to air quality analyzed above would be expected to occur regardless of the location of the spill’s source. An oil spill trajectory analysis is not provided.

A-7.2.5 Conclusion

A VLOS in the Beaufort Sea could emit large amounts of regulated potentially harmful pollutants into the atmosphere. The greatest deterioration of air quality would occur during Phase 1 and Phase 2, particularly if the spill occurs in the winter when fumigation conditions are more likely and precipitation is less frequent. Also, the potential of a Phase 1 fire and spread of surface oil would cause moderate to major levels of effect from PM and VOC emissions in the immediate vicinity of the flames. With distance from the fire and with further spreading of surface oil, the concentrations of VOC would be less severe but moderate effects could still occur around the Proposed Action Area. Impacts continue for days during Phase 1 but could continue for months under Phase 2. Therefore, while a major impact would likely occur during these two phases, and the emissions from the VLOS would be temporary and distributed over time, air quality in the Arctic would eventually return to pre-oil spill conditions. Due to dispersion, impacts on air quality would be limited to the immediate area of the spill and are expected to be temporary. Concentrations of criteria pollutants would likely not exceed air quality standards in any onshore areas. The impacts of a VLOS on air quality would be minor.

A-7.3 Effects of a VLOS on Lower Trophic Level Organisms

This section assesses the potential for the hypothetical VLOS scenario described in Section A-5.3 to impact the lower trophic organisms found within the physical environment of the OCS in the Beaufort Sea Planning Area and shoreward zone Alaska State waters. Lower trophic and benthic populations in Stefansson Sound could be strongly impacted by a VLOS, with a same-season to one-year loss of major proportions to all components of known lower trophic communities. The Boulder Patch would be impacted for more than one year, possibly decades. In all phases of a VLOS, one or more of the lower trophic communities described in this section would be affected by the byproducts of oil created by natural and anthropogenic processes. This lower trophic section will define and describe in brief the potentially affected communities of lower trophic organisms, summarize pertinent information concerning the effects of a VLOS on lower trophic organisms. The hypothetical VLOS scenario included three seasons: summer, winter, and break up or freeze up. While the impacts of exposure to spilled oil would largely be the same for all three seasons, the responses and the size of the area affected by the spill would be impacted by the season in which it occurs. One exception to this is that epontic communities are unlikely to be impacted by oil exposure if a spill occurs during the summer. Oil spill trajectories for VLOS are the same as for large oil spills (see Section A-5).

A-7.3.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

Lower trophic organisms could be exposed to impact producing factors such as explosion or fire, contact with oil, and contamination of or loss of access to preferred habitat during phase 1 of the VLOS scenario. An explosion and ensuing fire from a blowout of the well or pipeline would result in an increase of pressure and temperature of the immediate environment. Impacts would be similar to those discussed in the large oil spill section (FEIS Section 4.1.1.3). Near instantaneous changes in the chemical composition of the surrounding environment in the form of heat energy, followed by gas and oil being released to the surrounding seawater would initiate the release of oil to the water column. Severity of effects would be dependent upon released energy. The explosion and chemical changes in the water column would result in the loss of pelagic and epibenthic lower trophic organisms in the near vicinity of the wellhead. A localized event at that stage of the timeline would likely not cause effects at a population level. Sediment upheaval and re-distribution of sediments into the water column and their subsequent deposition on the seafloor could affect pelagic organisms within the plume and all benthic organisms buried by the sediments, respectively. The severity of the effects would depend on the force of the explosion, concentration within the water column, density of ejected sediments, and duration of the sediment plume within the water column before deposition to the sea floor. A fire at the surface could create localized effects on plankton populations due to heat of the fire and release of material as a result of the event, including oil, melting plastics and rubbers, and chemicals used by response crews in attempting to control the fire. Overall, the effects of an explosion and ensuing fire would likely not affect the lower trophic communities at a population level.

Oil is highly toxic to organisms with a small body size. Phytoplankton, zooplankton, and other lower trophic organisms are in contact with their aqueous environment through thin layers of membranous tissue, have short distances between those layers and internal organs, and rapid metabolic rates (Jiang et al., 2010; Newman and Clements, 2007). The smallest developmental stages of organisms with complex life cycles, such as the nauplii larvae of copepods and other crustaceans, are especially vulnerable to those effects (Hansen et al., 2011; USDOI, MMS, 2004). Furthermore, many lower trophic organisms have the capacity to accumulate oil and oil toxins if they are not killed outright, thereby leading to bioaccumulation and biomagnification in upper levels of the foodweb (Neff, 2002; Newman and Clements, 2007). In particular, this includes copepods and other crustaceans (Hansen et al., 2011; USDOI, MMS, 2004). The extent of effects is dependent upon numerous factors, including duration and volume of spill, persistence and dispersion of oil in the water column and the benthic surface, chemical composition of the oil and where it has accumulated (at the water surface, in the water column, or at the benthic surface), the efficacy of chemical dispersants should they be approved and utilized, the movement of oil through the water column, hours of daylight and UV intensity, seasonality and presence or absence of ice, how oil is incorporated into the ice during its formation, classification of ice, and presence or absence of polynyas and reaches. Potential effects of these factors on lower trophic populations are dependent upon their various combinations and include:

- Rapid accumulation of toxins within single cell algae and rapid death of these organisms within surface areas affected by oil slicks.
- If phytoplankton cell death does not instantly occur, drift and later ingestion by other organisms could lead to bioaccumulation at potentially large numerical scales.
- Although immediate effects of surface oil slicks could be serious to all affected components of neuston plankton populations, multi-year studies from previous oil spill events indicate population-level recovery should be relatively rapid (one year or less) in marine phytoplankton populations.
- Populations of meroplankton (including instars, zooids, and nauplii; early larval developmental stages of numerous benthic and pelagic species) and adults of those species, depending upon

factors listed above, may take one year or more to recover to pre-spill population levels if adults are affected by population-level losses from settling of oil on benthic surfaces.

- Results of experiments conducted on calanoid copepods indicated exposure to both sunlight and weathered Alaska North Slope crude oil resulted in mortality and morbidity (impairment of swimming ability and discoloration of lipid sacs) of 80 percent to 100 percent in test treatments of *Calanus marshallae*, while oil-only or sunlight-only treatments resulted in a 10 percent effect on mortality and morbidity.
- Adult copepods have a strong affinity for accumulation of polyaromatic compounds (PACs) within lipid storage vacuoles and an affinity to act as bioaccumulators of these toxins, enabling them to potentially be distributed by movements of water masses and affect upper-level predators away from primary spill area.
- Studies carried out with larval benthic King crabs and seagrass shrimp exposed to 2 ppm crude oil showed greater than 50 percent mortality in the first 6 hours of exposure.
- Pelagic communities including squid, jellyfish, ctenopohores, larvaceans, and pteropods are rarely affected by surface oil, but subsurface oil would affect these organisms and population effects would depend upon the area covered and persistence of oil in the water column. Use of dispersants could potentially negatively affect populations of these organisms, as knowledge of the efficacy of dispersants in cold water is limited.
- Benthic communities are affected by accumulation of oil at the ocean bottom, particularly when oil covers developing eggs and larvae of organisms that use the benthic surface for substrate attachment of these life stages, and when it penetrates the burrows of polychaetes, amphipods, and other organisms that create pathways through the upper surface layers of the benthic sediment.
- Similarly, epontic communities would similarly be affected by oil that accumulates under the subsurface of the ice, as many organisms (e.g., concentrations of ice algae) live on that surface and within the interstitial brine layers of the ice architecture.
- Persistence of oil through winter months to spring breakup could affect recovery and subsequent productivity of benthic communities, as ice algae in affected areas will not contribute to benthic productivity, and crustaceans (krill, for example) may not survive at population levels adequate to compare with pre-VLOS contributions to the productivity of under-ice pelagic and benthic communities and spring plankton blooms.
- Presence of oil in water or ice could affect attenuation (penetration) of light through the water column and ice by way of absorption and scattering of solar radiation.
- Presence of oil within polynyas and reaches would affect the capacity of these open-water biological hotspots to support algae and invertebrate populations that are sustained throughout the months of ice cover and contribute to benthic and pelagic productivity after the ice retreat.

Information for the bulleted list above was obtained from: Barron, 2007; Barron et al., 2008; Brandvik and Faksness, 2009; Brodersen, 1987; Iken, Bluhm, and Dunton, 2010; Hansen et al., 2011; Jiang et al., 2010; Newman and Clements, 2007; NRC, 2005; USDOI, MMS, 2003, USDOI, MMS, 2004, USDOI, MMS, 2008.

Habitat loss due to oil contamination could impact lower trophic communities, especially in the Boulder Patch. Studies by Dunton and Schonberg (2000) and Konar (2007) indicate the Boulder Patch kelp beds are slow to recover from disturbance. Dunton and Schonberg carried out experiments removing kelp from their holdfast attachment sites, after 3 years there was only a 50 percent recovery in the denuded patches. Suspecting invertebrate grazing as a factor, Konar repeated the experiment using cages to prevent access by potential herbivores and reported no recruitment after 2 years, again demonstrating the slow recovery rate of these communities.

Nearshore coastal marine environments, with intertidal and subtidal floral and faunal communities, would likely experience the longest-term effects resulting from contact with oil. Organisms inhabiting these diverse environments are subject to similar effects as those listed in the previous section, but some factors are specific to onshore contact. Among these are the effects of solar irradiance and the risks of photo-enhanced toxicity from oil in shallow water environments. Although this mainly refers to oil spills as opposed to drifting and previously weathered oil, it is of relevance to the intent of this section. The ultraviolet regions of solar radiation can substantially increase toxicity and risks of polycyclic aromatic hydrocarbons (PAH) through photochemical modification of oil (Barron et al., 2008). A 2004 study funded by BOEM (then MMS) investigated persistence of PAH compounds in laboratory tests using shoreline soils collected from the Beaufort Sea, Port Valdez, and Cook Inlet areas. Through experimental work they concluded that some interactions between aromatic hydrocarbons and sediment organic matter may be irreversible, with field tests indicating they persist in all their collection areas from previous oils spills and natural seeps. River and creek delta areas exhibiting estuarine habitats would be affected through wind and tidal exposure from oil, and the potential impact of storm events. In 1970, Reimnitz and Maurer (1979) observed the effects of tidal surges from a major storm event that inundated low-lying tundra and delta regions on the Beaufort Sea shoreline, leaving debris lines from flotsam as far as 16,500 feet inland. A storm of equal or greater magnitude could force weathered oil far inward and leave residue over wide areas of tundra and river shores. The effects to shoreward lower trophic communities would be reliant upon factors such as seasonality of spill, locations of onshore contact, and persistence of oil within the water before contact. Effects to lower trophic populations where oil contacts the shore zone could result in one to several years for recovery, depending upon area of contact and duration and severity of exposure.

A-7.3.2 Phase 2 (Spill Response and Cleanup)

Dispersants are a combination of surfactants and solvents that work to break surface oil into smaller droplets which then disperse on the surface and into the water column. The efficacy of the application of dispersants is dependent upon water temperature, water density, energy from wind and waves, solar radiation intensity, and exposure time, or residence time, of the dispersant in an environment (NRC, 2005). The application of dispersants can cause sinking of droplets and subsequent aggregation on the benthic surface (Word, Pinza, and Gardiner, 2008; NRC, 2005) and increased exposure of small organisms to oil due to the increased surface area from small particles created by dispersants.

In-situ burning is used to remove oil from the surface and to curtail oil slicks from reaching shorelines. In-situ burning could affect fish through elevation of surface-water temperature; boom dragging for oil collection; and sinking of residues. In-situ burning would cause elevated surface temperatures and creation and introduction of residues into the water column (Buist, 2003), and disturbance of the surface layers of the ocean, including the microlayer that serves as a concentration point for many forms of plankton (Wurl and Obbard, 2004). These effects on lower trophic organisms would differ depending on the time of year (open-water vs. ice-cover) and the size and duration of the burn. If an oil spill occurred in winter, in-situ burning would be limited by the lack of open water to collect oil and the area of open water in which to maneuver vessels and contain oil to an optimal thickness to burn (greater than 0.04-0.08 inch). If it could occur on a limited scale, sea ice would melt in the immediate vicinity of the burn and invertebrates associated with the ice would be negatively affected by the operation. Residues from in-situ burning can float or sink depending on the temperature and age of the residue. Floating residue can be collected; however, residues that sink could foul gills and expose benthic organisms to oil components as the residue degrades on the seafloor.

During the spill response and cleanup phase, lower trophic organisms could be exposed to a variety of effects from offshore vessel traffic. All activities requiring the use of watercraft would increase the disturbance of the lower trophic organisms and their habitats, particularly when these activities are carried out in nearshore environments. Skimming or vacuuming the microlayer would disturb chemical, physical, and biological processes that take place in this layer and could injure or kill sensitive pelagic life stages including Icebreakers would cause disturbance to ice habitat, and depending on the time of year, could affect the epontic community.

Spill response activities vary in their capacity to affect lower trophic populations. The length of time that response and cleanup activities continue would determine effects on lower trophic communities. In general, effects to phytoplankton and pelagic populations would likely be minor, but benthic and shore zone lower trophic populations could suffer greater effects of one or more years of recovery time.

A-7.3.3 Phase 3 (Post-Spill and Long-Term Recovery)

Impacts affecting lower trophic organisms in long-term recovery are similar to the previously described scenarios. As discussed with large oil spills, phytoplankton populations should recover quickly. Long-term and chronic effects would be most evident in populations of benthic and pelagic animals and organisms associated with the Boulder Patch kelp beds. Even with the recovery of zooplankton through the currents of surrounding waters and the reproductive capacity of resident populations of benthic and pelagic invertebrates, the recovery of invertebrate populations may take 1-2 years if the impacting factors analyzed in earlier sections should culminate in causing population-level effects to this diverse group of organisms.

A-7.3.4 Conclusion

The description of effects of contact and impacts should an oil spill contact lower trophic resources have been described in the preceding sections. Although the trajectories are similar, the amount of oil spilled would be greater, so the overall impact on lower trophic organisms would be greater. A VLOS would likely have less than a one year effect on phytoplankton populations. However, short-term, local-level effects would have greater potential to affect local food webs. Severity of effects would be determined by duration of oil spill, weather patterns, and the resultant distribution and geographic coverage of surface oil slicks. Invertebrate populations within benthic, pelagic, and onshore environments are at greater risks from a VLOS due to their slower reproductive rate, longer life spans, and the potential of adult breeding populations being negatively affected by the VLOS and leading to a longer recovery rate. Phytoplankton and zooplankton populations extirpated by oil slicks that are constantly shifting and forming in new areas due to influences of wind, weather, and waves, would not be available to organisms that depend on them for food and survival. Food webs can be very short in the Arctic, with interactions between megafauna (i.e. whales, seals, walrus) and lower trophic organisms often comprising one or two trophic levels due to the tight benthic and pelagic coupling on the shallow continental shelf off the Alaskan Arctic coast (Dunton et al., 2005; Grebmeier et al., 2006). Bioaccumulation and biomagnification in these foodwebs is a concern. Long lived copepods (such as Calanus glacialis) may live 2-3 years, store lipids in the body cavity, undergo diapause (a form of hibernation), and be consumed by upper level predators (Pacific cod, bowhead whales, etc.) at a later date (USDOI, MMS, 2004). Toxicity studies carried out with benthic crabs and shrimp indicate they may not immediately die from toxins (living 24-96 hrs, depending on exposure and oil type), thus allowing greater opportunities for consumption by upper-level predators and biomagnification to occur (Brodersen, 1987). Phytoplankton themselves may not die immediately from the effects of exposure to oil, allowing them to be consumed by other organisms in locations away from contamination sites (Jiang et al., 2010). Ice algae population effects would be determined by similar factors, as the presence of oil within polynyas and reaches, and if incorporated into first year ice would likely have at least a one-year effect on local populations due to effects on primary productivity and the probable inability of epontic communities reliant on ice algae to survive within oil-influenced ice. Recovery rates of one or more years may result from these effects on invertebrate populations, but cascading impacts would be expected throughout the food web. A VLOS would likely have major, persistent impacts on lower trophic communities in Stefansson Sound, especially to the Boulder Patch.

A-7.4 Effects of a VLOS on Fish

Very large oil spills could affect offshore and nearshore fish species in the path of or near the oil through effects such as acute toxicity or shifts in prey availability. The effects on fish and their populations would depend on a variety of factors including life stage, season of the reproductive cycle, species' distribution and abundance, locations of the species in the water column or benthos, the extent and location of spawning areas in riverine systems, and migratory patterns. The hypothetical VLOS scenario included three seasons: summer, winter, and break up or freeze up. While the impacts of exposure to spilled oil would largely be the same for all three seasons, the responses and the size of the area affected by the spill would be impacted by the season in which it occurs. Oil spill trajectories for VLOS are the same as for large oil spills (see Section A-5).

Many journal articles have been published on the effects of the DWH Oil Spill on fish. Table A-7-1 presents a summary of this journal literature. These articles document the injurious and acute effects of crude oil on the embryology, physiology, genetics, and behavior of various fish species and fish life stages.

Table A-7-1 Journal Literature on the Effects of the *Deepwater Horizon* Oil Spill on Fish

Title of Peer-Reviewed Article	Date	Authors
The effects of oil exposure on peripheral blood leukocytes and splenic melano-macrophage centers of Gulf of Mexico fishes	2014	Ali AO, Hohn C, Allen PJ et al.
Crude oil impairs cardiac excitation-contraction coupling in fish (1)	2014	Block B, Brette F, Cros C et al.
Crude oil impairs cardiac excitation-contraction coupling in fish(2)	2014	Brette F, Machado B, Cros C et al.
Oxidative stress responses of gulf killifish exposed to hydrocarbons from the *Deepwater Horizon* oil spill: potential implications for aquatic food resources	2014	Crowe KM, Newton JC, Kaltenboeck B et al.
Acute embryonic or juvenile exposure to *Deepwater Horizon* crude oil impairs the swimming performance of mahi-mahi (*Coryphaena hippurus*)	2014	Mager, EM, AJ Esbaugh, JD Stieglitz et al. 2014
Deepwater Horizon crude oil impacts the developing hearts of large predatory pelagic fish	2013	Incardona JP, Gardner LD, Linbo TL et al.
Influence of age-1 conspecifics, sediment type, dissolved oxygen, and the *Deepwater Horizon* Oil Spill on recruitment of age-0 red snapper in the Northeast Gulf of Mexico during 2010 and 2011	2014	Szedlmayer ST, Mudrak PA.
Spatio-temporal overlap of oil spills and early life stages of fish	2013	Vikebo, Ronningen, Lien et al.
Multitissue molecular, genomic, and developmental effects of the *Deepwater Horizon* Oil Spill on resident Gulf killifish (Fundulus grandis)	2013	Dubansky B, Whitehead A, Miller JT et al.
Exxon Valdez to *Deepwater Horizon*: Comparable toxicity of both crude oils to fish early life stages	2013	Incardona JP, Swarts TL, Edmunds RC et al.
Spatial, temporal, and habitat-related variation in abundance of pelagic fishes in the Gulf of Mexico: potential implications of the *Deepwater Horizon* Oil Spill	2013	Rooker JR, Kitchens LL, Dance MA et al.
Genomic and physiological footprint of the *Deepwater Horizon* Oil Spill on resident marsh fishes.	2012	Whitehead A, Dubansky B, Bodinier C et al.
Macondo crude oil from the *Deepwater Horizon* Oil Spill disrupts specific developmental processes during zebrafish embryogenesis	2012	de Soysa TY, Ulrich A, Friedrich T et al.
Response of coastal fishes to the Gulf of Mexico Oil disaster	2011	Fodrie FJ Heck KL, Jr.
Potential impacts of the *Deepwater Horizon* Oil Spill on large pelagic fishes	2011	Frias-Torres S, Bostater JC

A-7.4.1 Phase 1 (Well Control Incident, Offshore Spill. and Onshore Contact)

Fish could be exposed to impact producing factors such as explosion or fire, contact with oil, and contamination of or loss of access to preferred habitat during phase 1 of the VLOS scenario.

In a VLOS explosion, demersal and pelagic fish would both be affected. An explosion would send percussive shock waves through the water, causing rapid increase in pressure, density and temperature in the immediate area of the explosion. Fish eggs, larvae, and adults on the seafloor and in the water column would be injured or killed from shock waves from an explosive event when pressure, density, and temperature rise rapidly in the immediate vicinity. The lateral lines and swim bladders of fish could be severely damaged. Fish injured by the explosion would have physical, physiological, and behavioral effects that could interfere with swimming, feeding, reproduction, and predator escape. Acute or chronic effects on fish from an explosion could carry into longer-term effects on a population if a large proportion of the individuals were killed from a rare benthic community. Sensitive life stages in the surface waters (such as floating eggs of Arctic cod and drifting fish larvae) would be particularly affected by the explosion (shock wave, methane) and fire (heat and chemical reactions). The freshwater stages of anadromous fish would not be affected directly by an explosion and fire. An explosion could damage benthic habitat and cause high levels of suspended sediment and turbidity, which in turn could affect fish gills and respiration. Visibility for fish would be affected by the turbidity in the immediate area.

A fire would cause the surface water temperature to rise immediately which would be lethal for epipelagic fish, eggs and larvae. Subsurface water temperature would increase more slowly and could cause changes in physiological processes, particularly for benthic fish that are more sedentary. If a fire continued and sub-surface temperatures continued to rise, subsurface egg and larvae mortality could occur over time. Free-swimming fish not obligated to a specific habitat would likely move out of the area if the temperature continued to rise. Chemical reactions in the water, such as oxygen concentration, would be altered by rising temperature and this could also affect the physiology of fish.

Exposure to oil during a VLOS in Stefansson Sound could affect marine and anadromous fish and fish habitat through many pathways. Acute and chronic exposures could occur in riverine, estuarine, and marine environments which includes habitats in the water column, bottom sediment, and sea ice. The exposure pathways for fish include adsorption to outer body, respiration through gills, ingestion, and absorption of dissolved fractions into cells through direct contact. The severity of the effects on fish would depend on several factors including the type of oil/gas mixture spilled, the thickness of the oil spill, the duration of exposure on the surface, the season of the year (open-water, ice), and the life stage of the fish (egg, larvae, juvenile, adult). Following are the types of effects that could occur to fish from a very large oil/gas spill or release:

- Mortality of eggs and immature stages due to acute toxicity of oil and its weathered products
- Mortality of epipelagic eggs and larvae from acute coating with oil layer
- Mortality of adult fish in shallow coastal water bodies with slow water-exchange rates
- Mortality of eggs, immature and adult fish from shock waves from explosive event when pressure, density and temperature rise rapidly in the immediate vicinity
- Immediate loss of some marine, estuarine, and riverine habitats from physical oiling
- Contaminant effects on organs, tissues and gills, causing physiological responses including stress and altered respiration, irregular or reduced heart rate, and fluid accumulation; these effects can, in turn, affect swimming, feeding, reproductive and migratory behaviors and the physiologic adjustment for anadromous fish as they move between freshwater and saltwater environments
- Genetic damage to embryos resulting in morphological abnormalities which can affect ability to swim, feed, avoid predators and migrate
- Contaminant exposure in spawning or nursery areas causing abnormal development, or delayed growth through adsorption and ingestion; this abnormal development may repeat through generations if the population continues to spawn and/or rear offspring in contaminated areas
- Displacement of individuals or portions of a population from preferred habitat due to oiling
- Blocked or impeded access to or from spawning, feeding or overwintering freshwater habitats of anadromous fishes due to oiling of estuarine and freshwater environments

- Disruption or re-direction of coastwise migration of migratory and anadromous fish
- Reduction or elimination of prey populations normally available for consumption
- Reduction of individual fitness and survival, thereby increasing susceptibility to predation
- Long-term chronic contaminant effects in fish habitats from weathering oil which produces highly toxic Polycyclic Aromatic Hydrocarbons (PAHs), especially to lipid-rich eggs
- Decreased recruitment into the population due to mortality, abnormal development of eggs and larvae, truncated adult lifespan, reduced adult fitness, increased predation, increased parasitism, and zoonotic diseases
- Intraspecific cascade effects, such as loss of key individuals in social groups, which may show delayed effects on reproduction or feeding behaviors
- Modification of community structure due to increased mortality, reduced recruitment, decreased prey availability, loss of year classes and increased predation
- Modification of ecosystem due to reduction of fish eggs, larvae and adult fish available to predators including seals, sea birds, other fish species and toothed whales, indirectly to polar bears
- Cumulative effects from acute and chronic oil effects overlain on other contemporary stressful events such as water temperature rise, ocean acidity increase and decreasing sea ice

Information for the bulleted list above was obtained from: Nahrgang et al., 2010; Boertmann, Mosbech, and Johansen, 1998; Jonsson et al., 2010; Pearson, Woodruff, and Sugarman, 1984; Pinto, Pearson, and Anderson, 1984; Moles and Wade, 2001; Heintz et al., 2000; Christiansen and George, 1995; Mahon, Addison, and Willis, 1987; Ott, Peterson, and Rice, 2001; Rice et al., 2000; Carls, Harris, and Rice, 2004; Short et al., 2004; Peterson et al., 2003.

Loss of access to preferred habitat can impact the spawning, rearing, and feeding strategies of fish. Anadromous fish, because they depend on several environments in their complex life history, can be particularly impacted if oil reaches mouths and deltas of anadromous streams and rivers. Oil on the coastline presents a barrier to access (or egress) to spawning, feeding, overwintering and coastwise migration for anadromous species. A VLOS could wash over river deltas, into river mouths and be transported upstream by tidal action or anadromous fish returning to spawn and die in their natal waters. Oil in anadromous water bodies would present contaminants to sensitive spawning areas and life stages. There are many anadromous rivers, streams and lagoons along the Chukchi Sea Coast and Western Beaufort Coast from the Bering Strait to Nuiqsut. Anadromous fish that would be affected by a VLOS in the Beaufort Sea include: Pacific salmon (pink, chum, king, coho, sockeye), least cisco, Bering cisco, Dolly Varden, broad whitefish, humpback whitefish and Arctic char. Several fish species such as capelin, sand lance, saffron cod, and some sculpin species are not considered anadromous but they use nearshore substrates for spawning and rearing habitats. Nearshore species would be affected through similar pathways as anadromous fish if an oil spill hit the nearshore or shoreline, particularly during critical spawning or rearing times.

Acute and chronic effects of oil on nearshore and intertidal fish, eggs, and larvae can have cascade effects on fish populations over time. Sand lance would be especially affected in their nearshore habitats because they burrow in sand when they are not out foraging in the water column and they also overwinter in those burrows. Experiments have shown that sand lance are affected negatively by oiled sediments (Pearson, Woodruff, and Sugarman, 1984; Pinto, Pearson, and Anderson, 1984; Moles and Wade, 2001).

Offshore fish species would experience a variety of effects from a VLOS depending on its life history stage (adult, sub adult, egg, larvae); its habitat association (bottom dwelling, mid-water column, upper water column, beneath ice or in ice crevices); the range of depth inhabited; the breadth of the species habitat, prey and range; the life history and behaviors of the species (migratory, sedentary, reproductive strategy, etc.); and plasticity of the species to adjust to environmental stressors.

Sedentary, burrowing, territorial, benthic-obligated fish, fish eggs and fish larvae exposed to oil or gas would be limited in their ability to escape or avoid contaminants due to their limited swimming behaviors, obligate life history characteristics, behavioral traits, or spatial limitations. The exposure concentration that these species (including some poachers, eelpouts, sculpin, flounders, snailfish, nesting saffron cod) would experience could be greater than that to which free-swimming fish would be exposed. Fish that can swim relatively faster and more efficiently (such as salmon and cod) would more likely avoid some of the effects of oil at various concentrations if they have the sensory ability to detect oil or gas components.

Some fish species associate with sea ice to feed, hide, and spawn. Most notable of these in the Beaufort Sea is the Arctic cod which associates with ice in various life stages and seasons for shelter and as a forage habitat to feed on microorganisms on the underside of the ice. Under-ice amphipods are an important food source for Arctic cod (Lonne and Gulliksen, 1989; Gradinger and Bluhm, 2004). Rough, irregular textures of the underside-ice may provide preferred habitat for Arctic cod to avoid predators (Cross, 1982). Arctic cod migrate between offshore and onshore areas for seasonal spawning. They spawn under the ice during winter months (Craig et al., 1982; Craig, 1984; Bradstreet et al., 1986). Eggs hatch under the sea ice after 40-60 days and young larvae remain under the ice, eventually settling towards the bottom in September (Craig, 1984; Graham and Hop, 1995).

Oil and gas released in a winter scenario would pool under the ice in pockets presenting prolonged exposure to Arctic cod eggs and larvae, hiding adults, and amphipods inhabiting the under-ice environment. Pooled under-ice oil could take several pathways between winter and summer months: remain pooled on the underside of ice and drifting with ice; remain pooled in open leads; entrain or encapsulate in ice; dissolution into water column; or sinking adhered to sediment (Tables A.1-1, A.1-2). Melt-out of annual sea ice in spring and summer would release oil pooled underneath and trapped in ice and leads. All of these pathways would affect offshore and nearshore Arctic cod and other fish species, including those living in association with ice and those in the water column below ice and ultimately the benthic species affected by sinking oil-laden particulate.

A-7.4.2 Phase 2 (Spill Response and Cleanup)

Dispersants are a combination of surfactants and solvents that work to break surface oil into smaller droplets which then disperse on the surface and into the water column. Many factors affect the behavior, efficacy, and toxicity of a particular dispersant including water temperature, surface salinity, wave and wind energy, light regime, water depth, type of oil, concentration of dispersant, how the dispersant is applied (constant or intermittent spikes) and exposure time to organisms. Dispersants are used to degrade an oil spill more quickly through increasing surface area and to curtail oil slicks from reaching shorelines (Word, Pinza, and Gardiner, 2008).

Application of dispersants can cause toxic effects in fish and particularly fish eggs and larvae. Fish can be affected by dispersed oil through adsorption, ingestion, absorption of dissolved components and respiration (Word, Pinza, and Gardiner, 2008). As oil breaks into smaller droplets and sinks in the water column, the droplets are more likely to be ingested by fish that inhabit the water column. Because the surface area of oil increases as it is broken into droplets, there is an increased chance of fish, eggs and larvae in the water column coming into contact with the dispersed oil (Word, Pinza, and Gardiner, 2008). If oil droplets adhere to sediment and sink to the seafloor, benthic fish eggs and larvae would then be exposed to oil. In shallow nearshore waters, wind, wave and current action would more likely mix the dispersant-oil mixture into the water column and down to the seafloor which could foul gills and cause changes in histopathology of the gills (Khan and Payne, 2005).

The effect of dispersant application in a VLOS in the Beaufort Sea would be similar to the toxicity and fouling effects described above and in the large oil spill section. Epipelagic fish eggs and larvae would be particularly sensitive to effects of dispersant application. Fish in the water column and the benthos would be variably affected as a function of the species, life stage, depth inhabited, time of reproductive cycle, feeding strategy and ability to adapt by sensing the chemical changes and moving out of the range of toxic effects.

In-situ burning is used to remove oil from the surface and to curtail oil slicks from reaching shorelines. In-situ burning could affect fish through elevation of surface-water temperature; boom dragging for oil collection; and sinking of residues. These effects on fish would differ depending on the time of year (open-water vs. ice-cover) and the size and duration of the burn.

The upper-most layer of water (upper millimeter or less) that interfaces with the air is referred to as the microlayer. Important chemical, physical and biological processes take place in this layer and it serves as habitat for many sensitive life stages including fish eggs, fish larvae, and microorganisms important as prey for fish. Disturbance to this layer through boom-dragging to collect oil and temperature elevation from burning could cause lethal effects on fish life stages in this layer. In open water, the effects would be limited to the surface area burned and to the duration of a burn in any one area. Free-swimming adult fish not obligated to a specific habitat would likely move out of the area.

If an oil spill occurred in winter, in-situ burning would be limited by the lack of open water to collect oil and the area of open water in which to maneuver vessels and contain oil to an optimal thickness to burn (greater than 0.04 to 0.08 inch). If it could occur on a limited scale, sea ice would melt in the immediate vicinity of the burn and fish associated with the ice would be negatively affected by the operation. Residues from in-situ burning can float or sink depending on the temperature and age of the residue. Floating residue can be collected; however, residues that sink could foul gills and expose benthic organisms to oil components as the residue degrades on the seafloor.

The NOAA Office of Response and Restoration states that, “Overall, these impacts [from open-water in-situ burning] would be expected to be much less severe than those resulting from exposure to a large, uncontained oil spill” (http://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/resources/in-situ-burning.html).

During the spill response and cleanup phase, fish could be exposed to a variety of effects from offshore vessel traffic. Noise from ships, sound from seismic surveys and other sound sources would affect fish through interference with sensory orientation and navigation, decreased feeding efficiency, scattering of fish away from a food source, redistribution of fish schools and shoals, and producing a generalized stress response in some fish species which can weaken fish immune systems (Fay, 2009; Jobling, 1995; Radford et al., 2010; Simpson et al., 2010; Slabbekoorn et al., 2010; Purser and Radford, 2011; Wysocki, Dittami, and Ladich, 2006). Pelagic species, such as adult Arctic cod, adult salmon and similar species would startle and scatter as noise continues and, in theory, receive reduced levels of sound. Sedentary, burrowing, territorial, benthic-obligated fish, shallower near-shore fish, fish eggs and fish larvae in the area of the rig and oil spill would be exposed to higher noise levels due to their limited swimming behaviors, obligate life history characteristics, behavioral traits or spatial limitations. Foraging and reproduction behaviors of these benthic-obligate fish could be affected negatively by seismic activities and noise. Skimming or vacuuming the microlayer would disturb chemical, physical, and biological processes that take place in this layer and would injure or kill sensitive pelagic life stages including fish eggs, fish larvae and microorganisms that are important prey for fish. Icebreakers would cause disturbance to ice habitat, and depending on the time of year, could affect the eggs and young larvae or Arctic cod.

A-7.4.3 Phase 3 (Post-Spill and Long-Term Recovery)

In long-term recovery, there would be a continued presence of people in the area for monitoring and research. Monitoring and research would include small boat and aircraft landings on shorelines and people walking and wading through aquatic habitats. These activities could result in trampling of fish habitats, noise and disturbance to fish and removal of fish from the system for research purposes.

Over the long-term, contamination of aquatic environments from oil (and possibly dispersant residue on the seafloor) would continue from oil breakdown products such as PAHs. Sunlight (UV radiation) increases the toxicity of PAHs, so summer sunlight in Arctic Alaska may exacerbate the amount and degree of toxicity exposure.

Long-term chronic effects from oil would occur in fish that occupy estuarine, intertidal and freshwater habitats where oil accumulates and weathers, producing PAHs especially toxic to lipid-rich eggs. If chronic exposures persist, stress may manifest sublethal effects later in the form of histological, physiological, and behavioral responses, including impairment of feeding, growth, and reproduction (Heintz et al., 2000). Chronic toxicity and stress may also reduce fecundity and survival through increased susceptibility to predation, parasite infestation, and zoonotic diseases. The frequency of a single symptom does not necessarily reflect the effects of oil on the organism, so the cumulative effects of all symptoms of toxicity must be considered in evaluating acute and chronic effects of oil on fish.

Contaminant exposure can make a spawning site unavailable for multiple generations if the oil is detectable by the fish. If a population continues to spawn and/or rear offspring in oil-contaminated areas, abnormal development, genetic alterations or abnormal behavior may repeat through successive generations. The likely results would be fewer juvenile fish survive, so that recruitment from the early life stages is reduced and adult populations decline. Declining adult populations may not be replaced at sustainable levels. Ultimately, these cumulative effects on individuals can affect the population abundance and, subsequently, community structure (Patin, 1999; Ott, Peterson, and Rice, 2001; Rice et al., 2000). Moles and Norcross (1998) documented deleterious effects on juvenile flatfish species, including yellowfin sole, which were exposed to sediments laden with Alaska North Slope crude oil. The effects of this controlled laboratory experiment included changes in tissues and significant decreased growth rates in yellowfin sole juveniles at 30, 60 and 90 days of exposure.

Furthermore, as result of environmental stress and changes resulting from oil spills and a warming environment due to climate change, previously unknown fish populations could move into a new areas and complicate recovery (Cheung et al., 2009).

A-7.4.4 Conclusion

The impacts of a VLOS in the Beaufort Sea on a fish species and its population would depend on many factors including life stage affected, species distribution and abundance, habitat dependence (ocean water column, sea surface, benthos, sea ice, estuarine, freshwater), life history (e.g., anadromous, migratory, reproductive behaviors and cycle, longevity) and spawning location, exposure level to oil or dispersants, effects on the food web, and seasonality of the spill. Although the spill trajectories are the same as were described for large oil spills, the amount of oil spilled would be greater, so the overall impact on fish would be greater. Considering all these factors, especially food web and spawning requirements, a VLOS in Stefansson Sound would likely have major impacts on fish resource, and would persist for multiple generations. The species that would be particularly vulnerable to effects at individual and population levels include: saffron cod, Arctic cod, sand lance, capelin, nearshore sculpin species, nearshore flatfish, migratory least cisco, migratory Dolly Varden, migratory Arctic char, rainbow smelt, stickleback, and migratory whitefish. Other fish species that would be affected by a VLOS include snailfish, eelblennies, eelpouts, poachers, offshore sculpin, and alligatorfish.

A-7.5 Effects of a VLOS on Birds

BOEM analyzed effects of a Very Large Oil Spill (VLOS) greater than or equal to a worst case discharge of 4.61 million barrels of oil released over 90 days after a catastrophic event such as a developmental drilling well blowout. A VLOS is a low-probability event with the potential for major effects. Exposure to oil from a VLOS would have similar types of impacts on birds as spills of other magnitudes (FEIS Section 4.3.3); however, the area and the number of individuals, and possibly species, likely affected would increase, and the degree of impact would be more severe because of the much larger volume and duration of the oil spill. A VLOS can affect extensive areas of shoreline, and with the number of birds and habitat area affected, long-term and population-level impacts for some species could be incurred. The precise nature and magnitude of the effects on bird populations from a VLOS resulting from the Proposed Action would depend on the timing of the spill and environmental conditions such as sea ice presence, and the species, life stages, and range of habitats exposed to it. For purposes of analysis, the VLOS scenario is divided into phases, and the adverse effects on birds that could result during each phase are described in the following sections.

A-7.5.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

Oil in the Beaufort Sea would be a serious threat to waterbirds, including foraging waterfowl, phalaropes, seabirds and loons, because of its properties of forming a thin, liquid layer on the water surface. BOEM's VLOS modeling also shows that a very large oil spill originating in summer at the proposed LDPI would have a 17 percent chance of reaching the shore of the Sagavanirktok River Delta within 1 day, and 33 percent within 90 days (Tables A.2-25, A.2-29). Birds, if present, would therefore be vulnerable both in marine waters and in intertidal areas on shore during this phase.

As with large spills, seabirds and waterfowl are initially most vulnerable to offshore oil spills because they spend the majority of their time in marine waters and often aggregate in dense flocks. Direct exposure to oil would be the most critical VLOS impact on birds during Phase 1. Bird deaths due to oil spills are described in Section 4.3.3 and primarily arise from exposure from wetting and loss of thermoregulatory ability, loss of buoyancy and waterproofing, or from matted plumage, inability to fly or forage, ingestion and inhalation of vapors.

Waterbirds are vulnerable throughout the open-water season, beginning with their spring arrival in the open-water leads. Large numbers of shorebirds and waterfowl could come into contact with spilled oil along shoreline areas and could be affected during spring arrival, breeding, post-breeding, molt, or fall migration through oil exposure and subsequent hypothermia or other means of mortality. They could also be affected by eating contaminated intertidal prey or through mortality in their invertebrate food sources, as could scavengers and predators such as ravens and raptors. The species potentially impacted the most are the same as those previously described for a large spill (Section 4.3.3). Some species anticipated to have the highest rates of exposure and impacts in the case of an unlikely VLOS are discussed further below.

A-7.5.1.1 ESA-Listed Species

Like other sea ducks, spectacled and Steller's eiders must stage offshore in the spring open-water leads unless or until their local tundra breeding habitats become available in late May through mid-June. Between late June and the end of August, non-breeding, failed-breeding, and post-breeding spectacled eiders are commonly found foraging in the marine waters of the Proposed Action Area, including off the Sagavanirktok River Delta and in Foggy Bay. Approximately 540 spectacled eiders have been estimated outside of the barrier islands between Harrison Bay and Camden Bay in these months (Stehn and Platte, 2000), and a few birds may be present in to October. The birds are broadly distributed and do not tend to form dense flocks at this time of year, and a hypothetical VLOS would not be expected to spread uniformly in all directions, so it is unlikely that all birds present in the Central Beaufort Sea area would be directly contacted. Should a VLOS occur and spread during most periods of local eider activity, many, potentially on the order of 100, spectacled eiders could be contacted. Additionally, the fish and lower trophic resources on which eiders feed would be expected to incur major impacts from a VLOS. Female eiders are generally faithful to breeding sites, while males are not (Sexson, Pearce, and Petersen, 2014). Because VLOS prey impacts could persist for several years, they could have major impacts on the locally breeding females, as well as to new males each year of prey impacts. If not lethally impacted by contact therefore, hundreds of spectacled eiders could be otherwise adversely affected by prey contamination, and those impacts would be spread across several years, i.e., long-lasting. Impacts to 400-500 spectacled eiders, or about 3 percent of the estimated 14,800 ACP breeding population, that persist over several generations would be considered long-lasting and severe, and the loss of as few as a hundred spectacled eiders would be expected to have major impacts to the local Central Beaufort Sea breeding population for similar reasons.

Steller's eiders make little use of the Sagavanirktok River Delta and Foggy Bay, their ACP population is small (possibly less than 1,000) and their distribution is limited. One Steller's eider was recorded 25.5 miles offshore of the Maguire and Flaxman Islands in a September survey (Morgan, Day, and Gall, 2012), and a flight-capable brood was reported on an inshore lake near the Sagavanirktok River (Quakenbush, et al, 2002). BOEM's oil spill modeling (see below and Table A-7-2) indicates that, should a VLOS occur, there is no more than a 5 percent chance that oil would reach Prudhoe Bay waters or west, where Steller's eider are more likely to be found. While it is possible that two or three Steller's eiders could be contacted by oil should a VLOS occur, this would represent less than 1 percent of the total ACP breeding population, likely at the eastern limit of their current breeding range, and be considered a minor level of impact.

A-7.5.1.2 Non-Listed Species

Waterfowl

Long-tailed duck and king eider could experience mortality of hundreds or thousands of individuals if exposure occurs at periods of peak use of nearshore waters (lagoon system) between the barrier islands and mainland. Long-tailed duck is typically the most locally abundant sea duck species over the course of the open-water season, occurs in high density, flightless molting flocks, and would be likely to incur high rates of contact. Large numbers of sea ducks initially appear as leads open in marine waters in spring. Hundreds may be present initially but it is possible that several thousand long-tailed ducks and king eiders could use marine waters in the vicinity of the Proposed Action Area over the first year of a VLOS because of the on-going arrival of individuals moving through during migrations. For example, many king eiders stopping on spring migration breed locally while others go on to breed in Russia or farther east in Canada (Dickson et al, 2012, Quakenbush et al, 2009). A VLOS could impact not just local breeders but birds from some of these larger Arctic populations that move through the area during migration. These larger Arctic populations may number in the hundreds of thousands so losses in the thousands would not be expected to result in population-level impacts, but would be considered widespread. Other sea ducks such as common eider and scoters could also experience high rates of exposure and mortality to their local breeding populations, and some less severe mortality impacts to migrants and greater ACP populations. Additional numbers of surviving sea ducks would be affected by the year-long impacts on lower trophic prey, and possible decade-long impacts in the Boulder Patch.

Geese vulnerable to a hypothetical VLOS in the Proposed Action Area are greater white-front goose, Pacific black brant, lesser snow goose, and Canada goose. Greater white-fronts are the most abundant goose breeding on the ACP. Snow geese are colonial nesters that nest in only a few places in Alaska, all on ACP coastal habitat. One of their largest colonies has been on the Sagavanirktok River Delta where they nest on Howe Island, and sometimes Duck Island. Brant nest colonially primarily in shoreline habitat between the Colville and Canning Rivers, in the general Central Beaufort Sea coast vicinity of the Proposed Action Area. In the event of a VLOS, potentially thousands of geese would be vulnerable to contact while foraging or resting in nearshore waters during staging or breeding.

Post-breeding geese move, often in large flocks, in to protected deltas and inlets and on to nearby large lakes, including the lakes north of Teshekpuk Lake, to undergo a flightless molt. If a VLOS spread to the Colville River Delta or west, these molting geese would be vulnerable to direct contact and/or loss of forage, depending on time of year. They would also be vulnerable should oil be moved onshore by storm surges or ice movement in to lake molting habitat, which may move closer to shore over time with climate change-driven shoreline erosion (Flint, Whalen, and Pearce, 2014). If oil contamination of geese molting habitat caused food resources to be depressed for several years, long-term impacts would be expected. Tens of thousands of greater white-front geese can molt in the lakes northwest of Teshekpuk alone. Because they have a large overall population and have been increasing in abundance, impacts to greater white-front geese here would not have population-level, or likely more than moderate impacts. The other species also have relatively much larger populations overall beyond their Central Beaufort Sea coast populations, and also have been increasing in abundance, so VLOS effects would be generally limited to long-lasting but less than severe, and therefore moderate impact. Other potential waterfowl impacts could include dozens of breeding tundra swans foraging in marine and coastal habitat, but this species is also increasing across Alaska and these impacts would be considered minor. A large proportion of the Alaska-breeding population of lesser snow geese currently nests on the Sagavanirktok River Delta; therefore, this particular waterfowl population could potentially incur a major level of impact should a VLOS occur. In summary, waterfowl populations in the Proposed Action Area could experience impacts ranging from minor to major, should a VLOS occur.

Seabirds and Loons

Several species of seabirds could experience widespread mortality in pelagic waters from a VLOS. Arctic tern is a locally abundant forager in pelagic waters in the summer, and also a common breeder onshore in the Proposed Action Area. A VLOS could not only cause wide-spread mortality of adults, but of chicks as well, if adults bring contaminated food or residual oil on their feathers back to nests. The local population of this species could incur high levels of mortality and sublethal effects. As with many of the waterfowl discussed above, Arctic tern's wide ranging and abundant overall population would prevent the species itself from incurring more than minor impacts.

Impacts to black guillemots could be extensive if a spill extended to the ice edge, where these birds are known to forage. The abundance of prey items could be reduced or contaminated with oil, resulting in impacts to black guillemots, even if they are not directly exposed to oil. Because of their higher abundances outside of the Beaufort Sea, population-level effects are not expected; however, the greater relative abundance of piscivorous birds, and impacts to these birds, could potentially mean alterations of local trophic relationships.

Ross's gulls and ivory gulls are ice-associated birds and breed well outside the Proposed Action Area, but are regularly seen foraging in the Beaufort Sea. This species could incur mortality similar to black guillemot if a hypothetical VLOS was in close proximity to the ice edge, and as there are some indications that they may be in decline (Joiris, 2016), it is possible that they could sustain long-lasting impacts.

As a common breeder and pelagic forager, glaucous gull could be affected in large numbers through direct contact, contaminated food, and nest contamination. Owing to its overall large population, a VLOS would probably not have population-level effects. Sabine's gull is also a local breeder and pelagic, surface-feeding gull that begins arriving in the Proposed Action Area in late May, but occurs in lower abundances than glaucous gull. Foggy Island Bay appears to be an important ACP breeding area for Sabine's gull, however, and therefore a VLOS that impacts this population may have severe long-term impacts to the local population.

Hundreds or thousands of short-tailed shearwaters could be contacted and killed by spilled oil. Short-tailed shearwaters are widespread across the Beaufort Sea in summer and fall. Flocks of shearwaters could number in the tens of thousands. Most, but not all, foraging shearwaters tend to occur farther offshore however, so numerous flocks would be more likely to be encountered if the VLOS trajectory went in to offshore waters, beyond the barrier islands. They forage on patchily distributed zooplankton, euphausiids, and small fish in pelagic waters, and the non-uniform distribution of these birds could favor their survival during a VLOS or lead to extensive mortality. Their large population (20-30 million in the northern hemisphere) is unlikely to be affected, and impacts therefore considered temporary, even though large numbers of individuals could be contacted with oil or eat contaminated food.

Jaegers are present in low concentrations throughout the Beaufort Sea. Spilled oil could contact and kill jaegers as they spend most of their time foraging or resting on the sea surface. The likelihood of large-scale mortality and population-level impacts to jaegers is minimal because they occur in low densities and fewer than 100 would probably be affected.

Loons using the Beaufort Sea typically migrate close to shore until they are near their tundra breeding grounds. Loons using nearshore areas could be affected by oil contact early in the open-water season. A hypothetical VLOS could affect nearshore areas used by nonbreeding loons or, later in the open-water season, loon broods. Loons are known to occur far offshore once the water opens up however, and typically are widely dispersed while foraging. Pacific loons, typically the most numerous in the Proposed Action Area, could experience 100 or fewer deaths. Yellow-billed and red-throated loons may suffer dozens of mortalities. While these species may have incurred recent declines, impacts of this magnitude for species breeding across the ACP would be considered less than severe.

Shorebirds

Phalaropes, as common foragers on patchily distributed zooplankton in Beaufort Sea waters, could experience hundreds of mortalities. This would be particularly true late in the open-water season (i.e., post-breeding), when they are believed to be most abundant in marine waters. Red-necked phalaropes are considered more common in the Beaufort Sea and red phalaropes more common in the Chukchi Sea, but both regularly occur and could be vulnerable in the Beaufort Sea.

Given the high variability in shorebird abundance at migration stopover sites, a VLOS that contacted shoreline habitat could affect either a few shorebirds or almost every shorebird using an area, depending on when the spill occurred. Between July and September, migrating flocks can number in the thousands of birds, and new thousands can arrive from outside areas daily during peak migration. If several flocks were contacted by spilled oil, mortality in the thousands of one to several species of shorebirds could occur. See FEIS Section 4.3.3, Large Oil Spills, for a list of affected bird species. Prior to migration, dozens of locally breeding shorebirds or their nests could be contacted or contaminated by shoreline oil, and breeding and migration foraging habitat and food sources could be impacted or lost for years, impacting many more birds. The loss of thousands of several shorebird species each at a migratory stopover would be considered a widespread impact in the migratory sense, but not severe relative to many population sizes, and population recovery would likely occur in fewer than three generations (once oiled habitats had recovered) if population trends continued to be stable. Some species that are less abundant, declining, or have more restricted ranges, such as buff-breasted sandpiper, could potentially incur longer-lasting effects to a larger percentage of their population, and therefore severe impacts.

Other Birds

If oil from a hypothetical VLOS reached the shoreline or further inland, other birds could be impacted. For example, dozens of common ravens and raptors could be impacted if they fed on contaminated items at the shoreline, and could bring oil back to contaminate their nests. Dozens of

Lapland longspurs and other breeding landbirds could potentially be affected via prey, perch, nest, or water fouling if oil from a VLOS was moved ashore on to coastal breeding habitat. These birds are generally territorial in breeding distribution and not susceptible to exposure in high density numbers. Breeding habitat and food sources could be impacted for several years, but the loss of dozens of these abundant birds, even over several years, would likely be limited to a minor level of impact.

A-7.5.2 Phase 2 (Spill Response and Cleanup)

Spill response activities could disturb and displace birds, and potentially directly cause lethal impacts to some nests. The specific types of impacts that birds may experience from large spill response and cleanup as discussed in FIES Section 4.3.3 would also be experienced by birds in the event of VLOS response and cleanup. These include loss and damage of food resources from mechanical spill response; loss of nests to cleanup worker disturbance or inadvertent crushing; and disturbance and displacement from preferred foraging, nesting, brood-rearing, molting, or staging habitats, potentially leading to reduced fitness. It is possible that displacement could have net beneficial effects on some birds by intentionally or unintentionally moving them away from oiled areas. This displacement may move birds to unoiled areas, with low energetic costs, if these habitats were of similar quality. For purposes of conservative analysis, however, BOEM assumes that the majority of birds so displaced would be moved to either inferior habitats or nearby oiled areas, and therefore experience net negative impacts.

In the event of VLOS response and cleanup, there would be additional impacts beyond those detailed for large spills. Work camp and storage area construction could disturb birds, and damage or cause the loss of nesting or terrestrial foraging habitat. Arctic wetlands are slow to naturally rehabilitate, so unmitigated tundra or wetland damage could cause decades-long habitat impacts. However, such habitat impacts are not expected to be large in area relative to surrounding undisturbed habitat. Unless they occur in particularly unique or sensitive habitats, impacts should be localized. If, however, worker or camp presence was situated on the only unoiled shoreline available for several miles, or otherwise blocked access to nesting common eider or nighttime staging shorebird roosts, impacts could be amplified. Expected repeated and substantial anchoring of response vessels and spill containment booms could also lead to long-term degradation or loss of small but numerous areas of marine foraging habitat. Depending on location and the quality of food resources potentially damaged, these impacts too could have long-lasting impacts on birds. If present, birds themselves would also be purposely hazed in attempts to get them to avoid oiled habitats, and oiled birds may be chased, handled, kept confined, or otherwise in effect “hazed” as part of rescue attempts.

The magnitude and duration of spill response impacts would be larger for a VLOS than for a large spill. The duration of cleanup activities may preclude birds from successfully using the area for an entire season or more, which could disrupt survivorship or productivity. Cleanup of the Exxon Valdez VLOS took more than four summers (EVOSTC, 2014). If disturbance from either a summer or winter VLOS continued in an important habitat site for multiple years, these impacts could increase for certain birds such as nesting common eider. If response and cleanup impacts occurred for repeated years in the most vulnerable habitats when birds were present (e.g., common eider barrier island nest habitats and shorebird staging areas), response impacts alone could be long-lasting and widespread. As long as oil remained in the same environment, however, spill recovery efforts would have both negative and positive effects, in that they may keep some birds from additional contamination impacts. It is unlikely that response activities would occur in repeated years across large enough proportions of a population’s habitat to have major impacts, so Phase 2 net impacts would likely increase, but remain minor to major for most of the same species.

A-7.5.3 Phase 3 (Post Spill and Long-Term Recovery)

A VLOS would cause long-term adverse effects (i.e., 2 years or more in duration) to coastal and estuarine migratory bird habitats. Long-term loss of breeding and forage habitat would occur where shoreside camps and storage areas displace tundra. Contamination of food resources or nesting substrates could lead to reduced fitness and productivity. FEIS Sections 4.3.1 and 4.3.2, describe how spill response may have long-lasting impacts on shorezone and benthic lower trophic food resources (Section 4.3.1), and widespread and persistent impacts on fish prey resources (Section 4.3.2), which could in turn have long-term consequences for many bird species, including benthic feeding sea ducks, staging shorebirds, piscivorous seabirds and loons, and others. After the EVOS, the extent and degree of oiling on shorelines decreased rapidly over the first few years, and it was assumed that remaining oil would be reduced to negligible amounts soon thereafter (Neff et al., 1995). However, long-term studies have raised concerns that the tiny fraction of largely unweathered lingering oil remaining for decades in intertidal sediments of some beaches may have exposed a few fish and wildlife populations as well as the nearshore ecosystem to chronic impacts (Esler et al., 2015). Most marine bird populations appear to have recovered from the EVOS, but in some cases have taken 10 years or longer (Lance et al., 2001; Stephensen et al., 2001; Wiens et al., 2004; McKnight et al., 2006; Esler and Iverson, 2010). Harlequin duck, for example, appears to have experienced such long-term impacts (Esler et al., 2015), and although it does not occur in the Beaufort Sea, its experience could indicate that other sea ducks with nearshore benthic feeding requirements may have similar vulnerabilities. Despite differences in species composition between the Gulf of Alaska (GoA) and Beaufort Sea, Beaufort Sea birds would probably not have more resilience to VLOS impacts than GoA birds.

Post-spill avian impacts would also continue to be widespread because of the extreme migratory nature of Arctic-breeding birds. The DWH VLOS was reported to have potentially affected bird populations, depending on their migration patterns, as far away as Alaska and northern Canada, Central and South America, or the Caribbean (Corn and Copeland, 2010; Deepwater Horizon NRDA Trustees, 2016). In other words, almost all birds that could be impacted move to other places distant from the Proposed Action Area to molt, winter, and in some cases breed. As described under Effects for Phases 1 and 2, the numbers of birds affected relative to overall population levels for most species would keep the long-term and widespread impacts from becoming severe. However, for some populations that are more limited in geographic scope or abundance, or are potentially declining or increasingly vulnerable to climate change impacts, (e.g., common eider), severe impacts could continue through the post-spill recovery period.

A-7.5.4 Oil Spill Trajectory Analysis

BOEM uses the OSRA model to estimate oil spill trajectories and consider the likelihood of contact to important bird habitats. An ERA is a hypothetical polygon that represents a geographic area important to one or several bird species during a discrete amount of time. Given the wide variety of bird species that use the U.S. Beaufort Sea area and factoring in continuous changes in prey abundance and other biotic and abiotic factors that affect bird distribution, it is possible that large aggregations of some bird species could be contacted by a hypothetical VLOS. The ERAs are intended to define these areas and broad time periods of aggregation for the modeling effort. The ERA locations are described in Appendix A and Maps A-2a, A-2c, and A-2f. The ERAs important to birds, including the seasonal use patterns (i.e., vulnerabilities) of birds using the area, are summarized in Appendix A, Tables A.1-2 and A.1-5. Table A-7-2 summarizes the results (expressed as a percentage of trajectories contacting) estimated by the OSRA model of a hypothetical VLOS contacting an ERA. Only probabilities equal to or greater than one percent are shown in the table.

According to the OSRA model, if a VLOS were to occur there is a substantial chance that the Sagavanirktok River Delta and Foggy Island Bay marine habitats (“ERA 77”) would be contacted. This ERA would face the greatest risk of all of the bird resource areas, with a 33 percent chance of a VLOS that is initiated at any time contacting it, and a 68 percent chance of contact should the VLOS occur in the summer.

Thousands of molting long-tailed ducks in the Foggy Island Bay-vicinity coastal lagoons would be at risk in July and August. The overall population of molting long-tail ducks in the adjacent coastal lagoon habitat can be in the tens of thousands, although the probability of VLOS contact of these adjacent ERAs falls considerably according to the OSRA, and given the large overall population of this species, it is unlikely that they would face population-level effects. Nonetheless, it is difficult to predict where the largest flocks of mobile birds may occur at any one time, and it is clear that large numbers of this species could be at risk at this time of year. Depending on season and bird movement in the local area, up to thousands of post-breeding king eiders may also perish.

A summer VLOS in Foggy Island Bay waters would also result in the direct mortality of breeding common eiders, red and red-necked phalaropes, glaucous gulls, geese, and lesser numbers of jaegers, swans, and loons. Breeding adults of all of these species that initially survive would also bring oil back to tundra and barrier island nests, contaminating and killing eggs and chicks.

On the Sagavanirktok River Delta, oil would threaten thousands of staging and migrating shorebirds and waterfowl, potentially representing a dozen or more bird species.

If a VLOS occurs, there are roughly equal probabilities that, should it travel beyond Foggy Island Bay, it would reach the coastal and barrier island ERAs that are adjacent in all directions. For a spill originating at any time of year, there is between a 4 percent to 7 percent chance that it could reach the Gwyder Bay, West Dock, Cottle & Return Islands (72) to the east; Stockton and Mclure (9), Midway, Cross, and Bartlett (96) Islands to the outside; and Mikkelsen Bay (78) to the east of Foggy Island Bay. For a summer VLOS, the probabilities that it would reach these surrounding areas are somewhat higher, between 8 percent and 14 percent. While the OSRA model shows a noticeable drop in probabilities of VLOS contact of adjacent habitats that are just a few miles outside of Foggy Island Bay, contact is still possible in all directions, and could affect thousands of additional birds, even tens of thousands of molting long-tailed ducks and post-breeding king eiders and other waterfowl and seabirds in the marine lagoon habitat, and hundreds or even thousands of additional waterbirds including seabirds and loons, waterfowl, and shorebirds and their coastal or barrier island nests. The OSRA conditional probability model shows a 5 percent chance of a summer VLOS contact (2 percent annual) for the Colville River Delta ERA (69), a critically important shorebird migration stopover site in both spring and fall. Tens of thousands of migrating shorebirds and waterfowl, including about 20 species and 20,000 dunlin (Andres, 1994; Bart et al., 2012; USGS, 2016), could be affected if a VLOS were to damage the Colville River Delta in July or later. New birds arriving and attempting to depart constantly during the post-breeding period from late June–October would increase the widespread nature of the impacts.

According to the OSRA model, if a VLOS were to occur it would remain almost entirely confined, even at 360 days, to the Beaufort Sea east of Point Barrow and west of Kaktovik. On an Alaska Arctic Coastal Plain scale, some of the most critical avian marine ecosystems include the river deltas/ estuaries, barrier island/lagoon systems, and the Chukchi Sea spring lead system, including (seasonally) Peard Bay immediately west of Point Barrow. As described in the paragraphs above, if a VLOS were to occur there is up to a 68 percent chance that local portions of the first two ecosystem types (i.e., Sagavanirktok River Delta and Foggy Island Bay ERA) would be impacted. The highest chances of a VLOS, should one occur, contacting Peard Bay ERA (64) or the Chukchi Sea Spring Lead System ERA (19), on the other hand, are extremely low at 0.25 percent (summer trajectory launch) and 0.12 percent (winter trajectory launch), respectively (ERAs not listed in Table A-7-2; pictured on Map A-2d).

Table A-7-2 Conditional Probabilities for Bird ERA Contact 90 Days[1] after VLOS

ID Number[2]	Description	Annual Probability (%)	Summer Probability (%)
ERA 2	Point Barrow Plover Islands (between Point Barrow and Smith Bay)	1	2
ERA 5	Beaufort Sea Shelf Edge IBA (between Utqiaġvik and Nuiqsut)	2	4
ERA 8	Maguire and Flaxman Islands	2	4
ERA 9	Stockton and Mclure Islands	6	10
ERA 65	Smith Bay	1	1
ERA 68	Harrison Bay	3	6
ERA 69	Harrison Bay/Colville Delta	2	5
ERA 71	Simpson Lagoon, Thetis and Jones Island	3	6
ERA 72	Gwyder Bay, West Dock, Cottle & Return Island	7	14
ERA 73	Prudhoe Bay	2	5
ERA 77	Sagavanirktok River Delta/Foggy Island Bay	33	68
ERA 78	Mikkelsen Bay	6	10
ERA 96	Midway, Cross and Bartlett Islands	4	8
ERA 124	Chukchi Sea Nearshore IBA	1	2
LS 105	Point Brower, Sagavanirktok River, Duck Island	29	33

Notes: [1] Probabilities for all ERAs remain unchanged, with no additional ERAs with >1 after 360 days (see Tables A.2-6, A.2-24).

[2] ERA = Environmental Resource Area, LS = Land Segment

Source: Appendix A Maps A-2a, A-2c, A-2f, A-3c; Tables A.2-5, A.2-23, A.2-11, A2-29.

A-7.5.5 Opportunities for Prevention, Intervention, and Response

Should a VLOS occur, the Solid Ice Condition in Section A-6.2 would be expected to reduce the chance that it would occur during the seasons when the majority of birds are present or reach open water habitats used by birds. The benefits of this mitigation, however, would potentially be tempered by other factors such as the possible range of times needed to mobilize a relief rig and whether or not the spring broken ice season and bird arrival begins prior to achieving well control and containment.

A-7.5.6 Conclusion

Based on conditional probabilities a VLOS starting at the proposed LDPI would threaten some important bird use areas, especially marine waters between barrier islands and the mainland, nearby barrier islands, and the Sagavanirktok River Delta. If Phase 1 occurred during the open-water season when birds are present, direct oiling of many species of birds and contamination of a significant portion of local food resources would occur. Many potentially affected bird species have large overall abundances or ranges well beyond the expected VLOS contact trajectories, and some, like geese species, have been increasing in their abundances. The migratory nature of Arctic bird life histories would generally mean that the VLOS impacts would be widespread, but the relative abundances would keep the impacts confined to minor or moderate levels for most species. However, a few populations which are relatively smaller, more locally confined, declining, and/or particularly vulnerable to oil contact or multiple impacts including climate change impacts, could potentially incur longer-lasting, even severe and therefore major, impacts. These could include non-listed populations such as Beaufort Sea-breeding common eider, lesser snow goose and Sabine’s gull, and buff-breasted sandpipers that move through Beaufort Sea coastal areas during migration.

ESA-listed spectacled eiders could experience moderate levels of impact across their ACP range. If one considers just that portion of the spectacled eider population that breeds on the Central Beaufort Sea coast, it is possible though not likely, due to their relatively dispersed breeding population, that this portion could experience a major level of impact. The listed population of Steller’s eider rarely, or at low abundance and density, occurs in the expected extent of the trajectory of a hypothetical VLOS, and no more than a minor level of impact for that species would be expected.

In summary, effects from a VLOS could be expected to reach long-lasting and severe, and therefore major levels of impact for at least a few ACP populations of non-listed migratory birds, including, potentially, common eider, lesser snow geese, Sabine's gull, and buff-breasted sandpiper. A VLOS could have long-lasting and widespread, but less than severe, and therefore moderate impacts on numerous other ACP populations including ESA-listed spectacled eider, and non-listed phalaropes and other shorebirds, ice-associated gulls and other seabirds and loons.

Phase 1 and 2 impacts combined, including those from both a hypothetical VLOS associated with the Proposed Action and from spill response and cleanup activities, would also be major, varying with species and population. Spill response and recovery alone would contribute net negative impacts which would be additive with the existing minor to major Phase 1 impacts. The results would generally be only slightly higher levels of impact to the same species groups. Impacts from Phases 1, 2, and 3 combined would also continue to range up to major. As with Phase 1 alone, impacts would be minor for abundant species, and potentially major for ACP populations such as less-abundant or declining sea ducks and shorebirds using impacted shorezone, benthic, or local fish resources. The Solid Ice Condition described in Section 2.5.1.1 may potentially reduce the chance that a VLOS would occur and persist during the seasons when the majority of birds are present or reach open water habitats used by birds. Because of the importance, however, of other variables (e.g., the potential 30-day time range for relief rig mobilization, etc.), potential overall level of impact of a VLOS would likely remain moderate to major.

A-7.6 Effects of a VLOS on Marine Mammals

Impacts to marine mammals from a hypothetical oil spill were analyzed in Section **Error! Reference source not found.**. Those analyses found marine mammals could experience mortality, long-term and short-term sublethal impacts, and secondary impacts to prey availability. The primary difference between the effects from a VLOS and those of a large or small spill are in the greater magnitude of the potential effects associated with a VLOS. Most Environmental Resource Areas (ERAs), Land Segments (LSs), and Grouped Land Segments (GLSs) have less than a 5 percent probability of being contacted by any fraction of materials from a VLOS at the LDPI or the Pipeline. Based on the assumption that a less than or equal to 5 percent probability of contact indicates a less than or equal to 95 percent probability of no contact occurring, only those ERAs, LSs, and GLSs experiencing a greater than or equal to 95 percent contact probability are analyzed for marine mammals.

A-7.6.1 Initial Event

The hypothetical VLOS scenario would begin with a well-control incident resulting in a blowout and its immediate consequences. This phase would cause only negligible, temporary, non-lethal effects on cetaceans. This phase does not consider the release of oil or the effects of supporting aircraft or vessels; those will be analyzed in Phase 2 and Phase 4, respectively. Potential IPFs and associated effects on cetaceans from Phase 1 follow below.

The hypothetical VLOS scenario would begin with a well-control incident resulting in a blowout and its immediate consequences, but not the release of materials into the water, amounting to negligible, temporary, non-lethal effects on pinnipeds.

For Pacific walrus, the initial phase could include a large explosion of natural gas and a fire. The bermed perimeter of the proposed LDPI would muffle much of the lateral noise, directing most of the noise from an explosion vertically. Nonetheless, there is some potential for any Pacific walruses in the vicinity of the explosion to experience adverse effects to their hearing. If walruses were in close enough proximity to be able to hear the explosion, they may experience TTS or PTS, depending upon their proximity and the sound level of the explosion, and they may also be frightened into a panic and leave the area. During stampedes from coastal or ice floe haulouts, calves and smaller walrus are the most vulnerable to injury; however the low number of Pacific walruses in the Beaufort Sea would prevent any such instances from occurring. Falling ash and debris could also injure or haze walrus away from the area; however an explosion on the proposed LDPI should remain mostly contained on the island, Furthermore, the structure of the island would prevent an explosion from affecting benthic invertebrates in the area.

The initial event for polar bears would likely consist of a large explosion of natural gas and a fire. The impact producing factors that might affect polar bears would be the explosion itself (depending upon the size of the explosion) and the smoke and debris resulting from the fire. Drilling at the proposed LDPI could occur year-round, so polar bears might be in the area if the explosion occurred. Because of the bermed perimeter of the LDPI, much of the lateral noise from an explosion would be buffered and directed upwards; however any polar bears swimming or crossing ice in the vicinity of an explosion could be affected.

A-7.6.1.1 Explosion

Materials released during a blowout could ignite, causing an explosion. An explosion from the island would create a single pulse sound event that could injure cetacean or pinniped hearing, depending on sound levels. It is possible that any individual cetaceans within the vicinity could experience TTS or PTS. PTS would be considered a permanent injury, decreasing and individuals ability to successfully interact with their environment and, ultimately, leading to declining health and potential mortality. Bowhead and gray whales typically avoid waters in the vicinity of the LDPI as described in Section 3.2.4. Consequently, it is unlikely any cetaceans or pinnipeds would be close enough to an explosion to experience behavioral impacts or injury to the bermed perimeter of the island which would buffer much of the lateral sound from reaching the water’s surface, while directing much of the sound from an explosion vertically. Occasionally a few beluga whales may enter Stefansson Sound and under such circumstances could be exposed to the above ground noise from a blowout. The explosion would likely produce temporary non-lethal effects among belugas close to the LDPI, in the form of a startle response. Startle events (McCauley et al., 2000) may cause cetaceans to display short-term avoidance activity such as change of swim direction and/or speed that may be accompanied by short-term endocrine response.

A-7.6.1.2 Offshore Spill

Phase 2 of the scenario focuses on the continuing release of oil into offshore and nearshore waters. Of all the phases, the Offshore Spill has the greatest potential to affect cetaceans and their habitats. More severe impacts could also occur, and in some cases cetaceans may require three or more generations coincident with restored and unaffected habitat to restore distribution and populations.

Ice seals would be exposed to hydrocarbons in offshore areas during a hypothetical VLOS event. Oil in the Chukchi Sea could cause short-term physiological effects to ice seals, could affect their prey resources, and could cause mortalities of some seals. Additional information about potential impacts of crude oil on seals is available in the 2007 FEIS [Section IV.C.1.h (4)] and in FEIS Section 4.3.4.

Below are potential IPFs associated with Phase 2 that have the potential to affect cetaceans and pinnipeds.

Contact with Oil

Cetaceans could experience effects from contact with hydrocarbons, including:

- Inhalation of liquid and gaseous toxic components of crude oil and gas
- Ingestion of oil and/or contaminated prey
- Fouling of baleen (bowhead, and gray whales)
- Oiling of skin, eyes, and conjunctive membranes causing corneal ulcers, conjunctivitis, swollen nictitating membranes and abrasions

The vulnerability of individual ice seal species to contacting crude oil is largely a function of their seasonal use of different areas. Some coastal use areas, polynyas, and lead systems are the most likely areas for relatively larger numbers of seals to come in contact with spilled oil. These are all aggregation areas for different species of seals at different times of the year. Differences in ice seal distributions are noted in the subsections below.

Spotted seals are known to aggregate in coastal areas during summer months, mostly in Kasegaluk Lagoon, and the areas between Kotzebue and Wales, Alaska. However, they also occur in small numbers in Smith Bay, Peard Bay, Dease Inlet, and the Colville and Sagavanirktok River Deltas, Alaska; plus sections of the Chukotka coastline, particularly near Kolyuchin Bay and coastal areas to the south. During a recent shallow geohazard survey (BPXA, 2014) survey spotted seals were the most numerous marine mammal observed by PSOs working for industry in the proposed LDPI area.

During the open-water season, ringed and bearded seals mostly associate with areas of sea ice, where they occur in their highest numbers; however a few should remain in Stefansson Sound (BPXA, 2014) and other areas where they would feed and occasionally haul-out if necessary. In contrast ribbon seals are mostly found in the pelagic areas of the southern Chukchi Sea, away from the coast and areas of sea ice.

As ice encroaches south in the fall, all of the ice seal species move south in tandem with the development of winter sea ice, eventually occupying the Bering Sea. However, many ringed and some bearded seals remain in the Chukchi and Beaufort Seas, using breathing holes, or lead systems and polynyas to access water. During the months of winter and early spring ringed seals prefer areas of landfast ice, while bearded seals utilize leads and polynyas, and hauling out on ice floes and pack ice.

Ice seals have some ability to purge their bodies of hydrocarbons through renal and biliary pathways. They can develop lesions on their eyes and some internal organs after contacting crude oil, though some studies indicated many of the physiological effects self-correct if the duration of exposure is not too great (Engelhardt, Geraci, and Smith, 1977; Engelhardt,1982, 1983, 1985; Smith and Geraci 1975; Geraci and Smith 1976a, 1976b; St. Aubin, 1990). However, Spraker et al. (1994) observed lesions in the thalamus of harbor seal brains after they were oiled, possibly explaining motor and behavioral anomalies (Englehardt 1983), and Lowry, Frost, and Pitcher (1994) noted reproductive complications in harbor seals exposed to oil from the EVOS.

While seals may experience short-term physiological impacts from exposure to an oil spill, Engelhardt (1983) states that exposure studies in ringed seals reveals they have the capacity to excrete accumulated hydrocarbons via renal and biliary excretion mechanisms, clearing blood and most other tissues of the residues within 7 days. In harbor seals (*Phoca vitulina*), a related species, a more recent investigation found no significant quantities of oil in the tissues (liver, blubber, kidney and skeletal muscles) of harbor seals exposed to the EVOS (Bence and Burns 1995), and the decreasing trend in harbor seal numbers since EVOS (4.6 percent per year) may have been erroneous since harbor seal populations were declining before the spill (Frost et al., 1999). A further analysis of harbor seal population trends and movements in Prince William Sound suggested harbor seals moved away from some oiled haulouts during the EVOS (Hoover-Miller et al., 2001) and the original estimate of more than 300 harbor seal mortalities may have been overestimated.

The discontinuous area of a VLOS depends on when and where a spill occurred, the spill flow rate, and duration. Based on average ice seal densities, the size of the surface slick could contact tens of thousands of seals. If ice seals are able to successfully detect/avoid crude oil or hydrocarbons from their bodies, as has been suggested (Geraci and St. Aubin, 1988), there should be few seal mortalities from a VLOS. It is conceivable, however, that because thousands of ice seals could be contacted, a number of those seals could die, especially if a large amounts of spilled materials were to reach a lead system. For these reasons a several hundred bearded, and ringed seal mortalities could occur after a

VLOS. Considering the lower numbers of spotted seals believed to seasonally reside in the Beaufort Sea, spotted seal mortalities could number in the tens to low hundreds.

Changes in Prey Resources. A potential effect of a VLOS could be the loss of fishes and invertebrates from local populations, particularly Arctic and saffron cod, arthropods, mollusks, and other invertebrates. Adult ringed, spotted, and ribbon seals mostly rely on fishes for the majority of their diets, although young seals may consume large numbers of arthropods like euphausiids and copepods. Bearded seals mostly feed on mollusks, polychaetes and arthropods to a large degree, but sometimes fish also account for a substantial portion of their diet. Impacts to these food sources over a large area could have far-reaching effects that could last for years, reducing the quantitative and qualitative food base for high level predators such as seals. Such losses in prey would reduce productivity or even cause short-term absence of seal populations from that area.

The constituents in crude oil break down over time, and weather, ocean currents, and temperature interact to disperse and volatize oil slicks. Many, if not most, marine organisms produce large numbers of offspring which are dispersed by ocean currents. Consequently, the loss of biota from an area exposed to crude oil should be replenished by immigration from other areas within two or so years, especially when the high reproductive rates, mobility of many marine organisms, and the influx of immigrant organisms via ocean currents is considered. Some prey groups such as mollusks may recover more rapidly than others such as fishes because of differing maturation rates, and reproduction potentials. Any ensuing prey distribution changes could contribute to the absence of several thousand individual bearded, and ringed seals, and several hundred spotted seals from an area where the food stocks have been depleted or destroyed. Such absences could take years to recover.

Most Pacific walruses in the Arctic remain in the Chukchi Sea during winter and overwinter in the Bering Sea, and only a few of them forage in the Beaufort Sea during summer. For this reason few Pacific walruses in the Beaufort Sea should be affected by a VLOS originating at the LI or PL. Exposure to oil or associated fumes could cause respiratory distress and inflammation of mucous membranes and eyes, leading to damage such as abrasions and ulcerations. Walrus, which have large protruding eyes, would be particularly vulnerable. Walrus rely primarily on a thick layer of blubber for insulation and therefore are unlikely to suffer from hypothermia as a result of oiling. However, they could experience skin inflammation and ulcers as a result of oil exposure. Studies have found that tissue damage can occur if walruses ingest oil or oil contaminants (Kooyman, Gentry and McAlister, 1976). Ringed and Bearded seals have the ability to metabolize small amounts of hydrocarbons so that such tissue damage is temporary unless the exposure is chronic over time (Kooyman, Gentry and McAlister, 1976). Although similar studies have not been done with walrus, their physiology is consistent with that of other Arctic seals. If walrus share this ability, some short-term impacts may be mitigated. Chronic exposure may still result in lethal effects or long-term sub-lethal, fitness-reducing effects.

Walrus at haulouts have been shown to be very sensitive to smells. Walrus may avoid oil or oiled ice due to the smell, or may remain in the area in spite of the presence of oil. Studies on other seal species have indicated that seals intent on feeding will not avoid an area due to oil or oil sheens (Geraci and St. Aubin, 1990). Oil may impede the ability to dive by increasing buoyancy, which would in turn increase the energy expenditures of feeding, particularly for younger, smaller walrus. The VLOS scenario analyzes 27°American Petroleum Institute (API) oil, a light weight of oil. In general, lighter oils dissipate more quickly through evaporation, dissolution and dispersion. For comparison, the oil spilled in the EVOS was a medium weight of oil. Oil, especially heavy oils and weathered tarry oil, may impede swimming and diving by adhering to the walrus hide and reducing the ability of the animal to move its flippers efficiently. Sand, gravel or other debris may adhere to the oiled skin further impeding locomotion and impacting the walrus' ability to use their vibrissae to locate prey items along the sea floor.

Walrus primarily feed on benthic invertebrates, such as clams and marine worms. Benthic invertebrates that come into contact with the spill would ingest hydrocarbons from water, sediments and food. Invertebrates could concentrate contaminants because they metabolize hydrocarbons poorly. Long-term or chronic oil ingestion may result in kidney damage, liver damage, or ulcers in the digestive tracts of walrus. Depending upon the level of impacts to benthic invertebrates, walrus could be forced to travel farther to forage, resulting in increased energetic costs and perhaps increased competition among walrus for food sources.

Polar bears mostly rely on their subcutaneous layer of fat for insulation when swimming and rely on both fat and fur for insulation when out of the water. Consequently, any oiling could compromise the insulative value of their fur. Hurst and Oritsland found polar bear pelts were similar to those of sea otters and fur seals in terms of the loss of insulation once oiled (Hurst and Oritsland, 1982). Once oiled, polar bears could also ingest oil while grooming which could lead to renal, hematological, and biliary complications, and exposure to fumes from VLOS materials could cause respiratory distress, mucous membrane and eye inflammation, and ulcerations. High levels of exposure could result in death, while chronic low level of exposures may result in long-term sub-lethal effects that reduce fitness. Polar bears could also ingest oil by eating oiled seals or carcasses, with results similar to those described for grooming oiled fur.

Polar bears rely primarily on ringed and bearded seals as prey in the Beaufort Sea, but they will also take beluga, and regularly scavenge carcasses of harvested bowhead whales and other marine mammals that have died of natural causes. Polar bears have been observed biting cans of snowmobile oil and neoprene bladders of fuel. One polar bear died as the result of eating a car battery, while another died after ingesting ethylene glycol (Geraci and St. Aubin, 1990; Amstrup et al., 1989). Consequently, there is nothing to suggest polar bears scavenging on oiled seal carcasses would refrain from ingesting lethal doses of oil. Studies on seals indicate that individuals intent on feeding will not avoid an area due to oil or oil sheens (Geraci and St. Aubin, 1990). Polar bears may pursue seals into oiled waters. Though ringed and bearded seals have some ability to metabolize and eliminate hydrocarbons (Kooyman, Gentry and McAlister, 1976) long-term or chronic oil ingestion may result in kidney damage, liver damage, or ulcers in the digestive tracts of seals and any polar bears that feeding on them.

A-7.6.1.3 Onshore Contact

The only seal species likely to be affected by spills contacting coastlines would be spotted seals. Bearded, ringed, and ribbon seals spend their lives on or around sea ice and rarely if ever come ashore in coastal areas. Known spotted seal onshore haulouts along the Beaufort Sea coast occur at the mouths of the Colville and Sagavanirktok Rivers, Dease Inlet, and Smith Bay.

Depending upon the location of the spill site and other factors, oil could contact shore within 10 days of the initial event. Walrus could come into contact with oil at coastal haulouts. Regardless of whether contact occurred at sea, on ice or on land, the results to the physical health of the walrus would be the same as those described in FEIS Section 4.3.4.3.2. If walrus avoid coastal areas that have been fouled by oil, they may be excluded from important coastal resting areas once the sea ice retreats off of the continental shelf in late summer. Walrus cannot remain at sea indefinitely; they must haul out to rest and regain body heat. Calves and young walrus are more restricted in the amount of time that they can spend at sea, and unable to swim as far or for as long as adult walrus. This worst-case scenario should not produce population-level effects since most onshore contacts would occur in the Beaufort Sea where Pacific walruses are rare.

Depending upon the location of the spill site and other factors, BOEM has estimated that oil could contact shore within 10 days after a VLOS. Polar bears could come into contact with oil as they move along the coast or barrier islands, or while moving between shore and the ice edge. Regardless of whether contact occurred at sea, on ice or on land, the results to the physical health of the polar bear would be the same as those described for offshore oil spills. If polar bears avoid coastal areas that have been fouled by oil, they may be excluded from important travel corridors to feeding, resting or denning areas, which could impact fitness or reproduction.

Contact with Oil

The effects of seals contacting crude oil were described in FEIS Section 4.3.4.2.11, Phase 2, and in Section 4.3.4.

Contamination

Impacts may include ingestion of contaminated prey (prey that have consumed or absorbed oil fractions that remain in their bodies) and/or reduction of food source. Pollution stemming from an oil spill may contaminate environmental resources, substrates (water, air, and sediments), habitat, and/or food sources. Contamination may also cause mortality and or contamination of food sources during the long-term (multi-year) and short-term (current-year production, ice and oceanographic cycles).

The effects of oil contamination on spotted seals are the same as described in Phase 2. However, abrasive sediments and sands may scrub oil from the coats of some seals lessening the amount and duration of contamination that individual seals experience. Other individual seals that are oiled may inadvertently pick up debris and some sediment that adhere to the oil on their skins and hair. Nonetheless, Lowry et al. (1994) found that oiled seal skins shed their crude oil coating after about 7 days of immersions. Likewise, phocid seals rely on a thick layer of blubber for insulation which eliminates the potential for spilled oil to affect their thermoregulation abilities.

Loss of Access to Habitat (Disturbance and Displacement)

Cetaceans may be displaced from feeding areas, migration routes, and other life function habitats. The latter include areas critical to the maintenance of individuals and populations, including birthing, feeding, breeding, migration, rearing/nursing, and resting. Moreover, whales may lose access to feeding areas or to areas where prey concentrate due to avoidance of spilled oil—displacement, or movement away.

This analysis will address each of these potential effects for each species of cetaceans using the Beaufort Sea.

A VLOS that contacts the shoreline would not necessarily affect the foraging success of bearded or ringed seals since they feed in the water and prefer sea ice haulouts; however, a lingering spill contacting the shoreline, and remaining spread over large areas of water could affect foraging success for the different seals in the Beaufort Sea. Such effects might last across seasons and perhaps a few years.

A-7.6.2 Cetaceans

A VLOS originating in the Proposed Action Area could affect cetaceans in a variety of ways. Population size, distribution and habitat selection are often species specific, putting different cetacean species at varying degrees of contact risk from a VLOS.

Effects of a VLOS on each cetacean species are analyzed below using the hypothetical scenario in Section A-5.3. One ESA-listed endangered whale (bowhead whale), and two other whale species (beluga and gray whales) occur in the Beaufort Sea. Additional cetacean species occurring in the Chukchi Sea include minke, killer whales, and harbor porpoise, as well as ESA-listed (endangered) fin and humpback whales.

When responding to a VLOS, response contractor(s) would work with NMFS, USCG, and state authorities on marine mammal management activities. In an actual spill, the aforementioned groups would likely have a presence at the Incident Command Post to review and approve proposed activities and monitor their impact on marine mammals. As a member of the team, NMFS personnel would be largely responsible for providing critical information affecting response activities to protect marine mammals. Specific marine mammal protection activities would be employed as the situation requires and would be modified as needed to meet the current needs. In all cases long-term recovery to pre-spill abundance, distribution, and productivity is likely, but recovery period would vary, and require access to unaffected/restored habitat during the recovery period.

A-7.6.2.1 Beluga Whale

Beluga whales of three different stocks use habitats from along the Alaska Beaufort and Chukchi Sea coastline seaward to beyond the shelf break. The distribution of these stocks are seasonal, wintering in the Bering Sea and migrating to summer habitats in the Canadian Beaufort, Alaskan Beaufort and Chukchi Seas (Suydam et al., 2001; Suydam, Lowry, and Frost, 2005; Roseneau, 2010). Some belugas migrate through the spring lead systems concurrent with the bowhead migration during April through June. Summer aggregations of molting belugas and females with calves occur in coastal lagoons and there is apparently habitat preference for waters near the continental shelf edge during summer and fall, particularly in the vicinity of Kasegaluk Lagoon.

Contact with Oil

Contamination of the spring ice lead system from a VLOS could result in direct contact with spilled oil. Notable increased vulnerability of belugas exists in spring and early summer, when concentrations occur in the warm shallow waters of Kasegaluk Lagoon to molt. Concentrations of large numbers of beluga whales are observed in some years in unpredictable places and numbers. In July of 2010, 650+ belugas were observed for a number of days in Elson Lagoon north of Utqiaġvik (Monnett, 2010; NMFS, 2014c). Belugas are present in the Chukchi Sea and far western Beaufort Sea during the open- water season offshore as well as in coastal lagoons (Suydam et al., 2001; Suydam, Lowry, and Frost, 2005; and Ireland et al., 2009). Summer and fall observations indicate concentrations of belugas along and beyond the shelf edge, fall migration along the shelf edge, and some use throughout the shelf areas in the Chukchi and Beaufort Seas. There is acoustic evidence that some individuals may spend the winter period in the Alaska Arctic as well. They may, upon contacting spilled oil, experience inhalation, ingestion, skin and conjunctive tissue irritation similar to other whales, and also may exhibit detection and avoidance of spilled oil. Substantial injury and mortality due to physical contact inhalation and ingestion is possible to beluga whales, especially calves of the year and juveniles using habitats along the Alaska Chukchi Sea coast and the shallow lagoons situated there. Restoration of seasonal use patterns and abundance could take multiple generations and the potential for no recovery exists, depending on the extent of injury and mortality experienced. DFO (2010) indicates the factors and potential causes that may be hindering the recolonization of historic St. Lawrence beluga habitats after habitat degradation and loss of learned site fidelity through overharvest and extermination.

Ingestion

Beluga whales prey on fish (Arctic cod, saffron cod, herring, pollock) species as well as large copepods in the water column and on or near the surface, which may have spilled oil present. Consumption of contaminated prey, the reduction or mortality of local forage fish populations could create periods whereby summer prey would not be available for an undetermined time period depending on prey recovery rates and pioneering use of the restored prey. The fish populations in lagoons along the Chukchi Sea coast used by belugas for migration, molting and nursing are vulnerable to oil contamination and subsequent ingestion by large numbers of beluga whales (see the 2011 SEIS (Section IV.E.5)).

Oil components or chemical oil dispersant derived compounds could be consumed by belugas feeding on prey anywhere in contaminated water column layers to the sea floor. Belugas may ingest oil fractions from contaminated prey items. Ingestion of petroleum hydrocarbons can lead to subtle and progressive organ damage or to rapid death in mammals. Many polycyclic aromatic hydrocarbons are teratogenic and embryo toxic in at least some mammals (Khan et al., 1987). Maternal exposure to crude oil during pregnancy may negatively impact the birth weight of young. Oil ingestion can decrease food assimilation of prey eaten (St. Aubin, 1988). Decreased food assimilation could be particularly important in very young animals, those that seasonally feed, and those that need to put on high levels of fat to survive their environment. Wilson et al. (2005) examined CYP1A1 protein expression immunohistochemically in multiple organs of beluga whales from two locations in the Arctic and from the St. Lawrence estuary. These beluga populations have some of the lowest (Arctic sites) and highest (St. Lawrence estuary) concentrations of PCBs in blubber of all cetaceans. Cytochrome P450 1A1 (CYP1A1) is induced by exposure to polycyclic aromatic hydrocarbons (PAHs) and planar halogenated aromatic hydrocarbons (PHAHs) such as non-ortho polychlorinated biphenyls (PCBs). The systemic high-level expression of CYP1A1 in Arctic beluga suggests that effects of PAHs or PHAHs may be expected in Arctic populations. The high-level expression of CYP1A1 in the Arctic beluga suggests that this species is highly sensitive to CYP1A1 induction by aryl hydrocarbon receptor agonists. Samples from these populations might be expected to have different contaminant-induced responses, reflecting their different exposure histories. The pattern and extent of CYP1A1 staining in whales from all three locations were similar to those seen in animal models in which CYP1A has been highly induced, indicating a high-level expression in these whales. CYP1A1 induction has been related to toxic effects of PHAHs or PAHs in some species. The systemic high-level expression of CYP1A1 in Arctic beluga suggests that effects of PAHs or PHAHs may be expected in Arctic populations, as well. The high-level expression of CYP1A1 in the Arctic beluga suggests that this species is highly sensitive to CYP1A1 induction by aryl hydrocarbon receptor agonists.

Contamination and Reduction of Food Sources

Abundance and distribution may be modified or reduced in near shore areas in response to prey (fish and large copepods) reduction and contamination resulting from a VLOS. Prey recovery periods would determine recovery periods for beluga whale distribution and abundance to pre-spill levels (see the 2011 SEIS (Section IV.E.5)).

Displacement From and Avoidance of Habitat

The presence of oil could displace belugas from, or prevent or disrupt access to affected habitat areas. The loss of nearshore and lagoon habitats by beluga females with calves and juveniles for nursing and molting, depending upon the extent of injury or mortality experienced may not be recoverable or take multiple generations to recover the use and abundance of whales using these seasonally important habitats. Impacts to the distribution and abundance of prey, if they should occur, would largely determine the seasonal distribution and habitat use by belugas.

A-7.6.2.2 Bowhead Whale (Endangered)

Bowhead whales migrate in spring through the Chukchi Sea to summer feeding areas in the Beaufort Sea, and in fall to the Bering Sea wintering area with a relatively small number possibly staying in the Chukchi Sea throughout the summer (Moore and Reeves, 1993, Brueggeman et al., 1992). The spring migration is well documented with whales following the open leads in the sea ice running parallel to the Chukchi Sea coastline before veering eastward through the Beaufort Sea (Braham, Krogman, and Carroll, 1984; Moore and Reeves, 1993). Most whales pass through the Chukchi Sea by late June, and migration is occurring earlier than in the past according to traditional environmental knowledge (TEK) and research (Huntington and Quakenbush, 2009).

Since 2006, the fall migration has been more specifically documented by tracking 20 satellite-tagged bowhead whales from Utqiaġvik through the Chukchi Sea into the Bering Sea (Quakenbush et al., 2009). Most of the whales migrated westward above 71ºN latitude from Utqiaġvik to Wrangel Island and then down the Chukotka Coast before entering the Bering Sea. Some whales apparently migrated in a more southwesterly direction from Utqiaġvik to the Chukotka Coast, crossing through or near the Proposed Action Area (Quakenbush, Small, and Citta, 2010). Aerial and vessel surveys conducted in the Chukchi Sea in the 1980s and 1990s also suggest a southwesterly route based on scattered bowhead whale sighting locations (Ljungblad and Van Schoik, 1982, 1986, 1987; Brueggeman et al., 1991, 1992). Recent acoustic studies conducted from 2007 to 2009 indicated calling bowheads migrated across the Chukchi Sea in both a westerly direction following the 71°N latitude and a less defined route after leaving the Utqiaġvik area (Hannay et al., 2009; Martin et al., 2008). Eskimo whalers report whales travel westward and later during light ice years and southwestward during heavy ice years (Huntington and Quakenbush, 2009, Figure 26). These collective results suggest the location of the fall migration route may comprise a variety of paths dispersed widely across the Chukchi Sea. The fall migration of bowheads through the Chukchi Sea generally begins in early October and ends sometime in December, as sea ice advances into the Bering Sea. Clarke et al. (2014) noted bowhead whale feeding areas in the Canadian Beaufort Sea, and Rugh et al. (2014) observed bowhead feeding areas in the vicinity of Barrow Canyon and Utqiaġvik, Alaska. As summer begins to end, bowheads commence migrating from the Eastern Beaufort Sea to an aggregation and feeding area north of Utqiaġvik. From there they usually begin crossing the Chukchi Sea in mid to late September and continue the out-migration from the Beaufort Sea through November.

Contact with Oil

Bowheads are the most likely ESA-listed whale to experience effects of a VLOS as described in the Scenario, as they are common in the Chukchi and Beaufort Sea waters during their migrations (Harwood et al., 2010; Quakenbush, Small, and Citta, 2010). Acoustic studies suggest some bowheads inhabit the Chukchi Sea year-round; however, most bowheads spend their summer feeding in the Beaufort Sea before migrating to the Bering Sea to overwinter (Moore et al., 2010). Calling bowheads have been recorded in the Chukchi Sea during summer and winter (Berchok et al., 2009, Funk et al., 2010; Moore et al., 2010).

Nothing suggests the effects in the hypothetical scenario would differ between the alternatives. Additional information on bowhead presence in the western Beaufort Sea and northeastern Chukchi Sea from December through March is not essential to a reasoned choice among the alternatives.

There are few post-spill studies with sufficient details to reach firm conclusions about the effects, especially the long-term effects, of an oil spill on free-ranging populations of marine mammals, including bowhead whales. Given the very low probability of a VLOS event occurring and affecting large numbers of cetaceans, and the fact that the overall potential for impacts would vary only slightly under each action alternative, additional studies on the potential effects of oil exposure on free-ranging marine mammal populations is not essential to a reasoned choice among alternatives. Nonetheless, evaluation of available science permits the application of scientific judgment regarding potential effects.

Available evidence suggests that mammalian species vary in their vulnerability to short-term damage from surface contact with oil and ingestion. While vulnerability to oil contamination exists due to ecological and physiological reasons, species also vary greatly in the amount of information that has been collected about them and about their potential oil vulnerability. These facts are linked, because the most vulnerable species have received the most focused studies. However, it also is the case that it is more difficult to obtain detailed information on the health, development, reproduction and survival of large cetaceans than on some other marine mammals. The logistical, physical capability, technology and cost limitations that would provide data collection and evaluation of the potential for long-term sublethal effects on large cetaceans are prohibitive at this time. On the other hand, it may be that ecological and physiological characteristics specific to large cetaceans serve to buffer them from many of those same types of impacts. Unless impacts are large and whales die and are necropsied, most effects must be measured primarily using tools of observation. Unless baseline data are exceptionally good, determination of an effect is only possible if the effect is dramatic.

With whales, even when unusual changes in abundance occur following an event such as the EVOS (as with the disappearance of relatively large numbers of killer whales from the AB pod in Prince William Sound) (see Dahlheim and Matkin, 1994 and the following discussion), interpretation of the data varies and is controversial due to lack of carcasses for necropsy. Thus, predicting potential long-term sublethal effects (reduced body condition/ health/ productivity/fitness, etc.) or lethal effects on cetaceans from a VLOS is problematic.

The greatest threat to large cetaceans would be inhalation of fresh oil toxic hydrocarbons fractions. Prolonged inhalation of volatile toxic hydrocarbon fractions of fresh oil induces severe effects.

Inhalation of volatile hydrocarbon fractions of fresh crude oil can damage the respiratory system (Hansen, 1985; Neff, 1990), cause neurological disorders or liver damage (Geraci and St. Aubin, 1982), have anesthetic effects (Neff, 1990) and, if accompanied by excessive adrenalin release, cause sudden death (Geraci, 1988). Bowhead mortality could occur if they surfaced and breathed repeatedly in the fresh oil of a VLOS and freshly evaporated toxic aromatic hydrocarbon compound vapors occur at the sea surface. Effects upon bowhead whales range from negligible to acute toxic poisoning resulting in endocrine system and organ impairment or death. Lighter-than-air aromatic vapors dissipate rapidly into the atmosphere. Heavier than air components may linger near the surface during periods of calm winds, but otherwise atmospheric mixing allows these vapors to dissipate rapidly.

The dissipation of volatile components varies with temperature, wind, and characteristics of encapsulation of oil components into ice and the ice conditions that determine rate of release. Oil trapped in the mixed and fractured ice and interspersed open-water characteristic of polynya systems allows for varying amounts of toxic aromatic components to evaporate and dissipate during the winter period before migrating bowheads arrive in the Chukchi Sea spring lead system. Spilled oil that has aged to the point where initial evaporation of light toxic fumes is no longer present reduces the risk of prolonged inhalation exposure to toxic fumes.

Two situations of higher risk to bowhead whales could occur. These exceptions involve prolonged exposure of migrating or feeding bowheads to inhalation of volatile toxic components of fresh oil in the Chukchi Sea spring lead system during migration of the majority of the Western Arctic Bowhead population through the lead system and when feeding aggregations (such as those that occur northeast of Utqiaġvik in the fall) are similarly exposed to toxic fumes from a VLOS. During spring migration, females with newborn calves, whose movement is somewhat constrained by the polynya system, may endure exposure to some released toxic fumes from fresh oil trapped in ice between October 31 of the previous year to about January 4. It is likely that a major portion of the toxic fumes would have evaporated over the winter through the active cracks, ice movement, and movement through brine channels in the polynya ice cover when temperatures are at or above critical temperature (NORCOR, 1975; Fingas and Hollebone, 2003). Toxic fumes are likely to have dispersed in the atmosphere by May and early June, when most females with calves migrate through the Chukchi Sea spring lead system, and would not pose a prolonged toxic exposure. If high toxic vapor levels should occur and prolonged exposure of females with calves occurs, mortality could result. Volatile toxic fractions may be particularly toxic to newborn calves that must take more frequent breaths and spend more time at the surface than their mothers. As unlikely as it may seem, such exposure is not beyond the range of possibilities, and depending on the timing and numbers of females with calves contacting toxic vapors of fresh oil, mortality of a large portion of a year’s cohort of calves and perhaps some individual females and other age and sex classes could occur.

Options to migrate through adjacent ice covered waters are fewer for newborns as compared to older animals that may or may not be able to detect the spill and exercise alternate migration routing options. These adults may travel through considerable areas of up to 100 percent ice cover, which appears to not limit bowhead distribution (Quakenbush, Small, and Citta, 2010). There are anatomical data and observations that bowhead whales have the olfactory organs (Thewissen et al., 2010) and ability to detect smoke from dumps and potentially spilled oil such that they may modify movements to avoid a large or VLOS. Spring migration could be delayed or deflected around spilled oil (females with calves, and other age and sex classes, may attempt to detour through adjacent ice covered waters around the spill and associated toxic fumes). Newborn calves—having short breathing intervals and less capability to break breathing spaces in ice cover while following their mothers—risk separation, abandonment or mortality. A portion of an annual cohort of newborn calves and some older individuals could potentially experience such mortality under those conditions. Depending on numbers of calves that might die, loss of an annual cohort would be reflected in an immediate reduction in population that may take several years to replace. Also, there may be in the future reduced contribution of the individual females and their progeny to recruitment into the breeding female population (these females would have become sexually mature in 18-20 years). The loss of the lifetime reproductive contribution of these females to the population could depress population rate of increase slightly for several decades.

Another circumstance whereby effects could be experienced by large numbers of bowheads is when one or more large aggregations of bowheads contact a fresh oil spill (with high concentrations of toxic aromatic vapors) during the open-water season. Aggregations of between 50 and 100 bowheads have been observed in some, but not all years, during BOEM and NMFS aerial surveys and particularly in the feeding area identified northeast of Utqiaġvik under bowhead feeding studies (Moore, George, and Sheffield et al., 2010).

Spilled oil appears to have limited impact on cetacean skin. In a study on nonbaleen whales and other cetaceans, Harvey and Dahlheim (1994) observed 80 Dall's porpoises, 18 killer whales, and 2 harbor porpoises in oil on the water's surface from the EVOS. They observed groups of Dall's porpoises on 21 occasions in areas with light sheen, several occasions in areas with moderate-to-heavy surface oil, once in no oil, and once when they did not record the amount of oil. Thirteen of the animals were close enough to determine if oil was present on their skin. They confirmed that 12 animals in light sheen or moderate-to-heavy oil did not have oil on their skin. The 18 killer whales and 2 harbor porpoises were in oil but had none on their skin. None of the cetaceans appeared to alter their behaviors when in areas where oil was present. The authors concluded their observations were consistent with other reports of cetaceans behaving normally when oil is present. Some temporary irritation or permanent damage to conjunctive tissues, mucous membranes, around the eyes, abrasions, conjunctivitis and swollen nictitating membranes could occur (Geraci and Smith, 1976b; Davis, Schafer, and Bell, 1960).

Ingestion

Ingestion of dissolved, suspended, or floating oil components while feeding on or near the surface could occur during the open-water period, or if bowheads come into contact with oil in/on the seafloor during near-bottom feeding. Oil components or chemical oil dispersant derived compounds could be consumed by bowheads feeding on prey anywhere in contaminated water column layers to the sea floor. Bowheads may ingest oil fractions that sink to (and may persist in) the seafloor sediments that are disturbed when near-bottom feeding. Ingestion of petroleum hydrocarbons can lead to subtle and progressive organ damage or to rapid death in mammals. Many polycyclic aromatic hydrocarbons are teratogenic and embryotoxic in at least some mammals (Khan et al., 1987).

Maternal exposure to crude oil during pregnancy may negatively impact the birth weight of young. While the potential effects on bowhead to exposure to PAHs through their food are largely unknown, the very low probability of a VLOS event occurring and leading to widespread ingestion of PAHs, and the fact that the potential for such impacts would vary only slightly under each action alternative, means that additional studies of this potential are not essential to a reasoned choice among alternatives. That said, there currently exists information with pertinence to this issue. Oil ingestion can decrease food assimilation of prey eaten (for example, St. Aubin, 1988). Decreased food assimilation could be particularly important in very young animals, those that seasonally feed, and those that need to put on high levels of fat to survive their environment. Because of their extreme longevity, bowheads are vulnerable to long-term accumulation of pollutants. With increasing development within their range and long-distance transport of other pollutants, individual bowheads may experience multiple large and small polluting events within their lifetime. Tissue studies by Geraci and St. Aubin (1990) revealed low levels of naphthalene in the livers and blubber of baleen whales. This result suggests that prey have low concentrations in their tissues, or that baleen whales may be able to metabolize and excrete certain petroleum hydrocarbons.

Temporary baleen fouling could also occur, but the light weight of the spilled oil probable for the Beaufort Sea makes it less likely to adhere to and impair the hydraulic function of the baleen fibers as would more viscous, weathered or emulsified oil. Lighter oil should result in less interference with feeding efficiency. In a study in which baleen from fin, sei, humpback, and gray whales was oiled, Geraci (1988) found that 70 percent of the oil adhering to baleen plates was lost within 30 minutes (Geraci, 1990), and in 8 of 11 trials, more than 95 percent of the oil was cleared after 24 hours. The study could not detect any change in resistance to water flowing through baleen after 24 hours. The baleen from these whales is shorter, and in some cases finer, than that of bowhead whales, whose longer baleen has many hairlike filaments. Lambertsen et al. (2005, p. 350) concluded that results of their studies indicate that Geraci's analysis of physiologic effects of oiling on mysticete baleen "considered baleen function to be powered solely by hydraulic pressure," a perspective they characterized as a "gross oversimplification of the relevant physiology." A reduction in food caught in the baleen could have an effect on the body condition and health of affected whales. If such an effect lasted for 30 days, as suggested by the experiments of Braithwaite (1983), this could potentially be an effect that lasted a substantial proportion of the period that bowheads spend on the summer feeding grounds. Repeated baleen fouling over a long time, however, might also reduce food intake and blubber deposition, which could harm the bowheads. Geraci (1990) also pointed out the greatest potential for effects on bowheads would be if spilled oil occurred in the spring lead system.

Contamination and Reduction of Food Sources

Data from a recent study (Duesterloh, Short, and Barron, 2002) indicated that aqueous polyaromatic compounds (PACs) dissolved from weathered Alaska North Slope crude oil are phototoxic to subarctic marine copepods at PAC concentrations that would likely result from an oil spill and at UV levels that are encountered in nature. *Calanus marshallae* exposed to UV in natural sunlight and low doses (~2 micrograms (µg) of total PAC per liter of the water soluble fraction of weathered North Slope crude oil for 24 hours) showed an 80 percent to 100 percent morbidity and mortality as compared to less than 10 percent with exposure to the oil-only or sunlight only treatments. One hundred percent mortality occurred in *Metridia okhotensis* with the oil and UV treatment, while only 5 percent mortality occurred with the oil treatment alone. Duesterloh, Short, and Barron (2002) reported that phototoxic concentrations to some copepod species were lower by a factor of 23 to greater than 4,000 than the lethal concentrations of total PAC alone (0.05-9.4 mg/L).

This research also indicated that copepods may passively accumulate PACs from water and could thereby serve as a conduit for the transfer of PAC to higher trophic level consumers. Bioaccumulation factors were ~2,000 for *M. okhotensis* and about ~8,000 for *C. marshallae*. Calanus and Neocalanus copepods have relatively higher bioaccumulation than many other species of copepods because of their characteristically high lipid content. The authors concluded that phototoxic effects on copepods could conceivably cause ecosystem disruptions that have not been accounted for in traditional oil spill damage assessments. Particularly in nearshore habitats where vertical migration of copepods is inhibited due to shallow depths and geographical enclosure, phototoxicity could cause mass mortality in the local plankton population (Duesterloh, Short, and Barron, 2002, p. 3959).

The potential effects on bowheads of exposure to PACs through their food remain undocumented; however, bowhead whales may swallow some oil-contaminated prey and ingest some dissolved or floating oil fractions incidental to food intake, but it likely would be only a small part of their food. Bowhead whales may or may not leave a feeding area where prey was abundant following a VLOS. Some zooplankton, which are eaten by bowheads, consume contaminated oil particles contained in their prey. Tissue studies by Geraci and St. Aubin (1990) revealed low levels of naphthalene in the livers and blubber of baleen whales. This result suggests that prey have low concentrations in their tissues, or that baleen whales may be able to metabolize and excrete certain petroleum hydrocarbons. The probability that a VLOS would occur and affect bowhead whales through exposure to PACs or displacement from productive feeding areas is very small, and would vary only slightly under each action alternative. Additional information on these subjects is therefore not essential for a reasoned choice among alternatives.

A VLOS probably would not permanently affect zooplankton populations, the bowhead's major food source, and major effects are most likely to occur nearshore (Richardson et al., 1987, as cited in Bratton et al., 1993). The amount of zooplankton lost in a VLOS could be very small compared to what is available on the whales' summer-feeding grounds (Bratton et al., 1993). A VLOS, depending on the timing and location relative to the distribution and aggregations of zooplankton, could reduce feeding opportunities for a majority of the bowhead population during that year. The significance of the loss of that opportunity to bowhead health is dependent upon major feeding opportunities bowheads may find later in the year to meet annual energy demands. Fate, recovery, and availability of zooplankton populations to bowheads in similar quantities and locations as pre-spill conditions in the Chukchi and western Beaufort Seas in subsequent years would depend on a variety of factors, as is analyzed in the 2011 SEIS (Section IV.E.4). Oceanographic and climatic factors combine to aggregate zooplankton in some areas. Sources, transport of, and year to year persistence of plankton populations utilized by bowhead whales in and adjacent to the Proposed Action Area remain unclear.

While controlled studies of the potential effects on bowheads of exposure to PACs through their food remain infeasible at this time, bowheads are believed to be vulnerable to long-term accumulation of pollutants given their extreme longevity. With increasing development within their range and long-distance transport of other pollutants, individual bowheads may experience multiple large and small polluting events, as well as chronic pollution exposure, within their lifetime.

Displacement From and Avoidance of Habitat

Scientists have not had the opportunity to observe bowhead response to a VLOS, nor any displacement caused by subsequent spill response and cleanup operations. However, there are first-hand accounts of displacement effects on bowhead whales from a 25,000-gallon (595-bbl) oil spill at Elson Lagoon (Plover Islands) in 1944. Traditional knowledge provided by Brower (1980) explained that for the four years that oil was still present, bowhead whales made a wide detour out to sea when passing near Elson Lagoon/Plover Islands during fall migration. Bowhead whales normally moved close to these islands during the fall migration (when no oil was present). These observations indicate that some displacement of whales may occur in the event of a VLOS, and that the displacement may last for several years. Based on these observations, it also appears that bowhead whales may have some ability to detect an oil spill and avoid surfacing in the oil by detouring around the area of the spill. Anatomical data and observations that suggest bowhead whales have well-developed olfactory organs (Thewissen et al., 2010), and could detect spilled oil to such a degree that they may modify movements to avoid a VLOS.

Other investigators have observed various cetaceans in spilled oil, including fin whales, humpback whales, gray whales, dolphins, and pilot whales. Typically, the whales did not avoid slicks but swam through them, apparently showing no reaction to the oil. During the spill of Bunker C and No. 2 fuel oil from the *Regal Sword*, researchers saw humpback and fin whales, and a whale tentatively identified as a right whale, surfacing and even feeding in or near an oil slick off Cape Cod, Massachusetts (Geraci and St. Aubin, 1990). Whales and a large number of white-sided dolphins swam, played, and fed in and near the slicks. The study reported no difference in behavior between cetaceans within the slick and those beyond it. None of these observations are sufficient to prove cetaceans can detect oil and avoid it, or if long-term impacts occurred from exposure. Some researchers have concluded that baleen whales have such good surface vision that they rely on visual clues for orientation in various activities. In particular, bowhead whales have been seen “playing” with floating logs and sheens of fluorescent dye on the sea surface of the sea (Würsig et al., 1985, as cited in Bratton et al., 1993; Clarke et al., 2014). Such observations suggest oil present on the sea surface in recognizable quality or quantity may be recognizable and avoidable by bowhead whales (Bratton et al., 1993). However, the observation of their playing with dye could also indicate inability to avoid spilled oil.

After the EVOS, researchers studied the potential effects of an oil spill on cetaceans. Dahlheim and Loughlin (1990) documented negligible levels of effect on the humpback whale. Von Ziegesar, Miller, and Dahlheim (1994) found no indication of a change in abundance, calving rates, seasonal residency time of female-calf pairs, or mortality in humpback whales as a result of that spill, although they did see temporary displacement from some areas of Prince William Sound.

The presence of oil could prevent or disrupt access to and displace whales from habitat areas. Depending on oceanographic and climatic variables, zooplankton food concentrations that may normally result in feeding aggregations of bowhead whales may not be available. A VLOS could displace feeding whales from an active feeding event(s) or cause whales to avoid an otherwise available aggregated food source and feeding opportunity. Depending on the specifics and magnitude of a lost feeding opportunity and its contribution to the annual energy and nutrient requirement of individual whales, effects upon health and reproduction could occur. Situations where effects could be more important include impaired access to the relatively consistent food aggregations northeast of Point Barrow and any large aggregations of food attracting and holding large numbers of whales for an extended period of time (from a few days to weeks). Loss of access and use of the spring polynya system by migrating bowhead and beluga whales could result in variable mortality of newborn bowhead calves, delayed migration, and/or migration route avoidance or deflection and redistribution of migrating and spring feeding whales to adjacent areas with greater ice cover. Depending on the specifics of a given event, mortality of a portion of an annual cohort of calves could result, which in turn could have longer-term effects on population level recruitment and reproduction. It could also result in modification of migration pattern effects, as well as shorter-term body condition and health effects.

In most cases, a VLOS event would occur at a time of year when the toxic fumes would dissipate into the atmosphere rapidly so as not to allow for prolonged exposure to the majority of whales in the open-water and fall migration period. There is a potential that spilled oil could persist and be transported during ice covered seasons. A portion of the toxic volatile hydrocarbon fractions are likely to evaporate and dissipate into the atmosphere before remaining oil could be contacted by migrating bowheads during the next year. Thus, toxic fractions would occur in low enough densities to disallow prolonged (if any) exposure for cetaceans in the spring lead system. The northernmost portions of the spring lead system appear to be used by some spring migrating bowheads in the Chukchi Sea where contact with freshly spilled oil and fumes due to the shorter distance to an event site and shorter period that fresh oil has to age in the lead system could occur. There may be an opportunity for the individuals that have migration paths in those areas to be much closer to potential spill sites on existing leases, and they could be exposed to prolonged inhalation of toxic fumes if they do not exercise detection and avoidance responses. The potential for major impacts to an annual cohort of the bowhead population could occur under a narrow set of conditional circumstances during the spring migration through the spring lead system in the Chukchi Sea and the far western Beaufort Sea.

A-7.6.2.3 Gray Whale

Gray whales mostly summer in the Chukchi Sea where they feed before returning to wintering grounds in Mexico (Rugh et al., 1999; Rugh, Shelden, and Schulman-Jainger, 2001; Roseneau, 2010); however, they also occur in the Beaufort Sea in lower numbers. They occupy Arctic waters during the open-water season, generally arriving behind the retreat of the sea ice and leaving ahead of the early winter sea ice formation (Clarke, Moore, and Ljungblad, 1989; Brueggeman et al., 1992; Funk et al., 2010; Goetz et al., 2009). They are the most abundant cetacean reported in the Chukchi Sea during summer (Funk et al., 2010; Brueggeman et al., 1992) and widespread. Gray whales typically use nearshore habitat (less than 25 miles from shore) with highest concentrations north and east of Wainwright, and most sightings occurred between Wainwright and Cape Belcher during the 2008 and 2009 survey seasons (Brueggeman, 2010). More recent ASAMM sighting data in Clarke et al. (2014) supports the earlier surveys, indicating large gray whale concentration areas from Wainwright to Utqiaġvik in nearshore waters.

Recent acoustic data suggest some gray whales may over-winter in the Chukchi Sea (Stafford et al., 2007), but the numbers are likely small (Moore, DeMaster, and Dayton, 2000). Gray whales observed during a shallow hazards survey conducted by ConocoPhillips at Klondike Prospect area and a coring program between Klondike and the coast in 2008 were entirely nearshore (Brueggeman et al., 2009b) and 2009-2010 COMIDA surveys (COMIDA, 2009; 2010) found most gray whales feeding nearshore between Point Lay and Point Barrow from June to October.

Rugh et al. (2014) noted gray whales feeding in the vicinity of Barrow Canyon, with some individuals feeding to the west of Point Barrow, Alaska.

Gray whale movements vary annually depending on prey abundance and distribution (Nerini, 1984). Gray whales feed in soft sediments which support their primary prey: benthic ampeliscid amphipods (Nerini, 1984). Smaller numbers of gray whales historically concentrated in the region of Hanna Shoal, north and east of the Proposed Action Area between 160º and 165ºW, but none were seen there during the 2009 and 2010 COMIDA surveys (Clarke et al., 2011c); however, two were seen in the vicinity of Hanna Shoal during ASAMM surveys suggesting a few gray whales still frequent the Hanna Shoal area (Clarke et al. 2014).

Contact with Oil

Gray whales are present in the Chukchi Sea and far western and eastern Beaufort Sea (Rugh, 1981; Moore, DeMaster, and Dayton, 2000) during the open-water season, but there is acoustic evidence that individuals may spend the winter period in the Alaska Arctic as well (Stafford et al., 2007).

These whales occur in shallow shelf nearshore and offshore shoal habitats to feed on benthic prey. They may, upon contacting spilled oil, experience effects from inhalation, ingestion, baleen fouling, skin and conjunctive tissue irritation, but also may exhibit detection and avoidance of spilled oil similar to whale species analyzed earlier. Migrating gray whales show only partial avoidance to natural oil seeps off California.

Laboratory tests suggest gray whale baleen, and possibly skin, may be resistant to oil damage. Gray whales exhibiting abnormal behavior were observed in oil after the EVOS in an area where fumes from the spill were very strong (J. Lentfer as cited in Harvey and Dalheim, 1994). Subsequently, large numbers of gray whale carcasses were discovered. One of three of these had elevated levels of PAHs in its blubber. Loughlin (1994) concluded it was unclear what caused the death of the gray whales. An estimated 80,000 barrels of oil may have entered the marine environment off Santa Barbara in 1969, when gray whales were beginning the annual migration north. Whales were observed migrating through the slick. Subsequently, six dead gray whales were observed and recovered as well as a number of other marine mammals. No evidence of oil contamination was found on any of these whales. The Battelle Memorial Institute concluded the whales were either able to avoid the oil, or were unaffected when in contact with it. Based on all available information, if individual, small or large groups of gray whales were exposed to large amounts of fresh oil from a VLOS, especially through inhalation of highly toxic aromatic fractions, they might be seriously injured or die from such exposure. Although there is little definitive evidence linking cetacean death and serious injury to oil exposure, the deaths of large numbers of gray whales coincided with EVOS and observations of gray whales in oil. If fresh oil from a VLOS contacted important coastal or shoal habitats, the gray whale population could be at risk for multiple cases of injury or mortality when concentrated on summer feeding grounds, and could have limited options to avoid a spill and still meet annual nutrient and energy requirements in the Chukchi Sea.

Recovery of distribution, abundance, and habitats may take decades to recover or possibly more than three generations.

Ingestion

Gray whales may ingest oil fractions that sink to (and may persist in) the seafloor sediments that are disturbed when bottom feeding on benthic invertebrates, as is characteristic of the gray whale.

Chronic consumption of bottom accrued oil fractions or contaminated prey may result in impaired endocrine function, reproductive impairment, or mortality. Baleen whales may have the capability to metabolize ingested oil compounds.

Contamination and Reduction of Food Sources

In the Chukchi Sea, spilled oil could affect gray whales by contaminating benthic prey and sediments (please refer to the 2011 SEIS (Section IV.E.4)), particularly in prime feeding areas (Würsig, 1990; Moore and Clark, 2002). Any perturbation, such as a VLOS, which caused extensive mortality within a high latitude amphipod population with low fecundity and long generation times would result in marked decreases in secondary production (Highsmith and Coyle, 1992). For example, populations of amphipods off the coast of France were reduced by 99.3 percent following the *Amoco Cadis* oil spill in 1978 (approximately 70 million gallons). Ten years after the spill, amphipod populations had recovered to 39 percent of their original maximum densities (Dauvin, 1989, as cited by Highsmith and Coyle, 1992). Chukchi Sea amphipod populations with longer generation times and lower growth rates, probably would take considerably longer to recover from any major population disruption (Highsmith and Coyle, 1992).

Displacement From and Avoidance of Habitat

Reduction or mortality in benthic prey larval stages that live in the water column, reduced benthic biomass, and productivity of nearshore and offshore shoals may force gray whales to seek alternate, less optimal foraging areas of the shelf offshore for up to several years until nearshore or shoal benthic communities recover. Impacts to these whales could occur over a period of years depending on numbers and amounts of oil fractions chronically consumed or reduced from a VLOS and the quality and availability of alternate feeding habitat in the Alaska Arctic. Restoration of distribution and abundance of gray whales along the Alaska Chukchi Sea coast could take more than three generations to recover from a VLOS.

A-7.6.2.4 Fin Whale (Endangered)

Fin whales are present during the open-water season in the Chukchi Sea, (Funk et al., 2010; COMIDA, 2009; Roseneau, 2010), and are more common in the southwestern Chukchi Sea near Chukotka, Russia. They are widespread and more abundant in the Bering Sea (Melinger et al., 2010), but have never been documented in the Beaufort Sea. Their similarities to bowhead whales suggest they should experience effects similar to bowheads from VLOS exposure if a VLOS from the Proposed Action Area entered the Chukchi Sea. It is even possible that fin whales could be killed if they surfaced repeatedly in the midst of a large, fresh oil slick and inhaled high concentrations of volatile components of crude oil. Likewise, fin whales could exhibit the ability to detect and avoid spilled oil for the same reasons bowhead whales might. Available data following both the EVOS and the Glacier Bay, Alaska oil spills indicate it is unlikely large numbers of fin whales would be affected by a VLOS from the Proposed Action Area.

Because of their frequency of occurrence and distribution in the Chukchi Sea the primary areas for effect of a VLOS on fin whales would occur in the waters of the Chukchi Sea off Chukotka, especially near Cape Dezhnev in the summer, or in waters south of Cape Lisburne, Alaska.

A-7.6.2.5 Humpback Whale (Endangered)

Humpback whales are present during the open-water season in Chukchi Sea coastal waters and the far western Beaufort Sea (Clarke et al., 2014), but have not been observed near the Proposed Action Area. The nearest observations of humpback whales to the Proposed Action Area occurred approximately 250 miles to the west of the Area (Hashagen et al., 2009). They are regularly observed in waters of the southwestern Chukchi Sea adjacent to the Chukotka Peninsula, south of Cape Lisburne, and occasionally in Peard Bay, Alaska. Because they are also baleen whales they may, upon contacting spilled oil, experience similar inhalation, ingestion, baleen fouling, skin and conjunctive tissue irritation; but also may exhibit detection and avoidance of spilled oil as may bowhead and fin whales. Repeated surfacing within a VLOS with fresh oil with high levels of volatile toxic hydrocarbon fractions present could potentially lead to organ damage and/or mortality of humpbacks. These whales prey on schools of forage fish (capelin, sand lance, herring) species as well as copepods and euphausiids in the water column and on or near the surface which may have spilled oil present. Potential reduction or mortality of local forage fish populations could create periods whereby summer prey would not be available for an undetermined time period depending on prey recovery rates and pioneering use of the restored prey. A negligible number of the Central North Pacific population of humpback whales would be expected to experience temporary and non-lethal effects from a VLOS within the Proposed Action Area. However, if the humpback whales in the Proposed Action Area and adjacent Chukchi Sea originate from the Western North Pacific stock (a smaller and less well-understood stock), any injuries or losses of individuals could produce important population level effects. Under such circumstances, three or more generations could be required to re-establish distribution and abundance in the Alaska Chukchi and Beaufort Seas.

Studying the EVOS, von Ziegesar, Miller, and Dahlheim (1994) found no indication of a change in abundance, calving rates, seasonal residency time of female-calf pairs, or mortality in humpback whales as a result of that spill, although they did see temporary displacement from some areas of Prince William Sound. As analyzed in previous paragraphs, literature on the effects of crude oil on mammals indicates humpback whales could be vulnerable to such spills.

Because of their scarcity and distribution, the greatest effects on humpback whales would be from a VLOS contacting Chukchi Sea waters adjacent to the Chukotka Peninsula, or south of Cape Lisburne, Alaska. In summer and fall, humpback whales could be negatively affected by a VLOS contacting waters off the northern Chukotkan coastline, especially near Cape Dezhnev. Because of the increasing length of the open-water season, increases in humpback whale numbers and use of the Chukchi Sea are foreseeable. As such, greater numbers of humpback whales may use Chukchi Sea habitat, and the effects of a VLOS entering the Chukchi Sea could increase on the humpback whale population. Previous paragraphs noted that literature on crude oil effects on mammals suggests humpback whales could be vulnerable to such a VLOS.

A-7.6.2.6 Minke Whale

Minke whales from the Alaska Stock could occur in the Bering Sea and Chukchi Seas (Muto et al. 2017). Provisional population estimates of up to 2,020 individuals were calculated for the Bering Sea shelf

Minke whales are believed to be migratory summer residents of the Chukchi and Bering Seas, and move south of the Bering Sea to overwinter. A few have been observed in the northeastern Chukchi Sea during monitoring for oil and gas activities (Funk et al., 2011, Bisson et al., 2013a), and during aerial surveys in the Chukchi Sea (Clark et al. 2011a and b, Clarke et al. 2015, Clarke et al. 2017), and during shipboard surveys (Aerts et al., 2011; Aerts et al., 2014). Occasional sightings in the Chukchi Sea suggest their presence is less common in the Chukchi Sea than in the Bering Sea. They are believed to be much more common in the Pacific, Indian, and Atlantic oceans.

Minke whales are filter feeders, who use lunge-feeding strategies to capture and eat euphuasiids, copepods, sand-lance, and larger schooling fishes such as herring, pollock, and salmon (Guerrero and Peluso, 2018).

Contact with Oil

These whales occur regularly in low numbers in the Chukchi Sea during the open-water season, but not in the Beaufort Sea east of Utqiaġvik, Alaska (Ireland et al., 2008; Funk et al., 2010; Brueggeman, 2010; Roseneau, 2010). These whales are observed commonly as individuals or small groups. However, if a VLOS originating from the Proposed Action Area enters the Chukchi Sea, Minke whales may, upon contacting spilled oil, experience inhalation, ingestion, baleen fouling, skin and conjunctive tissue irritation similar to other whales, but also may exhibit detection and avoidance of spilled oil. Temporary and/or permanent, non-lethal injury could occur. When considering the numbers projected for the North Pacific and the potential numbers in the Alaska Arctic, population level effects are not anticipated; however, abundance, distribution patterns and frequency of occurrence in the Alaska Chukchi Sea could be reduced in response to possible reduction in abundance and distribution of prey resources. Recovery of minke whale to pre-spill abundance and distribution may be most dependent upon prey recovery timeframes.

Ingestion

Minke whales prey on schools of forage fish (capelin, sand lance, and herring) species as well as copepods and euphausiids in the water column and on or near the surface which may have spilled oil present. Consumption of contaminated prey, the reduction or mortality of local forage fish populations could create periods whereby summer prey would not be available for an undetermined time period depending on prey recovery rates and pioneering use of the restored prey (2011 SEIS (Section IV.E.5)). Compared to the Alaska stock/population of minke whales, a small number venture north of the Bering Strait and into the Chukchi Sea and the Proposed Action Area. Minke whales contacting oil could experience temporary and non-lethal effects within the Proposed Action Area.

Contamination and Reduction of Food Sources

These whales prey on schools of forage fish species (see the 2011 SEIS, IV.E.5, Fish Resources), as well as copepods and euphausiids in the water column and on or near the surface which may have spilled oil present. Oil-contacted whales would likely experience minor temporary and non-lethal effects similar to those described for humpback whales. When considering the numbers projected for the North Pacific, population level effects are not anticipated.

Displacement From and Avoidance of Habitat

Minke whales may be able to detect and choose to avoid a VLOS, causing displacement to other habitat areas that may or may not be as optimal as those affected by a VLOS. Impacts to the distribution and abundance of prey, if they should occur, would largely determine the seasonal distribution and habitat use by minke whales. When considering the numbers projected for the North Pacific, population level effects are not anticipated; however, distribution and abundance in the Chukchi Sea could be modified or reduced in relation to the potential modification to food source distribution and abundance as result of a VLOS originating from the Proposed Action Area.

A-7.6.2.7 Killer Whale

Killer whales are observed infrequently by Native hunters and others in very low numbers throughout the Alaska Chukchi and western Beaufort Seas (Frost, Lowry, and Burns, 1983; Lowry, Nelson, and Frost, 1987; Roseneau, 2010). Russian observations along the southwestern Chukchi Sea along the Chukotka Peninsula coast indicate greater abundance of killer whales in that area. They have been primarily observed in coastal areas rather than farther offshore (Brueggeman et al., 1992, George and Suydam, 1998; Roseneau, 2010), but this could be due to higher levels of human activity and observation opportunities nearshore. Conversely, acoustic recorders detected killer whale calls in 2007 and 2009 offshore between Cape Lisburne and Point Barrow from July until October (Delarue, Yurk, and Martin, 2010; Hannay et al., 2009; Martin et al., 2008). The combination of acoustic and visual data suggests killer whales occur both offshore and near shore with no clear inshore/offshore trend.

Contact with Oil

In the event that a VLOS originating from the Proposed Action Area entered the Chukchi Sea, Killer whales may, upon contacting spilled oil, experience inhalation, ingestion, skin and conjunctive tissue irritation similar to whales analyzed earlier, and also may exhibit detection and avoidance of spilled oil. Matkin et al. (1994) reported killer whales had the potential to contact or consume oil, because they did not avoid oil or avoid surfacing in slicks. In the two years following EVOS, significant numbers (13) of individual whales, primarily reproductive females and juveniles, disappeared from the AB pod.

Dahlheim and Matkin (1994) observed AB pod members swimming through heavy slicks of oil and 18 killer whales including three calves surface in a patch of oil. They concluded that there is a spatial and temporal correlation between loss of the whales and the EVOS, but there is no clear cause-and-effect relationship. Matkin et al. (2008) note the synchronous 33 percent and 41 percent initial losses from the AB Pod and the AT1 Group in the year following the EVOS, and that 16 years post spill the AB has not recovered to former numbers and the AT1 Group has continued to decline and is now listed as depleted under the MMPA. The synchronous losses of unprecedented numbers of killer whales from these two genetically and ecologically separate groups and the absence of other obvious perturbations strengthens the link between mortalities and the lack of recovery and the EVOS. The link, however, remains circumstantial and there is not agreement among the scientific community as to whether or not there likely was an oil spill impact on killer whales after the EVOS.

Contamination and Reduction of Food Sources

The killer whales in the Alaska Arctic are likely marine mammal predators as suggested by the few accounts of predation documented (George and Suydam, 1998). The fate of other marine mammals, and of potential prey fisheries, in detection and avoidance of a VLOS, declining or contaminated food sources causing redistribution, injury, contamination and fluctuations in prey numbers, and recovery of prey post spill would determine the persistence and use of the Proposed Action Area and adjacent areas. As an apex predator, killer whales could bioaccumulate petroleum residues in tissues. While they indicate some ability to metabolize hydrocarbon factions ingested or otherwise absorbed, they also indicate sensitivity to CYP1A1 induction by hydrocarbon receptors; however, abundance, distribution patterns and frequency of occurrence in the Alaska Chukchi Sea could be reduced in response to possible reduction in abundance and distribution of prey resources (Wilson et al., 2005).

Recovery of killer whale to pre-spill abundance and distribution would be dependent upon prey (marine mammals and fisheries) recovery timeframes.

Displacement From and Avoidance of Habitat

While no clear patterns of habitat use have developed from killer whale observations in the U.S. Arctic, toothed whales do not seem to consistently avoid oil they detect (Geraci, 1990). This would suggest that killer whales may not avoid or be displaced from habitat affected by a VLOS entering the Chukchi Sea. Contaminated food sources may cause killer whales to redistribute within their range in search of food. Matkin et al. (1994) reported killer whales had the potential to contact or consume oil, because they did not avoid oil or avoid surfacing in slicks. Dahlheim and Matkin (1994) observed AB pod members in Prince William Sound swimming through heavy slicks of oil and surfacing in oil after EVOS.

A-7.6.2.8 Harbor Porpoise

Harbor porpoises have been recorded in the Chukchi Sea as far as the Barrow Canyon (Suydam and George, 1992; Roseneau, 2010) and by surveys in the northeastern Chukchi Sea by Funk et al. (2010). It appears that small numbers of harbor porpoise transit through and feed in the Chukchi Sea during summer.

Contact with Oil

Harbor porpoise are present in the Alaska Chukchi Sea during the open-water period (Suydam and George, 1992). In the event that a VLOS originating from the Proposed Action Area entered the Chukchi Sea, harbor porpoises may, upon contacting spilled oil, experience inhalation, ingestion, skin and conjunctive tissue irritation similar to bowhead whales, and also may exhibit detection and avoidance of spilled oil.

Contamination and Reduction of Food Sources

The fisheries prey base of harbor porpoise could experience reduction in abundance, distribution and diversity from contact with oil and experience injury from consuming contaminated food items or from direct contact with oil fractions of a VLOS entering the Chukchi Sea. The fate of nearshore forage fish would determine their persistence, affecting the porpoises' use of the Chukchi Sea.

Displacement From and Avoidance of Habitat

Harbor porpoise could be excluded from the Chukchi Sea if the forage fish prey base was substantially reduced or eliminated for even a short period of time as a result of a VLOS entering the Chukchi Sea.

A-7.6.3 Oil Spill Response, Cleanup, Restoration, and Remediation

OSR, cleanup, restoration, and remediation (Phase 4) has the potential to affect the three ESA-listed endangered whales (bowhead, fin and humpback), and five additional species of cetaceans (gray, minke, beluga, killer whales and harbor porpoise), and their habitats if a VLOS originating from the Proposed Action Area in the Beaufort Sea entered the Chukchi Sea.

Potential impact producing factors of a VLOS include:

- Noise and disturbance from presence of vessels transiting to the Beaufort Sea, and activity including boom and skimming operations
- Aircraft overflights, including potential application of dispersants from low flying aircraft
- In-situ burning, including noise and disturbance from support operations
- Animal rescue, scientific recovery and disposal of contaminated carcasses

- Skimmer and boom team composition, number, distribution and noise
- Beaufort Sea relief well drilling and discharges, including support activities such as icebreakers, and vessel discharges
- Bioremediation activities, including short and long-term monitoring and research studies to evaluate effectiveness of cleanup actions, that treat affected areas to neutralize toxic effects or removal and disposal operations to eliminate risk from oil contaminated soil, water, and equipment (booms, cleaning wastes, and sewage from operations, personnel)

Please refer to the 2007 FEIS (Section IV.C.1.f(1)[pages IV-80 through IV-116]) for detailed discussion of the potential effects of noise and disturbance from most of these oil and gas related activities on endangered whales, and refer to 2007 FEIS (Section IV.C.1.h. [pps. IV-149 through IV-156]) for potential effects on unlisted species of cetaceans.

In most cases, noise and disturbance (including collisions) from vessels, aircraft, drilling, and discharges are as described for the effects of these same types of operations associated with exploration, development, and production, including drilling and support activities. In most cases temporary, non-lethal effects would result from contact with a VLOS. In some cases, a cetacean species may require two or more generations coincident with restored and unaffected habitat to restore distribution and populations.

The analysis below is organized by species, with IPFs analyzed for each. Thorough discussion of potential impacts to the endangered bowhead whale will often serve to introduce concepts applicable to other species.

A-7.6.3.1 Beluga Whale

Potential impacts to beluga whales during Phase 4 are similar to those described for bowhead whales, except as noted below. Belugas are high frequency sensitive odontocete whales and are sensitive to high frequency noise produced by industrial activities including icebreakers (Cosens and Dueck, 1993). Avoidance and flight responses have been observed.

Icebreaker cavitation noise modeled by Erbe and Farmer (2000a) indicated icebreaker noise was audible over ranges of 21.8 to 48.5 miles and zone of behavioral disturbance was only slightly smaller. Masking of beluga communication signals is predicted at 8.7 to 44 miles off the Canadian Coast Guard icebreaker *Henry Larson*.

Beluga whale rescue actions during a VLOS are considered highly improbable by NMFS. In the event that any rescue attempts are possible, they would occur in the lagoons, where contact with oil could occur in nearshore waters close to facilities, equipment, and personnel. Rescue efforts for injured or stranded belugas may bring small vessels into the vicinity of other belugas already stressed from oil contact and watercraft. Further injury or mortality could occur during rescue operations as well as during post rescue treatment and recovery. Recovery of stranded, floating, and otherwise dead or severely injured belugas or other marine species likely would be onshore (stranded) or shallow water and not likely to be in the company of other live belugas at sea. Stranded belugas may be in groups of live animal or with injured and mortalities included. Rehabilitation and treatment facilities likely would be on board a ship or land based and some mortality and injury could occur during transport from rescue site to such facilities. Population level defects are not expected from rescue operations that are likely handling animals already injured and may be predisposed to mortality.

A-7.6.3.2 Bowhead Whale (Endangered)

Noise and Disturbance from Vessel Presence and Activity

Cleanup operations following a large or very large spill would be expected to involve multiple marine vessels operating in the spill area for extended periods of time, perhaps over multiple years. Based on information provided in the above section on vessel traffic, bowheads react to the approach of vessels at greater distances than they react to most other industrial activities, and vessel and associated cleanup activities may be encountered by bowheads frequently and would likely induce avoidance responses that would cause extra expenditures of energy. According to Richardson and Malme (1993), most bowheads begin to swim rapidly away when vessels approach rapidly and directly. Avoidance usually begins when a rapidly approaching vessel is 0.62 to 2.5 miles away. A few whales may react at distances from 3 to 4 miles. Vessels deployed on skimmer/boom teams likely would be less than 75 feet in length (about the size of a fishing vessel) and booming operations would be operating at low speeds. These vessels and smaller vessels produce higher frequency noise that certainly add to the ambient noise levels but may not be in the frequency range for bowhead and other low frequency whales in some cases.

Cavitation noise, and onboard engine and equipment noise is not likely to propagate noise levels harmful to or causing avoidance response from bowhead whales more than 0.62 miles from the vessel. Therefore, bowheads would likely avoid the vessels at a distance of over 0.62 miles; however, during transit operations at high speeds at night or during low visibility conditions collision or propeller strikes could occur. Larger vessels for a relief well drilling operations create noise levels from propeller cavitation, and onboard engine noise that propagates at levels causing reaction from bowhead whales. Avoidance may be related to the fact that bowheads have been commercially hunted within the lifetimes of some individuals in the population and they continue to be hunted for subsistence use throughout many parts of their range. Avoidance usually begins when a rapidly approaching vessel is 0.62 to 2.5 miles away. A few whales may react at distances from 3 to 4 miles, and a few whales may not react until the vessel is less than 0.62 miles away. Received noise levels as low as 84 dB_{RMS} or 6 dB above ambient may elicit strong avoidance of an approaching vessel at a distance of 2.5 miles (Richardson and Malme, 1993).

In the Canadian Beaufort Sea, bowheads observed in vessel-disturbance experiments began to orient away from an oncoming vessel at a range of 1.2 to 2.5 miles and to move away at increased speeds when approached closer than 1.2 miles (Richardson and Malme, 1993). Vessel disturbance during these experimental conditions temporarily disrupted activities and sometimes disrupted social groups, when groups of whales scattered as a vessel approached. Reactions to slow- moving vessels, especially if they do not approach directly, are much less dramatic. Bowheads often are more tolerant of vessels moving slowly or in directions other than toward the whales. Fleeing from a vessel generally stopped within minutes after the vessel passed, but scattering may persist for a longer period. After some disturbance incidents, at least some bowheads returned to their original locations (Richardson and Malme, 1993). Some whales may exhibit subtle changes in their surfacing and blow cycles, while others appear to be unaffected. Bowheads actively engaged in social interactions or mating may be less responsive to vessels.

If drill vessels engaged in drilling relief wells are attended by icebreakers, as typically is the case during the fall in the Chukchi Sea, the drilling vessel noise frequently may be masked by icebreaker noise, which often is louder. Response distances would vary, depending on icebreaker activities and sound-propagation conditions. Based on models, bowhead whales likely would respond to the sound of the attending icebreakers at distances of 1.24 to 15.53 miles from the icebreakers (Miles, Malme, and Richardson, 1987). This study predicts that roughly half of the bowhead whales show avoidance response to an icebreaker underway in open water at a range of 1.25 to 7.46 miles when the sound to noise ratio is 30 dB. The study also predicts that roughly half of the bowhead whales would show avoidance response to an icebreaker pushing ice at a range of 2.86 to 12.4 miles when the sound to noise ratio is 30 dB.

Based on all of the above information, there could potentially be displacement of bowhead whales from a feeding area following a VLOS, and this displacement could last as long as there are spill response and cleanup vessels present and possibly longer. The severity of impacts depends on the value of the feeding area affected. In the event that a high value area is affected and alternate feeding areas of similar value are scarce, effects to nutritional fitness, reproductive capacity, fetal growth rates, and neonatal survivorship could occur.

Noise and Disturbance from Aircraft

After a VLOS, it is likely that overflights using helicopters and fixed-winged aircraft would track the spill and determine distributions of wildlife that may be at risk from the spill. Most bowheads are unlikely to react noticeably to occasional single passes by helicopters flying at altitudes above 500 feet. At altitudes below 500 feet, some bowheads probably would dive quickly in response to the aircraft noise (Richardson and Malme, 1993; Patenaude et al., 1997) and may have shortened surface time (Patenaude et al., 1997). Bowhead reactions to a single helicopter flying overhead probably are temporary (Richardson, 1995a). Whales are likely to resume their normal activities within minutes.

Fixed-wing aircraft flying at low altitudes often cause hasty dives. Reactions to circling aircraft are sometimes conspicuous if the aircraft is below 1,000 feet), uncommon at 1,500 feet), and generally undetectable at 2,000 feet. Repeated low-altitude overflights at 500 feet) sometimes caused abrupt turns and hasty dives (Richardson and Malme, 1993). The effects from an encounter with aircraft are brief, and the whales should resume their normal activities within minutes. Under the intensive and frequent overflight patterns of large aircraft dispensing chemical dispersants at low level flight altitudes (less than 984 feet), bowheads would likely respond more severely and, depending on the situation, could harass bowheads and haze them in the direction of flight lines for considerable distances.

Based on all of the above information, the conclusion is that there could potentially be harassment of bowheads away from movement corridors and displacement of bowhead whales from feeding areas following a VLOS, and this displacement could last as long as there is a large amount of oil and related cleanup aircraft (especially dispersant application operations) present. Intensive and frequent low elevation overflights associated with spill response and assessment, monitoring, wildlife monitoring, and media operations could potentially harass and displace bowheads within the spill area or between the VLOS and shore-based facilities. Hazing of whales away from a hazardous spilled oil slick is possible. This is especially true during the fall migration when large numbers of whales attempt to cross the Chukchi Sea or take advantage of feeding opportunities where there is exposure to hazardous oil (that associated with large amounts of aromatic components, concentrations of prey lying within the spill contaminated surface slick, or where consumption of oil by surface feeding whales is a hazard). Hazing of migrating whales, while stressful, may be justified to prevent whales from intercepting or migrating through extended areas of spilled oil, and to encourage them to detour around hazardous accumulations of oil and continue migration to the west.

In-Situ Burning

Deployment of burning operations would primarily occur near the localized origination point of the spill and in prioritized nearshore areas. Spill origination site boom and burn operation noise would likely be masked by the noise emanating from the relief drilling effort, which bowhead whales could avoid as is described in the next subsection. There would also be monitors ensuring that marine species would not be in the vicinity of the burning.

Noise and disturbance associated with skimmer and boomer operations. Booming efforts and associated skimmers utilize vessels to conduct operations, and noise effects as described above apply to bowhead whales. Offshore skimmer operations appear to be restricted to the localized area of the spill source and the specific high value nearshore and coastal sites where infrastructure and facilities for crews and equipment are available. Effects on bowhead whales from these operations are likely to be minor because the nearshore operations, noise, and sensitive coastal sites are not important fall migratory habitat to these whales. Effects are expected to be negligible.

Noise and Disturbance from Drilling a Relief Well and Support Activities

Drilling a relief well is a source of noise and disturbance to bowhead whales with essentially the same impacts as the drilling of the exploration well that failed. Relief well drilling operations are likely to employ drilling vessels (with icebreaker support vessels, if necessary) and are estimated to operate at a given well site for a period of about 34 days. The greatest potential for bowhead whales to encounter relief well operations would occur during the fall migration when the majority of the population migrates westerly across the Chukchi Sea and the Proposed Action Area. Satellite tagging studies since 2006 indicate that migrating whales could be migrating across the Chukchi Sea from September to mid-December and could encounter drilling throughout the entire migration period.

Some bowheads in the vicinity of drilling operations would be expected to respond to noise from MODUs by adjusting their migration speed and swimming direction to avoid closely approaching these noise sources. Miles, Malme, and Richardson (1987) predicted the zone of responsiveness to continuous noise sources. They predicted that roughly half of the bowheads likely would respond at a distance of 0.62 to 2.5 miles from a drillship drilling when the signal-to-noise ratio is 30 dB. A smaller proportion would react when the signal-to-noise ratio is about 20 dB (at a greater distance from the source), and a few may react at a signal to noise ratio even lower or at a greater distance from the source. Bowhead whales are likely to detour around an operating relief drilling effort and continue their westward migration. These whales may encounter noise from booming, skimming, support vessels and other activities after detouring around a relief drilling operation. Reactions are likely to be localized, temporary and non-lethal. Please refer to the previous sections on noise and disturbance from vessel presence and activity, and noise and disturbance from aircraft, as well as the 2007 FEIS (Section IV.C.1.f(1)(d)) for detailed discussions of effects from these similar support activities associated with relief well drilling efforts.

Drilling a relief well would also result in discharges that could impact bowhead whales; there could be alterations in bowhead habitat as a result of exploration-related localized pollution and habitat destruction. Bottom-founded MODUs may cover areas of epibenthic invertebrates used for food by bowhead and gray whales, but would be localized and inconsequential in comparison to the vast foraging habitat available in the Chukchi Sea. Any potential effects on whales from discharges are directly related to whether or not any potentially harmful substances are released into the marine environment; what their fate in that environment is (for example, different hypothetical fates could include rapid dilution or biomagnification through the food chain); and thus, whether they are bioavailable to the species of interest. Effects likely would be negligible, because bowheads feed primarily on pelagic zooplankton and the areas of sea bottom that are impacted would be inconsequential in relation to the available habitat.

Animal Rescue, Scientific Recovery, Rehabilitation, and Disposal

Bowhead whale rescue actions are not anticipated; however, rescue efforts for some other species may bring small vessels into the vicinity of bowheads. Negligible effects are anticipated from small vessels as bowheads would likely avoid the activity and larger vessel operations that would serve as facilities from which smaller craft may be operating (see the above section on noise and disturbance from vessel presence and activity). Recovery of stranded, floating, or otherwise dead or severely injured bowheads or other marine species would be onshore (stranded) or not likely to be in the company of other bowheads at sea.

Rehabilitation and treatment facilities likely would be on board a ship or land based and not practical for large whales. Disposal of contaminated carcasses (if any), tissues and oil contaminated materials (absorbent pads, protective gear, etc.) would likely be at an authorized disposal site onshore. Negligible effects are anticipated.

Bioremediation and Restoration (Short- and Long-Term)

Bowhead whales would experience a wide variety of exposure to aircraft and vessel noise and traffic and effects would be similar to those analyzed above under sections for noise and disturbance from vessel presence and activity, and noise and disturbance from aircraft, as well as within the Lease Sale Final EIS (USDOI, MMS, 2007b (Section IV.C.1.f(1)(d)(3) - Effects of Noise from Icebreakers; Section IV.C.1.f(1)(d)(4) - Effects from Other Vessel Traffic Associated with Seismic Surveys; and Section IV.C.1.f(1)(d)(5) - Effects from Aircraft Traffic) (USDOI, MMS, 2007b). Aircraft and vessel operations would support many short-term efforts during the initial spill response as well as throughout the spill containment and treatments to minimize volume, spread, and environmental consequences. These include a wide variety of surveillance missions, placement of transmitter equipped buoys (to track spill edge in real time), media coverage, monitoring wildlife, dispersant application, treatments to shorelines and waters, as well as various activities associated with spill research, monitoring, and evaluation. The fate of and effects of dispersant application upon productivity, survivorship and contamination of benthic sediments and invertebrates are addressed in the 2007 FEIS (Section IV.E.4). Overall it is possible that the use of dispersants, if permitted, could lead to effects through either reduction of food availability, bio-accumulation, or contamination. The same would be true for any cetacean.

A-7.6.3.3 Gray Whale

Potential impacts to gray whales during spill response and cleanup are similar to those described for bowhead whales, except as noted below.

Gray whales feed upon benthic invertebrates that occur on and in the bottom sediments. Drilling muds and cuttings from the relief well may cover portions of the seafloor and cause localized pollution. However, the effects likely would be negligible, because areas of sea bottom that are impacted would be inconsequential in relation to the available habitat.

Chemical dispersants are used to break up surface oil and disperse it into the water column, some of which may sink and affect benthic organisms preyed upon by gray whales. If their use is permitted, dispersants could potentially affect productivity, survivorship, and contamination of benthic sediments and invertebrates (the primary gray whale prey), as well as pelagic zooplankton near shore and in the Arctic marine and ice environments over the shallow continental shelf in the Chukchi Sea. Impacts to food availability and potential bioaccumulation could occur.

A-7.6.4 Additional Cetacean Species Found in the Chukchi Sea

The following species would be affected by a VLOS originating in the Proposed Action Area if oil from the VLOS entered the Chukchi Sea.

A-7.6.4.1 Fin Whale (Endangered)

Potential impacts to fin whales during spill response and cleanup are similar to those described for bowhead whales, except as noted below. Fin whales are low frequency sensitive whales and though thresholds for response to noise may be species specific, the general discussion relative to bowhead whales applies to fin whales. The summary of information about the current and historic distribution of fin whales indicates that a few individuals or small groups of these species could be exposed to potential noise impacts. Such effects should be temporary and minor.

A-7.6.4.2 Humpback Whale (Endangered)

Potential impacts to humpback whales during spill response and cleanup are similar to those described for bowhead whales, except as noted below. Humpback whales are low frequency sensitive whales and although thresholds for response to noise may be species specific, the general discussion relative to bowhead whales applies to humpback whales. The summary of information about the current and historic distribution of humpback whales indicates that a few individuals or small groups of these species could be exposed to potential noise impacts. Such effects should be temporary and minor.

Potential impacts to minke whales, killer whales, and harbor porpoises during spill response and cleanup are similar to those described for bowhead whales.

In the event that a VLOS enters the Chukchi Sea from the Proposed Action Area and affected any of the following Chukchi Sea-centric species, long-term recovery may have some effects on fin, humpback, Minke and killer whales, as well as harbor porpoises. It is reasonable to assume some direct monitoring effort will be directed as a post-spill cetacean response to a VLOS event.

Whales may experience some effects from increases in research and monitoring efforts directed at them as well as by other potential increases in post-spill research and monitoring actions. Aircraft (fixed wing) and vessel traffic are currently and would remain the main impact producing factors upon cetaceans.

A-7.6.5 Long-Term Recovery

Over the long-term, marine mammals including cetaceans would experience continued exposure to aircraft and vessel noise and traffic. Effects would be similar to those analyzed in the sections above. Aircraft and vessel operations would be supporting many longer-term efforts for monitoring the recovery of resources, fate of oil and/or dispersants in the Arctic environment, and research and monitoring on the effectiveness of various cleanup and restoration practices. It would be speculative at this time to provide an estimate of the numbers, spatial and temporal framework, diversity of or effects of various post-spill research, monitoring, follow-up treatments, or intensity of post-spill activities. BOEM acknowledges the need and reality of long-term post-spill activities as such events offer the unique opportunity to prevent, mitigate, and restore damaged resources and human values in the future. Research monitoring and studies are subject to scientific research permits issued by NMFS, while industrial monitoring and resource studies are subject to MMPA authorizations issued by NMFS. These MMPA permits and authorizations provide stipulations and best practices to protect cetaceans from effects, as well as enforcement measures. Vessel maneuvers, aircraft elevation limitations, limits to seasonal period of activity, tagging and handling limits, requiring marine mammal observers are some of these. Minimum impacts to individuals and large numbers of animals are the objective of these required actions. Effect to any given species of cetaceans area expected to be minimal, as subsequent determinations of studies and other efforts are to be carried out through MMPA authorizations from NMFS.

A-7.6.5.1 Beluga Whale

Beluga whales have been the subject of numerous studies in the in the Bering, Chukchi and Beaufort Seas. They have been indirectly affected by other ongoing efforts including BWASP, COMIDA, BOWFEST, and industry research and monitoring activities. Aircraft (fixed wing) and vessel traffic are currently and would remain the main impact producing factors upon beluga whales. It is reasonable to expect direct monitoring efforts to be directed at post-spill beluga whales as result of a VLOS event

A-7.6.5.2 Bowhead Whale (Endangered)

Bowhead whales have been the subject of numerous research and monitoring efforts by agencies and industry for over three decades. New efforts are likely to continue into the future with or without a VLOS event, which may serve to increase the level of research and monitoring of this species.

A-7.6.5.3 Gray Whale

Gray whales have been the subject of numerous studies in the 1980s and 1990s in the Bering, Chukchi, and Beaufort Seas. Since that time they have been subject to BWASP, COMIDA, BOWFEST, and industry research and monitoring activities. Aircraft (fixed wing) and vessel traffic are currently, and would remain, the main impact producing factors upon gray whales. It is reasonable to assume some direct monitoring effort to be directed at post-spill gray whale response to a VLOS event.

A-7.6.6 Oil Spill Trajectory Analyses

Table A-7-3 Summer Contact Probabilities for Marine Mammal ERAs

ID	ERA	1 day LI	1 day PL	3 day LI	3 day PL	10 day LI	10 day PL	30 day LI	30 day PL	90 day LI	90 day PL	360 day LI	360 day PL
20	East Chukchi Offshore	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
22	AK BFT Bowhead FM 2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	1	1	1
24	AK BFT Bowhead FM 3	<0.5	<0.5	<0.5	<0.5	1	<0.5	2	2	2	2	2	2
25	AK BFT Bowhead FM 4[3.]	<0.5	<0.5	1	<0.5	4	2	5	3	5	3	5	3
26	AK BFT Bowhead FM 5[3.]	<0.5	<0.5	<0.5	<0.5	3	1	5	3	6	3	6	3
27	AK BFT Bowhead FM 6	<0.5	<0.5	<0.5	<0.5	1	<0.5	3	2	4	2	4	2
28	AK BFT Bowhead FM 7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	1	3	1	3	1
29	AK BFT Bowhead FM 8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1
61	Point Lay-Point Barrow BH GW SFF	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	1	2	1
65	Smith Bay[1]	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1	1	1
68	Harrison Bay[2, 3]	<0.5	<0.5	<0.5	<0.5	1	<0.5	5	3	6	3	6	3
69	Harrison Bay/ Colville Delta[2,4]	<0.5	<0.5	<0.5	<0.5	1	<0.5	4	2	5	3	5	3
108	Point Barrow Feeding Aggregation	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	4	2	4	2
110	AK BFT Outer Shelf & Slope 1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
111	AK BFT Outer Shelf & Slope 2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1	1	1
112	AK BFT Outer Shelf & Slope 3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	1	2	2	2	2
113	AK BFT Outer Shelf & Slope 4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	4	2	4	3	4	3
114	AK BFT Outer Shelf & Slope 5	<0.5	<0.5	<0.5	<0.5	1	<0.5	4	2	4	3	4	3
115	AK BFT Outer Shelf & Slope 6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	1	3	2	3	2
116	AK BFT Outer Shelf & Slope 7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	2	1	2	1
117	AK BFT Outer Shelf & Slope 8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	2	2	2	2
118	AK BFT Outer Shelf & Slope 9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	2	1	2	1
119	AK BFT Outer Shelf & Slope 10	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	2	1	2	1

Notes:

[1.] ERA 65 is important to seals and cetaceans.
[2.] ERAs 68 and 69 are important to seals
[3.] ERAs 25, 26, and 68 have ≥5% probability of oil contact from an LDPI Spill at 30, 90, and 360 days
[4.] ERA 69 has a ≥%5 probability of oil contact from the LDPI at 90 days
All other ERAs listed in this table are important to cetaceans.

Table A-7-4 Winter Contact Probabilities for Marine Mammal ERAs

ID	ERA	1 day LI	1 day PL	3 day LI	3 day PL	10 day LI	10 day PL	30 day LI	30 day PL	90 day LI	90 day PL	360 day LI	360 day PL
25	AK BFT Bowhead FM 4	<0.5	<0.5	<0.5	<0.5	1	1	1	1	1	1	1	1
26	AK BFT Bowhead FM 5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	1	1	1	1	1
27	AK BFT Bowhead FM 6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5	1	<0.5
28	AK BFT Bowhead FM 7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5	1	<0.5
30	Beaufort Spring Lead 1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
31	Beaufort Spring Lead 2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	1	1	1
32	Beaufort Spring Lead 3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5	1	<0.5
34	Beaufort Spring Lead 5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
35	Beaufort Spring Lead 6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
48	Chukchi Lead System 4[2]	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5	1	<0.5
65	Smith Bay[1]	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
68	Harrison Bay[2]	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	2	1	2	1
69	Harrison Bay/Colville Delta[2]	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	1	1	1
112	AK BFT Outer Shelf & Slope 3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1
113	AK BFT Outer Shelf & Slope 4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1
114	AK BFT Outer Shelf & Slope 5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	1	1	1
115	AK BFT Outer Shelf & Slope 6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1
116	AK BFT Outer Shelf & Slope 7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1

Notes:
[1] ERA 65 is important to seals and cetaceans.
[2] ERAs 48, 68 and 69 are important to seals
All other ERAs listed in this table are important to cetaceans.

Table A-7-5 Annual Contact Probabilities for Marine Mammal ERAs

ID	ERA	1 day LI	1 day PL	3 day LI	3 day PL	10 day LI	10 day PL	30 day LI	30 day PL	90 day LI	90 day PL	360 day LI	360 day PL
24	AK BFT Bowhead FM 3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1	1	1
25	AK BFT Bowhead FM 4	<0.5	<0.5	<0.5	<0.5	2	1	2	1	2	1	2	1
26	AK BFT Bowhead FM 5	<0.5	<0.5	<0.5	<0.5	1	1	2	1	2	1	2	1
27	AK BFT Bowhead FM 6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1	1	1
28	AK BFT Bowhead FM 7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	1	1	1
30	Beaufort Spring Lead 1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
31	Beaufort Spring Lead 2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
32	Beaufort Spring Lead 3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
61	Point Lay-Point Barrow BH GW SFF	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
65	Smith Bay[1]	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
68	Harrison Bay[2]	<0.5	<0.5	<0.5	<0.5	1	<0.5	2	1	3	1	3	1
111	AK BFT Outer Shelf & Slope 2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
112	AK BFT Outer Shelf & Slope 3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1	1	1
113	AK BFT Outer Shelf & Slope 4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	2	1	2	1
114	AK BFT Outer Shelf & Slope 5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	2	1	2	1
115	AK BFT Outer Shelf & Slope 6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	2	1	2	1
116	AK BFT Outer Shelf & Slope 7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1
117	AK BFT Outer Shelf & Slope 8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1

ID	ERA	1 day LI	1 day PL	3 day LI	3 day PL	10 day LI	10 day PL	30 day LI	30 day PL	90 day LI	90 day PL	360 day LI	360 day PL
118	AK BFT Outer Shelf & Slope 9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
119	AK BFT Outer Shelf & Slope 10	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5

Notes:
[1] ERA 65 is important to seals and cetaceans.
[2] ERA 68 is important to seals
All other ERAs listed in this table are important to cetaceans.

Table A-7-6 Seasonal Contact Probabilities for Marine Mammal LSs

ID	LS	1 day LI	1 day PL	3 days LI	3 days PL	10 days LI	10 days PL	30 days LI	30 days PL	90 days LI	90 days PL	360 days LI	360 days PL
Summer 85	Utqiaġvik, Browerville, Elson Lagoon	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5	<5	1	<5	1	<5
Winter none	None	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Annual 85	Barrow, Browerville, Elson Lagoon	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5	<5	1	<5	1	<5

Note: LS 85 is important to polar bears and/or Pacific walruses.

Table A-7-7 Contact Probabilities for Marine Mammal GLSs

ID	GLS	1 day LI	1 day PL	3 days LI	3 days PL	10 days LI	10 days PL	30 days LI	30 days PL	90 days LI	90 days PL	360 days LI	360 days PL
Summer		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
169	Smith Bay Spotted Seal Haulout	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	2	1	2	1
173	Harrison Bay Spotted Seal Haulout	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	1	1	1
176	98-129 Summer	12[1]	27[1]	28[1]	40[1]	40[1]	46[1]	43[1]	48[1]	43[1]	48[1]	43[1]	48[1]
178	104-129 Fall	12[1]	26[1]	25[1]	34[1]	30[1]	37[1]	30[1]	37[1]	30[1]	37[1]	30[1]	37[1]
179	Foggy Island Bay	24[1]	53[1]	48[1]	72[1]	57[1]	77[1]	58[1]	78[1]	58[1]	78[1]	58[1]	78[1]
Winter		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
176	98-129 Summer	4	9[1]	10[1]	13[1]	14[1]	16[1]	16[1]	17[1]	17[1]	18[1]	17[1]	18[1]
178	104-129 Fall	4	11[1]	9[1]	16[1]	13[1]	18[1]	14[1]	18[1]	14[1]	19[1]	14[1]	19[1]
179	Foggy Island Bay	21	51	46	69	55	76	57	77	57	77	57	77
180	110-124 Winter	<0.5	<0.5	<0.5	<0.5	1	1	2	2	3	2	3	2
Annual		LI	PL	LI	PL	LI	PL	LI	PL	LI	PL	LI	PL
169	Smith Bay Spotted Seal Haulout	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	<0.5
176	98-129 Summer	6[1]	14[1]	14[1]	20[1]	21[1]	24[1]	23[1]	25[1]	24[1]	25[1]	24[1]	25[1]
178	104-129 Fall	6[1]	15[1]	13[1]	20[1]	17[1]	23[1]	18[1]	23[1]	18[1]	23[1]	18[1]	23[1]
179	Foggy Island Bay	22[1]	51[1]	46[1]	70[1]	56[1]	76[1]	57[1]	77[1]	57[1]	77[1]	57[1]	77[1]
180	110-124 Winter	<0.5	<0.5	<0.5	<0.5	1	1	2	1	2	2	2	2

Notes:
[1] Cells with contact probabilities ≥5%.
[2] Light blue cells represent ERAs important to seals.
[3] White cells represent ERAs important to polar bears or Pacific walruses.

A hypothetical VLOS could contact offshore areas when and where marine mammals may be present. The location, timing and magnitude of a VLOS and the concurrent seasonal distribution and movement of cetaceans would determine whether or not contact with the oil occurs. The Oil Spill Risk Analysis (OSRA) models oil spill trajectories from 6 launch areas (LAs). The LAs are shown in Appendix A, Map A-5.

This section describes the results estimated by the OSRA model for a hypothetical VLOS originating at the proposed LDPI or the associated pipeline contacting specific Environmental Resource Areas (ERAs), Land Segments (LSs), or Grouped Land Segments (GLSs). ERAs, LSs, and GLSs are spatial representations (polygons) that indicate a geographic area important to one or more marine mammal species. Fresh oil contributed to the marine environment after October 31 would be considered a "winter spill." The effectiveness of OSR activities is not factored into the results of the OSRA model.

The following discussion presents the results estimated by the OSRA model of the hypothetical VLOS contacting ERAs important to cetacean species. The dynamics of oceanographic, climatic, and biotic factors affecting the distribution and abundance of prey, timing of accessibility to habitats, and corridors for movement determine the opportunity for cetaceans and oil to come into contact. There are situations where aggregations of cetaceans of one or more species can contact oil. Trajectory contact with an ERA does not indicate the entire ERA is oiled, only that it is contacted somewhere.

A-7.6.6.1 Beluga, Fin, Humpback, Minke, and Gray Whales

No ERAs for beluga, fin, humpback, minke (Table A-7-5) or gray whales had a greater than or equal to 5 percent probability of being contacted at any time, and so ERAs are unlikely to be individually contacted. Bowhead Whale (Endangered)

Summer. The OSRA model estimates ERAs 25 and/or 26 have a greater than or equal to 5 percent summer contact probability between 30 and 360 days after spill materials are released (Table A-7-8). Both ERAs represent sections of the fall migration corridor used by migrating bowhead whales leaving the Beaufort Sea. All other ERA summer contact probabilities are less than 5 percent and so those ERAs are unlikely to be contacted individually.

Winter All winter contact probabilities for ERAs had less than 5 percent probability of occurring and so are unlikely to occur on an individual basis.

Annual All annual contact probabilities for ERAs had less than 5 percent probability of occurring and so are unlikely to occur on an individual basis.

Table A-7-8 Bowhead Whales–Summer, Winter, and Annual Fraction of VLOS

ID	ERA	1 day LI	1 day PL	3 day LI	3 day PL	10 day LI	10 day PL	30 day LI	30 day PL	90 day LI	90 day PL	360 day LI	360 day PL
Summer 25	AK BFT Bowhead FM 4	<0.5	<0.5	1	<0.5	4	2	5	3	5	3	5	3
Summer 26	AK BFT Bowhead FM 5	<0.5	<0.5	<0.5	<0.5	3	1	5	3	6	3	6	3

Notes: Bowhead Whales - Fraction of a VLOS (expressed as a percent of trajectories) Contacting a Certain ERA within 1, 3, 10, 60, 90 or 360 Days during Summer or Winter from any LA.
ERA 25 Fraction ≥5% at 30, 90, and 360 days from spill.
ERA 26 Fraction ≥5% at 30, 90, and 360 days from spill.
There are no Winter or Annual Fractions of VLOS for Bowhead Whales
LA = Launch Area, ERA = Environmental Resource Area
Source: Appendix A, Tables A.1-11, A.2-28, 30, and 54, Maps A-2a through 2f.

A-7.6.6.2 Harbor Porpoise

No ERAs for harbor porpoises have been established, and they are not documented east of Point Barrow in the Beaufort Sea. No marine mammal ERAs in the Chukchi Sea had a less than or equal to 5 percent probability of being contacted (Table A-7-5) at any time, and so ERAs for harbor porpoises are unlikely to be individually contacted.

A-7.6.6.3 Killer Whale

No ERAs for killer whales have been established, however they prey on other marine mammals in the Chukchi Sea. No marine mammal ERAs in the Chukchi Sea had a less than or equal to 5 percent probability of being contacted (Table A-7-5) at any time, and so ERAs of killer whale prey species are unlikely to be individually contacted.

A-7.6.7 Conclusion

Direct contact with spilled oil resulting from a VLOS would have the greatest potential to affect bowhead whales migrating through their fall migration corridor at ERAs 25 and 26, particularly if toxic fumes from fresh oil are inhaled where bowheads aggregate.

Most cetaceans would likely avoid OSR and cleanup activities, possibly resulting in displacements from preferred feeding habitats, and temporary interference with migrations. Presence of oil on and in the water may be avoided by some cetaceans, but not others, depending on the timing, volume, contents, and duration of a VLOS. Cetaceans generally could experience some loss of seasonal habitat, reduction of prey, and/or contamination of prey. Consumption of contaminated prey may also affect the distribution, abundance and health of cetaceans. A variety of effects on cetaceans could result from contact with and exposure to a VLOS ranging from no effect, to avoidance, to some mortality depending the circumstances unique to a spill event. Several cetacean species occur in the Chukchi Sea where the contact probabilities are all less than 5 percent, but only 3 regularly occur in the Beaufort, and of the cetacean species in the Beaufort Sea, only bowhead whales have ERAs that have more than or equal to 5 percent contact probabilities (Table A-7-3). Of the Beaufort Sea cetacean ERAs that could be contacted, only ERAs 25 and 26, representing two segments of the bowhead whale fall migration corridor, were contacted, while all other contact probabilities were less than 5 percent, and not reasonably foreseeable.

More species-specific summary and conclusions are provided below.

A-7.6.7.1 Beluga Whale

Beluga whales are vulnerable to contact with a VLOS when they feed across the Beaufort Sea. The fate of beluga prey, especially Arctic cod and other Arctic fisheries, could affect seasonal habitat use, determine if toxic amounts of contaminated fish are ingested, or possibly change distribution of these whales until fisheries recover. Temporary and/or permanent injury and non-lethal effects could also occur. Toxic levels of ingestion could alter endocrine system and reproductive system function and in severe cases might result in some mortalities.

Few belugas would come into contact with the human activities associated with cleanup operations in near shore areas, where localized intensive boom and skimming efforts to protect lagoons and other coastal resources would occur. Avoidance behavior and stress to some belugas in coping with concentrated cleanup activities is likely. Beluga whales could inhale toxic fumes from spilled oil. Prolonged inhalation of toxic fumes or surface oil could result in temporary and/or permanent injury or mortality to some individuals.

Displacement from, or avoidance of, nearshore habitats could occur over several years after a spill; however, no contact probabilities more than or equal to 5 percent for beluga whale ERAs are documented in the Beaufort, or the Chukchi Seas. Since no ERAs for belugas had contact probabilities more than or equal to 5 percent, contact of those ERAs are not reasonably foreseeable.

Post spill recovery of belugas to pre-spill abundance and habitat use patterns would be dependent upon the recovery periods necessary to restore pre-spill levels of prey populations and the quality of preferred habitats. Recovery would also depend on the amount of human activity in and adjacent to the preferred habitats.

A-7.6.7.2 Bowhead Whale (Endangered)

Bowhead whales could experience contact with fresh oil during summer and fall feeding events aggregations and migration in the Beaufort Sea. Skin and eye contact with oil could cause irritation and various skin disorders. Toxic aromatic hydrocarbon vapors are associated with fresh oil, and prolonged inhalation of such vapors could lead to impaired endocrine system function that adversely affect reproductive function (that may be temporary or permanent), and/or bowhead mortality in situations where prolonged exposure occurs. Dissipation of toxic fumes into the atmosphere from the rapid aging of fresh oil, and disturbances from response-related noise and activity limits the potential for prolonged inhalation of toxins.

The exposure of bowhead whale aggregations, especially if calves are present, could result in mortalities, and surface-feeding bowheads may ingest surface and near-surface oil fractions with their contaminated prey. Incidental ingestion of oil factions in bottom sediments could also occur during near-bottom feeding. Ingestion of oil may result in temporary and permanent damage to bowhead endocrine function and reproductive system function; and if sufficient amounts of oil are ingested mortality of individuals may also occur.

Population level effects are not expected; however, there is a small possibility of a high impact VLOS event in which large numbers of whales experience prolonged exposure to toxic fumes and/or ingest large amounts of oil, injury and mortality is possible to a population level effect.

Bowhead whales could be exposed to a multitude of short and longer-term additional human activity associated with initial spill response, cleanup and post event human activities that include primarily increased and localized vessel and aircraft traffic associated with reconnaissance, media, research, monitoring, booming and skimming operations, in-situ burning, dispersant application and drilling of a relief well. These activities would be expected to be intense during the spill cleanup operations and expected to continue at reduced levels for potentially decades post event. Specific cetacean protection actions would be employed as the situation requires and would be modified as needed to meet the needs of the response effort. The response contractor would be expected to work with NMFS and state officials on wildlife management activities in the event of a spill. The two aforementioned groups most likely would have a presence at the Incident Command Post to review and approve proposed activities and monitor their impact on cetaceans. As a member of the team, NFMS personnel would be largely responsible for providing critical information affecting response activities to protect cetaceans in the event of a spill.

Bowheads would be expected to avoid vessel supported activities at distances of several miles depending on the noise produced by vessel sound sources; drill rig; numbers and distribution, size and class of vessels. Migrating whales would be expected to divert around relief well drilling operations and up to a few miles around vessels engaged in a variety of activities. Most activity would occur inside Stefansson Sound, where bowhead whales are rarely documented. Temporary and non-lethal effects are likely from the human activities that would be related to VLOS response, cleanup, remediation, and recovery. Displacement away from or diversion away from aggregated prey sources could occur, resulting in important feeding opportunity relative to annual energy and nutrition requirements. Frequent encounters with VLOS activities and lost feeding opportunities could result in reduced body condition, reproductive performance, increased reproductive interval, decreased in vivo and neonatal calf survival, and increased age of sexual maturation in some bowheads. Effects from displacement and avoidance of prey aggregations and feeding opportunities as a result of human activities associated with spill response, cleanup, remediation and recovery are not expected to result in population level effects.

A-7.6.7.3 Fin and Humpback Whales (Endangered), Killer and Minke Whales, and Harbor Porpoises

The absence of fin, humpback, killer, and minke whales as well as harbor porpoises in the Beaufort Sea, low numbers in the Chukchi Sea, and the low contact probabilities with areas where these species may occur indicates a VLOS has a remote likelihood of affecting them. Consequently, the overall effects of a VLOS on fin, humpback, killer, and minke whales or harbor porpoises should be negligible.

A-7.6.7.4 Gray Whale

Gray whales do not aggregate in the Beaufort Sea, and have only been documented as the occasional individual or small group scattered along the Beaufort Sea Shelf. Aggregations consistently occur near shore along the Alaska Chukchi Sea coast from west of Wainwright to northeast of Point Barrow.

Oil contamination of benthic sediments leading to mortality loss of benthic invertebrate prey species for gray whales might require many years to recover from a VLOS, and lead to the abandonment of some feeding areas. A potential secondary effect to feeding area abandonment could be a reduction in health due to low energy reserves that would compromise a gray whales ability to migrate to wintering areas in the Sea of Cortez, perhaps even leading to mortalities. A large loss in the Western North Pacific stock of gray whales could take decades to recover, depending on the magnitude of the losses.

No gray whale ERAs had contact probabilities greater than or equal to 5 percent, so the potential for large numbers of gray whales being exposed to materials from a VLOS is extremely unlikely and not reasonably foreseeable. Of the marine mammal ERAs that were contacted, the only ones with greater than or equal to 5 percent contact probabilities were ERAs 25 and 26 in the Beaufort Sea. Since those ERAs are associated with the fall bowhead whale migration corridor, and have little to do with gray whales, it is reasonable to assume that no more than a few gray whales in the Beaufort Sea would likely contact spill materials from a VLOS originating at the LI.

For these reasons a VLOS should have no population-level effects on gray whales, and would most likely have negligible to minor effects on a small number of individual whales dispersed between the LI and ERAs 25 and 26. Consequently, a VLOS would most likely have negligible effects on the gray whale population, and negligible to major effects on a few individuals.

A-7.6.7.5 Pinnipeds

A-7.6.7.5.1 Ice Seals

A VLOS would affect bearded, ringed, and spotted seals, and could affect a few ribbon seals in the vicinity of Point Barrow. Ice seals have some capacity to rid their bodies of accumulated hydrocarbons via renal and biliary mechanisms, mostly within 7 days (Engelhardt, 1983), and in most instances where seals have been contacted by oil they fully recover. Onshore contact is only expected to affect spotted seals in localized areas in the Beaufort Sea and those in the Chukchi Sea should remain unaffected by a VLOS from the LI. Ringed and bearded seals are most vulnerable during the winter when they concentrate more along lead systems and shear zones that provide them access to the ocean. Ribbon seals have not been documented in the Beaufort Sea east of Point Barrow, Alaska, and are highly unlikely to be affected by a VLOS. In all cases, each species should recover from the effects of a VLOS within three generations or less. Furthermore, both spotted and ribbon seals, along with the majority of bearded and ringed seals seasonally migrate out of the Beaufort Sea and into the Chukchi and Bering Seas, placing them beyond the immediate area of effects from a winter VLOS.

Spill Response and Cleanup

Spill response activities could disturb and displace seals from affected marine and coastal areas. Negative short-term impacts from disturbance would be outweighed by beneficial effects from intentionally or unintentionally hazing seals away from oiled areas.

The effects of vessel and aircraft traffic associated with an OSR and cleanup may displace seals. Such effects have been observed in numerous ship and air-based surveys in the Beaufort and Chukchi Seas over the years (Blees et al., 2010; Brewer et al., 1993; Brueggeman et al., 1991, 2009a, 2010; Funk et al., 2010; Treacy, 1996) and were described in Section **Error! Reference source not found.**. Some activities such as in-situ burning, animal rescue, the use of skimmers and booms, drilling relief wells, etc. could have additive effects, most likely displacing seals even more. Marine mammal observers would be used, but only a few seals should be temporarily frightened from the area, since many would have already left the area after detecting the spilled material from the VLOS. Moreover, if the prey base is adversely affected most seals would leave the affected area out of necessity so that they could feed. The use of dispersants are unlikely to have any immediate direct effects on seals in an area exposed to a VLOS event; however, there may be some adverse consequences to using certain types of dispersants which may affect the food web, and the long-term effects of dispersant use may extend beyond the proposal area to varying degrees.

Cleanup activities such as beach cleaning may be performed with a high degree of success using newer technologies such as ionic solutions (Hogshead, Evangelos, Williams et al., 2010; Painter, 2011). However, other activities such as spill cleanup under ice or in areas of broken ice may be more problematic. The effects of these activities on seals could vary, depending upon the presence of seals in an area, and pre-existing stress levels. Due to the pervasive permafrosted soils along the Arctic coastline, and a general lack of rocky coastal areas on the Beaufort Sea coast in Alaska, the materials spilled from a VLOS should have a limited ability to spread through the soil profile, making cleanup of shoreline areas easier than in areas where oil and other hydrocarbons can seep down into the soil matrix since the ice in permafrost should repel hydrocarbons towards the soils surface.

In addition, hazing seals from oiled areas could preclude many of the most severe potential impacts from occurring.

Long-Term Recovery

Long-term is defined as affecting populations for more than 2 years. The possible loss of several thousand spotted, bearded, and ringed seals could continue for 2 years and potential recovery may enter the long-term phase. The recent listing of bearded seals under the ESA was based on a concern that the species could experience population declines due to the future effects of climate change. For the purposes of this analysis, the described mortality levels may recover within three generations if ice seal populations are capable of maintaining their present populations. If ice seal population trends begin a prolonged downward trend, the losses from a VLOS event may not be recoverable, leading to major effects to seal populations. Such effects would depend on the severity of climate induced population declines, available habitat, predation, habitat quality, etc., and are merely speculative.

Oil Spill Trajectory Analysis

A VLOS could contact offshore and nearshore areas where seals may be present. The percent of trajectories contacting depends on the location, timing, and magnitude of the spill. The OSRA model uses two launch areas that include the LDPI (LI) to model the origin of spill trajectories.

Drilling from the LDPI could occur year-round, so both summer and winter spills could occur. A VLOS occurring during winter from the LI would most likely spill out onto the surface of landfast sea ice, and would be less likely to enter the water before being collected and sent to a processing area. A VLOS that occurred during the summer could spread, however the proximity of the LI and the PL to the coast lowers the potential for many areas to be contacted. By being close to the coast it is safe to assume significant portions of any VLOS would contact the nearby coastline and spread no farther.

As time progresses after a release event, a VLOS becomes patchy and more widely distributed, which would then permit some seals to leave the area, or remain without the level of adverse consequences associated with an extensive, widespread layer of spilled materials.

A VLOS continuing after October 31 is treated as a winter spill. Since the hypothetical oil spill could continue after October 31 and/or melt out of ice during the following spring, potential trajectories are also assessed over an assessment period of 360 days.

In the event of a VLOS not all of the hydrocarbons are discharged at once, as often occurs with marine accidents such as the EVOS in Prince William Sound, Alaska. Instead they flow into the ocean at rates that decrease over time. For the briefest spill period, BOEM assumes that a spill could persist on the surface of the water for up to three weeks; therefore, a 60 day period of potential contact was analyzed. However, if a spill were to occur late in the open-water season, the liquid hydrocarbons may freeze into the sea ice, and could remain overwinter without any extensive amount of weathering. If this were to happen, quantities of unweathered oil could end up being transported to different areas in the Chukchi and Beaufort Seas and be released in the spring. To address concerns such as this, BOEM has also analyzed a period of 360 days.

This section describes the results estimated by the OSRA model of a hypothetical VLOS in the Beaufort Sea from LI or PL contacting specific ERAs important to ice seals. An ERA noted in this section is a polygon used to represent an area important to one or more seal species at some stage in their life cycle. During winter bearded and ringed seals are the only species expected to be present in the area and their primary winter habitats include polynyas, lead systems, and landfast or pack ice for ringed or bearded seals respectively. During the summer (open-water) season ringed, spotted, and bearded seals may be found swimming in open water, though their numbers increase with proximity to areas of sea ice. Spotted seals are seasonal visitors to the Beaufort and Chukchi Seas, and mostly occupy nearshore areas, bays, and lagoon systems where they periodically haul out, sometimes in large numbers. A few individual spotted seals typically haul out on river bars in the Sagavanirktok and Colville River Deltas. Ribbon seals are mostly pelagic, and tend to occupy the southern and western Chukchi Sea and are not known to occur in the Beaufort Sea beyond Point Barrow. With the exception of hauled out spotted seals, other ice seals do not tend to be gregarious for social reasons as much as to exploit limited resources such as available polynyas and lead systems.

ERAs and GLSs ice seal concentrations are shown in Table A.1-14, and the likelihood of any species being affected by a VLOS would be determined by a number of factors including: seasonality, occurrence of a species; spill avoidance abilities of a species; presence; distribution; habitat use; diet; timing of a spill; spill constituents; spill magnitude; spill duration; and a species' ability to persist in a contaminated area. Bearded and ringed seals occur in the Chukchi and Beaufort Seas year-round, although a very large proportion of their populations winter south in the Bering Sea ice areas. In contrast, ribbon seals mostly summer in the northern Bering Sea and in the southern Chukchi Sea, where little ice persists during the open-water season. Many spotted seals winter in the Bering Sea; however, large aggregations (hundreds and thousands) may be found in Kasegaluk Lagoon, Avak Inlet, and between Kotzebue and Wales on the Seward Peninsula coast, while lower concentrations (tens) occur in Admiralty, Smith, Kugrua and Peard Bays; and the Colville River Delta during summer.

The following paragraphs present the results (expressed as a percentage of trajectories contacting) estimated by the OSRA model of a hypothetical very large spill contacting habitats that are important to seal species.

The OSRA model estimates that trajectories from the LI or PL could contact ERAs or GLSs important to ice seals. The OSRA model results, unless otherwise noted, are expressed as percent of trajectories contacting within 1 and 360 days during summer, winter, and annually (Table A-7-3 through Table A-7-5).

A-7.6.7.5.2 Bearded Seals (Threatened)

Bearded seals are less common in the Beaufort Sea compared to the Chukchi Sea, occurring around coastal areas during summer, they are also more common near the ice front and in areas of drifting sea ice than in large expanses of open water. Since they forage for benthic species, bearded seals must associate with continental shelf waters, and so their population densities tend to be higher in the Chukchi Sea and lower in the Beaufort Sea which has a narrow continental shelf zone. Though the

Chukchi Sea has a large continental shelf area, the shelf in the Beaufort Sea tends to be narrow and ultimately the water depths suitable for prolonged bearded seal occupancy may determine the presence and numbers of bearded seals in the Beaufort Sea. Consequently, in some years bearded seals in the Beaufort Sea may forage farther from the ice front than those in the Chukchi Sea. The number of resident bearded seals in the Beaufort Sea is estimated at around 3,150 as compared to the estimated 27,000 residing year-round in the Chukchi Sea (Cameron et al., 2009), though both resident populations are considered to be part of the Beringian Distinct Population Segment (DPS) of bearded seals.

Grouped Land Segments were not analyzed for bearded seals because this species is strongly associated with sea ice and generally are not found on the shoreline. During winter months their presence is strongly linked to polynyas, areas of broken ice, and lead systems where they can access water and food resources. During summer bearded seals do not aggregate, spending much of their time foraging at sea. Throughout the year bearded seals avoid nearshore areas including areas of landfast ice. The ERAs for seals were described in Appendix A, Table A.1-76. The OSRA model results, unless otherwise noted, are expressed as percent of trajectories contacting between 1 and 360 days during summer, winter, and annually (Table A-7-3 through Table A-7-5).

No ERAs, or LSs reserved for bearded seals had greater than or equal to 5 percent contact probabilities.

A-7.6.7.5.3 Ringed Seals

As with bearded seals, ringed seals have a strong association with sea ice. However, ringed seals prefer to overwinter in landfast ice, particularly where heaves and irregularities create icy hummocks that protect their lairs from polar bears. During summer, ringed seals associate with sea ice in the open waters and so may occur in the open ocean where they forage on fishes. It is assumed that their presence and densities in any given area depends upon the food stocks in a local area, as well as the presence or absence of sea ice. Consequently, no GLS, ERA or BS was identifiable for ringed seals; however, they do concentrate in polynyas and lead systems if those features are available. The OSRA model results are expressed as percent of trajectories contacting between 1 and 360 days during summer, winter, and annually (Table A-7-3 through Table A-7-5).

No ERAs, LSs, or GLSs reserved for ringed seals had greater than or equal to 5 percent contact probabilities.

A-7.6.7.5.4 Ribbon Seals

Very low numbers of ribbon seals have been detected during marine mammal surveys in the Chukchi Sea, and none in the Beaufort Sea (Funk et al., 2010; Blees et al., 2010; Brueggeman et al., 1991, 2009, 2010). Ribbon seals spend most of their lives in the open ocean, relying on sea ice to whelp and molt, then returning to the water for the remainder of the year. Most ribbon seals are found in the southern and western regions of the Chukchi Sea, and are sometimes observed in the eastern and east-central Chukchi Sea, and rarely a ribbon seal is observed near Point Barrow, Alaska. Whelping occurs in the Bering Sea, and perhaps in a few areas of the southern Chukchi Sea, and so there should be little risk to ribbon seals from the a VLOS. Any ribbon seals that could be affected by a VLOS would be in the open water, in very low densities.

Limited observations of ribbon seals in the Chukchi Sea preclude the designation of ERAs, GLSs, LSs, or BSs for ribbon seals. At most, less than one hundred ribbon seals could be affected by a VLOS at the LI. If a VLOS occurred, a fraction of the ribbon seals could be killed, while the remainder would likely recover within a few days. Such effects would not affect ribbon seal stock in U.S. waters.

No ERAs, LSs, or GLSs reserved for ribbon seals had greater than or equal to 5 percent contact probabilities.

A-7.6.7.5.5 Spotted Seals

Spotted seals are summer visitors to the Chukchi Sea and to a much lesser extent, the Beaufort Sea. Their primary haulout sites in the Chukchi Sea include Kasegaluk Lagoon, areas around Kotzebue Sound, and some areas along the Chukotka coast, particularly Kolyuchin Bay. The number of seals using haulout sites in the Beaufort Sea are small by comparison to some Chukchi Sea haulouts, which support thousands of spotted seals. Verified spotted seal haulouts in the Beaufort Sea include Dease Inlet/Admiralty Bay, Smith Bay, the Sagavanirktok River Delta, and Oarlock Island in the eastern Colville River Delta. Possible haulouts may also occur on the shore of western Camden Bay, Alaska, but have not been verified. In the following analyses the appropriate ERAs, LSs, and GLs are analyzed to estimate the percentage of trajectories contacting spotted seal habitat in the proposal area. During the Arctic summer spotted seals are not as strongly associated with ice as are bearded and ringed seals, and most use nearshore and coastal habitat. From late fall through late spring spotted seals reside at the southern edge of the winter sea ice front in the Bering Sea and could not be affected by a VLOS.

As with bearded, ringed, and ribbon seals, any VLOS in open-water conditions is likely to contact some individual spotted seals; however, slicks would weather and disperse over time. The VLOS analyzed in the OSRA could be expected to contact less than two hundred spotted seals in the Beaufort Sea or perhaps even a few thousand spotted seals in the Chukchi Sea. The largest aggregation of spotted seals that could be oiled occurs in Kasegaluk Lagoon (ERA 1) between Icy Cape and Wainwright, SUA: and Peard Bay (ERA 64), both of which lie along the Chukchi Sea coastline. Smaller haulout areas occur in along the Beaufort Sea coastline at Smith Bay (ERA65), Harrison Bay (ERA68), Harrison Bay/Colville Delta (ERA69), Kolyuchin Bay (GLS 148), Smith Bay Spotted Seal Haulout (GLS 169), and Harrison Bay Spotted Seal Haulout (GLS 173) (Table A.1-76). The OSRA model results, unless otherwise noted, are expressed as percent of trajectories contacting between 1 and 360 days during summer, winter, and annually (Table A-7-7).

Summer. ERA 68 has 5 percent of being contacted by trajectories after 30 days, and ERA and a 6 percent chance of contact from the LI within 90 days and 360 days (Tables A.2-23 and A.2-24). ERA has a 6 percent chance of contact from the LI at 90 days. No other ERAs, LS, or GLSs had contact probabilities greater than or equal to 5 percent. No ERAs, LSs or GLSs had annual or winter contact probabilities greater than or equal to 5 percent, and so are not reasonably foreseeable.

A-7.6.7.5.6 Conclusion

In the event of a VLOS, ice seals could be affected to varying degrees depending on distribution, activity, number affected, season, and various spill characteristics.

Spotted seals are the only phocid species in the analysis area that habitually use shore-based haulouts. Their largest haulout location most likely to be affected by a VLOS lies in the Colville River Delta. Kasegaluk Lagoon may be the largest haulout location that could be affected, and is several times larger than all others combined, but should not be contacted from a VLOS at the LI or PL. Though spotted seals forage for fishes in nearshore areas, their presence is not known to be strongly correlated with pelagic areas and the ice front during summer. Consequently, their presence is associated with haulout areas and nearshore areas with open water. In a 2014 survey by BPXA spotted seals were the most frequently observed marine mammal at the site for the proposed LDPI.

Both bearded and ringed seals closely associate with sea ice throughout the year, and do not typically use shore habitat. Both species prefer to remain in proximity to the ice front during summer, though some use open-waters areas away from sea ice. Bearded seals feed on benthic organisms in shallow (less than 656 feet depth) areas on the continental shelf (ADF&G, 2016), while ringed seals forage for fishes and some invertebrates in the water column. These differences in food selection and foraging behavior help determine the presence or absence of each of these species in an area. Bearded seals are essentially restricted to areas over the continental shelf and the ice front where they can reach the seafloor to feed on benthic organisms, while ringed seals may be found under areas of solid ice as well as in the ice front where they predate fishes such as Arctic and saffron cod.

Ribbon seals are a pelagic ice seal species that have not been documented in the Beaufort Sea east of Point Barrow, and so are highly unlikely to occur near the LDPI. Even in the northern Chukchi Sea biological surveys have only observed them occasionally. Because of their scarcity in the northern Chukchi Sea, and absence from the Beaufort Sea, the ribbon seal population should remain unaffected by a VLOS from the LDPI.

Presently there are no areas identified as important ringed, bearded, or ribbon seal habitat during the summer months. However, during the winter, conditions change drastically with the southward advance of sea ice, when only bearded and ringed seals persist in the Chukchi and Beaufort Seas.

During winter, bearded seals loosely congregate around polynyas, and lead systems, generally avoiding areas of landfast ice. Ringed seals, select landfast ice zones as their preferred habitat where they survive by making and maintaining breathing holes through the ice and by constructing subnivean lairs. A VLOS contacting a polynya or lead systems could therefore have moderate to major effects on ringed and bearded seal populations, potentially oiling or even killing hundreds to thousands of bearded and/or ringed seals. The impacts would be determined by the number of ringed or bearded seals exposed in oiled leads or polynyas. The numbers of seals using an oiled lead system or polynya would likely be a function of the time of year, food resources, and lead or polynya size. For example, if 10,000 adult ringed seals and their pups happened to be using the a lead system during April and that lead system were to became oiled from a VLOS, the effects would likely be major, with many thousands of seals dying from crude oil exposure, especially ringed seal pups.

A contrasting example would be if a VLOS occurred during February when most ringed, and bearded seals, and all spotted, and ribbon seals are overwintering in the Bering Sea. In this example a few thousand ringed seals would probably be at risk of being contacted with spilled crude oil. While a percentage of those seals would likely die, the numbers of fatalities could not approach what was described in the first example because of the numerical difference of adult seals using the leads, and the fact that female ringed seals have yet to whelp. Seal pups are the demographic group most likely to succumb to oil spills, and their absence from lead systems would reduce the number and proportion of mortalities in the population. Furthermore, in such an event there would be no spotted or ribbon seal mortalities and most likely negligible levels of effect to any spotted or ribbon seals due to their absence from the area.

Potential effects of a VLOS event on fishes and invertebrates are analyzed in greater detail in Sections A-7.3 and A-7.4. Because ice seals rely on these organisms for food, any major impacts on fishes or invertebrates could have serious consequences to seal populations. A massive die off of prey species would most likely cause seals to leave the area to seek food elsewhere. While such movements would entail some energetic cost, it is unlikely many seals would immediately starve to death. Displaced seals would compete with seals elsewhere for limited food resources, perhaps lowering the overall fitness of a local population, or even contributing to population losses through malnutrition. Consequently, a VLOS has the potential to affect large numbers of ringed, bearded, and spotted seals in part due to the effects their prey and the local food-web, but not that many ribbon seals. Mortality from a hypothetical VLOS could result in temporary population-level effects for bearded, ringed, and spotted seals, but not ribbon seals due to their scarcity in the northern Chukchi Sea. Most of these effects would correct within a generation; however, due to differences in generation times between species, such recoveries could easily take over five years.

Because of the low probability of VLOS materials contacting any ringed or bearded seal ERAs, LSs, or GLSs it is highly unlikely a VLOS from LI or PL would affect more than one hundred ringed, bearded, or spotted seals, and based on trajectories, no ribbon seals would likely be affected. The greatest effect from a VLOS would occur within Stefansson Sound during summer, and affect a few ringed, bearded, and spotted seals. Spill response and cleanup activities would likely displace some of those affected seals, making them to relocate to other, quitter, less busy areas unaffected by the activity or the VLOS materials.

A-7.6.7.5.7 Pacific Walrus (Candidate Species)

A VLOS could affect Pacific walrus at sea, on sea ice, or at coastal haulouts. Effects could result from direct contact with oil, inhalation or exposure to toxic fumes from the oil (such as PAHs), ingestion of oil or contaminated prey, habitat loss, or prey loss. Additional effects could occur during cleanup and well control work. These impacts could include inhalation or exposure to toxic fumes from cleanup products, disturbance at important on ice or terrestrial haulout sites, disturbance at important foraging sites, and destruction of prey species.

The impacts that occur during each phase of a blowout and subsequent cleanup are analyzed below. The most direct impacts would occur as a result of the oil spilled offshore and onshore. The most recent estimate of the Pacific walrus population suggests a minimum of 129,000 walrus (Speckman et al., 2011). Some researchers believe that the population may be in decline based on age structure and productivity information (Garlich-Miller, Quakenbush and Bromaghin, 2006) due to changes in sea ice and prey availability (Taylor and Udeitz, 2014). The Pacific walrus is a candidate for listing under the ESA due to the continuing loss of sea ice habitat caused by climate change (76 FR 7634, Feb 10, 2011). With a population in decline, any loss of large numbers of walruses, walrus habitat, or prey species would exacerbate that decline. Recovery would not occur unless the population begins to rebound from other factors that may be limiting population productivity or growth, such as decreasing sea ice extent, prey availability or harvest.

Spill Response and Cleanup Activities

Spill response and cleanup activities would involve large numbers of boats of various sizes, skimmers, airplanes, and helicopters. In-situ burning and corralling oil with boom material, or booming off sensitive nearshore habitats may occur. Although the Alaska Regional Response Team (ARRT) has not pre-approved the use of dispersants in the Arctic, they could be considered on an incident-specific basis. Dispersants could be ingested by benthic invertebrates, and have impacts similar to oil if ingested by walrus. Depending upon the type of chemical dispersant used, dispersants could also cause direct impacts to walrus by irritating eyes, mucous membranes, or respiratory systems. Dispersants could also cause effects by killing prey species and displacing walrus from foraging or resting areas.

In the initial aftermath of a spill, activity would be concentrated in the immediate area of the spilled oil. Walrus would likely avoid the area due to the large amount of noise and activity. Walrus, particularly females with young calves, are easily displaced by boat and aircraft traffic. This displacement which may reduce the likelihood that they would be oiled or be exposed to PAHs which tend to evaporate relatively quickly (within a few days, unless frozen into ice). Gas (primarily methane and ethane) would quickly dissipate into the atmosphere at the spill site and walrus are not likely to be exposed to gas in the event of an explosion and spill. Immediate responses, in addition to seeking to control the well and stop the flow of oil, may include attempts to cap the flow or repair the rupture. In-situ burning has been shown to be very effective with freshly spilled oil, but the oil becomes more difficult to ignite as it ages and the aromatic hydrocarbons burn or evaporate. In-situ burning would release soot and other pollutants into the air, but it is unlikely that walrus would remain in the vicinity of such activity or be exposed to enough smoke and soot to suffer respiratory effects.

As the spill response continues, the oil (and thus the response) would become spread out over a larger area. Walrus are particularly vulnerable to disturbance events at coastal haulouts, which can result in increased mortality, particularly among calves, (Udevitz et al., 2013). If the spill occurs between November and May, walrus would already have moved out of the Beaufort Sea and could not be impacted by oil or cleanup efforts during that season (Jay, Fischbach and Kochnev, 2012; USGS, unpublished tagging data).

Even after the flow of oil has been stopped, responders would continue cleaning any remaining oil that can be located. Cleanup efforts could focus on oiled shoreline, and hot washing methods or dispersants could be used. The coastlines being cleaned would be unavailable to walrus for resting. Dispersants may cause skin irritations, respiratory impacts or impacts to sensitive tissues around the eyes, nose, or mouth. This process may be continued the year following the spill. Oil frozen in ice over winter would melt out in the spring through brine channels and into leads and polynyas.

Long-Term Recovery

After cleanup efforts have ceased, the remaining oil would continue to weather and be subject to microbial degradation. This process is likely to be very slow in Arctic waters. Oil that has been suspended in the water column or in the sediment may continue to be ingested by the benthic organisms that walrus prey upon. Walrus may continue to be exposed to hydrocarbons through their prey, which may lead to reduced fitness and possibly population-level effects over time.

VLOS materials suspended in the water column or in sediments may continue to be ingested by the benthic organisms bearded seals and walrus prey upon. Ringed seals are less likely to accumulate hydrocarbons through the fish that they eat (Geraci and St. Aubin, 1990). Polar bears consuming bearded seals or walrus may continue to be exposed to hydrocarbons through their prey, which may lead to reduced fitness over time.

Damage assessment studies would occur as a part of the natural resource damage assessment (NRDA) process. Depending upon the types of studies conducted, some may lead to increased disturbance of walrus by adding additional boat, plane, and shoreline traffic to the Chukchi Sea.

Oil Spill Trajectory Analysis

This OSRA analysis focuses on terrestrial walrus haulout locations at along Chukchi Coastlines, on Wrangel and Kolyuchin Islands. There are no documented haulout areas for Pacific walruses along the Beaufort Sea coastline. Historically Pacific walrus summer haulouts occur on Wrangel Island and the Chukotka coastline; however in recent years they have been hauling out in large numbers along the U.S. side of the Chukchi Sea coast particularly near the community of Wainwright (Jay, Fischbach, and Kochnev, 2012). BOEM also has additional information about at sea distribution from tagging studies and surveys, and has developed new ERAs that more accurately identify which areas are truly important to Pacific walruses. Where practicable, BOEM uses ERAs and GLSs rather than land segments to delineate terrestrial haulouts so.

Though a VLOS could contact offshore or onshore areas where walrus may be present, there were no instances where VLOS contact probabilities were more than or equal to 5 percent. Consequently, trajectories indicate there is less than 5 percent likelihood that any ERAs, LSs, or GLSs important to Pacific walruses would be contacted by VLOS materials from the LI (Table A-7-3 through Table A-7-5). For this reason it is unlikely and not reasonably foreseeable that any spilled VLOS materials would contact areas biologically important to Pacific walruses.

Conclusion

In the event of a VLOS, the OSRA model estimates it is extremely unlikely any Pacific walrus habitats outside of the Beaufort Sea would be contacted. Though there are some walruses that enter the Beaufort Sea during summer, sightings of such individuals are rare, while the bulk of the walrus population hauls out on the Russian side of the Chukchi Sea. Between the small numbers of walruses using the Beaufort Sea, the stock distribution during summer, and the low likelihood of Pacific walrus ERA/LS/GLS contacts by a VLOS the Pacific walrus stock should remain unaffected by a VLOS from the LI. Due to the scarcity of walruses in the Beaufort Sea, particularly near the proposed LDPI, no more than 10 walruses should be affected by the a VLOS from the LI, and only during summer when walruses would be present in the Chukchi and Beaufort Seas, coinciding with the only time when a VLOS could potentially disperse over a broad area of the ocean.

A-7.6.7.6 Polar Bears (Threatened)

Polar bears are listed under the ESA as threatened throughout their range. A VLOS could affect polar bears and polar bear critical habitat on sea ice, barrier islands or on the coast.

Effects could result from direct contact with oil, inhalation or exposure to toxic fumes from the oil (such as PAHs), ingestion of oil or contaminated prey, habitat loss or a lack of available prey. Additional effects could occur during cleanup. These impacts could include inhalation or exposure to toxic fumes from cleanup products, fouling of fur, disturbance at important on ice or terrestrial sites, and continued contamination or loss of prey species or contamination of important coastal or sea ice habitats.

The impacts that occur following a blowout and subsequent cleanup are analyzed below. The most direct impacts would occur as a result of offshore oil spill and onshore contact, which entail an offshore oil spill and onshore contact.

Spill Response and Cleanup Activities

In the initial aftermath of a spill, activity would be concentrated in the immediate area of the spilled oil. Because of the location of the proposed LDPI, some polar bears could be resting or foraging along the coast or on nearby barrier islands, and a few might be swimming through an area exposed to VLOS materials. A study of polar bear reactions to snowmobiles found reactions differed by sex and age class. Smaller bears and females with cubs reacted more often with avoidance behavior than did adult males or single adult females (Anderson and Aars, 2008), so the smaller individuals and females with cubs should be more likely to avoid an area where spill response activities occur. In contrast, hungry, or nutritionally stressed polar bears might be attracted to the spill response activity or engaged in scavenging the carcasses of marine mammals that have died from exposure to VLOS materials. Increased activity in polar bear habitat (e.g., vehicle travel over tundra or sea ice) may increase the likelihood of disturbance to maternal dens. Additional human-polar bear interactions could result in an increase in polar bear take through hazing or in defense of human life. It may be possible to sedate and capture oiled polar bears, and to clean their coats. However, if such bears had already ingested oil, they might be less likely to survive.

Both ringed seal distribution and ice conditions affect polar bear densities and a VLOS could affect this important prey species. Polar bear populations have been observed to increase or decline as seal populations increase or decline (Stirling, 2002), therefore, impacts to ringed seal populations from a VLOS would also impact polar bear populations. Polar bears hunt ringed seals in spring leads, pack ice, fast ice, and at their breathing holes and dens. In spring, polar bears preferentially hunt pups in lairs (Stirling and Archibald, 1977). The potential for exposure to oil that has overwintered increase through these hunting techniques.

Oil Spill Trajectory Analysis

The degree of contact polar bears would have with oil would depend upon the location, timing, and magnitude of the spill. The OSRA model uses the Liberty Island (LI) to model the spill trajectories of up to 4,610,000 bbl of materials spilled over a 90-day period (Section A-5.2).

Drilling from the proposed LDPI would occur year round, and the estimated time to drill a relief well is 90 days based on the amount of time needed to mobilize a second drilling rig, drill the well, and kill the blowout. A VLOS occurring during winter would be unlikely to spread to many areas, especially those in the Chukchi Sea, while a summer spill could be more widely dispersed.

Thetis, Jones, Cottle, and Return Islands (ERA 92) was the only ERA where trajectories indicate contact probabilities more than or equal to 5 percent. Summer contact probabilities for ERA 92 were from 5 percent to 11 percent at 10 to 360 days for spills originating at LI. Summer contact probabilities for ERA 92 for spills originating at PL were 5 percent for 90 and 360 days. Winter and annual contact probabilities were between 7 percent and 10 percent for the 10- to 360-day time periods and only from the LI (Table A-7-4 and Table A-7-5). No LSs had trajectories that contacted greater than or equal to 5 percent, and so there is a greater than or equal to 95 percent likelihood that no LSs for polar bears would be contacted by a VLOS (Table A-7-7).

The Foggy Island Bay (GLS 179), 104-129 Fall (GLS 178), 98-129 Summer (GLS 176) and 110-124 Winter (GLS 180) showed trajectory contacts greater than or equal to 5 percent. During summer GLSs 176, 178, and 179 were contacted by VLOS materials originating at LI or the PL with probabilities ranging from 12 percent to 78 percent. During winter GLSs 176, 178, and 179 showed contact probabilities between 9 percent and 77 percent from 3 to 360 days. Winter contact probabilities for GLSs 176, 178, and 179 on Day 1 were between 9 percent and 51 percent for a VLOS originating at the PL, and GLS also showed a 21 percent contact probability for a VLOS originating at the LI (Table A-7-7). No other GLSs, and no LSs had contact probabilities greater than or equal to 5 percent, and so are not reasonably foreseeable.

Conclusion

The majority of the CBS polar bear stock is believed to den and come ashore on the Russian side of the Chukchi Sea, particularly at Wrangel Island. The majority of the SBS stock of polar bears come ashore and den further eastward in the Beaufort Sea. However, there is a large area of overlap between the CBS stock and the SBS stock out on the sea ice in the northeastern portion of the Chukchi Sea. If a VLOS were to occur, it could result in the loss of some polar bears, most probably along GLSs 176, 178, and 179, and less likely, ERA 92. This might not have a major impact on the SBS and/or CBS polar bear stocks, especially after considering the trajectories of a VLOS from the LI. In all likelihood much of the effects of a VLOS would be felt in Foggy Island Bay and not in the Chukchi Sea, or throughout most of the Beaufort Sea for that matter. For this reason some polar bears could be affected by a VLOS from the proposed LDPI, however massive area-wide effects are not anticipated. The effects to the SBS and CBS polar bear stocks are anticipated to be moderate.

A-7.7 Effects of a VLOS on Terrestrial Mammals

Impacts to terrestrial mammals from a hypothetical oil spill were analyzed in FEIS Section 4.3.5. Those analyses found terrestrial mammals could experience mortality, long-term and short-term sublethal impacts. The primary difference between the effects from a VLOS and those of a large or small spill are in the greater magnitude of the potential effects associated with a VLOS. Most Environmental Resource Areas (ERAs), Land Segments (LSs), and Grouped Land Segments (GLSs) have less than a 5 percent probability of being contacted by any fraction of materials from a VLOS at the LDPI. Based on the assumption that a less than or equal to 5 percent probability of contact indicates a greater than or equal to 95 percent probability of no contact occurring, only those ERAs, LSs, and GLSs experiencing a greater than or equal to 95 percent contact probability are analyzed for terrestrial mammals. The limited diameter and length of the pipeline would prevent a potential VLOS event from occurring along the pipeline by restricting the potential volume of a spill. A VLOS occurring during winter, when the LI would be surrounded by solid sea ice, would prevent terrestrial mammals, other than the occasional Arctic fox, from being contacted by spilled materials. Consequently caribou, muskox, and grizzly bears could not be affected by a VLOS during winter.

When responding to a VLOS, response contractor(s) would work with USCG, NMFS, and State of Alaska authorities on wildlife management. In an actual spill, the aforementioned groups would likely have a presence at the Incident Command Post to review and approve proposed activities and monitor their impact on marine mammals. Specific terrestrial mammal protection activities would be employed as the situation requires and modified as needed to meet current needs. In all cases long-term recovery to pre- spill abundance, distribution, and productivity is likely, but recovery period might vary, and require access to unaffected/restored habitat during the recovery period.

A-7.7.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

The hypothetical VLOS scenario would begin with a well-control incident resulting in a blowout and its immediate consequences. This phase would not affect caribou, and does not evaluate an oil release, or the effects of supporting aircraft or vessels; which are analyzed in Phase 2 and Phase 4, respectively.

The potential impacts of the initial event on terrestrial mammals would likely be limited to the effects of smoke from spill materials burning at the proposed LDPI, contacting spilled VLOS materials in coastal areas, or in the case of Arctic foxes, on the fast ice near the LDPI. Any terrestrial mammal within the plume of smoke could be affected, with the level of impact related to the volume of smoke produced and environmental conditions during the fire. Wind strength and direction would be key elements determining the direction of the smoke plume, the amount of smoke reaching the shoreline, and the degree to which the plume is dispersed before reaching the shoreline. Larger species such as grizzlies may be affected to a greater extent than smaller species such as Arctic foxes, which typically occupy ground-level habitats that tends to be clear of smoke. Larger mammals, while potentially more exposed to the smoke plume, would also be more capable of avoiding the smoke plume by moving from its path. It is unlikely that smoke from the proposed LDPI could reach the shore without dispersing, considering distances between the proposed LDPI and the coastline.

A-7.7.1.1 Offshore Spill

Terrestrial mammals by definition occur in onshore areas. Some terrestrial mammals may be affected by killing or scavenging prey contaminated by oil. Contamination may then be passed on through the food web potentially resulting in short- and/or long-term health impacts. These impacts were described in more detail in FEIS Section 4.3.5.

Onshore Contact

In the event that oil from a VLOS reaches shore, caribou populations could be impacted if VLOS constituents contaminate coastal insect relief areas during the peak (mid-July through late August) insect harassment period. The muskox, grizzly bear, and Arctic fox populations should not experience major impacts, though a few individuals could potentially die from contacting spilled hydrocarbons. Direct contact with oil and contamination of food items could have short- and/or long-term impacts to animal health. A loss of foraging areas or food resources could result in animals shifting to alternate diet resources, or malnutrition if there are not enough edible resources remaining to maintain adequate health.

Loss of other important habitat (e.g., scavenging, insect relief, and calving areas) could cause some behavioral changes, but would be unlikely to disrupt local populations. As described in FEIS Section 4.3.5, tissue irritation and hypothermia are possible effects of heavily oiling on animals. The greatest direct contamination risk would arise from ingestion of oil through food and grooming of oiled fur, and inhalation of oil constituents in the air. Ingested oil can result in numerous health effects, depending on the quantity of oil consumed and the physical and chemical state of the oil at the time of ingestion.

Loss of food resources by the animal populations that depend on them could result in the animals seeking alternate sources of nutrition that may be less nutritious or less available than those they typically use. The search for replacement food items may lead affected animals into unfamiliar or less frequently used areas where they may come into conflict with resident animals in the unaffected areas over available resources or be subject to increased predation. Loss of food resources could result in a decrease in nutritional status for affected animals, impacting overall fitness and survival.

During winter caribou other than the Teshekpuk Lake Caribou Herd (TCH) and those in Tuktoyaktuk migrate to wintering grounds south of the ACP. Meanwhile grizzly bears hibernate at inland denning sites and muskox settle in to their smaller winter home ranges in riparian areas. Conversely Arctic foxes take to the sea ice where they wander great distances seeking food such as ringed seal pups, or carrion from polar bear kills.

An oil spill affecting salmon populations and reducing the size of spawning runs, while directly impacting species such as brown bears through the reduction or elimination of a food source, could have an indirect impact on caribou, and muskox. Salmon runs provide an annual nutrient surge linking marine and terrestrial ecosystems (Reimchen et al., 2003), and the loss of this seasonal nutrient input could reduce the quality and quantity of riparian vegetation, reducing the forage base for ungulates. In addition to being a source of food, streamside vegetation also provides shelter for muskox.

A-7.7.2 Phase 2 (Spill Response and Cleanup)

Spill response activities could increase disturbance in the affected area, potentially driving some animals into alternate and less suitable habitat, which in turn may result in reduced nutrition, increased energy expended in foraging, increased predation, and increased competition over habitat and food resources. Spill response activities would involve the use of vessels and aircraft, resulting in increased activity at shore bases and airports. Spill response activities may increase the possibility of encounters between cleanup crews and animals into whose habitat the cleanup crews intrude. Many of the areas likely to be contacted by oil in summer are river deltas and beaches heavily used by caribou, brown bears, and Arctic foxes, while a winter VLOS would most likely affect the shorefast ice immediately surrounding the proposed LDPI. The presence of cleanup crews in these areas may deny access to caribou, muskox, grizzlies, or Arctic foxes what rely on foods occurring in contaminated areas.

Owing to the high nutritive value of resources such as carrion, bears and Arctic foxes may be unwilling to forsake the area and perceive cleanup crews as competitors or prey. Actions would be taken to protect the safety of cleanup crews, which may result in reduced access to bears, possible tranquilization, relocation, or killing of “problem animals.” Impacts of OSR activities affecting salmon streams may be reduced to some extent if bears are able to relocate to stretches of river not impacted by cleanup activities.

Deployment of in-situ burning operations would primarily occur near the localized origination point of the spill and in prioritized nearshore areas. Effects on all terrestrial mammal species from these operations are likely to be minor since most burning would occur near the source of the spill; however, nearshore operations, noise, and sensitive coastal sites could remain important to terrestrial mammal species. Burning in nearshore areas would discourage any terrestrial mammal species from remaining in the area, considering their innate fear of fire. For this reason in-situ burning would have negligible effects on any terrestrial mammal species.

VLOS cleanup activities include the use of air support to transport people and materials to and from contaminated areas. The noise and disturbance from aircraft would have effects similar to those described in FEIS Section 4.3.5. Another effect from aircraft noise and disturbance would be the displacement of caribou from areas where aircraft would be operations, such as contaminated stretches of coastline. Though there would be some energetic costs to caribou from being displaced in such a way, individual animals might benefit by having a lesser likelihood of contacting any spilled hydrocarbons.

Cleanup activities may further impact contaminated habitats, for example killing marsh vegetation or forcing oil deeper into sediments (Mendelssohn et al., 2012) by using inappropriate methods in an attempt to remove contamination. Poaching of some species may increase as a VLOS could affect certain sectors of the economy.

For these reasons ground/on-ice cleanup activities, and aircraft operations would have negligible effects on all terrestrial mammal species as long as minimum altitude flying restrictions (1,500 feet AGL) are maintained. Furthermore, any aircraft avoidance by terrestrial mammals would have the benefit of encouraging individual animals to avoid spill areas where aircraft would operate. Disposal of contaminated carcasses (if any), tissues and oil contaminated materials (absorbent pads, protective gear, etc.) would likely be at an authorized disposal site onshore. Negligible effects are anticipated.

A-7.7.3 Phase 3 (Post Spill and Long-Term Recovery)

Animals depending on coastal vegetation to meet nutritional needs would be forced to seek alternative food sources that may be less plentiful and nutritious. Soil contamination may persist for years with toxins transferred to growing plants and on to animals feeding on these plants. Likewise, any contamination in the food web could have long-term ecologic and biologic effects on individual caribou, muskoxen, grizzlies, or Arctic foxes that were exposed to the contents of a VLOS.

While crude oil coating a beach may be removed within a few months by cleanup efforts or via natural processes, contamination of the soil may continue for years. Toxins sequestered in the sediments would likely be ingested by bears or Arctic foxes scavenging coastal food sources such as carrion or beach castings. Salmon eggs in natal streams could absorb toxins deposited within the sediments, causing mortality or mutation of fish larvae (Peterson et al., 2003). The indirect long-term effects of a substantial decrease in salmon populations could result in a loss of important nutrients in some area rivers, causing a decrease in streamside vegetation, which serves as food and habitat for terrestrial mammal species (Reimchen et al., 2003). The overall level of effects of the post spill activities and long-term recovery would likely remain negligible, after considering the added effect of coastal erosion on lessening the potential for spilled VLOS materials to remain in the soil.

A-7.7.3.1 Long-Term Recovery

Over the long-term, terrestrial mammals other than caribou would not likely experience population level effects from a VLOS. The low numbers and widespread distribution of most species would make any population level effects improbable under the worst circumstances. Caribou populations, particularly the smaller populations in Western Canada, would be more likely to experience adverse population level effects from a VLOS if they were to contact the spilled materials during a period of insect relief (mid-July through late August) when large numbers of animals enter coastal waters to escape biting insects. Such effects could take anywhere between one year to many years to recover, depending on the population size, number of individuals exposed, and the severity of exposures. The long-term effects on grizzly bears, muskox, and Arctic foxes would most likely recover within a year or two since they occur in low numbers which are widely dispersed (grizzly bears and muskox), or because they are extremely prolific (Arctic foxes).

A-7.7.3.2 Oil Spill Trajectory Analyses

A hypothetical VLOS could contact GLSs where terrestrial mammals may be present. The location, timing and magnitude of a VLOS, and the concurrent seasonal distribution and movement of caribou, muskox, grizzly bears, or Arctic foxes would determine whether or not contact with the oil could actually occur. The Oil Spill Risk Analysis (OSRA) models oil spill trajectories from Liberty Island (LI). While a VLOS originating at the proposed pipeline was modeled, such an event could not actually occur since the pipeline would be incapable of producing the minimum volume for the modeled VLOS.

This section describes the results estimated by the OSRA model for a hypothetical VLOS originating at the proposed LDPI contacting specific Environmental Resource Areas (ERAs), Land Segments (LSs), or Grouped Land Segments (GLSs) that are important to terrestrial mammals. ERAs, LSs, and GLSs are spatial representations (polygons) that indicate a geographic area important to one or more terrestrial mammal species. The effectiveness of OSR activities is not factored into the results of the OSRA model.

The following discussion presents the results estimated by the OSRA model of the hypothetical VLOS contacting areas important to terrestrial mammal species. The dynamics of oceanographic, climatic, and biotic factors affecting the distribution and abundance of prey, timing of accessibility to habitats, and corridors for movement determine the opportunity for terrestrial mammals to contact spilled VLOS materials. Trajectory contact with any ERA/LS/GLS does not indicate the entire area is oiled, or that all of the spilled hydrocarbons ended up in that area, only that the area was contacted somewhere by some amount of spill materials from the VLOS.

Only those contacts where greater than or equal to 5 percent of the trajectories contacted the ERA/LS/GLS are analyzed below. Any contacts below less than 5 percent indicate there is over a greater than 95 percent confidence that the area would not be contacted in the event of a VLOS based on the modeled trajectories. Contact probabilities less than 5 percent are therefore considered so unlikely as to be unforeseeable. No ERAs or LSs were contacted in the OSRA model and only a few GLSs were contacted with any regularity.

Table A-7-9 Summer Conditional Probabilities for Terrestrial Mammal GLSs

ID	GLS	1 day LI	3 day LI	10 day LI	30 day LI	90 day LI	360 day LI
167	TCH Insect Relief/Calving	<0.5	<0.5	<0.5	4	5	5
174	CAH Insect Relief/Calving	12	28	40	42	42	42
183	PCH Insect Relief/Calving	<0.5	<0.5	<0.5	1	1	1

Table A-7-10 Winter Conditional Probabilities for Terrestrial Mammal GLSs

ID	GLS	1 day LI	3 day LI	10 day LI	30 day LI	90 day LI	360 day LI
167	TCH Insect Relief/Calving	<0.5	<0.5	<0.5	1	2	2
174	CAH Insect Relief/Calving	6	14	20	22	22	22
177	Beaufort Muskox Habitat	<0.5	1	4	5	5	5

Table A-7-11 Annual Conditional Probabilities for Terrestrial Mammal GLSs

ID	GLS	1 day LI	3 day LI	10 day LI	30 day LI	90 day LI	360 day LI
167	TCH Insect Relief/Calving	<0.5	<0.5	<0.5	2	3	3
174	CAH Insect Relief/Calving	7	17	25	27	27	27
177	Beaufort Muskox Habitat	<0.5	<0.5	<0.5	4	4	4

Caribou and Muskox

GLS 167 (TCH Insect Relief/Calving, MAP A-4b) had a 5 percent contact probability at 90 and 360 days from a summer VLOS event. GLS 174 (CAH Insect Relief/Calving, MAP A-4b) had a 12 percent to 42 percent contact probability from a summer VLOS event between days 1 and 360, a 6 percent to 22 percent contact probability from a winter VLOS event between days 1 and 360, and Annual Conditional contact probabilities of 7 percent to 27 percent between days 1 and 360.

GLS 177 (Beaufort Muskox Habitat, MAP A-4b) had Winter Conditional Probabilities of 5 percent at 30, 90, and 360 days. The Annual Conditional probabilities for GLS 177 were 7 percent to 27 percent between days 1 and 360.

Grizzly Bear and Arctic Foxes

No GLSs for grizzly bears or Arctic foxes were contacted with greater than or equal to 5 percent of the simulations.

A-7.7.3.3 Conclusion

Direct contact with spilled oil resulting from a VLOS would have the greatest potential to affect CAH, and to a much lesser extent TCH caribou engaged in calving or during the insect harassment period. If large numbers of caribou were to enter water contaminated by materials from a VLOS there could be a large number of individuals directly affected, and the effects of such an event could take many years to recover from. For this reason a VLOS event at the proposed LDPI would likely have a moderate level of effects on caribou.

Muskoxen could be affected along the Beaufort Sea coastline; however, they occur much more sporadically and in much smaller groups than do caribou. Furthermore, muskox are sedentary and not prone to traveling extensive distances as do caribou. For this reason, only a few muskoxen at most could reasonably be expected to come into contact with hydrocarbons released in a VLOS event. Consequently, a VLOS should not produce any population level effects on muskoxen, and would most likely have a negligible level of effects on muskox on the ACP.

Similarly, grizzly bears are widely distributed across the ACP, but only as individuals or females with cubs, and without the large aggregations observed in the southern areas of Alaska where immense runs of salmon can support greater concentrations of individuals. If a VLOS were to occur, a small number – probably less than 20 bears – would likely be affected as they scavenged for carrion and edible beach castings. During winter, the grizzly bears would be hibernating in inland areas away from the coast, and should remain unaffected by a VLOS. For this reason, a VLOS event would most likely have a minor level of effects on grizzly bears.

As with grizzlies, Arctic foxes are distributed across the ACP; however, they remain active throughout the years, venturing out onto the sea ice in the winter to scavenge and hunt ringed seal pups. During summer, some Arctic foxes would likely come into contact with VLOS materials when scavenging in coastal areas, and in winter they could encounter contaminants on the shorefast ice. In either circumstance several individuals could die; however, unlike the other terrestrial mammals on the ACP, Arctic fox fecundity should permit the population to recover within a year or two years at the most. For this reason, the level of effects of a VLOS on Arctic foxes is expected to be minor.

A-7.8 Effects of a VLOS on Vegetation and Wetlands

Contamination of coastal vegetation and wetlands would likely occur during a VLOS and associated cleanup efforts. The potential for spilled oil to contact vegetation and wetland environments is influenced by timing of a VLOS, the seasonal effects of currents and subsequent advection of oil, timing and duration of oil spill, presence, or absence of fast or pack ice, and general weather patterns (wind and storm events). The Beaufort Sea shoreline is characterized by small tides and moderate winds of the region (Section 3.2.6), creating a low potential for spilled oil to reach beyond the intertidal area. However, seasonal storm events could force oil into upper shoreline areas into wetlands and inside delta areas as far inland as 3.1 miles along the Beaufort Sea (Reimnitz and Maurer, 1979). Placement of booms around sheltered embayments and streams where diadromous and marine fish species congregate could prevent loss of fish, their habitat, and benthic communities that support their ecosystems. The occurrence of shorefast ice along the coastline of the Beaufort Sea prevents the growth of aquatic macrophytes in many littoral areas.

A-7.8.1 Phase 1 (Well Control Incident, Offshore Spill, and Onshore Contact)

At Phase 1, direct exposure to oil is an impact-producing factor that can affect vegetation and wetlands. The potential of oil from a VLOS contacting the coastal vegetation and wetlands would be dependent upon timing of a VLOS, the seasonal effects of currents and subsequent advection of oil, timing and duration of the oil spill, presence or absence of fast or pack ice, and general weather patterns (wind and storm events). The amount of impact would be a function of the size of the oiled area and the duration of the VLOS.

Oil stranded on beaches may occur on the surface, or it could penetrate into subsurface layers. Permeable substrates, generally associated with larger sand grain sizes, and holes created by infauna could increase oil penetration, especially that of light oils and petroleum products. Oil will not penetrate the water-saturated sediments; however, in areas of high suspended sediment concentrations, the oil and sediments could mix resulting in the deposition of contaminated sediments on the flats (NOAA, 2010). Penetration into coarse-grained sand beaches may allow oil to penetrate and accumulate in the soil (Pezeshki et al., 2000). Light oils may penetrate peat shores; however, peat resists penetration by heavy oils (NOAA, 2010). Although any residual oil that could remain following cleanup might be largely removed in highly exposed locations through wave action, oil could remain in the shallow subsurface for extended periods of time. In some locations, oil might become buried by new sand or gravel deposition. Natural degradation and persistence of oil on beaches are influenced by the type of oil spilled, amount present, sand grain size, degree of penetration into the subsurface, exposure to weathering action of waves, and sand movement onto and off shore. Although petroleum-degrading microbial communities are present, biodegradation along Arctic coastlines would likely be slow (Prince, Owens and Sergy, 2002; Braddock, Lindstrom and Price, 2003) and is limited to only a few months per year. Spilled oil could persist for many years, with continued effects on potential recovery (Owens et al., 1983; Braddock, Lindstrom and Price, 2003; Owens, Taylor and Humphrey, 2008). On sheltered beaches, heavy oiling left for long periods could form an asphalt pavement relatively resistant to weathering (Hayes et al., 1993). Lagoon shorelines include low-energy beaches where spilled oil would likely persist for many years. Spilled oil may persist for extended periods on peat shores; however, if cleaned up, it would be expected to persist for less than a decade (Owens and Michel, 2003). If the spill reached shoreline areas, the probability of adverse impacts on the tundra and marshes would depend on wind and wave conditions. Due to the low tidal range typical in such environments, stranded oil would be subject to low rates of abrasion and dispersal by littoral processes.

Oil deposition above the level of normal wave activity would occur if the spill takes place during spring tides or during storm surges. In such case, oil stranded in emergent vegetation is expected to persist for long periods due to the low rates of dispersion and degradation. Impacts would include the destruction of emergent vegetation if the oil slick sinks into the root system and reduces oxygen exchange between the atmosphere and the soil (Stebbing, 1970; Caudie and Maricle, 2014). Impacts to wetlands from a VLOS oil slick in the vicinity of the coast during a storm surge could result in injury or mortality of vegetation and invertebrates in or on the substrate. Other effects of spills could include a change in plant community composition or the displacement of sensitive species by more tolerant species. Impacts to soil microbial communities might result in long-term wetland effects, and wetland recovery would likely be slowed. Impacts to wetland vegetation may cause plant mortality and loss of wetland areas.

Various factors influence the extent of impacts to wetlands. Impacts would depend on site-specific factors at the location and time of the spill. The degree of impacts are related to the oil type and degree of weathering; the quantity of the spill (lightly or heavily oiled substrates); duration of exposure, season, plant species; percentage of plant surface oiled; substrate type; soil moisture level; and oil penetration into the soil (Hayes et al., 1992; Hoff, 1995; NOAA, 2010; Pezeshki et al., 2000). Higher mortality and poorer recovery of vegetation generally result from spills of lighter petroleum products (such as diesel fuel), heavy deposits of oil, spills during the growing season, contact with sensitive plant species, completely oiled plants, and deep penetration of oil and accumulation in substrates. Vegetation regrowth and recovery are generally better where oil spills occur in flooded areas, or on saturated soils rather than on unsaturated soils (BLM, 2002). Coastal wetlands in sheltered areas (such as embayments and lagoons) and that are not exposed to strong water circulation or wave activity, would be expected to retain oil longer with longer-lasting effects on biota (Culbertson et al., 2008).

A-7.8.2 Phase 2 (Spill Response and Cleanup)

Spill cleanup operations might adversely impact coastal beaches if the removal of contaminated substrates affects beach stability and results in accelerated shoreline erosion. Vehicular and foot traffic during cleanup could mix surface oil into the subsurface, where it would likely persist for a longer time (Hoff, 1995). Manual cleanup rather than use of heavy equipment would minimize the amount of substrate removed due to effects of motorized vehicles on fragile tundra soils. Skimming, booming, in-situ burning, and other spill response and cleanup operations can be effective means of preventing offshore oil spills from reaching coastal wetlands and other vegetation. However, spill response activities could also disturb, trample, or otherwise damage these resources through the transportation and use of equipment. In addition to mechanical cleanup and recovery activities, additional response strategies such as the use of dispersants could be employed and intentionally introduced into the environment, likely at the sea surface, and applied using aircraft or vessels. Dispersants may have an adverse effect on coastal and estuarine habitats depending upon the type of dispersant and its fate in the coastal ecosystem. The effects from these activities would be similar to the temporary impacts associated with pipeline construction, onshore construction. These temporary losses of vegetative resources would be minimized through appropriate spill response planning and protocols.

A-7.8.3 Phase 3 (Post-Spill and Long-Term Recovery)

Long-term is defined as an effect that affects populations for more than 2 years. Long-term effects are possible for coastal areas due to severity of the VLOS and OSRA projections. Storm surges are a concern. In 1970, Reimnitz and Maurer (1979) observed the effects of tidal surges from a major storm event that inundated low-lying tundra and delta regions on the Beaufort Sea shoreline, leaving debris lines from flotsam as far as 16,500 feet inland. A storm of equal or greater magnitude could force weathered oil far inward and leave residue over wide areas of tundra and river shores. In such cases, full recovery of wetlands, including invertebrate communities, may require more than 10 years depending on site and spill characteristics (Culbertson et al., 2008). Oil could remain in some wetland substrates for decades, even if it was cleaned from the surface. Heavy deposits of oil in sheltered areas of coastal wetlands or in the supratidal zone could form asphalt pavements resistant to degradation (Culbertson et al., 2008).

A-7.8.4 Oil Spill Trajectory Analysis

A-7.8.4.1 Conditional and Seasonal Chance of Contact

The majority of Land Segments (LSs) would have a less than 5 percent chance of being contacted by a large oil spill. The effects of a large offshore spill on vegetation and wetlands include oil fouling, smothering, asphyxiation, and poisoning of plants.

If a large spill were to oil onshore wetlands along the coast of Foggy Island Bay during the summer season, oil spill cleanup personnel would trample vegetation while removing some of the oil from the shoreline. Gravel shorelines such as the Endicott causeway, where adsorption booms could be effective in oil recovery, can preclude oil from contacting western channels of the Sagavanirktok River Delta. Cleanup of contaminated-oiled wetlands would be difficult. Oil removal by mechanical means would alter or destroy vegetation, and flushing techniques could drive some of the oil into the soil and roots, smothering wetland plants. The OSRA model estimates a 1 percent to 50 percent chance of a large spill contacting sheltered vegetated low banks, salt/brackish water marshes, and inundated low-lying tundra that 1 to 30 days and 90 to 360 days (Table A-7-12) assuming a spill greater than or equal to 1,000 bbl occurs at the Island Launch Area (LA) or Pipeline LA. Only LS105 and LS106 would have a more than 5 percent chance of being contacted by a large oil spill during the summer, while a large oil spill occurring during winter would have a more than 5 percent chance of contacting LS107 (including Tigvarik Island and Shaviovik River), as well as LS105 and LS106.

LS105 includes Point Brower, the Sagavanirktok River, and Duck Island and is immediately to the west of the LDPI (LS106). The Endicott Causeway is within LS105; the causeway is a manmade physical barrier with two breaches. Depending upon conditions, it is conceivable for spill response booms and skimmers to be positioned along the eastern side of the causeway to intercept an oil spill and limit contact with wetlands of the western channels of the Sagavanirktok River Delta and Duck Island.

Summer Season Day 1 to Day 30. The OSRA model estimates a 17 percent to 33 percent chance of LS105 being contacted by a large oil spill originating from the LDI LA, and a 15 percent to 24 percent chance originating from the subsea pipeline LA. LS106 would have a 6 percent to 20 percent chance of being contacted by a large oil spill originating from the LDI LA; and a 37 percent to 49 percent chance originating from the subsea pipeline LA.

Summer Season Day 90 and Day 360. The OSRA model estimate a 33 percent chance of LS105 being contacted by a large oil spill originating from the LDI LA, and a 24 percent chance originating from the subsea pipeline LA. LS106 would have a 20 percent chance of being contacted by a large oil spill originating from the LDI LA, and a 49 percent chance originating from the subsea pipeline LA.

Winter Season Day 1 to Day 30. The OSRA model estimates a 14 percent to 28 percent chance of LS105 being contacted by a large oil spill originating from the LDI LA, and a 13 percent to 21 percent chance originating from the land or subsea portion of the pipeline LA. LS106 would have a 6 percent to 22 percent chance of being contacted by a large oil spill originating from the LDI LA, and a 36 percent to 50 percent chance originating from the land or subsea portion of the pipeline LA. LS107 would have a 7 percent to 8 percent chance of being contacted by a large oil spill originating from the LDI LA, and a 6 percent chance originating from the land or subsea portion of the pipeline LA.

Winter Season Day 90 and Day 360. The OSRA model estimate a 28 percent chance of LS105 being contacted by a large oil spill originating from the LDI launch area of the spill, and a 21 percent chance originating from the land or subsea portion of the pipeline LA. LS106 would have a 22 percent chance of being contacted by a large oil spill originating from the LDI LA, and a 50 percent chance originating from the land or subsea portion of the pipeline LA. LS107 would have an 8 percent chance of being contacted by a large oil spill originating from the LDI LA, and a 6 percent chance originating from the land or subsea portion of the pipeline LA.

Table A-7-12 **Summer or Winter Fraction of a Large Oil Spill Contacting Land Segments with Sheltered Vegetated Low Banks, Salt/Brackish Water Marshes, or Inundated Low-Lying Tundra**

Season / Analysis Period	% Range to LSs ≥1%	LS IDs with any value ≥1%
Summer 1, 3, 10, and/or 30 days	1-5% at 14 LSs; 6-49% at 2 LSs	LS88, LS91, LS92, LS93, LS99, LS100, LS101, LS102, LS103, LS104, LS105, LS106, LS107, LS108, LS109, LS110, and LS112
Winter 1, 3, 10, and/or 30 days	1-5% at 9 LSs; 6-50% at 3 LSs	LS92, LS100, LS101, LS102, LS103, LS104, LS105, LS106, LS107, LS108, LS109, LS110
Summer 90-360 days	1-5% at 16 LSs; 30-49% at 2 LSs	LS85, LS88, S91, LS92, LS93, LS99, LS100, LS101, LS102, LS103, LS104, LS105, LS106, LS107, LS108, LS109, LS110, and LS112
Winter 90-360 days	1-5% at 13 LSs; 6-50% at 3LSs	LS85, LS88, LS91, LS92, LS93, LS99, LS100, LS101, LS102, LS103, LS104, LS105, LS106, LS107, LS108, LS109, LS110, and LS112

Notes: LA= Launch Area, LS = Land Segment
Geographic Name of Land Segments Contacted in Alaska: LS85 Utqiaġvik, Browerville, Elson Lag.; LS88 Cape Simpson, Piasuk R.; LS92 Cape Halkett, Garry Creek; LS93 Atigaru Pt., Eskimo Isl., Kogru R.; LS100 Milne Point, Simpson Lag.; LS101 Beechy & Back Pt., Sakonowyak R.; LS102 Kuparuk R., Pt. Storkersen; LS103 Pt. McIntyre, West Dock, Putuligayuk R.; LS104 Prudhoe Bay, Heald Pt.; LS105 Pt. Brower, Sagavanirktok R., Duck I.; LS106 Foggy Island Bay, Kadleroshilik R.; LS107 Tigvariak Island, Shaviovik R.; LS108 Mikkelsen Bay, Badami Airport; LS109 Bullen, Gordon & Reliance Pts.; LS110 Pt. Hopson & Sweeney, Thomson; LS111 Staines R., Lion Bay; LS112 Brownlow Point, West Canning River
Expressed as a percent of chance of a Large Oil Spill contacting a certain LS within 30 days, and 90 to 360 days during summer or winter from the proposed LDPI LA and the Pipeline LA.
Source: Appendix A, Table A.2-2, Map A-3C, Figure A-7-1

Sheltered Vegetated Low Banks. Only LS101 (Beechy and Back Points, Sakonowyak River) has 5 percent or more sheltered vegetated low banks (Table A.1-1 column 9B). There would be a 1 percent to 2 percent chance that LS101 with habitat of this description would be impacted by a large oil spill.

Salt/Brackish Water Marshes. Five LSs (LS101, LS105, LS106, LS108, and LS109) have 5 percent or more salt/brackish water marshes (Table A.1-1 column 10A). There would be a 1 percent to 3 percent chance that LS101 (Beechy and Back Points, Sakonowyak River) and LS109 (Bullen Point, Gordon Point and Reliance Point) with habitat of this description would be impacted by a large oil spill. Salt/brackish water marshes comprise 15 percent of LS105, 8 percent of LS106, and 3 percent of LS107; the same chance that these three LSs are discussed above for large oil spills.

Inundated Low-Lying Tundra. This habitat description designates most of the 18 LSs that have a chance to be contacted by a large oil spill and have 5 percent or more inundated low-lying tundra. They include LS85, LS88, LS92, LS93, LS99, LS100, LS101, LS102, LS103, LS104, LS105, LS106, LS107, LS108, LS109, LS110, LS111, and LS112. The OSRA model estimates that within 90 days (Table A-7-12) only LS105, LS106, and LS107 would have more than a 5 percent chance of a large oil spill contacting inundated low-lying tundra.

Overall, the effects of a large spill on the LSs with vegetation and wetlands considered by the OSRA would not differ for the Proposed Action or Alternatives 3, 4A, 4B, 5A, 5B, or 5C.

The following paragraphs present the results (expressed as a percent of trajectories contacting) estimated by the OSRA model of a hypothetical very large oil spill contacting coastal areas. The probability of an oil spill contacting the coastal areas would depend on the location, timing, and magnitude of the spill, ocean currents, weathering, etc. The OSRA model uses two launch areas (LAs) to model the origination of spill trajectories. The Beaufort Sea summer (open-water) season lasts from July 15 to October 31, which is when any drilling related spills would occur. In the unlikely event of loss of well control, BOEM has determined that 39 to 74 days would be required for another drill ship to transit to the site and drill a relief well. In the event of a VLOS, not all hydrocarbons are discharged at once; they flow into the ocean at rates that decrease over time. For the briefest spill period, BOEM assumed a 3-week discharge window and a 60-day period of potential contact was analyzed. However, if a spill were to occur late in the open-water season, the liquid hydrocarbons could freeze into the sea ice and remain overwinter without any extensive amount of weathering. If this were to happen, un-weathered oil could be transported to non-spill zone areas in the Chukchi and Beaufort seas and be released in the spring. To address concerns such as this, BOEM has also analyzed a spill window of 360 days. A VLOS continuing after October 31 is treated as a winter spill. Oil could still be released during this period, so 360 days is the most conservative assessment period for this hypothetical situation.

The intertidal and subtidal coast of the Beaufort Sea lack vegetation and are summarized here as coastal barrens. The predominance of shorefast ice along these shorelines precludes most vegetation and benthic fauna from establishing themselves on the coastal barrens. The coastal barrens include the following 13 shoreline types: exposed rocky shore; exposed solid man-made structures; exposed wave-cut platforms in bedrock, mud or clay; fine to medium-grained sand beaches; tundra cliffs; coarse grained sand beaches, mixed sand and gravel beaches; gravel beaches; exposed tidal flats; sheltered rocky shore and sheltered scarps in bedrock, sheltered solid man-made structures; peat shorelines; sheltered tidal flats; and other shores. Due to the physical components of coastal barrens, lack of fauna and flora, and the presence of underlying permafrost, oil spill slicks may be cleaned more effectively in these areas.

This analysis focuses on coastal areas featuring two valuable vegetation wetland types: sedge/grass, moss wetlands (W1) and sedge, moss, dwarf-shrub wetlands (W2). These vegetation types were described in Section 3.2.6 as onshore/inland vegetative communities. These communities contribute more to the higher trophic-levels and are a higher source of nutrients to the surrounding waters than the coastal barrens because they include vegetation and animal life. Only one other vegetation type is included in the land segments (LS) where OSRA's conditional probabilities indicated onshore contact: tussock-sedge, dwarf-shrub, moss tundra wetland (G4) is a small portion of LS93. W1 and W2 are only considered in the application of the OSRA at Land Segments (LSs) where either one comprised 1 percent or more chance the VLOS would contact (Table A-7-12).

Table A-7-13 Fraction of a VLOS Contacting Vegetative Wetlands*

Season / Analysis Period	% Chance Range of LSs ≥1%	LS IDs with any value ≥ 1%
Summer 1 and/or 3 days	1-5% at 5 LSs; 6-48% at 2 LSs	LS103, LS104, LS105, LS106, LS107, LS108, and LS109
Winter 1 and/or 3 days	1-5% at 4 LSs; 6-47% at 2 LSs	LS104, LS105, LS106, LS107, LS108, and LS109
Summer 10-30 days	1-5% at 15 LSs; 6-49% at 2 LSs	LS88, LS92, LS93, LS97, LS99, LS100, LS101, LS102, LS103, LS104, LS105, LS106, LS107, LS108, LS109, LS110, and LS112
Winter 10-30 days	1-5% at 9 LSs; 6-50% at 3 LSs	LS92, LS100, LS101, LS102, LS103, LS104, LS105, LS106, LS107, LS108, LS109, and LS110
Summer 90-360 days	1-5% at 17 LSs; 30-49% at 2 LSs	LS85, LS88, S91, LS92, LS93, LS97, LS99, LS100, LS101, LS102, LS103, LS104, LS105, LS106, LS107, LS108, LS109, LS110, and LS112
Winter 90-360 days	1-5% at 13 LSs; 6-50% at 3LSs	LS88, LS92, LS93, LS100, LS101, LS102, LS103, LS104, LS105, LS106, LS107, LS108, LS109, LS110, LS111, and LS112

Notes: * Land Segments (LSs) with Sedge/Grass, Moss Wetlands (W1), and Sedge, Moss, Dwarf-Shrub Wetlands (W2) during Summer or Winter.
Geographic Name of Land Segments Contacted in Alaska: LS85 Utqiaġvik, Browerville, Elson Lagoon; LS88 Cape Simpson, Piasuk River; LS92 Cape Halkett, Garry Creek; LS93 Atigaru Point, Eskimo Island, Kogru River; LS 97 (Kupigruak Channel, Colville River LS99 Oliktok Point, Ugnuravik River; LS100 Milne Point, Simpson Lagoon; LS101 Beechy & Back Point, Sakonowyak River; LS102 Kuparuk River, Point Storkersen; LS103 Point McIntyre, West Dock, Putuligayuk River; LS104 Prudhoe Bay, Heald Point; LS105 Point Brower, Sagavanirktok River, Duck Island; LS106 Foggy Island Bay, Kadleroshilik River; LS107 Tigvariak Island, Shaviovik River; LS108 Mikkelsen Bay, Badami Airport; LS109 Bullen, Gordon & Reliance Points.; LS110 Point Hopson & Sweeney, Thomson; LS111 Staines River, Lion Bay; LS112 Brownlow Point, West Canning River.

W1 – Sedge/Grass, Moss Wetlands

During summer the LSs featuring 1 percent or more chance of the VLOS contacting W1 wetlands include: LS85 (Utqiaġvik, Browerville. Elson Lagoon), LS88 (Cape Simpson, Piasuk River), LS91 (Lonely, Pitt Point, Pogik Bay, Smith River), LS92 (Cape Halkett, Garry Creek), LS93 (Atigaru Pt., Eskimo Island, Kogru River) which has a small portion of W1, LS99 (Oliktok Point, Ugnuravik River), LS100 (Milne Point, Simpson Lagoon), LS101 (Beechy & Back Point, Sakonowyak River), LS102 (Kuparuk River, Point Storkersen), LS103 (Point McIntyre, West Dock, Putuligayuk River), LS104 (Prudhoe Bay, Heald Point), LS105 (Point Brower, Sagavanirktok River, Duck Island), LS106 (Foggy Island Bay, Kadleroshilik River), LS107 (Tigvariak Island, Shaviovik River), LS108 (Mikkelsen Bay, Badami Airport), LS109 (Bullen, Gordon & Reliance Points), and LS110 (Pt. Hopson & Sweeney, Thomson).

During winter the LSs featuring 1 percent or more chance of the VLOS contacting W1 wetlands include: LS88, LS93 which has a small portion of W1, LS100, LS101, LS102, LS103, LS104, LS105, LS106, LS107, LS108, LS109, LS110, and LS111 (Staines River, Lion Bay) which has approximately equal portions of W1 and W2.

W2 – Sedge, Moss, Dwarf-Shrub Wetlands

During summer the LSs featuring 1 percent or more chance of the VLOS contacting W2 wetlands include: a small portion of W2 at LS88 (Cape Simpson, Piasuk River), LS93 (Atigaru Pt., Eskimo Island, Kogru River) which also has a small portion of G4, LS 97 (Kupigruak Channel, Colville River), and LS112 (Brownlow Point, West Canning River).

During winter the LSs featuring 1 percent or more chance of the VLOS contacting W2 wetlands include: a small portion of W2 at LS92, LS93 which also has a small portion of G4, LS111 (Staines River, Lion Bay) with an equal portion of W1, and LS112.

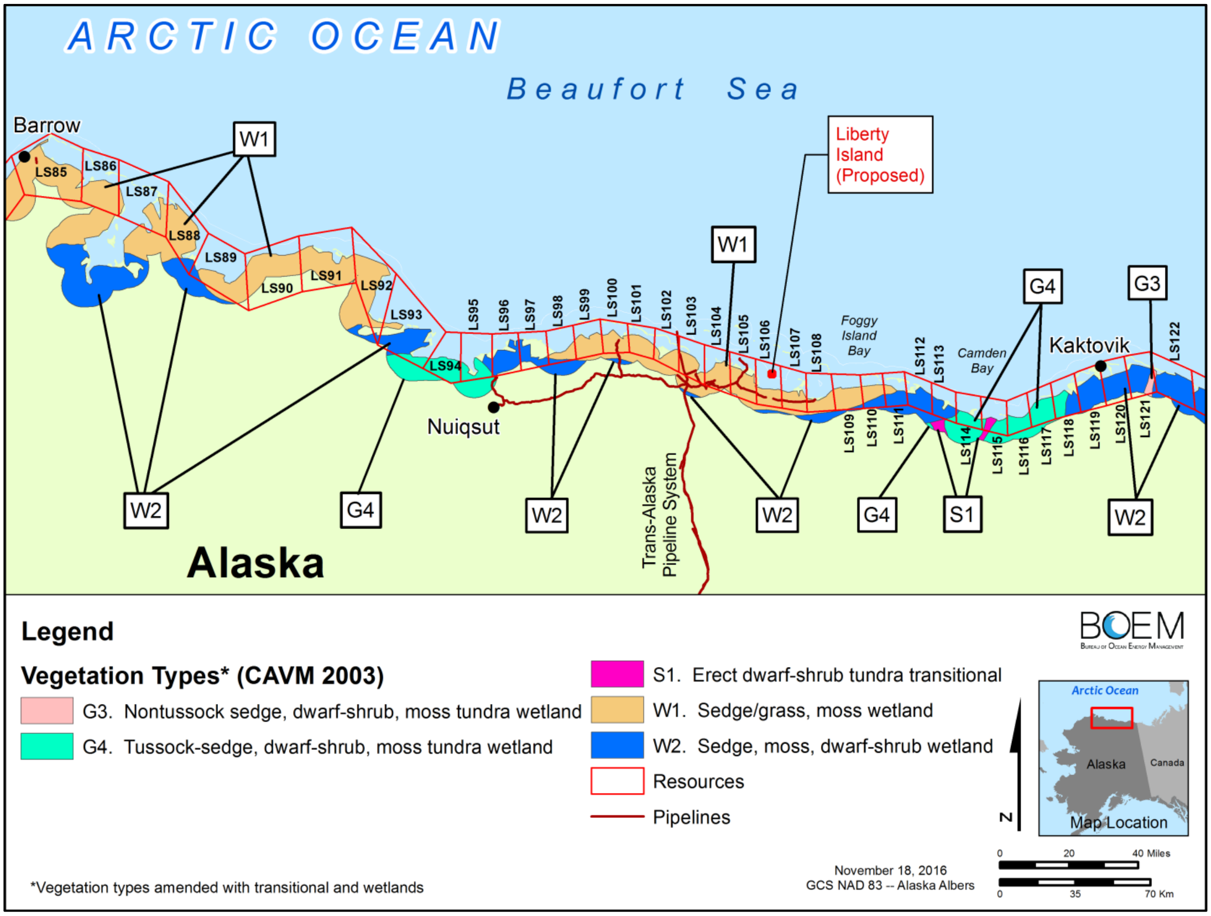

Figure A-7-1 Land Segments (LS) and Onshore/Inland Vegetative Communities Potentially Impacted by a VLOS

OSRA LSs have been amended to simplify polygons for a cartographic visual depiction. LSs actually end at the shoreline.

A-7.8.4.2 OSRA

The only LSs with coastal areas that would have a 5 percent to as much as a 50 percent chance of VLOS contact include the Proposed Action Area and immediately adjacent LSs. They include LS105, LS106, and LS107. The onshore/inland vegetation community at these LSs is W1. The coast of these LSs would be contacted if the VLOS occurred during summer or winter; and if the VLOS originated from either the LDPI or from the subsea pipeline. The OSRA model estimates that within 1 to 3 days there is 6 percent to 48 percent chance of the VLOS trajectories contacting LS106; for both the 10- to 30-day and the 90- to 360-day periods there is 20 percent to 50 percent chance of the VLOS trajectories contacting LS106. Given various oceanographic conditions that result in predominant westward coast currents, there is VLOS contact with LS105 than LS107. The OSRA model estimates for LS105 that within 1 day there is 13 percent to 17 percent chance of the VLOS trajectories contact and within 3 days there is an 18 percent to 27 percent chance of contact. While the OSRA model estimates that for LS107 within 1 day there is a 1 percent chance of the VLOS trajectories contact and within 3 days there is 3 percent to 5 percent chance of contact, for both the 10- to 30-day and the 90- to 360-day periods there is 4 percent to 8 percent chance of the VLOS trajectories contacting LS107. There is a 1 percent to 5 percent or less chance of the VLOS trajectories contacting 12 other LSs east of the LAs, and the 5 other LSs west of the LAs; those VLOS trajectories contacting LSs beyond LS105, LS106, and LS107 would mostly be between 30 and 360 days.

A-7.8.5 Conclusion

Potential impacts from spills would be expected to occur from the direct effects of oil on coastal vegetation and wetlands. Shoreline and inundated areas of vegetation lost to the effects of a VLOS would recover slowly providing an opportunity for accelerated erosion during recovery time. Wetland areas would be affected if the onshore contact is concurrent with a storm surge. Oil contamination could persist for 10 years or more during which time the oil in the sediments could be slowly released back into the environment as a result of erosion or exposure of oiled sediments and soils. Response and cleanup efforts have the potential to cause negative effects by exposing shoreline areas to anthropogenic disturbance. Overall, the effects of oil exposure on vegetation and wetlands would be considered major and could take from 2 to 10 years for recovery, depending on the severity and duration of a VLOS.

A-7.9 Effects of a VLOS on Sociocultural Systems

For this EIS, BOEM analyzed the effects of a VLOS (greater than or equal to 4.6 million barrels of oil) at the end of 90 days after a catastrophic event such as a loss of well control (Section A-5). A VLOS is a low-probability event with the potential for major effects. BOEM analyzed the potential effects on sociocultural systems for Nuiqsut, Kaktovik, and Utqiaġvik from a VLOS originating 6 miles from shore at the proposed LDPI in Foggy Island Bay. For more details on the effects of a VLOS to subsistence practices and harvest patterns, see Section A-7.11.

A VLOS could affect sociocultural systems in a number of ways (USDOI, MMS, 2002). Overall effects on subsistence harvest patterns could be major (Section A-7.11) because one or more important subsistence resource could become unavailable, undesirable for use, or available only in greatly reduced numbers for one or more seasons. Any disruption of the bowhead whale harvest from a VLOS or from potential contamination of the *mataaq* and whale meat anywhere during the bowhead migration and summer feeding could disrupt whaling for an entire season.

If a VLOS contacted and extensively oiled habitats, the presence of hundreds of spill response workers, boats, and aircraft for spill response and cleanup activities would most likely increase the displacement of subsistence resources and alter or reduce access to subsistence resources. These disruptions could lead to a breakdown of kinship networks and sharing patterns, and increased social stress in communities. Participating in spill response and cleanup, as local residents did in the EVOS in 1989, could cause residents to 1) not participate in subsistence activities, 2) have a surplus of cash to spend on material goods, and 3) not seek or continue employment in service positions in their communities. A sudden and dramatic increase in income earned from working on cleaning up the EVOS and being unable to pursue subsistence harvests because of the spill caused substantial amounts of social distress and related problems (Fall and Field, 1996; Gill et al., 2011; Impact Assessment, 2001).

A disruption of social organization in the form of sharing networks could lead to a decreased emphasis on the importance of the family, cooperation, and sharing. Multi-year disruptions of subsistence harvest patterns, especially to bowhead whaling, could disrupt sharing networks, subsistence task groups, and whaling crew structures and would most likely severely disrupt the subsistence way of life. Other effects might be a decreased emphasis on subsistence as a livelihood and an increased emphasis on wage employment, individualism, and entrepreneurism (USDOI, BOEM, 2015). Increased social problems, breakdown in family ties, and a weakening of community well-being could lead to additional stresses on the health and social services available in communities. If a VLOS occurred, local employment in spill response and cleanup could disrupt subsistence harvest patterns for one or more seasons and disrupt the function of some formal institutions such as whaling captains' associations. Contemporary subsistence practices and harvest patterns could be severely altered and community infrastructures severely stressed by drawing local workers away from village service jobs. Effects on the sociocultural system from response and cleanup for a VLOS could be major and last for one or more subsistence seasons.

Conclusion

A VLOS starting at the proposed LDPI could threaten some important subsistence harvest areas on which sociocultural systems rely. Of particular importance is the offshore bowhead whaling area used by crews from Nuiqsut (Figure 3.3.3-4; Table 4-41).

If offshore oil from a VLOS directly contacted migrating or resident marine mammals, seals, fish, caribou, and/or migratory waterfowl, contaminated traditional harvest areas, and persisted in subsistence harvest areas, sociocultural systems would be severely reduced and interrupted, particularly bowhead whale hunting. This could create severe reductions in access to traditional nearshore and offshore harvest areas lasting one or more seasons. Social organization, cultural values, and formal institutions would most likely be disrupted for one or more seasons. Overall, BOEM anticipates impacts to sociocultural systems from a VLOS to be severe and thus major for Nuiqsut.

BOEM anticipates long lasting and widespread impacts from a VLOS on sociocultural systems for Kaktovik and Utqiaġvik. Impacts to sociocultural systems from VLOS spill response and cleanup activities could be moderate to major for Nuiqsut, Kaktovik, and Utqiaġvik depending on how long cleanup would take and to what extent residents of these communities participated in response and cleanup work. If VLOS cleanup activities persisted longer than one season on the North Slope and resources and workforce were substantially drawn from all three communities, effects to sociocultural systems could become severe and thus major for Nuiqsut, Kaktovik, and Utqiaġvik. Overall, BOEM anticipates moderate to major effects to the sociocultural system from a VLOS for Kaktovik and Utqiaġvik.

Long-term recovery from a VLOS could severely disrupt sociocultural systems for more than one year, resulting in major impacts in Nuiqsut. Impacts of long-term recovery to sociocultural systems for Kaktovik and Utqiaġvik are anticipated to be long lasting and widespread but less than severe and thus moderate**.**

A-7.10 Effects of a VLOS on Economy

BOEM analyzed the effects of a VLOS (greater than or equal to 4.6 million barrels of oil) at the end of 90 days after a catastrophic event such as a loss of well control (Section A-5). A VLOS is a low probability event with the potential for major effects. The NSB is a mixed cash-subsistence economy. This section discusses economic impacts from a potential VLOS in terms of traditional measures of employment, labor income, population and revenues; it does not attempt to provide information on the full economic consequences of a VLOS (e.g., valuing injuries to natural resource services that would likely be damaged from a VLOS). For analysis of potential impacts to subsistence harvest patterns and sociocultural systems, please see Sections A-7.11 and A-7.9, respectively.

Section A-6.1 characterizes the VLOS scenario into three distinct phases. Of these, phase 2 (Spill Response and Cleanup) and phase 3 (Post-Spill, Long-Term Recovery) are the most relevant to analyzing the economic effects.

As discussed in FEIS Section 4.4.2.1, the EVOS spill was 240,000 bbl and generated substantial employment of up to 10,000 workers doing cleanup work. Smaller numbers of cleanup workers returned in the warmer months of each year following 1989 until 1992. During the EVOS, numerous local residents quit their jobs to work on the cleanup, often at significantly higher wages. This generated additional adverse effects in the form of sudden and significant inflation in the local economy (Cohen, 1993). Similar short-term adverse effects on the NSB as a result of a very large spill could be mitigated due to the likelihood that cleanup activities, including administrative personnel and spill cleanup workers, would likely be housed in existing enclave support facilities.

Employment, Labor Income, and Population

If a VLOS of 4.6 MMbbl occurred, it would likely generate several thousand direct, indirect, and induced jobs and millions of dollars in personal income associated with OSR and cleanup. The number of workers would likely be much larger than the number of workers who cleaned up the EVOS. See Section A-6 for assumptions on number of staging locations, vessels, workers, and booming teams involved in response as well as a discussion on how seasonal conditions could affect response and cleanup activities. Based on these descriptions, it is likely that employment during winter cleanup and response would be less than employment for summer cleanup and response operations; however, the overall short-run employment created for response and cleanup would likely be substantial for any season of occurrence. Fewer job losses (i.e. adverse employment/labor income effects) are expected in the NSB or other parts of Alaska because of a VLOS given that there are few other industries in the area that would likely be directly or indirectly impacted. Thus, the net employment/labor income effects are expected to be positive at both the State of Alaska (SOA) and NSB level.

The incremental impact of annual jobs and labor income associated with cleanup and response would represent less than 1 percent of the total Alaska employment and labor income, and would likely result in little to no effect on employment in other sectors of the SOA economy resulting in a negligible effect.

The effects of employment and labor income on the NSB economy would ultimately depend on the extent to which Borough residents are employed in the cleanup efforts. Given the relatively small size of the existing labor force in the NSB, relative to the number of response and cleanup workers that could be employed, the incremental impacts to the NSB economy would likely be major, although the employment and its beneficial economic effects would be short-term in nature.

A VLOS is expected to have negligible beneficial and adverse effects on SOA employment and associated labor income. Response and cleanup workers would likely come from the NSB, other parts of Alaska, and then other states. A VLOS is likely to have little to no impact on the population base of the SOA or the NSB due to the temporary nature of the response and cleanup jobs, physical separation of worker housing, and low likelihood of workers permanently relocating to the NSB.

Revenues

Positive revenue impacts on the SOA and NSB from a potential VLOS would include property tax revenues from any new onshore infrastructure put in place to support cleanup efforts. In addition, a hypothetical VLOS would result in a Natural Resource Damage Assessment (NRDA). The National Ocean and Atmospheric Administration (NOAA) conducts NRDAs through a process that includes determination of the injuries from a spill, quantification of those injuries, and then restoration planning. For a description of the approaches and methods that NOAA uses to identify and value injuries to natural resources that have been damaged from an event like a VLOS, please refer to NOAA's Damage Assessment, Remediation, and Restoration Program (U.S. DOC, NOAA, 2017). The result of the NRDA process could have substantial revenue impacts as the population of interest is compensated for a range of natural resource service values damaged by the hypothetical VLOS and come at a high cost to the responsible parties.

As context, the April 2010 DWH oil spill in the Gulf of Mexico resulted in the largest offshore oil spill in U.S. history. The DWH NRDA determined the nature and extent of injury to the nation's natural resources caused by the spill, and the kind and amount of restoration needed to restore the Gulf to the condition it would be in if the spill had not occurred. On April 4, 2016, the court approved a historic $20.8 billion global settlement agreement with BP, the party ruled primarily responsible for the DWH oil spill. According to the settlement, BP will pay the Trustees up to $8.8 billion for restoration to address injuries to natural resources. These funds will be used to implement the Trustees' Programmatic Damage Assessment and Restoration Plan and Programmatic Environmental Impact Statement. The plan and associated documents are posted on the Trustees' web site (DWH NRDA Trustees, 2016). The settlement also includes $5.5 billion in CWA penalties. As required by the RESTORE Act, 80 percent of those funds will be directed to Gulf restoration as determined by the RESTORE Council members.

There would also be adverse impacts to SOA revenues if TAPS throughput is reduced because of the oil spill, either through a temporary moratorium on oil and gas activities or space-use conflicts with producing fields. Space-use conflicts may occur because clean up resources would be competing with existing onshore oil and gas operations. Potential space/use conflicts or a moratorium could also delay permitting for other future exploration and production activities that could reduce economic activity in general including employment, personal income, and revenues. Loss of access from congested shipping routes and crowded ports could have a short-term adverse effect on Alaska's economic output as delivery of goods and services could be reduced. A VLOS could also displace future economic activity that currently is relatively minor or could potentially exist in the Arctic (e.g., a VLOS could limit the opportunities of future jobs and revenues that may be generated by increased marine shipping activities occurring in the region).

The beneficial and adverse effects of a VLOS on SOA and NSB revenues could be substantial. The most notable beneficial effects would result from compensation because of the NRDA process and property tax revenues from any new onshore infrastructure put in place to support cleanup efforts. The magnitude of potential long-term adverse effects is more uncertain; effects would ultimately depend on the degree to which the VLOS affects future economic activities in the SOA and NSB. The potential effects of a VLOS on the SOA and NSB economies are likely to be major.

Conclusion

Table A-7-14 presents the conclusions on economic measures used to analyze the effects of a VLOS on the SOA and NSB economies.

Table A-7-14 Effects of a VLOS on Economic Measures

Economic Measure	State of Alaska	NSB
Employment / Labor Income	Negligible	Major
Revenue	Major	Major
Population	Negligible	Negligible

A VLOS is expected to have negligible adverse and beneficial effects on SOA employment and labor income, and major effects on revenues. The beneficial impacts on NSB employment, labor income, and revenues are likely to be major. A VLOS is likely to have little to no impact on the population base of the SOA or the NSB.

Overall, a VLOS is expected to have a major impact on the SOA and NSB economy.

A-7.11 Effects of a Very Large Oil Spill on Subsistence Activities

BOEM analyzed effects of a VLOS (greater than or equal to 4.6 MMbbls of oil) at the end of 90 days after a catastrophic event such as a loss of well control. A very large oil spill is a low-probability event with the potential for major effects. In this section, BOEM analyzes the potential effects on subsistence activities and harvest patterns for Nuiqsut, Kaktovik, and Utqiaġvik from a VLOS originating 6 miles from shore at the proposed LDPI in Foggy Island Bay.

Adverse effects from a VLOS on subsistence activities and harvest patterns in and around the Proposed Action Area and the communities of Nuiqsut, Kaktovik, and Utqiaġvik would most likely be severe and thus major (USDOI, BOEM, 2015; USDOI, MMS, 2002). One or more important subsistence resource could become unavailable for one or more seasons due to a VLOS. The adverse and severe impacts would result from direct contact of crude oil with shorelines and resources and potential contamination of resources used as subsistence foods and would most likely result in the following outcomes:

- Reduced numbers of species used for subsistence purposes
- Displacement of people from traditional harvest areas
- Displacement of subsistence resources
- Increased competition for subsistence resources
- Loss of or reductions in traditional subsistence practices
- Social and psychological distress over potential losses of cultural values and identities
- Undesirability of subsistence resources as foods and avoidance of oiled resources and areas
- Contaminated resources unfit for human consumption
- Changes in traditional diets
- Decreased nutritional health
- More difficult pursuit of resources resulting in increased harvester effort
- Increased risk and cost of hunting and fishing due to increased travel distances

A-7.11.1 Phase 1: Well Control Incident, Offshore Spill, and Onshore Contact

During the open-water season, direct impacts of a VLOS on subsistence harvest resources and harvest practices could be immediate and widespread in the initial phases of the blowout event in Foggy Island Bay and the Sagavanirktok River Delta. This is because the proposed LDPI is only 6 miles offshore and winds and currents from the northeast would most likely push oil to shore relatively quickly. In the winter season with complete sea ice cover, oil from a VLOS may linger on the ice in the vicinity of the proposed LDPI or move relatively slowly away from the proposed LDPI, or spilled oil from a VLOS could linger under the ice and disperse rather slowly in cold Arctic seawater.

Depending on the response time and extent of coverage of the incident by the news media and local social media coverage, the initial impacts of the VLOS on residents of Nuiqsut, Kaktovik, and Utqiaġvik from hearing news and viewing images of the event would most likely be severely traumatic for these subsistence harvesters and community residents. This would likely produce long lasting, widespread, and severe stress and anxiety over the safety and availability of resources and accessibility to harvest areas. Community fears about reduced or contaminated food resources, contaminated habitats and harvest areas, reductions in the ability to harvest traditional foods, and concerns related to general food safety would most likely cause social and psychological stress (USDOI, MMS, 2007).

In this phase, offshore resources, including resources at the surface of the sea, in the water column, and on the sea floor could come into direct contact with spilled oil from a VLOS. Onshore resources and habitats could also be oiled. Pollution stemming from an oil spill may contaminate environmental resources, habitats, and subsistence food sources. The presence of oil and the initial response to the spill event could prevent or disrupt access to and use of affected subsistence use areas.

Initially, marine mammals such as whales and seals would most likely swim to avoid the spilled oil from a VLOS. North Slope whalers know that bowheads have the ability to smell and avoid areas where oil is present (USDOI, BOEM, 2015). The probability of oil contacting whales is likely to be less than the probability of oil contacting bowhead habitat and traditional harvest areas. The number of whales contacting spilled oil would depend on the location, size, timing, and duration of the spill and the whales' ability or inclination to avoid contact. If oil gets into leads or ice-free areas frequented by migrating bowheads, some portion of the population could be exposed to spilled oil. Whales travelling under the ice or feeding near the bottom could experience contamination.

Oil contamination of beaches, barrier islands, and sea ice would have impacts on marine mammal hunting because Iñupiaq whalers and seal hunters would be unwilling and/or unable to bring whales and seals ashore or onto the ice for butchering. Some harvest seasons could cease until resources were determined to be safe for harvest, sharing, and eating. In the event of a VLOS, all bowhead whaling communities in Alaska could share concerns over the safety of these subsistence foods and the health of the bowhead whale stock. This widespread concern could cause social and psychological stress especially if communities experienced reductions of this culturally preferred food. The loss of opportunities to harvest whales would threaten a pivotal element of indigenous culture on the North Slope. Whaler avoidance due to a VLOS would most likely vary depending on the timing and volume of a spill, persistence of oil in the environment, time necessary for recovery of offshore subsistence use areas, and community confidence that bowhead whales and seals were once again safe to eat. Traditional practices of harvesting, sharing, and processing whales and other marine resources could be severely disrupted if there are concerns over potential contamination of bowhead whales or their feeding areas. A VLOS could have severe and thus major effects on the subsistence uses of bowheads both within and beyond the Proposed Action Area because of reduced sharing of whale products in the region and the migratory nature of the species (Galginaitis, 2014b; NOAA, 2013).

The effects from a VLOS on ringed and bearded seals could occur from: 1) oiling of skin and fur; 2) inhaling hydrocarbon vapors; 3) ingesting oil-contaminated prey; 5) loss of food sources, and 6) temporary displacement from some feeding areas. In general, a VLOS could cause injury or death to seals or cause them to move from of their normal areas making them unavailable for subsistence harvesting for one or more seasons. Impacts to subsistence seal hunting could be major for Nuiqsut hunters and moderate for hunters from Kaktovik and Utqiaġvik.

Migratory seabirds and waterfowl used by subsistence harvesters could be most vulnerable during this phase of a VLOS because they spend the majority of their time on the sea surface and often aggregate in dense flocks. Many bird species important to subsistence harvests by the Beaufort Sea communities are associated primarily with coastal areas and in sea ice leads. Impacts to subsistence waterfowl hunting caused by oiling of birds during the offshore spill phase are expected to be severe and thus major for Nuiqsut. For Kaktovik and Utqiaġvik, impacts of a VLOS to waterfowl hunting could be moderate.

Terrestrial mammals could be affected by a VLOS to the extent they reside in coastal habitats and feed near contaminated shorelines (USDOI, BOEM, 2015). In June through August, caribou frequent barrier islands and shallow coastal waters during periods of heavy insect harassment; caribou could become oiled and could eat contaminated vegetation as a result of a VLOS. Nuiqsut, Kaktovik, and Utqiaġvik hunt for caribou along the coast in July and August and could be severely disturbed by oiled caribou and oiled shorelines. If a VLOS occurred during the open-water season or during winter and subsequently melted out of the ice during spring, caribou frequenting coastal habitats could be directly contaminated by the spill along the beaches and in shallow waters. Contact and contamination would occur during periods of insect escape activities, usually during summer months. It is likely that many caribou would be deflected from contaminated areas by the presence of people, vessels, and aircraft during spill response and cleanup activities. During late winter and early spring, caribou move out onto the ice, licking sea ice for salt and could be exposed to oil if a VLOS had contaminated the ice. Impacts to subsistence caribou hunting could be major for Nuiqsut and Kaktovik. BOEM expects moderate effects to caribou hunting for Utqiaġvik in the event of a VLOS.

A VLOS could affect offshore and nearshore fish species in the path of or near the oil through either acute toxicity or shifts in prey availability. A VLOS contacting intertidal or estuarine spawning and rearing habitats used by subsistence fish could result in impacts to local fish breeding populations. Recovery to a species' former status after a VLOS by dispersal from nearby population segments could require more than three generations and thus, anadromous fish can be particularly impacted if oil reaches the mouth and delta of anadromous streams and rivers. Depending on timing, extent, and persistence of a VLOS, some migratory fish populations could become reduced in number or eliminated. Some local fish stocks could become unavailable subsistence harvests for one or more seasons. A VLOS could have major effects on subsistence fishing for Nuiqsut and moderate impacts on fishing for harvesters from Kaktovik and Utqiaġvik.

Oil spills have the greatest potential for affecting large numbers of birds due to toxicity to individual birds, contamination of their prey, oiling of feathers leading to hypothermia, difficulties involved in oil spill cleanup in remote areas, and a wide variety of vegetative and ice conditions. The loss of groups of waterfowl on the North Slope due to a VLOS would most likely cause harvest disruptions that would be severe for subsistence hunters who regard waterfowl hunts and harvest and sharing of waterfowl to be of primary importance. A VLOS could cause major impacts to goose and eider hunting for Nuiqsut and moderate impacts to goose and eider hunting for Kaktovik and Utqiaġvik.

Contamination of subsistence food resources as a result of a VLOS could severely curtail the harvesting, sharing, and processing of subsistence resources. These practices could be interrupted for one or more seasons. Subsistence use areas directly oiled and offshore and onshore areas used for staging for OSR and cleanup would most likely not be available for use by subsistence hunters for some time following a spill. Impacts of a VLOS related to potential contamination and hunter avoidance could be moderate to major for Nuiqsut, Kaktovik, and Utqiaġvik.

A-7.11.2 Phase 2: VLOS Response and Cleanup

During spill response and cleanup of a VLOS, disturbances to subsistence practices would most likely occur from disruptions to daily life from an influx of outsiders coming to the area to work and staying in communities. There would most likely be increased noise and physical habitat alterations associated with cleanup of a VLOS. Other disturbances to subsistence harvest patterns could come from: 1) vessels and aircraft supporting cleanup, 2) noise of drilling relief wells, 3) burning of spilled oil, 4) hazing and capture of wildlife and sending animals to rehabilitation centers, 5) chemical dispersants could be introduced to the marine environment, 6) influx of new job opportunities, and 7) physical washing and cleaning of oil from beaches and shorelines.

Spill cleanup could provide opportunities for local, high-paying wage work and could likely displace many local hunters from traditional subsistence pursuits. Cleanup for a VLOS could disrupt subsistence harvest activities for an entire season or more. This disruption would be due to employment of local hunters during cleanup potentially causing them to be unable to take time for traditional hunting and fishing activities.

Spill cleanup strategies could potentially reduce the amount of spilled oil in the environment and could reduce the effects of contact with crude oil and contamination of subsistence resources. In the case of a VLOS in winter, fewer subsistence resources would be present and cleanup is likely to be more effective.

Equipment used during spill response and cleanup includes skimmers, workboats, and barges; which could cause whales and seals to be temporarily displaced altering their migration pathways and causing them to avoid traditional harvest areas. Whales and seals could become more wary and difficult to harvest. The operations of small vessels, cleanup crews, support vehicles, and heavy equipment could disturb coastal subsistence resource habitats, displace subsistence species, reduce hunter access to traditional hunting use areas or species, and alter or extend the annual subsistence hunts for one or more seasons.

During the open-water or breakup seasons, disturbances to and diversion of bowhead whales, seals, caribou, and migratory waterfowl could increase due to spill response and cleanup. Deflection of subsistence resources from the combination of a VLOS and spill response and cleanup activities could persist beyond a single season perhaps lasting several years (USDOI, MMS, 2007).

Another disruption to hunting activities could be caused by the response of cleanup crews. These crews may require local knowledge, experience, and vessels belonging to whaling captains in the community as expert resources. By utilizing these resources, cleanup crews could divert the whaling captains and their equipment to spill response and cleanup activities with the potential to impact subsistence whaling or other hunting activities due to commitments to cleanup work.

The overall result would be a major effect on subsistence harvests and those in the communities who depend on subsistence. North Slope residents and communities could experience adverse impacts to cultural and spiritual values due to the loss of subsistence resources and harvest opportunities. Residents could experience a decrease in their nutritional health and mental well-being. Impacts from a VLOS from spill response and cleanup activities could be moderate to major depending on how long cleanup would take. Cleanup of the EVOS took more than four summers (EOSTC, 2014). If cleanup activities persisted longer than one season on the North Slope, effects could become severe and thus major.

A-7.11.3 Phase 3: Post Spill and Long-Term Recovery

In this phase of a VLOS, the impacts to subsistence harvest patterns could occur from 1) unavailability or increased difficulty in obtaining and utilizing subsistence resources, 2) long-term contamination stemming from the oil spill, 3) altered traditional use patterns due to contaminated resources, 4) co-opting of human resources and equipment required to study long-term impacts of the spill, and 5) long lasting psychological and social distress in communities.

In the long-term recovery phase, adverse impacts to subsistence resources could transform into sociocultural impacts. Subsistence practices and harvest patterns are closely intertwined with sociocultural systems, socioeconomics, community health, and environmental justice issues. Long-term subsistence impacts during recovery from a VLOS could create a perception of chronic disruptions to social organization in the form of ritualistic harvests and sharing of bowhead whales.

Potential contamination of the whale *mataaq* and meat as bowhead whales pass through the VLOS area during migration could cause long-term disruptions in patterns and practices of bowhead whaling, which could lead to a breakdown of kinship networks, sharing patterns, and increased social stressors in communities affected by a VLOS (USDOI, BOEM, 2015). Communities farther from the oil spill area would most likely assist communities affected by a VLOS by sharing subsistence foods with them, potentially taxing the resources of those subsistence regions and communities (USDOI BOEM, 2015; USDOI, MMS, 2007).

If local subsistence harvesters were employed in long-term monitoring studies of impacts of the VLOS, their time, workforce, and equipment may be diverted away from subsistence practices or community services. Participation in long-term recovery work on the part of local people could cause non-participation in subsistence activities and fewer people to seek employment in the community services sectors if spill recovery jobs paid higher wages. Increased income could be beneficial to some families in that having extra cash on hand would allow individuals to purchase fuel and equipment needed for effective subsistence harvests or give cash to family members who have more time for harvesting. Rapid increases in income could have adverse effects as well. Extra cash could be spent on alcohol, less nutritional store bought foods, or families could quarrel over what to do with extra income or become jealous of families or communities whose incomes increased (Wooley, 1995).

After a VLOS during long-term recovery, communities could experience severe stress and anxiety over the long-term loss of or reduction in subsistence practices, contamination of resources, fear of the health effects of eating contaminated wild foods, fear of changes to harvest regulations, and dependence on the knowledge of outside experts to inform them about levels of environmental contamination and when it would once again be safe to consume traditional foods (USDOI, BOEM, 2015). Individuals and communities could be increasingly stressed as they modified subsistence harvest patterns and changed harvest areas. If new harvest areas were farther away from communities or unfamiliar, there would be increased safety risks and costs associated with travel and hunting in unfamiliar areas. An affected community would most likely not be able to hunt or fish in someone else’s territory without permission. Sociocultural organization of subsistence activities among kinship groups could be disrupted during long-term recovery. Relationships could be weakened among those who customarily process and share subsistence harvests and would most likely need to be modified during long-term recovery.

Effects of long-term recovery from a VLOS could adversely impact whaling crew structure and disrupt Iñupiaq cultural values central to the subsistence way of life. These disruptions could cause a breakdown in sharing patterns, family ties, and the community's sense of well-being. Sharing linkages with other communities could be disrupted. Long-term recovery from a VLOS could disrupt subsistence harvest patterns for one or more seasons and could cause severe and thus major impacts in Nuiqsut. Impacts of long-term recovery for Kaktovik and Utqiaġvik are anticipated to be long lasting and widespread, but less than severe and thus moderate.

A-7.11.4 Oil Spill Trajectory Analysis

Based on conditional probabilities on an annual basis (January through December), a VLOS starting at the proposed LDPI would most likely threaten some important subsistence harvest patterns and practices. The oil from a VLOS could contact subsistence use areas important to Nuiqsut, Kaktovik, and Utqiaġvik. The chances of contact are estimated from the conditional probabilities, which represent the percent of spill trajectories launched from the proposed LDPI that could contact an environmental resource area or a subsistence use area (Table A-7-14; Appendix A).

Table A-7-15 summarizes the conditional probabilities for several critical subsistence use areas and resources both annually and for the summer season, July 1 through September 30. BOEM included the summer trajectories because these subsistence use areas are generally more vulnerable during the open-water season because that is when most subsistence activities occur at these places. Ninety days after a VLOS event, there is a chance that 11 percent of the spill trajectories starting from the proposed LDPI would contact Nuiqsut's bowhead whaling area near Cross Island (i.e., ERA 43); in summer, this increases to 26 percent. Thetis Island is an important place for seal hunters from Nuiqsut; there is a chance that 10 percent of the VLOS trajectories would contact and oil Thetis Island (i.e., ERA 92). The stretch of coastline between the Colville River and Canning River deltas is an important caribou use area that is part of Nuiqsut's and Kaktovik's historic caribou hunting area (i.e., GLS 175). This portion of the shoreline has a chance of being contacted by 13 percent of the spill trajectories from a VLOS; in summer when these animals are hunted, the chance increases to 42 percent.

Table A-7-15 Conditional Probabilities for Subsistence Use Areas 90 Days after VLOS

ID*	Description	Annual Probability (%)	Summer Probability (%)
ERA 12	Nuiqsut-Colville River Delta-Fishing, Seal hunting, Waterfowl and Caribou	3	6
ERA 42	Utqiaġvik East Arch-Whaling, Seal hunting, Fishing, Waterfowl	1	4
ERA 43	Nuiqsut-Cross Island-Whaling, Seal hunting, Waterfowl	11	26
ERA 44	Kaktovik Offshore-Whaling, Seal hunting, Fishing, Waterfowl	<0.5	1
ERA 92	Nuiqsut-Thetis Island-Seal hunting	10	11
ERA 105	Nuiqsut-Fish Creek-Fishing	3	4
GLS 168	Utqiaġvik/Nuiqsut-Summer Caribou	2	5
GLS 175	Nuiqsut/Kaktovik-Summer Caribou	13	42
GLS 183	Kaktovik-Summer Caribou	<0.5	1

Notes: [1] ERA = environmental resource area; GLS = grouped land segment, in this case representing stretches of coastline important for caribou hunting.

Source: Appendix A

A-7.11.5 Conclusion

Based on conditional probabilities a VLOS starting at the proposed LDPI would most likely threaten some important subsistence harvest areas (Table A-7-14).

In Phase 1, if offshore oil from a VLOS directly contacted migrating or resident marine mammals, seals, fish, caribou, and/or migratory waterfowl, contaminated traditional harvest areas, and persisted in subsistence use areas, subsistence practices would be severely curtailed and interrupted – particularly bowhead whale hunting. This could create severe reductions in access to traditional nearshore and offshore harvest areas lasting one or more seasons. Impacts to subsistence activities and harvest patterns are anticipated to be severe and thus major for Nuiqsut.

For Phase 2 of a VLOS, impacts from spill response and cleanup activities could be moderate to major for Nuiqsut, Kaktovik, and Utqiaġvik depending on how long cleanup would take and to what extent residents of these communities participated in response and cleanup work. If VLOS cleanup activities persisted longer than one season on the North Slope and resources and workforce were substantially drawn from all three communities, effects could become severe and thus major for Nuiqsut, Kaktovik, and Utqiaġvik. Overall, BOEM anticipates moderate to major impacts from a VLOS on subsistence activities and harvest practices for Kaktovik and Utqiaġvik.

During Phase 3, long-term recovery from a VLOS could disrupt subsistence harvest patterns for one or more seasons and could cause severe and thus major impacts in Nuiqsut. Impacts of long-term recovery for Kaktovik and Utqiaġvik are anticipated to be long lasting and widespread, but less than severe and thus moderate.

A-7.12 Effects of a VLOS on Community Health

BOEM analyzed the effects of a VLOS (greater than or equal to 4.6 million barrels of oil) 90 days after a catastrophic event such as loss of well control from the LDPI. For more details on the effects of a VLOS to subsistence practices, harvest patterns, and sociocultural systems, see Sections A-7.9 and A-7.11). BOEM expects impacts of a VLOS on community heath to be similar to impacts from a VLOS on subsistence activities and sociocultural systems because these are the primary determinants of community health in the NSB.

A VLOS could adversely affect community health in a number of ways (USDOI, BOEM, 2015, p. 606). For example, a VLOS could cause adverse impacts to air and water quality, which in turn could have long lasting and widespread effects on community health related to respiratory illnesses and contaminated marine and freshwaters used for hunting and fishing. A VLOS also could severely impact subsistence harvest patterns.

Overall effects on subsistence harvest patterns could be major because one or more important subsistence resources could become unavailable, undesirable for use, or available only in greatly reduced numbers for one or more seasons. Any disruption of the bowhead whale harvest from a VLOS or from potential contamination of the *mataaq* and whale meat during the bowhead migration route could disrupt whaling for an entire season. Long lasting, widespread and severe impacts could occur to community health due to increased food insecurity, declines in nutritional health, and compromised social organization and cultural well-being.

The arrival and presence of hundreds of OSR and cleanup workers, support vessels, and aircraft would most likely increase displacement of subsistence resources and alter or reduce access to subsistence resources. These disruptions could lead to a breakdown of kinship networks and sharing patterns and increased social stress in communities. A disruption of sharing networks could lead to a decreased emphasis on the importance of cooperation and sharing at both the family and community levels.

Multiyear disruptions of subsistence harvest patterns, especially to bowhead whaling, could disrupt sharing networks, subsistence task groups, and whaling crew structures and would most likely severely disrupt the subsistence way of life. This would compromise cultural well-being and could severely and adversely impact community health. Increased social problems, breakdown in family ties, and a weakening of community well-being could lead to additional stresses on the health and social services available in communities. See Section A-7.12 for additional information about the effects of a VLOS on subsistence harvest patterns and sociocultural systems.

If local residents substantially participated in spill response and cleanup work, as local residents did in the EVOS in 1989, they could experience both adverse and beneficial effects to their health and well-being. Local employment in spill response and cleanup for a VLOS could disrupt subsistence harvest patterns for one or more seasons and disrupt some formal institutions such as whaling captains' associations. Contemporary subsistence practices and harvest patterns could be severely altered and community healthcare systems severely stressed by drawing local workers away from village service jobs. Effects on community health from response and cleanup for a VLOS could be major and last for one or more subsistence seasons.

A-7.12.1 Conclusion

If offshore oil from a VLOS directly contacted migrating or resident marine mammals, seals, fish, caribou, and/or migratory waterfowl; contaminated traditional harvest areas; and persisted in subsistence harvest areas, sociocultural systems would be severely reduced and interrupted. This would most likely lead to moderate to major impacts to community health from food insecurity, poor nutritional status, increased metabolic disorders, and low cultural well-being. Social organization, cultural values, and health and social services would most likely be disrupted for one or more seasons. Impacts to community health from a VLOS are anticipated to be severe, and thus major for Nuiqsut.

Impacts from VLOS response and cleanup activities to community health could be moderate to major for Nuiqsut, Kaktovik, and Utqiaġvik depending on how long cleanup would take and to what extent residents of these communities participated in response and cleanup work. If VLOS cleanup activities persisted longer than one season on the North Slope and resources and workforce were substantially drawn from all three communities, effects to community health could increase to severe, and thus major for Nuiqsut, Kaktovik, and Utqiaġvik. Some of these impacts would most likely be beneficial to community health through increased employment and income. Overall, BOEM anticipates moderate to major effects from a VLOS on community health for Kaktovik and Utqiaġvik.

Long-term recovery from a VLOS could severely disrupt community health for more than one year, resulting in major impacts in Nuiqsut. Impacts of long-term recovery to community health for Kaktovik and Utqiaġvik are anticipated to be long lasting and widespread, but less than severe and thus moderate.

A-7.13 Effects of a VLOS on Environmental Justice Communities

BOEM analyzed effects of a VLOS (greater than or equal to 4.6 MMbbls of oil) at the end of 90 days after a catastrophic event such as loss of well control. A VLOS is a low-probability event with the potential for major effects. For more discussion on the effects of a VLOS to subsistence practices and harvest patterns see Sections A-7.11 and A-7.9, respectively.

A VLOS starting at the proposed LDPI could threaten some important subsistence harvest areas on which EJ communities rely. Of particular importance are the offshore bowhead whaling area used by crews from Nuiqsut and the coastal lands used by Nuiqsut and Kaktovik for subsistence caribou hunting during July through August (FEIS Figure 3.2.5-1; Table 4-41).

If offshore oil from a VLOS directly contacted migrating or resident marine mammals, seals, fish, caribou, and/or migratory waterfowl; contaminated traditional harvest areas; and persisted in subsistence harvest areas, subsistence harvest patterns would be severely interrupted, particularly bowhead whale hunting. This could create severe reductions in access to traditional nearshore and offshore harvest areas lasting one or more seasons. Social organization, cultural values, and formal institutions would most likely be disrupted for one or more seasons.

Impacts to sociocultural systems and community health from a VLOS are anticipated to be major for Nuiqsut. If these impacts occurred as anticipated as a result of a VLOS, BOEM expects disproportionately high and adverse environmental, social, and health impacts to occur for Nuiqsut.

Some impacts from VLOS spill response and cleanup activities to sociocultural systems and community health could be major for Nuiqsut, Kaktovik, and Utqiaġvik depending on how long cleanup would take and to what extent residents of these communities participated in response and cleanup work. If VLOS cleanup activities persisted longer than one season on the North Slope, effects to sociocultural systems and community health would most likely be major for these EJ communities. Therefore, BOEM would expect disproportionately high and adverse environmental, social, and health impacts for these EJ communities from VLOS response and cleanup.

Long-term recovery from a VLOS could cause major disruptions to sociocultural systems and community health for more than one year in Nuiqsut. Accordingly, BOEM would expect disproportionately high and adverse environmental, social, and health impacts for Nuiqsut due to long-term recovery from a VLOS.

A-7.14 Effects of a VLOS on Archaeological Resources

A VLOS is initiated by a hypothetical blowout from the proposed LDPI. The scenario considers a worst-case analysis without mitigating factors. Thus, the VLOS in the Proposed Action Area would have an assumed volume of 4.6 MMbbls of oil and a duration of 90 days. Cleanup activities for a VLOS may involve the use of chemical substances. These substances, depending on which chemicals are actually employed, may affect archaeological sites. The full effect of the agents on archaeological sites and shipwrecks is unknown. However, some evidence exists that the use of these substances may result in the contamination of any carbon-14 samples, making the dating of sites difficult (Borrell, 2010).

A VLOS from the proposed LDPI (LI) is not expected to affect marine cultural resources because there are no reported shipwrecks in the subject area, and acoustic remote-sensing did not discover any archaeological or historic resources on the seabed. Because the OSRA assesses trajectories to the point of contact (the intertidal zone), it is not anticipated that a VLOS would result in direct effects on those archaeological and historic resources located on land. However, a VLOS could result in minor to major impacts on a large number of archaeological and historic resources during the spill response and cleanup phase. Cleanup crews would be needed in a greater number of locations. The greatest threat to archaeological and historic resources during a VLOS would result from the larger number of response crews being employed. Following the EVOS, most impacts to archaeological and historic resources during spill responses were the result of vandalism or physical damage from spill response activities (Bittner, 1996; Reger et. al., 2000). A VLOS could result in large impacts to numerous archaeological and historic resources from spill response and clean-up activities. Given the number of resources to be considered and personnel limitations, timely monitoring of affected sites may not be possible (Reger et al., 2000).

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