Beaufort Region Strategic Environmental Assessment

Data Synthesis and Assessment Report

July 31, 2020

Prepared for:
Inuvialuit Regional Corporation,
Inuvialuit Game Council
and
Crown-Indigenous Relations and Northern Affairs Canada

Prepared by:
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Inuvik, NT

Project Number: 123513135

KAVIK-STANTEC

Preface

KAVIK-Stantec Inc. (KAVIK-Stantec) was retained by the Inuvialuit Regional Corporation (IRC; represented by Duane Ningaqsiq Smith), the Inuvialuit Game Council (IGC; represented by various members) and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC; represented by Mark Hopkins) “to support the BRSEA through the development and delivery of an Assessment, Synthesis and Report Package for the Strategic Environmental Assessment for the Beaufort Sea Region.” (Terms of Reference, Appendix A, this report). A Steering Committee for the BRSEA, made up of Jennifer Parrott and Bob Simpson of the IRC and Daniel Van Vliet and Martin Tremblay of CIRNAC, provided ongoing direction to KAVIK-Stantec.

Using Traditional and Local Knowledge (TLK) and western science, the goal of the Data Synthesis and Assessment Report is to provide the Co-Chairs (IRC, IGC and CIRNAC) with an understanding of the type and potential outcomes of likely adverse effects and improved benefits that might arise from different types and intensities of oil and gas activities, and other industrial activities and human use in the BRSEA Study Area. This includes understanding the mechanisms through which adverse effects and improved benefits could occur, as well as the aspects that influence the severity or extent of these likely effects (e.g., project design, mitigation, management, climate change, cumulative effects). The intent is to inform future research and monitoring efforts, legislation and policy needs, industry guidance, management approaches, and community engagement and involvement.

Executive Summary

E1 BACKGROUND AND PURPOSE[1]

The Beaufort Region Strategic Environmental Assessment (BRSEA) forms "part of the science-based review included in the December 20, 2016 US-Canada Joint Arctic Leaders' Statement. The BRSEA is intended to be a proactive planning tool in which hypothetical future industrial development scenarios are assessed to provide an understanding of the mechanisms through which adverse and positive effects could occur, the potential outcomes (e.g., adverse effects and positive benefits), and applicable management approaches, as well as important information gaps and research needs (https://brsea.inuvialuit.com/About).

The spatial limit of the BRSEA is the marine area of the Inuvialuit Settlement Region (ISR) (i.e., the Canadian Beaufort Sea within the Inuvialuit Settlement Region (ISR) up to the ordinary highwater mark of the coastlines) (Figure E-1). Environmental effects of human and industrial activities on land and fresh water systems within the ISR are outside the geographic scope of this assessment. The temporal limit of the assessment is from 2020 to 2050.

Seasonal designations for the assessment were based on sea ice conditions (i.e., Ice, Spring Transition, Open Water and Fall Transition seasons) as opposed to calendar dates or seasons (i.e., winter, spring, summer and fall). Sea ice seasons better reflect how seasonal changes influence the physical and biological environment, and the distribution, intensity and types of traditional uses of marine areas by the Inuvialuit.

E2 LIMITATIONS AND ASSUMPTIONS

The study duration and budgetary constraints for this Data Synthesis and Assessment Report required that the assessment be tightly scoped to focus on Valued Components (VCs) of greatest importance to the Inuvialuit, and the effects most likely to affect the sustainability of the selected biophysical, socio-cultural and economic VCs.

The Data Synthesis and Assessment Report used and cited a large number of primary sources, existing compendiums and information syntheses for TLK and western science[2], with a focus on information on existing conditions and trends for the VCs that are most likely to be affected by human and industrial activities, as well as on effect mechanisms, pathways, and outcomes. A comprehensive synthesis of what is known for every VC was not within the scope of this study. No quantitative physical, biological, or economic modelling was undertaken to predict the effects of potential future development on VCs.

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1 Section of the Executive Summary are prefaced by the letter E (e.g., Section E1.1.1); sections in the main report are referred to using only numbers (e.g., Section 1.1.1).

2 Sources of TLK and western science that were available as of November 30, 2019 were used in the preparation of this report. While a number of additional studies undertaken by the BRSEA became available after this date, they were not able to be used in the State of Knowledge or the assessment of environmental effects.

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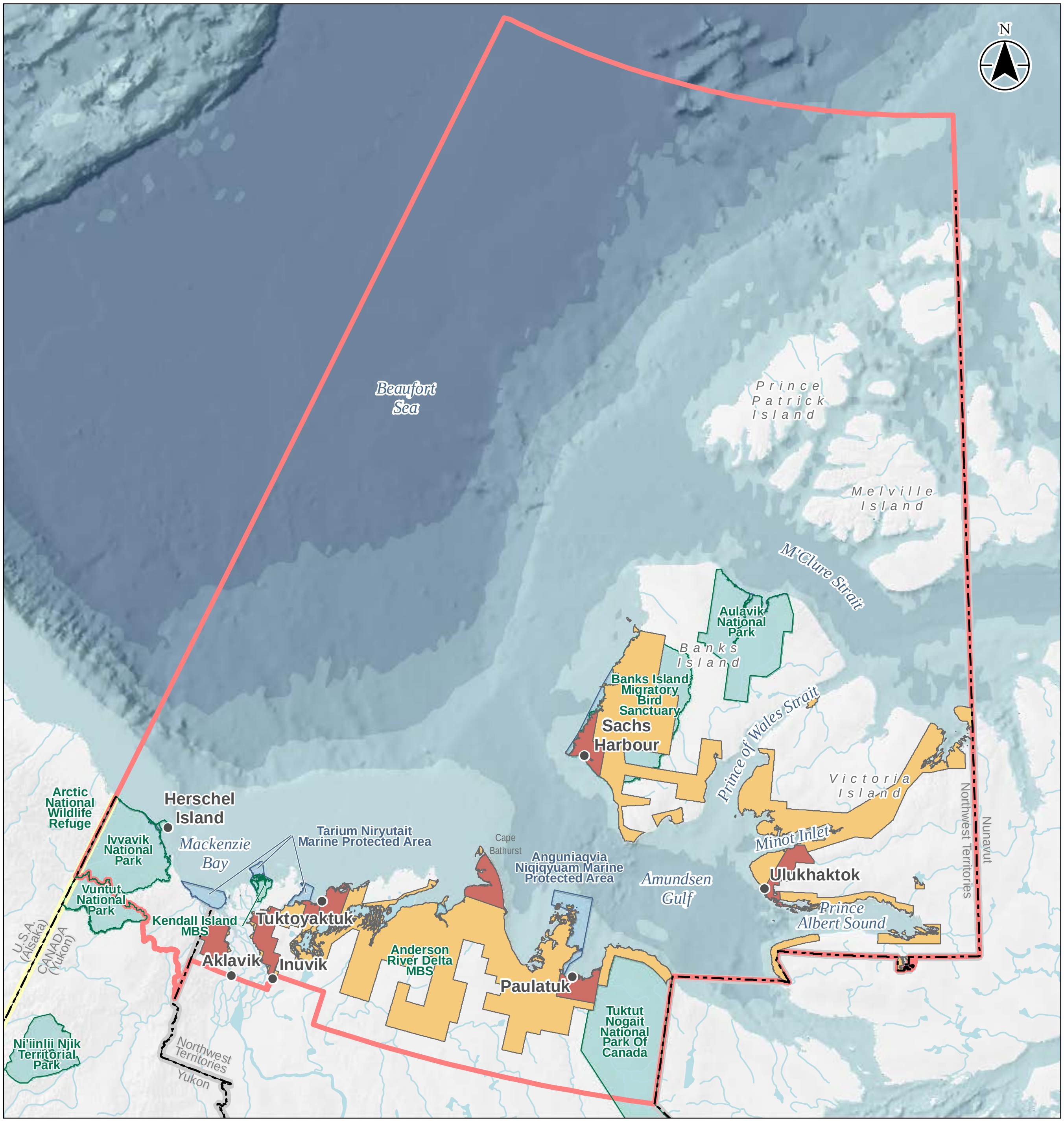

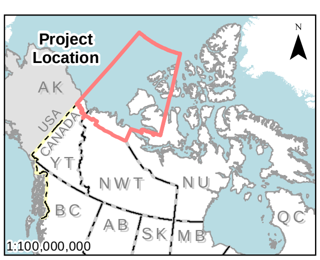

- Community
- International Boundary
- Territorial Boundary
- Watercourse
- Waterbody
- Marine Protected Area
- Terrestrial Protected Area

Bathymetry Depth (m)

- < 200
- 200 - 1000
- 1000 - 2000
- 2000 - 3000
- > 3000

Boundary of the Inuvialuit Settlement Region

Aboriginal Lands of Canada Legislative Boundaries

- 7(1)a Private Lands
- 7(1)b Private Lands

0 50 100 150 200 250 300 km

1:8,000,000 (at original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Natural Resources Canada

KAVIK-STANTEC

INUVIALUIT REGIONAL CORPORATION

Project Location
Beaufort Sea, Northwest Territories, Canada

Project Number 123513135
Prepared by LTRUDELL on 20200313
Discipline Review by JGREEN on 20200313

Client/Project
Inuvialuit Regional Corporation
Beaufort Region SEA

Figure No.
E-1

Title
The BRSEA Study Area includes all marine areas within the ISR

The scenarios used for this assessment deliberately reflected different types and intensities (i.e., low to high) of human and industrial activities and were loosely based on past oil and gas activities in the region. While the scenarios realistically reflect how certain activities might be carried out, they are not real projects, nor are they site- or temporally-specific.

Given these factors and regional nature of the assessment, the discussion of regulatory requirements, existing conditions, potential effects, mitigation measures, and recommendations for monitoring are, in most cases, not spatially- and temporally-specific.

These aspects do not detract from the value of this Data Synthesis and Assessment Report; rather they are in line with the scope of a Strategic EA (as opposed to a regulatory EA), and help define the scope and focus and set realistic expectations as to their outcomes.

E3 APPROACH

The assessment of potential environmental effects was supported by three major tasks:

- scoping and development of the three foundational elements for the assessment: the scenarios, use of TLK, and the prediction of climate change
- preparation of the State of Knowledge - an overview of information from TLK and western scientific sources on existing and changing conditions in the BRSEA Study Area centred on the VCs selected for the BRSEA
- development of the assessment methodology

E3.1 Foundational Elements

E3.1.1 Scenarios

Five (5) hypothetical scenarios were developed for the assessment: the Status Quo Scenario, three oil and gas development scenarios that reflect increasing levels of development activity (e.g., low, moderate and high), and a large oil release event[3].The scenarios were used to assess how various types of existing and future industrial development might affect the physical, biological, socio-cultural, and economic VCs of the BRSEA Study Area (Chapter 3). The scenarios are intended as a means to explore and evaluate plausible futures for the region and aid decision makers and organizations to make informed management choices. None of the scenarios are actual future projects or events.

The ***Status Quo Scenario*** (Scenario 1) describes existing and future human use and industrial activities, that are likely to occur in the BRSEA Study Area over a time frame similar to that for the three development scenarios (e.g., 2020-2050). As this scenario does not include oil and gas activities, it provides a basis for considering potential residual effects on biophysical and socio-economic VCs in the absence of oil and gas activity over the 30-year time frame. Activities considered in this scenario included: commercial shipping, cruise ship tourism, local boat and snowmobile traffic, ship-based

[3] While a large release is a low probability event, effects of an accidental oil spill in the BRSEA Study Area on marine ecosystems, human uses and cultural vitality are of high concern to the Inuvialuit, other northern residents, government agencies and a broad range of public stakeholders in Canada and internationally.

resupply and export for communities and mine-exploration, renewable energy projects, scientific research cruises, military vessels and exercises, and low-level aircraft overflights.

To explore how environmental effects might vary in relation to the intensity of oil and gas development, three oil and gas development scenarios were formulated to deliberately include different general locations within the BRSEA Study Area (e.g., nearshore, moderate depth water and deep water), different mixes and timing of activities, and different intensities of development. The three oil and gas development scenarios were:

- ***Export of Natural Gas and Condensates*** (Scenario 2) describes a potential offshore development in the nearshore for export of natural gas and condensate from existing land-based reserves on the Mackenzie Delta. The development involves construction and operation of a twin subsea pipeline system and an offshore Gravity-based Structure (GBS) loading facility that is located 15-20 km offshore of the Mackenzie Delta. LNG and condensate would be loaded onto dual-action[4] Class 3 ice breaking LNG carriers and condensate tankers which would be loaded approximately once every five days and operate year-round using a western route via Alaska. Tuktoyaktuk would serve as a logistical base, while Inuvik would serve as the administrative and business centre. This scenario represents a low level of offshore development activity.
- ***Large Scale Oil Development on the Continental Shelf*** (Scenario 3) involves the hypothetical development and production of oil reserves from existing Significant Discovery Licenses (SDLs) in moderate depth water (< 40 metres) on the continental shelf, 40 to 50 km offshore. A 3D seismic survey would be conducted over a 60,000 ha area during the Open Water Season to delineate the field. An offshore GBS would be positioned in the SDL to provide a base for drilling, oil production and storage, and loading of tankers. Logistical support would be provided from a wareship, moored next to the production GBS, with additional support from Tuktoyaktuk and Summers Harbour. Inuvik would serve as the administrative and business centre. Dual-acting Class 3 ice breaking oil tankers would take oil out of the Beaufort Sea via an Alaska route year-round with one inbound and one outbound transit each week. This scenario represents a moderate level of offshore development activity.
- ***Large Scale Oil Development within Exploration Licenses (EL) on the Continental Slope*** (Scenario 4) considers an exploration program and hydrocarbon development within Exploration Licenses (ELs) located in deep water (>100 m to 1200 m water depth) in an area on the slope of the continental shelf approximately 100 km offshore. A 3-D seismic program would be conducted over an area of up to 120,000 ha within one Open Water Season to delineate the oil reserves. Two exploration wells would be completed by a dynamically-positioned drill ship over a period of four years, followed by the completion of two delineation wells over the next four years. Up to 50 production and injection wells, grouped within six manifolds on the sea bottom, would be drilled seven to twelve years after discovery. During production, a single FPSO vessel would be used year-round for processing and loading of oil onto dual-action tankers. The tankers would exit the Beaufort Sea westward through Alaska year-round (one inbound and one outbound transit every 5-6 days) and eastward through the

[4] Dual-action vessels are an icebreaking ship designed with a typical bow for running in open water and thin ice, but with a stern design that provides greater ice protection and some icebreaking capabilities; in heavy ice conditions, the vessel turns and advances stern-first to provide icebreaking capabilities.

Northwest Passage during the Open Water to early-Fall Transition seasons (one inbound and one outbound transit each month). This scenario represents a high level of development activity.

The ***Large Oil Release Event*** (Scenario 5) examines how an accidental subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker could affect the biophysical, socio-cultural and economic VCs in the BRSEA Study Area[5]. Rather than assess a specific spill location and volume for a large oil release event, a qualitative approach was used that allowed the assessment team to examine a range of potential outcomes based on oil spills and associated response measures occurring under different combinations of conditions related to:

- a surface release versus a subsea release
- season (Ice, Spring Transition, Open Water and Fall Transition seasons)
- location of the oil release relative to the Mackenzie River Plume (inside or outside the plume)
- movement of oil by ocean currents in the Beaufort Sea

E3.1.2 Use of Traditional and Local Knowledge

Through generations of living on the land, the Inuvialuit have developed intricate knowledge systems about the interrelationship between the land, waters, plants, and animals upon which traditional uses depend. In addition, from observations and direct experience over the past 60+ years of oil and gas activities in the ISR, Inuvialuit have an understanding of how oil and gas development has affected and may affect the biophysical environment and socio-cultural and economic aspects. TLK also provides insight on how climate change has and is continuing to affect traditional and cultural uses.

Given this, the Data Synthesis and Assessment Report used and integrated TLK and western science to describe economic, socio-cultural, and biophysical conditions and trends; predict environmental effects; identify mitigation measures; and design monitoring and follow-up programs (Chapter 5). To facilitate the use of TLK, a TLK Framework was developed that includes:

- a database of Inuvialuit knowledge and observations
- guidance to the assessors on the use of TLK and the citing and referencing of TLK
- processes to corroborate how TLK was used and cited

The Inuvialuit Regional Corporation (IRC) and Inuvialuit Game Council (IGC) identified the specific TLK studies and other information to be included in the TLK Framework. These included eight TLK studies completed specifically for the BRSEA.

Three Inuvialuit beneficiaries -- James Pokiak (Tuktoyaktuk), Doug Esagok (Inuvik) and Trevor Lucas (Sachs Harbour) -- participated as members of the TLK assessment team. In addition to providing TLK, they helped corroborate the interpretation and use of TLK in the assessment.

[5] Of note, accidents involving cruise ships, cargo vessels, military vessels or research vessels could result in a large oil release and similar environmental effects.

E3.1.3 Prediction of Climate Change

Inuvialuit TLK and western science have documented substantial changes in climate and associated changes in the physical and biological environment in the BRSEA Study Area over the past several decades. In turn, these changes have altered Traditional Activities, Cultural Vitality, Public Health, Infrastructure, and the Economy, and directly affected human safety.

Given the 30-year temporal scope of the assessment, a consistent approach for consideration of climate change was needed (Chapter 6; Appendix C). To achieve this, a single climate change emissions scenario was chosen from among the potential future greenhouse gas concentration trajectories developed by the Intergovernmental Panel on Climate Change (IPCC); these are referred to as Representative Concentration Pathways (RCPs)[6]. Based on the comparison between observations of key variables and the predicted trajectories under different RCPs from 2005 to present, the RCP 8.5 scenario was chosen as the most robust climate prediction for the BRSEA Study Area. The RCP 8.5 scenario has been called a 'worst case' or 'business as usual' scenario, and predicts a mean global temperature rise of 5-6° C by 2100.

Current trends and future predictions for key physical attributes under RCP 8.5 are described, including air and ocean temperatures, precipitation (rain and snow), frost-free days, wind (direction, speed, variability, frequency of extreme events), sea level rise (including frequency and severity of storm surges), sea ice (extent, thickness, type, timing, including landfast ice), waves, currents, permafrost conditions, freshwater runoff, and coastal exposure and erosion. These trends and predictions were used to describe how climate change might modify:

- the types and seasonal timing of activities and choice of equipment for each oil and gas scenario
- the distribution, seasonal movements and populations of marine species, as well as socio-cultural and economic conditions
- the effect pathways or mechanisms for each valued environmental or social component

E3.2 State of Knowledge

The State of Knowledge (Chapter 7) describes the existing conditions and trends for the biophysical, socio-cultural, and economic VCs in the BRSEA Study Area (Table E-1) with a focus on the information required to support the assessment of activity-specific effects and cumulative effects; specifically:

- the importance of the biophysical, socio-cultural and economic VCs to the Inuvialuit
- the conservation status or importance of the VCs (e.g., federal and territorial governments, Inuvialuit organizations, and international agreements)
- the spatial and temporal distributions of the VCs within the BRSEA Study Area
- past and current trends of VCs
- potential trends in VCs as a result of climate change

[6] The RCPs considered have been adopted by the Intergovernmental Panel on Climate Change (IPCC) for its fifth Assessment Report (AR5) (IPCC 2013).

Table E-1 Valued Components selected by the IRC, IGC and CIRNAC for use in the BRSEA.

Physical Environment	Biological Environment	Human Environment (Socio-Cultural and Economic Aspects)
• Atmospheric Environment • Climate and Weather • Oceanography • Sea Ice • Coastal Dynamics and Sea Floor Geology • Coastal Habitat	• Rare and Endangered Species and Communities • Marine Lower Trophic Levels • Marine Fish and Habitat • Migratory Birds • Seabirds • Marine Mammals • Polar Bear • Caribou • Invasive Species	• Economy • Demographics • Infrastructure • Traditional Activities • Cultural Vitality • Public Health

E3.3 Assessment Methodology

While the assessment of effects in this report follows a similar set of steps as a project-based environmental and social impact assessment (ESIA)[7], its objective is to describe the range of potential residual effects on the biophysical, socio-cultural and economic VCs in the BRSEA Study Area that might occur relative to different development intensities and types of human activities. The assessment methods are described in Chapter 4. The detailed assessment of potential environmental effects can be found in Appendix D, and are summarized in Chapter 8 relative to development intensity (which increases from Status Quo through Scenarios 2 to 4), types of routine activities, and a large oil release event.

The detailed assessment is structured first by the VC and then scenario, examining potential effect pathways based on the activities described for each hypothetical scenario. Residual effects[8] are then discussed using standard effect characterization terms for direction, magnitude, geographic extent, frequency, duration, reversibility, and ecological and socio-economic context. For the assessment of cumulative effects, the activities in the Status Quo scenario were assumed to be occurring within the same temporal scope as each of the three oil and gas development scenarios.

Effects of climate change were considered for both activity-specific residual effects and cumulative effects; specifically, the assessment describes how climate change might modify the effect pathways and residual effects characterization for each biophysical, socio-cultural, and economic VC.

[7] Typical steps in a project-specific ESIA include: issues identification, scoping, assessment of effects, identification of mitigation, assessment, characterization, and significance determination of residual effects and cumulative effects; and identification of monitoring and follow-up actions).

[8] Residual effects assume that proponents and operators of the hypothetical developments would fully comply with applicable environmental legislation, regulations and guidelines, as well as the additional mitigation measures identified in the assessment.

E4 ENVIRONMENTAL EFFECTS

Based on the assessment of effects for the Status Quo and the three oil and gas scenarios (Chapter 8 and Appendix D), existing and future industrial activities and human use are expected to result in a mixture of potential adverse residual effects and improved benefits for VCs within the BRSEA Study Area. Adverse effects are typically associated with impacts to the physical and biological environment and some aspects of the human environment (e.g., strains on Infrastructure and Public Health; changes in Traditional Activities and Cultural Vitality). Improved benefits largely occur through positive changes in the local and regional economy, increased employment, and wage income; the ability to purchase equipment and supplies to support traditional and other activities, and improvements to or development of new infrastructure. The specific outcomes (i.e., the degrees to which potential residual effects may be adverse or beneficial) vary depending on the intensity of industrial development and human use, the type of activity, and the VC. Potential residual effects from a large oil release event are predicted to be adverse.

To provide a visual summary for each potential adverse effect or benefit on a VC relative to development intensity and types of activity, the residual effects characteristics for geographic scope, duration, magnitude, and direction were used to derive a single metric referred to as an “effect condition”. Effect condition was ranked using a simple index scale of negligible, low, moderate and high. Methods for determining the effect condition for development intensity is provided in Section 8.4.1.1 and for activities in Section 8.4.2.1.

E4.1 Effects of Increasing Intensity of Development

Table E-2 shows the effect condition for each VC and scenario[9]; additional details are provided in Section 8.4.1. Because the effect condition may not be the same throughout the year, the seasons during which the effects may occur are indicated and, to be conservative, the highest predicted potential effect condition across all seasons is illustrated by the shading. The residual effect conditions shown in Table E-2 assume that mitigation measures applicable to routine operations for each of these activities have been implemented (e.g., best practices or government regulatory requirements that industry would implement as part of their authorization terms and conditions).

As shown in Table E-2, effect conditions in the Status Quo and the three oil and gas development scenarios for the ***Physical and Biological VCs*** range from negligible to low. Potential environmental effects on all VCs should be manageable through project planning and design, environmental protection and mitigation. The Status Quo scenario and low intensity development (Scenario 2) are expected to result in negligible effect conditions on all biophysical VCs. Moderate and high intensity development (Scenarios 3 and 4) are expected to result in low effect conditions for Sea Ice, Marine Fish and Habitat, Migratory Birds, Seabirds, and Marine Mammals, and negligible effect conditions for the remaining biophysical VCs. High intensity development would also result in a low effect condition for Marine Lower Trophic Levels.

[9] Details on predicted residual effects and mitigation measures are provided in Appendix D; mitigation measures are summarized in Section 9.2 and listed in Appendix F. Recommendations for monitoring needs related to potential effects that result from these routine activities are discussed in Section 9.3.

Table E-2 Potential Residual Effect Conditions of VCs under Each Development Scenario

Development Intensity →				
Possible Scenarios →	**Scenario 1** Status Quo	**Scenario 2** Export of Natural Gas and Condensate	**Scenario 3** Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf	**Scenario 4** Large Scale Oil Development within Exploration Licenses on the Continental Slope
Physical VCs				
Atmospheric Environment (Air Quality, GHG, Noise, Light)				
Climate and Weather	NA	NA	NA	NA
Oceanography (water quality)				
Sea Ice			Ice, Spring, Fall	Ice, Spring, Fall
Coastal Dynamics and Sea Floor Geology				
Coastal Habitat				
Biological VCs				
Marine Lower Trophic Levels				Year-round
Marine Fish and Habitat			Open Water	Open Water
Migratory Birds			Spring, Open Water	Spring, Open Water
Seabirds			Spring, Open Water, Fall	Spring, Open Water, Fall
Marine Mammals			Year-round	Year-round
Polar Bear				
Caribou				
Human VCs				
Economy	Year-round	Year-round	Year-round	Year-round
Demographics		Year-round	Year-round	Year-round
Infrastructure		Year-round; Year-round	Year-round; Year-round	Year-round; Year-round
Traditional Activities		Year-round; Year-round	Year-round; Year-round	Year-round; Year-round
Cultural Vitality		Year-round	Year-round	Year-round
Public Health	Year-round			

Potential Residual Effect Condition	
	high adverse effect condition
	moderate adverse effect condition
	low adverse effect condition
	negligible effect condition
	low positive effect condition
	moderate positive effect condition
	high positive effect condition

NOTE: Seasons when effect conditions would be present are indicated. Split cells indicate that certain scenarios may result in both adverse and positive effect conditions.

Effects on socio-cultural and economic VCs within the BRSEA Study Area are variable and range from high positive effect conditions through to medium adverse effect conditions; specifically:

- All scenarios are expected to result in positive effect conditions (i.e., improved benefits) to the ***Economy*** due to employment of residents from the ISR, purchase of goods and services from Inuvialuit and other local businesses, activities involving the transfer of equipment, materials, and personnel, and taxes and royalties. Effect conditions are expected to range from a moderate benefit for Status Quo to a high benefit for the three development scenarios.
- ***Demographic effects*** reflect the potential for projects to help retain residents and attract new residents and workers within the ISR (due to job availability and economic benefits); effect conditions range from negligible for Status Quo to low benefits for Export of LNG and Condensate (Scenario 2) and moderate benefits for the offshore oil developments (Scenarios 3 and 4).
- Effect conditions for ***Infrastructure*** are a mixture of adverse effects due to increased pressure on local and regional infrastructure, utilities, waste management and services (e.g., medical and emergency), and improved benefits associated with potential upgrading of existing infrastructure, building of new infrastructure, improved resiliency of new and improved infrastructure to climate change, and associated legacy benefits. Effect conditions are negligible for Status Quo. For the three oil and gas development scenarios, effect conditions are expected to include a mixture of low adverse effects and low benefits (e.g., energy security).
- ***Traditional Activities*** can be adversely affected by direct interference with harvesting activities and associated travel, as well as indirect effects on harvesters (e.g., noise or presence of activities and operations) or changes in the distribution and abundance of harvested species. However, a wage economy may help individuals purchase equipment and supplies to support traditional activities. Flexible work schedules and rotations may also allow individuals to participate in the wage economy and still participate in traditional activities. Effect conditions are expected to be negligible for the Status Quo, low benefits and medium adverse for export of LNG and condensate (Scenario 2) (due to the potential for greater overlap of development activities with nearshore traditional harvesting) and, low adverse and low benefits for Scenarios 3 and 4.
- ***Cultural Vitality***, like Traditional Activities, is expected to experience a mixture of adverse and positive effect conditions. Wage economies and the presence of increased industrial activities in the BRSEA Study Area could reduce participation of Inuvialuit in traditional activities, the use of traditional and cultural sites and travel routes, participation in creative expression, and the use and transmission of the Inuvialuktun language. However, wage economies also could allow individuals to purchase equipment and supplies to support cultural activities and associated travel to cultural sites. Government and corporate programs could also help sustain the use of Inuvialuktun and support Inuvialuit art, cultural activities and traditional harvesting. The Status Quo is expected to result in negligible effect conditions for Cultural Vitality while the three oil and gas development activities are expected to lead to low adverse effect conditions (i.e., adverse effects are expected to slightly outweigh the positive effects).

- ***Public Health*** includes aspects such as physical and mental health outcomes, personal health, community and family health, social determinants of health, and health risk behaviours. Health behaviours can be influenced both positively and negatively by changes in household income that could result from wage employment. The Status Quo is expected to result in low adverse effect conditions on Public Health, continuing the current declining trend in Public Health. The three oil and gas development scenarios would likely result in negligible effect conditions on Public Health (i.e., some adverse effects but potential for benefits through improvements in programs and facilities).

E4.2 Effects of Routine Industrial and Human Activities

To summarize how different routine industrial and human activities might affect VCs, activities from the Status Quo and the three oil and gas development scenarios were sorted into six categories:

- vessels (commercial, recreational, ice-breaking)
- seismic surveys
- offshore structures and related activities (e.g., drilling, pipelines, dredging)
- aircraft activities (fixed wing and helicopters)
- routine discharges and waste management
- logistical and administrative facilities

Since these routine activities could occur throughout the BRSEA Study Area at varying intensities depending on the scenario, effect conditions were ranked and shaded as adverse (blue), negligible (white), positive (green) or mixed (gray) effects (Section 8.4.2.1) (Table E-3). More detailed considerations of the geographic scope, duration, and magnitude effect characteristics, as were done in Table E-2, were not possible given the large range of effects from these activities across scenarios and seasons. Residual effect conditions for different types of activities (Table E-3) assume that mitigation measures applicable to routine operations for each of these activities have been implemented[10].

Vessels: Operation and movement of vessels are expected to result in negligible or adverse effect conditions for physical and biological VCs and some Human VCs (i.e., Infrastructure, Traditional Activities, Cultural Vitality and Public Health). These adverse effect conditions result primarily from noise, light, GHGs and other air emissions, habitat disturbance and displacement of biota, wildlife mortality, and increased pressures on infrastructure. However, vessels can also result in positive effect conditions for the Economy and Demographics VCs, associated with infrastructure improvements and development, capacity building, and job opportunities. These same aspects could result in a mix of adverse and positive effect conditions for the Infrastructure, Traditional Activities, Cultural Vitality and Public Health VCs. Because all vessels carry fuel either as cargo or propellant, their increased presence and movement in the BRSEA Study area increases the risk of oil spills.

[10] Details on predicted residual effects and mitigation measures are provided in Appendix D; mitigation measures are summarized in Section 9.2 and listed in Appendix F. Recommendations for monitoring needs related to potential residual effects that may result from these routine activities are discussed in Section 9.3.

Table E-3 Potential Residual Effect Conditions of VCs for Selected Types of Activities

Activities	Vessels (commercial, recreational, ice-breaking)	Seismic Surveys	Offshore Structures and related activities (e.g. drilling, pipelines, dredging)	Aircraft activities (helicopters and planes)	Routine Discharges and Waste Management	Logistical and Administrative Facilities
Physical VCs						
Atmospheric Environment (Air Quality, GHG, Noise, Light)	Noise, light, air quality	Noise, light, air quality	Noise, light, air quality	Noise, light, air quality		Light
Climate and Weather	GHG emissions count towards Canada GHG targets	GHG emissions count towards Canada GHG targets	GHG emissions count towards Canada GHG targets	GHG emissions count towards Canada GHG targets		
Oceanography (water quality)			Water quality through increased suspended sediments		Water quality through grey water discharges	
Sea Ice	Black carbon on ice		Black carbon on ice	Black carbon on ice		
Coastal Dynamics and Sea Floor Geology			Dredging, pipelines and drilling impacts on coastal erosion and sub-sea permafrost			
Coastal Habitat			Dredging and pipeline impacts on coastal habitat			Coastal habitat disturbance
Biological VCs						
Marine Lower Trophic Levels			Minor impacts on plankton; dredging, pipelines and drilling impacts on benthos		Habitat quality impacts	
Marine Fish and Habitat	Coastal habitat disturbance	Seismic noise effects on behaviour, physiology, mortality of eggs, larvae and benthic species	Dredging, pipelines and drilling impacts on fish benthic habitat			
Migratory Birds	Sensory disturbance from in-air noise and light		Sensory disturbance from light	Sensory disturbance from in-air noise		
Seabirds	Sensory disturbance from in-air noise and light; habitat disturbance from ice breaking	Seismic noise effects on behaviour of diving seabirds	Sensory disturbance from light	Sensory disturbance from in-air noise		
Marine Mammals	Habitat disturbance through ice-breaking, collision and entrapment risk	Seismic noise effects on behaviour, physiology, mortality of marine mammals		Sensory disturbance from in-air noise		
Polar Bear	Habitat disturbance through ice-breaking		Habitat alteration			
Caribou	Habitat disturbance through nearshore ice-breaking			Sensory disturbance from in-air noise		
Human VCs						
Economy	Increased employment from tourism	Increased employment	Increased employment	Increased employment from tourism and increased commercial traffic		Real estate development
Demographics	Reduce out-migration or increase immigration with increased job opportunities		Reduce out-migration or increase immigration with increased job opportunities	Reduce out-migration or increase immigration with increased job opportunities		Reduce out-migration or increase immigration with increased job opportunities
Infrastructure	Use of on-shore infrastructure development or increased maintenance, increased use Industry improvements in marine infrastructure		Use of on-shore infrastructure development or increased maintenance, increased use Industry improvements in marine, airports, roads, municipal and other	On-shore infrastructure development or increased maintenance, increased use Improvements in airports and roads		Real estate development Improvements in airports, roads, municipal and other infrastructure
Traditional Activities	Reduced participation and food security; subsistence activities could be affected through changes in harvested species Wage economy could allow improvements in equipment and supplies for harvesting	Reduced participation and food security; subsistence activities could be affected through changes in harvested species	Reduced participation and food security; subsistence activities could be affected through changes in harvested species Wage economy could allow improvements in equipment and supplies for harvesting	Reduced participation and food security; subsistence activities could be affected through changes in harvested species Wage economy could allow improvements in equipment and supplies for harvesting		Wage economy could allow improvements in equipment and supplies for harvesting
Cultural Vitality	Adverse effects through changes in harvested species and presence of non-Inuvialuit; benefits from language programs and wage economy	Adverse effects through changes in harvested species	Adverse effects through changes in harvested species and presence of non-Inuvialuit; benefits from language programs and wage economy	Adverse effects through changes in harvested species		Adverse effects through presence of non-Inuvialuit; benefits from language programs and wage economy
Public Health	Impacts of these activities on public health could be positive and negative. The ability to generate more household income can lead to better education and training levels, which improves mental health and public health overall. Increased household incomes could also improve the ability of households to purchase market foods, but these may not be healthier than subsistence foods. Participation in wage-based employment could result in less time spent on traditional harvesting; however, greater disposable household income could also be used for the purchase of equipment and supplies needed to undertake harvesting activities. Human health risk may result from exposure to contaminants, including direct exposure, such as to airborne or waterborne contaminants, and exposure via the consumption of contaminated foods. The fear (or perception) that foods may be subject to contamination can also have health-related consequences, such as avoidance behaviours or mental stress. Impacts on cultural vitality may lead to a decline in public health.					

Potential Residual Effect Condition	
	Activity could cause adverse effect condition on VC
	Activity could have negligible effect condition on VC
	Activity could lead to positive effect condition for the VC
	Activity could result in positive or adverse effect conditions on VC

NOTE: Text in the cells provides a summary explanation of the effect pathways leading to the indicated effect condition.

Seismic Surveys: Aside from the potential impacts from the vessels themselves described above, underwater noise emitted during seismic operations has the potential to result in adverse effect conditions for Atmospheric Environment and Climate and Weather (e.g., various emissions), and for Marine Fish, Seabirds and Marine Mammals (e.g., mortality, injury and interference with behaviour and communications). Effect conditions for Traditional Activities and Cultural Vitality also could be adverse due to interference with activities and changes in harvested species. In contrast, positive effect conditions are expected for the Economy VC (e.g., training, job creation), and both adverse and positive effect conditions for the Public Heath VC.

Offshore Structures: Offshore structures and their related activities are expected to result in adverse effect conditions for most physical and biological VCs; adverse effect conditions are associated with noise, light, and air emissions, effects on water quality, and habitat disturbance at the ocean surface and the ocean floor. Effects conditions for Marine Mammals and Caribou are expected to be negligible. Effect conditions for some aspects of the Traditional Activities and Cultural Vitality VCs are expected to be adverse because of the indirect effects on physical and biological resources, potential interference with traditional and cultural activities (infrastructure and operations closer to shore would have a greater effect than developments further offshore), and the direct effect of an increased presence of non-Inuvialuit workers. The Economy, Demographics and some aspects of the Traditional Harvesting VCs would experience positive effect conditions due to training and employment from offshore activities, demographic benefits (e.g., in-migration to region including Inuvialuit and others), and onshore infrastructure upgrades and development. While the presence of offshore oil and gas structures in the BRSEA Study Area would increase the risk of oil spills, these activities are strongly regulated; projects would be required to employ measures to reduce the likelihood of operational accidents and be ready to respond quickly and effectively to spills.

Aircraft: Aircraft will emit noise, light and air pollutants that are expected to result in adverse effect conditions for the Atmospheric Environment VC (through GHG emissions and black carbon deposition), as well as for the Migratory Birds, Seabirds, Marine Mammals, Caribou, Traditional Activities and Cultural Vitality VCs through in-air noise and physical disturbances. However, standard and easily implementable mitigation measures (e.g., overflight exclusion zones, minimum flight altitudes) can effectively mitigate these effects. Increased aircraft activities could result in positive effect conditions for the Economy and Demographics VCs, and some aspects of the Infrastructure and Traditional Activities VCs through infrastructure improvements and development, increased employment opportunities, and positive demographic changes.

Routine Discharges and Waste Management: Because routine discharges and waste management are heavily regulated on an international and national basis and monitored, these activities are expected to result in a negligible effect condition for most VCs; the only exceptions are Oceanography and Marine Lower Trophic Levels which may experience adverse effect conditions due to changes in water and sediment quality.

Logistical and Administrative Facilities: Depending where and how the new facilities are constructed, they could result in adverse effect conditions for the Atmospheric Environment (increased light pollution) and the Coastal Habitat VCs. The development and use of logistical and administrative facilities would be a positive outcome from activities associated with Scenarios 1 to 4. New development would generate onshore employment opportunities, thus benefiting the Economy and Demographics VCs and some aspects of the Traditional Activities VC (e.g., ability to purchase new equipment and supplies). Depending on the scale of the developments and hiring practices, Cultural Vitality could be adversely affected through an increased presence of resident non-Inuvialuit workers but positively affected by a wage economy, and support for cultural activities and language retention.

E4.3 Large Oil Release Event

A large oil release event would result in adverse effect conditions for all VCs except Climate and Weather, although the adverse effects to VCs may differ based on the location and timing of the oil release, the susceptibility of the VC to oil, and the temporal and spatial overlap of the VC in relation to the oil release and trajectory (Table E-4).

For the physical environment, adverse effect conditions from an oil spill are expected to be most severe for the Oceanography (water quality) and Coastal Habitat VCs, both of which would affect other VCs such as Marine Lower Trophic Levels, Marine Fish and Habitat, Migratory Birds, Seabirds, Marine Mammals, Traditional Use, Cultural Vitality, and Public Health.

Clean-up activities for large oil releases could result in adverse effect conditions for the biophysical and human environment VCs, as well as require substantial increases in coastal vessel and aircraft traffic to support clean-up activities. Proponents and operators of a proposed future oil and gas project would be required to plan and be prepared to mobilize a spill response and have the financial resources to complete the clean-up of a spill and restore damaged areas.

E4.4 Cumulative Effects

Cumulative effects were assessed for the activities within Status Quo (Scenario 1) scenario, and separately for each of the three oil and gas development scenarios (Scenarios 2 through 4) in combination with the activities in Scenario 1. Cumulative effects were not assessed for a large oil release.

E4.4.1 Cumulative Effects and the Biophysical Environment

Few cumulative effects are expected for the physical environment VCs.

Cumulative effects could affect some biological VCs, especially where habitat disturbance from some activities may overlap with direct behavioural, physiological or health effects from others. For the Migratory Bird VC, disturbance effects resulting from multiple human activities could act cumulatively with changes in habitat quality and result in higher magnitude effects. For the Marine Mammal VC, the intensity, longer duration, and geographic overlap of human activities in Scenarios 1 to 4 could increase seasonal exposure to underwater noise events and have a measurable effect on marine mammal habitats in the region. In addition, the rapid shift in marine habitat quality and availability from climate change could amplify effects on Migratory Birds, Seabirds, Marine Mammals and Polar Bear to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change, resulting in higher magnitude effects than at present.

Table E-4 Potential Resdiual Effect Conditions of VCs for Scenario 5

Possible Scenario →	Scenario 5 Large Scale Oil Release	
Physical VCs		
Atmospheric Environment (Air Quality, GHG, Noise, Light)	Open Water	
Climate and Weather	NA	
Oceanography (water quality)	Year-round	
Sea Ice	Ice, Spring, Fall	
Coastal Dynamics and Sea Floor Geology	Spring, Open Water, Fall	
Coastal Habitat	Open Water	
Biological VCs		
Marine Lower Trophic Levels	Year-round	
Marine Fish and Habitat	Year-round	
Migratory Birds	Spring, Open Water	
Seabirds	Spring, Open Water, Fall	
Marine Mammals	Year-round	
Polar Bear	Year-round	
Caribou	Open Water	
Human VCs		
Economy	Year-round	
Demographics	Year-round	
Infrastructure	Year-round	Year-round
Traditional Activities	Year-round	
Cultural Vitality	Year-round	
Public Health	Year-round	

Potential Residual Effect Condition	
	high adverse effect condition
	moderate adverse effect condition
	low adverse effect condition
	negligible effect condition
	low positive effect condition
	moderate positive effect condition
	high positive effect condition

NOTE: Seasons when effects would be present are indicated. Split cells indicate that the scenario may result in both adverse and positive effect conditions.

Negligible cumulative effects from industrial and human activities in the four scenarios are expected on the Marine Lower Trophic Levels, Marine Fish and Fish Habitat, and Caribou VCs. However, climate change induced effects on Marine Fish and Fish Habitat could reduce the overall resiliency of populations and communities and result in lower ability to withstand effects from multiple activities.

E4.4.2 Cumulative Effects and the Human Environment

Cumulative effects on human environment VCs are likely to involve a combination of beneficial and adverse effects. Offshore development activities described in Scenarios 2 to 4, combined with activities of Scenario 1, would result in a beneficial cumulative effects to the Economic and Demographics VC within the ISR, NWT and Yukon through an increase in and diversification of employment opportunities. Cumulative effects on the Infrastructure VC are likely to occur but are difficult to predict; adverse effects from increased pressure on infrastructure, businesses and services may be balanced to some degree by infrastructure upgrades, new infrastructure and businesses, and improvements in existing infrastructure for resiliency to climate change.

Cumulative effects on Traditional Activities, Cultural Vitality and Public Health are predicted to be adverse. The direct and indirect effects of construction activities, offshore structures and increased vessel and air traffic could lead to changes in traditional harvesting and other cultural activities. Human-associated effects in combination with effects of climate change on harvested species and habitats may act synergistically to reduce the amount of traditional food per household, opportunities to transmit harvesting knowledge and culture activities between generations, and the use of Inuvialuktun and other Indigenous languages. Benefits of the wage economy and support of cultural programs and traditional activities by government and industry would help to balance some of these adverse effects.

Public health is a complex response to a variety of circumstances and, thus, is susceptible to potential cumulative effects associated with the wage economy, household income, traditional practices, and the availability of health and education services. Climate change could further influence the cumulative effects on Public Health by reducing traditional harvesting and consumption of traditional foods, as well as contributing to additional human health risks related to food spoilage and northward migration of insect and mammal disease vectors.

E4.5 Effects of Climate Change on Environmental Effects

Over the last few decades, TLK holders and western scientists have observed substantial changes in weather patterns and ice conditions in the BRSEA Study Area which could affect how industry may conduct their activities in the offshore, as well as modify the predicted range of environmental effects from industrial activities and human use. Climate change is also altering the baseline conditions of VCs and is likely to change potential effect pathways.

E4.5.1 Effects of Climate Change on the Physical Environment

While the effect of climate change on the Atmospheric Environment (e.g., air noise, and light emissions from increased vessel activity during a longer Open Water Season) is small, the effects on other physical VCs are expected to be substantial. The combined changes in sea ice extent, dynamic processes, and timing of sea ice formation and breakup are key effects of climate change that directly affect ongoing industrial and socioeconomic activities throughout the ISR. Climate change is also contributing to coastal erosion along all parts of the coastline of the BRSEA Study Area at varying rates depending on local and regional geological, permafrost and oceanographic conditions. Water temperatures are also rising due to loss of sea ice and warm water inputs to the Beaufort from the Pacific Ocean.

E4.5.2 Effects of Climate Change on the Biological Environment

From a biological perspective, climate change effects are likely to overwhelm effects on VCs from human activities (except for a large oil release; Scenario 5). Physical stressors on marine species (e.g., altered ocean temperature, reduced extent and quality of sea ice, increased ocean acidification) may shift species assemblages and distributions, affect species fitness, and make biological VCs less resilient to human pressures. The shift in the distribution of sea ice and open water habitat will adversely affect Marine Fish and Fish Habitat, Migratory Birds, Seabirds, and Marine Mammals by altering the timing of migration and length of time spent in the BRSEA Study Area. Changes in sea ice also could affect reproductive strategies, the distribution of prey species and alter available sea ice habitat.

E4.5.3 Effects of Climate Change on the Human Environment

The predicted effects of climate change on the Human Environment VCs and the effects from scenario related activities are mixed. Climate change effects on the Economy and Demographics could be beneficial or adverse. Climate change effects such as sea level rise, increases in storm surge frequency and strength, waves, sea ice extent and location, and permafrost degradation are predicted to adversely affect the Infrastructure, Traditional Activities and Cultural Vitality VCs in the BRSEA Study Area. These changes would directly and adversely affect travel and safety, as well as indirectly affect harvested species and the landscape. In turn, Public Health could be adversely affected through changes in food security, dietary changes and increased risk of disease. As for the biological VCs, the direct and indirect effects of climate change are likely to overwhelm any effects from local human activities on the Human VCs, except for the Economy.

E5 CONSIDERATIONS FOR FUTURE INFORMATION AND MANAGEMENT DIRECTIONS

As described in the Terms of Reference (Appendix A), the BRSEA is intended to support informed decision-making around possible future resource development and management, including offshore oil and gas development, as well as environmental conservation programs, community sustainability and subsistence activities, and other complementary commercial activities (Terms of Reference, Appendix A).

During the preparation of the Data Synthesis and Assessment Report, opportunities were identified to proactively manage adverse risk and improve the potential for benefits to biophysical, socio-cultural and economic VCs by applying concepts and outcomes of the assessment to future planning programs, policy directions, management approaches and perhaps legal instruments. In addition, information needs - pertaining to TLK and western science - were identified in relation to baseline data gaps, improving our understanding of effect pathways, monitoring the effectiveness of mitigation measures and best practices, and adaptive management (Chapter 9). Recommended management directions and information needs are described for:

- management of human, commercial and industrial activities in the Beaufort Region
- research and monitoring needs
- effects management
- planning, preparedness and response to a large oil release event

E5.1 Management of Human, Commercial and Industrial Activities in the Beaufort Region

A variety of human, commercial and industrial activities will continue to occur within the BRSEA Study Area over the next three decades, including traditional and local use, recreational use, community resupply, infrastructure development, coastal tourism, cruise ship activities, military patrols and exercises, shipping transits, and aircraft activity. Regardless of whether existing activities continue (e.g., Status Quo), new types of industrial projects are proposed (e.g., offshore wind energy, subsea mining), or some level of oil and gas development proceeds, impact management will require enforcement of existing federal, territorial, and local legislation, regulations and permitting requirements, as well as ongoing evolution of these instruments to adapt to changing conditions and technology. Adherence to international agreements (e.g., MARPOL) also will be required. There also will be a need to monitor performance and compliance of regulatory requirements and address deficiencies if identified.

A number of collaborative initiatives involving the federal government, the IRC, other Inuvialuit organizations, the Government of the Northwest Territories (GNWT) and Government of the Yukon, are currently underway to address a wide range of policy, planning and regulatory instruments that are consistent with the Inuvialuit Final Agreement. These include: jurisdictional controls, vessel management, management of cruise and coastal tourism, use and management of renewable and non-renewable resources, marine planning and protected areas, socio-cultural resiliency, and revenue sharing and benefits. These combined initiatives will support informed decision-making for future development and management that balance risks and benefits at local, regional and national scales, with an end goal of social and environmental sustainability, cultural vitality, complementary commercial activities and associated economic sustainability.

E5.2 Research and Monitoring Needs

While a wealth of TLK and western science has been gathered on the status and trends of the VCs for the BRSEA Study Area, an assessment of environmental effects, such as described in this report, require specific types of information and understanding that is not easily observed nor a frequent focus of scientific research. In summarizing relevant baseline information (Chapter 7) and conducting the detailed effects assessment (Appendix D), targeted research and monitoring needs were identified with respect to:

- establishing a better baseline for key VCs
- improving our understanding of effects of certain activities on VCs
- detecting potential effects and managing change

Specific research and monitoring needs are described for each of the physical, biological, socio-cultural and economic VCs in the detailed assessment (Appendix D) and are summarized in Section 9.2.

Consistent with the approach to the BRSEA, these research and monitoring programs should be co-lead by the IRC and the Government of Canada. Collaboration of Inuvialuit and western science specialists should occur throughout the full life cycle of each study or program to gain the greatest benefit from these two knowledge systems. Inuvialuit TLK holders and western scientists should be co-involved in the study scope and design, execution of the work, analysis and interpretation of information, reporting and communication of findings, and follow-up actions. In addition, Inuvialuit communities must have opportunities to be informed of the studies or programs and provide input during the planning stages, with regular updates and input as the study or program progresses. The Inuvialuit communities also must be provided with a final presentation on findings and conclusions (including providing digital and hard copies of materials and a public language summary).

E5.3 Effects Management

Approaches for management of environmental effects are discussed in relation to:

- environmental management and mitigation measures
- adaptive management

E5.3.1 Environmental Management and Mitigation Measures

The effects assessment in this report assumes that standard mitigation measures, best industry practices and environmental management requirements and conditions as specified in operating permits and licenses are followed to reduce environmental impacts from specific routine activities (e.g., vessels, seismic surveys, offshore activities, aircraft activities, routine discharges and management). Mitigation measures and environmental standards are summarized in Section 9.3.1 for the six types of routine activities (Section E4.2). In addition, measures are described to mitigate potential adverse effects on socio-cultural and economic aspects for communities in the ISR, NWT and Yukon. A full list of mitigation measures from the detailed effects assessment is provided in Appendix F.

E5.3.2 Adaptive Management

Managing complex-adaptive social-ecological systems requires an adaptive integrated approach that addresses the interplay between societal choices and the associated socio-cultural and ecological cumulative impacts. The focus is on managing human interactions with the ecological system, not about managing the ecological system (e.g., fisheries ecosystem-based management), or even one component of it (e.g., caribou). General principles, development, and implementation of an adaptive integrated management framework for the BRSEA Study Area are discussed in Section 9.3.2, with a focus on seven principal elements:

1. Goals
2. Governance
3. Indicators
4. Limits and Thresholds
5. Monitoring
6. Actions
7. Evaluations

An adapted integrated management framework that integrates key ecological, socio-cultural and management principles can move the current findings and recommendations forward to an actionable tool that would help to adaptively safeguard the social-ecological integrity and values of the ISR in the face of inevitable future changes.

E5.4 Planning, Preparedness and Response for a Large Oil Release Event

Effects of an accidental oil spill in the BRSEA Study Area on marine ecosystems, human uses and cultural vitality are of high concern to the Inuvialuit, other northern residents, government agencies and a broad range of public stakeholders in Canada and internationally. Although this report focuses on an accidental large oil release during offshore oil and gas activities, oil spill events also could result from a collision or accident involving large ocean-going vessels.

While a large oil release is a low probability event, a rapid, well-organized and effective spill response is critical to the overall success for spill containment, oil removal, site cleanup and site restoration. It is also important in reducing and managing effects of released oil on the biophysical environment and socio-cultural and economic aspects. A number of considerations for the BRSEA Study Area are described in Section 9.4 with respect to the command structure, the spill response organization, spill response planning, spill response preparedness, and adoption of new technology, tactics and decision-support tools. The end goal of these measures should be the establishment of a spill response structure and process that allows for rapid deployment of an initial local response by the Inuvialuit to contain and remove released oil, followed by deployment and management of appropriate tiers for spill response involving additional regional, national and international skills, resources, and equipment, as appropriate.

A multi-level government agency working group should lead this initiative[11]. For the BRSEA Study Area, members should include Transport Canada and the Canadian Energy Regulator (the regulators for ship-based and oil and gas related spills), in collaboration with the IRC, the GNWT and Government of the Yukon. Inuvialuit organizations and communities should be engaged in the planning of the spill response

[11] This working group could be similar to the existing Northwest Territories/Nunavut Spills Working Group.

organization and the development and updating of spill responses plans. In addition, Inuvialuit organizations and communities and regional organizations (e.g., Mackenzie Delta Spill Response Corporation, Canadian Rangers, Canadian Coast Guard Auxiliary) should be directly involved in spill preparedness, including establishment and maintenance of equipment caches, training, and participation in spill response drills.

E6 CONCLUSIONS

- Throughout the Data Synthesis and Assessment Report, Inuvialuit TLK and western science have been used together to provide valid, reliable information about environmental conditions and trends, environmental effects, and mitigation.
- In responding to future human use and industrial activities in the BRSEA Study Area, the Inuvialuit and the Government of Canada should co-lead initiatives on mitigation and management of environmental effects, addressing important knowledge gaps, planning and undertaking research, ongoing monitoring, and adaptive management, as well as planning and readiness for accidents and malfunctions.
- Climate change has and is continuing to adversely change the physical and biological environment and human uses and systems within the BRSEA Study Area. Effects of climate change will have a far greater influence on the sustainability and health of biophysical, socio-cultural and economic systems in the BRSEA Study Area than the effects of local industrial development and human use.
- Existing and future industrial uses and human activities in the BRSEA Study Area have resulted and could result in both adverse effects and improved benefits, some of which may act additively or synergistically with effects of climate change. Adverse effects are typically associated with impacts to the physical and biological environment and some aspects of the human environment (e.g., strains on Infrastructure and Public Health; changes in Traditional Activities and Cultural Vitality). Improved benefits largely occur through positive changes in the local and regional economy, increased employment and wage income, government and industry support of cultural programs and traditional activities, and possible development of new infrastructure.
- Adverse effects of activities associated with the Status Quo and the three oil and gas scenarios range from negligible to moderate and could be mitigated or managed effectively using project planning and design, existing mitigation measures and technology, conservation strategies, protected areas, and management plans.
- A large release of oil in the BRSEA Study Area, regardless of whether it is associated with current and future shipping, other human activities, or oil and gas development, would be a major threat to the physical, biological and human systems of the region. Measures to reduce the likelihood of an oil release from existing or future regional and Arctic transits by vessels or a future oil and gas development are critical to avoiding such spills. Advance spill response planning and preparedness is essential to being able to respond quickly and effectively and reduce impacts.
- Targeted research and monitoring programs are required to address current and critical information needs as identified through the data synthesis and assessment for the Status Quo and the three development scenarios.

- Monitoring and follow-up programs, including associated applied research, should employ TLK and western science to identify issues associated with environmental effects and the effectiveness of mitigation and management approaches, as well as to adapt these approaches to better address the issues of concern.
- The assessment of effects and the characterization of residual effects for the Status Quo and the three oil and gas development scenarios assumes that standard mitigation measures, best industry practices and environmental management requirements and conditions under operating permits and licenses will be followed to reduce environmental impacts from specific routine activities.
- Successful effects management requires the implementation of an adaptive management framework that integrates key ecological, cultural and management principles. Implementation of such a framework should capitalize on the substantial work and monitoring completed to date and, through an actionable plan, progress towards adaptively safeguarding the social-ecological integrity and values of the ISR in the face of inevitable future changes

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Appendices

Abbreviations

%	percent
μg/m^3	micrograms per cubic metre
μm	microns
2D	two dimensional
3D	three dimensional
4D	four dimensional
ABSORB	Alaskan Beaufort Sea Oil Spill Response Body
ACP	Arctic Community Pack
ALERT	Atlantic Emergency Response Team
ANMPA	Anguniaqvia Niqiqyuam Marine Protected Area
AR5	Assessment Report 5 (IPCC)
BOP	blowout protection
BREA	Beaufort Region Environmental Assessment
BRSEA	Beaufort Region Strategic Environmental Assessment
CBM	Community Based Monitoring
CCHIP	Climate Change Hazards Information Portal
CCP	Community Conservation Plan
CCSR-SRES-A1F1	Center for Climate System Research - Special Report on Emissions Scenarios A1F1
CEA Agency	Canadian Environmental Assessment Agency
CER	Canadian Energy Regulator
CERA	*Canadian Energy Regulator Act*
CH_4	methane

CIRNAC	Crown-Indigenous Relations and Northern Affairs Canada
cm	centimetre
CMIP	Coupled Model Intercomparison Project (number following abbreviation is the Phase number)
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COGOA	*Canadian Oil and Gas Operations Act*
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPRA	*Canada Petroleum Resources Act*
CPUE	catch per unit effort
CRI	Caisson retained Island
dB	decibel
dBA	A-weighted decibels
dBrms	decibel root mean square
DST	Drill stem testing
ECRC	Eastern Canada Response Corporation
EEM	Environmental Effects Monitoring
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIRB	Environmental Impact Review Board
EISC	Environmental Impact Screening Committee
EL	Exploration License
EMOBM	Enhanced mineral oil-based mud
EPP	Environmental Protection Plan

FIFO	Fly-In Fly-Out
FJMC	Fisheries Joint Management Committee
FOC	Frequency of Change
FPSO	Floating Production, Storage and Offloading
GBS	Gravity Based Structure
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNWT	Government of the Northwest Territories
GRP	Geographic Response Plans
GT CO_2	gigatons of carbon dioxide
GWP	Global Warming Potential
h	hour
ha	hectare
Hs	mean significant wave height
HTC	Hunters and Trappers Committee
IAA	Impact Assessment Act
ICS	Incident Command System
IDF	Intensity-duration-frequency
IFA	Inuvialuit Final Agreement
IGC	Inuvialuit Game Council
IMO	International Maritime Organization
INAC	Indian and Northern Affairs Canada
IPCC	International Panel on Climate Change
IRC	Inuvialuit Regional Corporation

ISB	In situ burning
ISR	Inuvialuit Settlement Region
KAVIK-Stantec	KAVIK-Stantec Inc.
km	kilometre
km/hr	kilometres per hour
kt	kilotonnes
LNG	Liquified Natural Gas
m	metre
m^2	square metre
MARPOL	International Convention for the Prevention of Pollution from Ships
MART	Marine Aerial Reconnaissance Teams
MDSRC	Mackenzie Delta Spill Response Corporation
mg/L	milligrams per litre
MPA	Marine Protected Area
MW	megawatt
N_2O	nitrous oxide
NEBA	Net Environmental Benefits Analysis
NM	nautical miles
NMR	Nuclear Magnetic Resonance
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NOTAMS	Notice to Pilots
NPRI	National Pollutant Release Inventory
NWT	Northwest Territories

OBM	Oil Based Mud
°C	degrees Celsius
OHF	Oil Handling Facilities
OROGO	Office of the Regulator of Oil and Gas Operations
OSC	On-Scene Commander
PAH	polycyclic aromatic hydrocarbon
PM_{10}	particulate matter of 10 microns in diameter or less
$PM_{2.5}$	particulate matter of 2.5 microns in diameter or less
Ppb	parts per billion
PSU	Practical Salinity Unit
RAT	Rapid Air Deployable
RCP	Representative Concentration Pathway
Rms	root mean square
RSEA	Regional Strategic Environmental Assessment
RSI	Risk Sciences International
RVA	Response Viability Analysis
SBM	Synthetic-Based Mud
SDL	Significant Discovery License
SEA	Strategic Environmental Assessment
SIMA	Spill Impact Mitigation Assessment
SLP	Sea Level Pressure
SO_2	sulphur dioxide
SPL	Sound Pressure Level
SSDC	Single steel drilling caisson

SST	Sea Surface Temperature
STOL	Short Takeoff and Landing Aircraft
t CO2e	tonnes of carbon dioxide equivalent
t/y	tonnes per year
TEK	Traditional Ecological Knowledge
TLK	Traditional and Local Knowledge
T_{mol}	Teramole
TNMPA	Tarium Niryutait Marine Protected Area
Tp	peak wave period
UC	Unified Command
UTC	Coordinated Universal Time
UV	ultraviolet
VC	valued components
VOC	volatile organic compounds
W/m^2	watt per square metre
WCMRC	Western Canada Marine Response Corporation

1 BACKGROUND

1.1 Beaufort Region Strategic Environmental Assessment and the Five Year Science Review

The background and context for the Beaufort Region Strategic Environmental Assessment (BRSEA) is described on the project website (https://brsea.inuvialuit.com/About; November 5, 2019); specifically:

> *"Following on the recommendations of the Beaufort Sea Strategic Regional Plan of Action, the Beaufort Regional Environmental Assessment (BREA) produced scientific and socio- economic data to inform regulatory decisions for oil and gas activities and integrated environmental management in the Beaufort Sea Region. ….. Partners in the BREA [Beaufort Region Environmental Assessment] expressed interest in continuation of the research and monitoring activities and established the Beaufort Region Strategic Environmental Assessment (BRSEA) to continue research and monitoring programs and prepare a regional strategic environmental assessment to support informed decision making around future resource development and management in the Beaufort Sea.*
>
> *Partners in the BREA have expressed an interest in ongoing commitments by Government to advance research and monitoring priorities related to resource management and conservation objectives. The BRSEA will provide an opportunity to ensure continuity and continued interest in the outcomes of the Beaufort Regional Environmental Assessment. Elements of the BRSEA will include: providing a framework in which to support efficient future environmental assessments and regulatory decision-making; examining the cumulative effects of multiple activities or forecasted development and conservation scenarios; setting desired economic and environmental outcomes and thresholds; addressing regional interests and policy issues; and, take into account the risks and benefits of changes In the state of the ecosystem."*

The purpose of the BRSEA in its entirety is to:

> *"…assess the potential effects, including cumulative effects, on the human and environmental systems of the Beaufort Sea Region as monitored through the Valued Ecosystem Components[13], of alternative strategic initiatives, plans or programs (collectively "Scenarios"), associated with potential offshore oil and gas activities in the Beaufort Sea Region. This assessment is therefore, not simply expanding the scope of the spatial and temporal boundaries of a particular project, rather, it encompasses a comprehensive examination of the interrelationships between the environment, social, cultural and economic conditions, the traditional use and wildlife harvesting of natural resources and decision-making by Inuvialuit, regulatory and planning authorities. The outputs of the BRSEA do not represent decisions, but rather the results of a systematic*

[13] The term Valued Component (VC) will be used in this report; it includes Valued Ecosystem Components and Valued Social Components. Additional details are provided in Section 4.1.1.1.

evaluation of options such that a strategic direction can be identified, and informed regional policies, plans, programs and project development decisions can be made." (Terms of Reference; Appendix A, this report)

The Data Synthesis and Assessment Report (this report) is one of the studies funded by the BRSEA.

1.2 Purpose of the BRSEA Data Synthesis and Assessment Report

KAVIK-Stantec Inc. (KAVIK-Stantec) was retained by the Inuvialuit Regional Corporation (IRC; represented by Duane Ningaqsiq Smith), the Inuvialuit Game Council (represented by various members) and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC; represented by Mark Hopkins) "to support the BRSEA through the development and delivery of an Assessment, Synthesis and Report Package for the Strategic Environmental Assessment for the Beaufort Sea Region." (Terms of Reference, Appendix A, this report). A Steering Committee for the BRSEA, made up of Jenn Parrot and Bob Simpson of the IRC and Daniel Van Vliet and Martin Tremblay of CIRNAC, provided ongoing direction to KAVIK-Stantec.

Using Traditional and Local Knowledge (TLK) and western science, the goal of this Data Synthesis and Assessment Report is to provide the Co- Chairs (IRC, IGC and CIRNAC) with an understanding of the type and potential outcomes of likely adverse effects and benefits that might arise from different types and intensities of oil and gas activities, other industrial activities and human use in the BRSEA Study Area. This includes understanding the mechanisms through which adverse effects and benefits occur, as well as the aspects that influence the severity or extent of these likely adverse effects and benefits with the intent of informing future research decisions, legislation and policies, industry guidance and community engagement and involvement. Based on the Terms of Reference (Appendix A), the Data Synthesis and Assessment Report project has the following technical objectives:

- Document the current status, trends and predict future conditions of the Valued Components (VCs) identified in the Terms of Reference.
- Identify the potential interactions between offshore oil and gas activities and the VCs, including the mechanisms by which these activities may affect the VCs.
- Evaluate the potential adverse effects and benefits to VCs under a range of development scenarios, including activity-specific and cumulative effects.
- Assess how climate change may affect the baseline state of VCs, as well as effect pathways and the characteristics of predicted effects.
- Provide recommendations for the mitigation, monitoring and management of potential adverse effects and benefits to VCs.
- Identify important data gaps and provide recommendations on how to address these data gaps.
- Prepare a Data Synthesis and Assessment Report, which incorporates western science and TLK, to support the preparation of the Strategic Environmental Assessment report by the Co-Chairs.
- Based on the Data Synthesis and Assessment Report, prepare Knowledge Transfer Materials in support of community engagement activities in the Inuvialuit Settlement Region (ISR).

1.3 Scope and Limitations

The conduct of a Strategic Environmental Assessment (SEA) is a complex undertaking. It requires synthesis of information about existing conditions, development of scenarios for use in the strategic assessment, assessment of effects (including activity-specific and cumulative effects), and predictions of future conditions (including potential effects of climate change). Because a strategic assessment is meant to inform future management decisions and policy, it is regional in nature, focusing on potential effects pathways, not project-specifics. As such, for this assessment, potential activities, infrastructure and effects are neither site-, nor temporally-specific.

As a result of oil and gas activity in the Beaufort Region over the past 60 years, a large volume of TLK and western science data has been collected and compiled on the biophysical environment, socio-cultural aspects (including traditional use) and economic impacts. This knowledge spans existing conditions and trends, climate change, impacts of oil and gas and other human activities, cumulative effects, effects of the environment on projects, mitigation and environmental protection, benefit programs, and accidents and malfunctions (including oil releases and spill response). Because this volume of primary information is challenging, a full synthesis of what is known on every topic in not within the scope of this Data Synthesis and Assessment.

The development of future scenarios for use in the assessment was strongly influenced by the long history of oil and gas activities in the BRSEA Study Area, and the familiarity of the Inuvialuit, federal and territorial governments and industry with past projects. Of note, the scenarios needed to realistically reflect how certain activities have been and would be carried out, but not be so specific as to jeopardize the regional nature of the assessment.

The Data Synthesis and Assessment project was formally initiated on March 26, 2019, with a final report due within approximately 12 months. This relatively short time period required that the strategic assessment be tightly scoped to focus on the VCs of greatest importance to the Inuvialuit, and the effects most likely to affect the sustainability of the selected biophysical, socio-cultural and economic VCs. These time and budget driven limitations do not detract from the value of the BRSEA but help define scope and focus and set realistic expectations as to its outcomes. These include:

- While assessors for the VCs did use and cite a large number of primary sources, they also had to rely heavily on existing compendia and syntheses of technical information (western science). The Data Synthesis included in this report is not a comprehensive review of all information; instead the review focuses on TLK and western science that directly inform the scoping and assessment of environmental effects.
- Traditional knowledge sources were focused on sources identified by the IRC; these focused on sources from the Inuvialuit and industry-funded studies that the IRC felt were most useful to the BRSEA.

- Discussions of regulatory requirements, existing conditions, potential effects, mitigation measures, and recommendations monitoring are general in nature given the regional nature of the assessment, and that the development scenarios are not spatially- and temporally-specific.
- No quantitative physical, biological or economic modelling was undertaken to predict the effects of potential future development on VCs. Instead the assessment is informed by information from TLK and western science on past trends; an understanding of the physical and biological marine systems and the people that depend on them; and in depth insights into activities associated with oil and gas developments, their potential effects, best practices, and proven mitigation measures.
- To incorporate potential effects of climate change in the assessment, a single Representative Concentration Pathway (RCP 8.5) and a 30-year horizon were selected for use in the Data Synthesis and Assessment Report (Section 6). Although limited re-analyses of data was conducted, the predictions of key physical variables under RCP 8.5 are based on a review of current forecasts and information. Predictive modelling of the potential effects of climate change on specific VCs was outside the scope of this assessment. Instead, these potential effects are based on scientific references, TLK and professional judgement.
- While some original figures and summary tables were prepared specifically for the Data Synthesis and Assessment Report, the authors largely relied on existing figures and summary tables where possible.

1.4 BRSEA Governance and Coordination

The Inuvialuit (represented by the IRC and Inuvialuit Game Council (IGC)) and the Government of Canada (represented by CIRNAC) are responsible for leading the BRSEA (Appendix A, Terms of Reference). As a Co- Chair, the IRC is responsible for coordinating the participation of Inuvialuit groups, including the IGC, other Inuvialuit organizations and communities in the ISR. CIRNAC is responsible for coordinating the participation of federal departments and agencies in the BRSEA, including the Department of Fisheries and Oceans Canada, Environment and Climate Change Canada, Natural Resources Canada, Canadian Coast Guard, and Transport Canada.

An Advisory Committee was established to provide advice to the Co- Chairs on the BRSEA, based on their specific perspectives. Members of the Advisory Committee (In alphabetic order) are:

- ArcticNet
- Canada Energy Regulator
- Canadian Association of Petroleum Producers
- Canadian Coast Guard
- CIRNAC Canada
- Department of Fisheries and Oceans Canada
- Government of the Northwest Territories
- IGC
- IRC
- Joint Secretariat
- Polar Knowledge Canada
- Yukon Government

1.5 Summary of Community Engagement for BRSEA

The Co-Chairs have actively engaged the Inuvialuit communities throughout the BRSEA process. Key meeting and activities are summarized in Table 1-1. Public comment on drafts of this report were requested through the BRSEA Online Public Comment Forum.

Following the completion of the draft final report, the Co-Chairs will prepare knowledge transfer materials for use during follow-up community and stakeholder engagement activities; these include:

- a summary of findings for the BRSEA
- a plain language synthesis report suitable for distribution within the ISR
- presentation materials (e.g., presentation decks, fact sheets, etc.) suitable for use by the Co-Chairs in presentation to regional stakeholders

1.6 Temporal and Spatial Limits

This assessment considers the potential environmental effects for a range of future activity scenarios in the BRSEA Study Area (Section 3).

The temporal limit of the assessment is from 2020 to 2050; this 30-year duration reflects a reasonable time horizon for:

- Climate change: changes in climate will continue to alter biophysical and socio-cultural conditions in the region. Prediction of responses by the biological environment and socio-cultural and economic aspects to climate change become increasingly speculative beyond 30 years given these complex adaptive systems.
- Technology: Technology to support different phases of oil and gas exploration and development and measures to reduce carbon emissions are rapidly advancing and changing. It is increasingly difficult to envision technological advancements beyond ten years. The same applies to oil spill response technology.
- Hydrocarbon Demand and Uses: Demand and uses are expected to change as global communities shift to a lower carbon economy. The impact of this shift on far future (i.e., beyond 2050) oil and gas activities in the Beaufort is not known.

As the assessment is intended to support management decisions and policy around future offshore oil and gas activity in the Beaufort Sea, the spatial limit of the assessment is the marine areas of the ISR (i.e., the Canadian Beaufort Sea up to the ordinary highwater mark of the coastlines within the ISR[14]) (Figure 1-1). Environmental effects on land areas and fresh water within the ISR, including the Mackenzie River delta, are outside the scope of this assessment.

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[14] Under the Northwest Territories Lands and Resources Devolution Agreement and the Yukon Act and Devolution Transfer Agreement, the administration and management of coastal areas falls under the jurisdiction of the government of the NWT and Yukon, as well as the IRC, depending on the specific resource or use. The BRSEA Study Area, for the intent of this assessment, includes lands referred to as the Adjoining Area under the Yukon Act.

Table 1-1 Community Engagement Activities for the BRSEA (2017-2019)

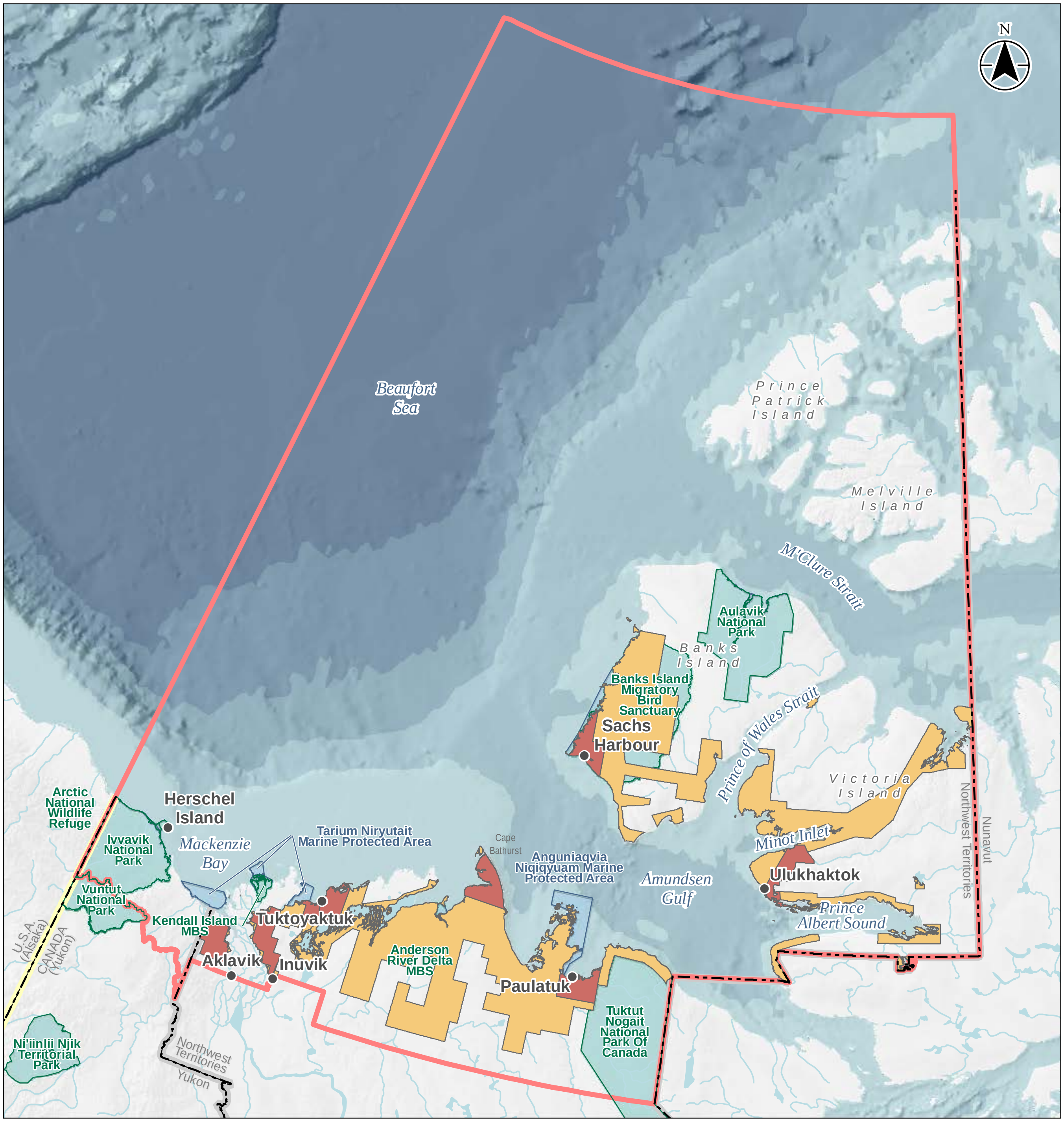
Activity	Participating Organizations	Communities	Goal of Tour
1st BRSEA Community Engagement Tour (Spring 2017)	• Inuvialuit Regional Corporation • Inuvialuit Game Council • Fisheries Joint Management Committee • Crown-Indigenous Relations and Northern Affairs Canada • Hunters and Trappers Committees • Community Corporations • Community K-12 Schools • Community members	• Sachs Harbour (March 29, 2017) • Aklavik (March 31, 2017) • Inuvik (April 4, 2017) • Tuktoyaktuk (April 5, 2017) • Paulatuk (April 6, 2017) • Ulukhaktok (April 6, 2017)	• provide introduction to the BRSEA • discuss cumulative effects indicators • seek input on process • discuss development of science priorities
Traditional Knowledge Community Tour (Fall 2017)	• Inuvialuit Regional Corporation • Inuvialuit Game Council • Crown-Indigenous Relations and Northern Affairs Canada • Hunters and Trappers Committee • Community Corporation • Elders Committees • Community members	• Aklavik (November 8 and 9, 2017) • Paulatuk (November 13, 2017) • Ulukhaktok (November 21, 2017) • Tuktoyaktuk (November 24, 2017) • Inuvik (November 27 and 28, 2017) • Sachs Harbour (November 28, 2017)	• mapping and discussion on the importance of the ice • mapping, interviews and surveys on key species of the Beaufort • discussing project design and interview questions on the role of harvest.
2nd BRSEA Community Engagement Tour (Winter 2018)	• Inuvialuit Regional Corporation • Inuvialuit Game Council • Fisheries Joint Management Committee • Crown-Indigenous Relations and Northern Affairs Canada • Hunters and Trappers Committees • Community Corporations • Elders Committees • Youth Committee • Community K-12 Schools • Community members	• Sachs Harbour (February 26, 2018) • Ulukhaktok (February 27, 2018) • Paulatuk (February 28, 2018) • Aklavik (March 1, 2018) • Inuvik (March 20, 2018) • Tuktoyaktuk (May 23, 2018)	• provide annual updates and reporting related to the BRSEA • seek community input on process and priorities • provide updates on the Inuvialuit Harvest Study

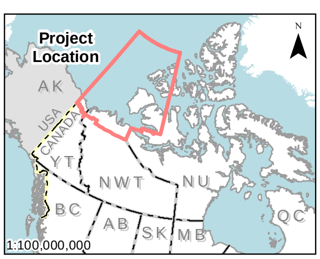
Table 1-1 Community Engagement Activities for the BRSEA (2017-2019)

Activity	Participating Organizations	Communities	Goal of Tour
3rd BRSEA Community Engagement Tour and Community Based Monitoring Program (March 2019)	• Inuvialuit Regional Corporation • Inuvialuit Game Council • Fisheries Joint Management Committee • Crown-Indigenous Relations and Northern Affairs Canada • Hunters and Trappers Committees • Community Corporations • Elders Committees • Youth Committee • Community K-12 Schools • Community members • Community-based Monitoring Program • KAVIK-Stantec	• Sachs Harbour – March 11, 2019 • Ulukhaktok – March 12, 2019 • Paulatuk – March 13, 2019 • Aklavik – March 14, 2019 • Inuvik – March 18, 2019 • Tuktoyaktuk – March 19, 2019	• overview of the BRSEA work, goals and objectives. • brief summary of the assessment steps used by KAVIK-Stantec • overview of the Inuvialuit Harvest Study and the 2018-2019 results • specific discussions on community harvests • engage K-12 students on EIAs and environmental change
BRSEA Online Data Verification Platform (April 2019)	• Hunters and Trappers Committees • Community Corporations • Elders Committees	• Tuktoyaktuk - 12 participants • Aklavik - 14 participants • Paulatuk - 7 participants • Sachs Harbour - 5 participants • Uluhaktok – 3 participants • Inuvik – 10 participants	• review and verify previously collected data associated with BRSEA research • quality control the data collection phase of all TLK-related BRSEA studies
4th BRSEA Community Engagement Tour (Winter 2019)	• Inuvialuit Regional Corporation • Inuvialuit Game Council • Crown-Indigenous Relations and Northern Affairs Canada • Hunters and Trappers Committees • Community Corporations • Elders Committees • Community members	• Tuktoyaktuk (November 6, 2019) • Aklavik (November 7, 2019) • Paulatuk (November 7, 2019) • Sachs Harbour (November 8, 2019) • Uluhaktok (November 8, 2019) • Inuvik (November 9, 2019)	• provide annual updates and reporting related to the BRSEA • seek community input on approach relative to use of TLK scenarios, and climate change predictions. as well as high level summaries of key effects for each scenario (by season). • seek community feedback on mitigation methods (e.g., ship routes) • discuss next steps

Table 1-1 Community Engagement Activities for the BRSEA (2017-2019)

Activity	Participating Organizations	Communities	Goal of Tour
BRSEA Online Public Comment Forum (Winter 2020)	• Forum was open to the public from January to March 2020	• 300 participants • 43% of respondents identified as Inuvialuit	• to engage all Inuvialuit beneficiaries or ISR residents • gather feedback on BRSEA report, engagement and activities
5th BRSEA Community Engagement Tour (Winter 2020)	• Inuvialuit Regional Corporation • Crown-Indigenous Relations and Northern Affairs Canada • Hunters and Trappers Committees • Community Corporations • Elders Committees • Youth Committee • Community K-12 Schools • Community members	• Aklavik (February 21, 2020) • Paulatuk (February 25-26, 2020) • Tuktoyaktuk (March 4, 2020) • Inuvik (March 5, 2020) • Ulukhaktok (March 9-10, 2020) • Sachs Harbour (Cancelled: COVID19)	• provide an update on the BRSEA report. • gather feedback, questions and comments on the BRSEA report and overall program • engage K-12 students on the BRSEA and associated research





- Community
- International Boundary
- Territorial Boundary
- Watercourse
- Waterbody
- Marine Protected Area
- Terrestrial Protected Area

Bathymetry Depth (m)

- < 200
- 200 - 1000
- 1000 - 2000
- 2000 - 3000
- > 3000

- Boundary of the Inuvialuit Settlement Region

Aboriginal Lands of Canada Legislative Boundaries

- 7(1)a Private Lands
- 7(1)b Private Lands

0 50 100 150 200 250 300 km

1:8,000,000 (at original document size of 11x17)

KAVIK-STANTEC

INUVIALUIT REGIONAL CORPORATION

Project Location
Beaufort Sea, Northwest Territories, Canada

Project Number 123513135
Prepared by LTRUDELL on 20200313
Discipline Review by JGREEN on 20200313

Client/Project
Inuvialuit Regional Corporation
Beaufort Region SEA

Figure No.
1-1

Title
The BRSEA Study Area includes all marine areas within the ISR

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Natural Resources Canada

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1.7 Seasonal Designations

Throughout this report, seasonal designations are described with respect to sea ice and water conditions (EPPR 2017) as opposed to calendar dates or seasons (i.e., winter, spring, summer and fall). These seasonal designations influence the distribution, intensity and types of traditional uses of marine areas by the Inuvialuit, while also reflecting major changes in the biophysical and human environment, including operational seasons for vessels and community re-supply barges. The seasons considered in this assessment are:

- **Ice**: characterized by a solid ice cover, which may be in motion but essentially is a continuous surface of ice that may be flat, hummocky, ridged, snow-free, snow covered or have ephemeral leads or patches of open-water. This also includes landfast ice.
- **Spring Transition (break-up)**: characterized by the breakup of the ice cover (ice floes, landfast ice. broken ice, melt pools and leads) with a geographically varying and constantly changing distribution of ice with respect to open water
- **Open Water**: the ice-free season, although individual ice floes or drifting pack ice may be present at any place or time
- **Fall Transition (freeze-up)**: characterized by the freezing of the surface waters with increasing amounts of ice cover (frazil, slush, pancakes and ice floes) with a geographically varying and constantly changing distribution of ice with respect to open water.

1.8 Outline of the Data Synthesis and Assessment Report for the BRSEA

The Data Synthesis and Assessment Report is made up of nine chapters plus references and appendices; The chapters are as follows:

- Chapter 1: Background - provides an overview of the BRSEA program, as well as the specific objectives, the temporal and spatial scope, limitations and other considerations for the Data Synthesis and Assessment Report. Community engagement is also discussed.
- Chapter 2: Oil and Gas Development Life Cycles - describes key legislation and regulations for oil and gas exploration and development in the ISR; the requirements for project-specific environmental assessment and permitting and community engagement; typical activities and phasing of activities over the life cycle of an oil or gas project in the region; important environmental considerations; potential accidents and malfunctions (including oil spills); and an overview of financial responsibilities for accidents and malfunctions.
- Chapter 3: Scenarios for the Strategic Environmental Assessment - describes the purpose of the five scenarios; the process for development and review of the scenarios; approval of the scenarios by the Co-Chairs; an overview of how different oil and gas projects might be supported by one or more land-based logistical centres; a high level review of how climate change may affect human and oil and gas activities; and the specific components and activities involved in each of the five scenarios.

- Chapter 4: Methodology for the Strategic Environmental Assessment - describes the specific steps and methods used to undertake the Strategic Environmental Assessment.
- Chapter 5: Traditional and Local Knowledge -describes the role of TLK in the Strategic Environmental Assessment; the sources of TLK sources used; how a TLK inventory was developed from these sources for use by the assessment team; and guidance to the assessment team on use of TLK.
- Chapter 6: Predictions of Climate Change - provides a high level overview of how a common set of climate change predictions (RCP 8.5) were developed for use in the assessment. A detailed description of the major physical climate changes that might occur over the period of 2020-2050 associated with RCP 8.5 is provided in Appendix C.
- Chapter 7: State of Knowledge – using TLK and western science, this chapter describes the current status of VCs with a focus on characteristics and conditions of most relevance to the assessment of future adverse effects and benefits.
- Chapter 8: Environmental Effects: Summary of Findings[15] - this chapter summarizes the main findings from the detailed assessment of environmental effects found in Appendix D. Using TLK and western science, the potential residual environmental effects that could result from each of the five scenarios are summarized for the physical, biological and human VCs. For the Status Quo and the three oil and gas development scenarios, residual effects are summarized relative to (i) how an increasing intensity of industrial development and human activities might alter potential residual effects to the VCs; and (ii) how different types of routine industrial and human activities (regardless of development scenario) can result in different residual effects to the VCs. Residual effects of a large oil release and cumulative effects on VCs are also summarized. Effects of climate change on the residual effects (e.g., potential effect pathways and characteristics) and on the VCs (e.g., changes in seasonal distributions) are also described.
- Chapter 9: Recommended Information and Management Directions – using TLK and western science, this chapter provides a summary of recommended information needs, monitoring, follow-up programs, and effect mitigations detailed based on the detailed effects assessment in Appendix D. It also suggests management directions to improve our understanding of baseline conditions and effects, and explores elements for successful effects management. These combined considerations are intended to "support informed decision-making around possible future resource development and management in the BRSEA Study Area".
- Chapter 10: References – provide the citations for TLK and western science that were referenced in the Data Synthesis and Assessment report, including all its appendices.

[15] Chapter 8 is a summary of environmental effects based on the detailed assessment of environmental effects in Appendix D.

There are also six appendices:

- Appendix A: Terms of Reference: Beaufort Region Strategic Environmental Assessment (BRSEA), Synthesis and Report Package
- Appendix B: List of Traditional and Local Knowledge (TLK) Source used in the TLK Inventory
- Appendix C: Climate Change Predictions for the Strategic Assessment. (Note: this appendix provides detailed information on climate change predictions. Chapter 6 is a summary of the information in the appendix.)
- Appendix D: Detailed Assessment of Potential Environmental Effects to the Biophysical and Human Environment (Note: this appendix provides detailed information on the assessment of environmental effects and cumulative effects by VC and scenario. It also describes potential effects of climate change on environmental effect pathways and the assessment.)
- Appendix E: Summary of Residual Effects by Valued Component and Scenario
- Appendix F: Summary of Mitigation Measures by Activity and Valued Component

2 OIL AND GAS DEVELOPMENT LIFE CYCLES

2.1 Purpose of the Overview

The overview of oil and gas development life cycles in the Beaufort Region is intended to provide readers with a general and high level background on how oil and gas development has proceeded in the past and might proceed in the future; this section includes information on:

- the history of offshore oil and gas in the region
- management regimes for offshore oil and gas projects
- regulatory requirements for project approvals, environmental protection and project execution
- requirements for community consultation and engagement
- the sequence of activities associated with development of oil and gas resources in offshore areas
- the types of activities and a high level description of equipment used to support different phases of oil and gas development
- brief description of well management and control, including blowout protection (BOP) valves
- types of support vessels and infrastructure used in offshore oil and gas development
- approaches for logistical support of offshore oil and gas development
- requirement for benefits agreements and local and Inuvialuit economic development
- oil spill response, including information on management regimes and responsibilities, response planning requirements and processes; type of response actions and equipment; and financial liability for spills

This overview is not intended to be a comprehensive compendium for any of these topics. Rather, the information is offered to provide readers with a better understanding of the breadth of regulatory and permitting processes and requirements for offshore oil and gas projects and the timelines and steps to advance from initial exploration, to field development, production and decommissioning. The assessment of the three oil and gas development scenarios, as described in this report, are based on full compliance with the required permitting processes and regulatory requirements, as well as development of benefit agreements with the Inuvialuit.

2.2 History

The history of oil and gas activities in Mackenzie Delta and Beaufort Sea are discussed by LTLC Consulting and Salmo Consulting Ltd. (2012) and CAPP (2017). Between 1972 and 2006, a total of 92 offshore exploration wells were completed in the Canadian Beaufort Sea (LTLC Consulting and Salmo Consulting Ltd. 2012).

Based on these two reports, and additional input from the IRC, CIRNAC and some members of the Advisory Committee, key activities and dates are summarized in Table 2-1. This summary is intended to provide a high level overview of the scope and scale of activity, as well as applicable government initiatives with respect to legislation, regulations, guidelines and policy. It is not intended to be a comprehensive summary of all activities or initiatives that have occurred in the BRSEA Study Area with respect to offshore oil and gas exploration and development.

Table 2-1 Key Activities and Events with respect to Oil and Gas Activities in the BRSEA Study Area

Year	Activity	Details
1957	Reconnaissance aerial surveys	Reconnaissance-level ground and air studies
1961	Exploration drilling	First exploratory drilling in the Mackenzie Delta.
1974	Project Proposal	First proposed Mackenzie Valley Pipeline
1972-1973	Exploration Drilling	First offshore exploration well drilled in the Beaufort Sea on Hooper Island (Imperial)
1973-1976	Exploration drilling	Use of artificial islands (sandbags, sacrificial beaches); 11 programs
1976-1979	Exploration Drilling	First use of a drillship for offshore exploration drilling (Canmar); four wells drilled
1982	Exploration Drilling	Use of concrete caisson (Tarsuit) at Tarsiut (Gulf)
1983	Exploration Drilling	Use of the SSDC (Single steel drilling caisson) barge to drill Uviluk (Dome)
1983	Exploration Drilling	Use of the CRI (Caisson retained Island) to drill Kadluk site (Imperial)
1983	Exploration Drilling	Use of the Kulluk (a customized round drill ship) to drill Amauligak (Gulf)
1984	Exploration Drilling	Use of the Mollikpaq (a steel bottom-founded drill platform) to drill West Tarsiut (Gulf)
1986	Regulatory	National Energy Policy terminated
1986	Regulatory	Canada Petroleum Resources Act comes into force
1989	Exploration Drilling	Imperial Oil Isserk well spudded
2006	Exploration Drilling	Use of SSDC to drill the Paktoa Site (Devon 2004a); (last exploration well drilled)
2008-2012	Seismic and Exploration Drilling	Ajurak and Pokak deep water sites (Imperial Oil Ventures Limited and British Petroleum); seismic completed and Project Description filed for exploration drilling (exploration drilling did not occur)
2009	Regulatory	New Canada Oil and Gas Drilling and Production Regulations come into effect
2009	Planning	The Integrated Oceans Management Plan for the Beaufort Sea: 2009 and beyond is completed following several years of planning efforts by the Inuvialuit, Territorial and Federal government departments, management bodies, and northern coastal community residents.

Table 2-1 Key Activities and Events with respect to Oil and Gas Activities in the BRSEA Study Area

Year	Activity	Details
2010	Planning	Tarium Niryutait Marine Protected Area, made up of three individual areas - Niaqunnaq, Okeevik, and Kittigaryuit in proximity to the Mackenzie River delta - is established.
2010-2011	Regulatory	Arctic Offshore Drilling Review and guidelines
2011	Regulatory	Confirmation of the same-season relief well policy
2016	Planning	Anguniaqvia niqiqyuam Marine Protected Area, located in Darnley Bay, NWT, is established
2016	Regulatory	Prime Minister Justin Trudeau announces that Canadian Arctic waters are indefinitely off limits to new offshore oil and gas licencing, to be reviewed every five years through a science-based review
2018	Regulatory	Government of Canada announces the “Next Steps on Future Arctic Oil and Gas Development” which includes a freeze on the terms of the existing licences in the Arctic offshore; co-development of the scope and governance framework for a science-based, life-cycle impact assessment review; and a Beaufort Sea oil and gas co-management and revenue sharing agreement with the governments of the Northwest Territories, Yukon and the IRC
2019	Regulatory	Changes to the Canadian Petroleum Resources Act made by Bill C-88 gave the federal cabinet the power to prohibit certain oil and gas work in Arctic offshore areas, and the authority to freeze the terms of licence holders in those areas during the ongoing moratorium
2019	Regulatory	Order Prohibiting Any Work on Existing ELs and SDLs in the Beaufort Sea

2.3 Management Regimes for Offshore Oil and Gas in the Canadian Beaufort Sea

The management of offshore oil and gas resources in the Canadian Beaufort Sea involves Inuvialuit organizations and federal government agencies. The Government of the Northwest Territories and Yukon Government also have legislative mandates that include some aspects relevant to offshore oil and gas. The following is an overview of the management regimes for offshore oil and gas in the BRSEA Study Area; it is not intended to be a comprehensive overview of all management roles and responsibilities.

2.3.1 Inuvialuit Final Agreement

The Government of Canada and the Inuvialuit signed the Inuvialuit Final Agreement (IFA) in 1984 and amended the agreement in 1987 (Indian and Northern Affairs Canada [INAC] 1987). It was the first comprehensive land claim agreement signed north of the 60th parallel and only the second in Canada at that time (http://irc.inuvialuit.com/inuvialuit-final-agreement; November 05, 2019).

The basic goals of the IFA, as expressed by the Inuvialuit and recognized by Canada, are to:

- preserve Inuvialuit cultural identity and values within a changing northern society
- enable Inuvialuit to be equal and meaningful participants in the northern and national economy and society
- protect and preserve the Arctic wildlife, environment and biological productivity. ((https://www.irc.inuvialuit.com/document/inuvialuit-final-agreement; November 5, 2019)

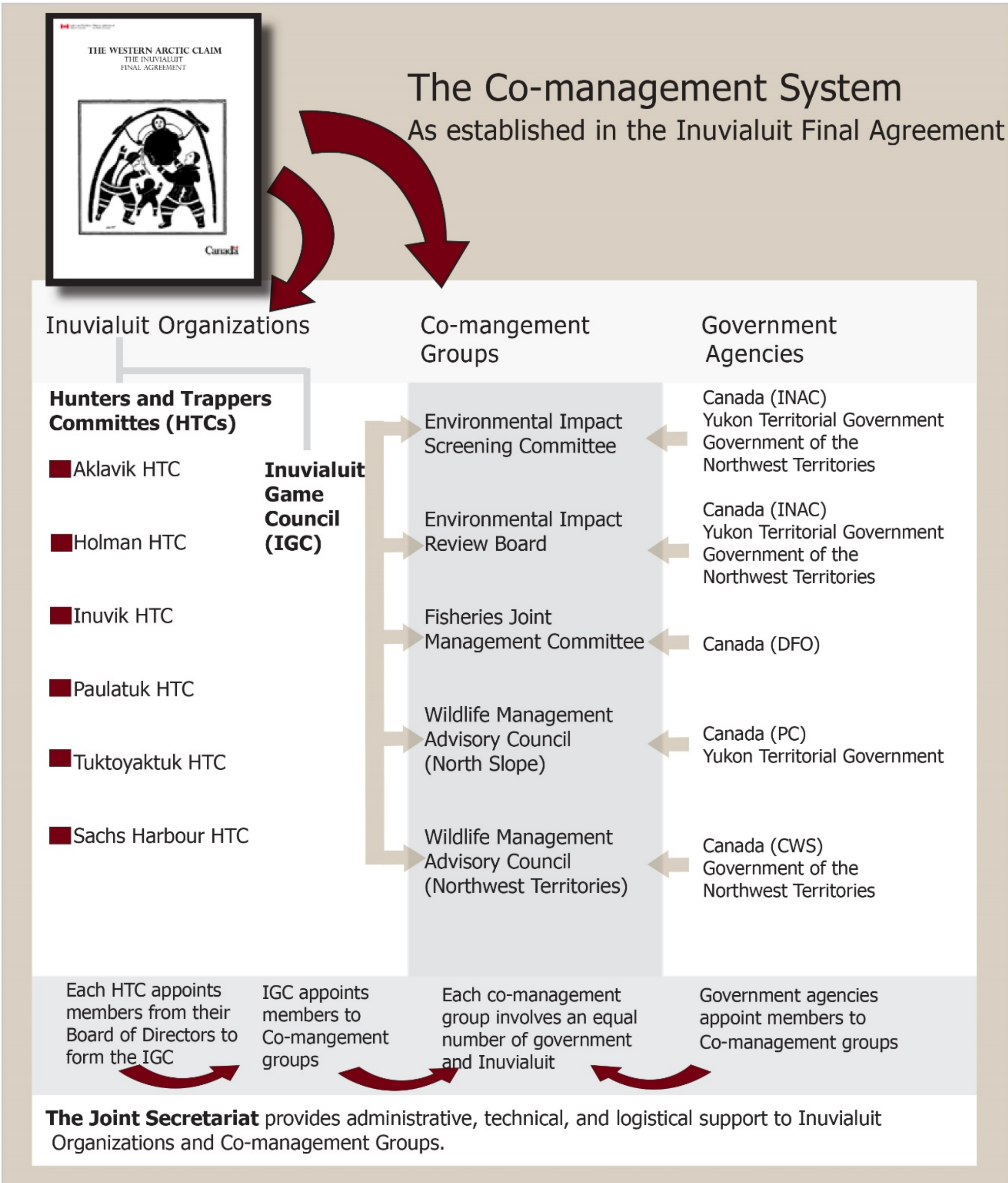
A number of Inuvialuit corporations were established to receive and manage the rights and benefits of the IFA. The Inuvialuit Lands Administration was set up to manage Inuvialuit lands. The Inuvialuit Trust was established to manage the distributions to Inuvialuit. As an Inuvialuit Board, the Inuvialuit Game Council, represents the collective Inuvialuit interest in all matters pertaining to the management of wildlife and wildlife habitat in the ISR (https://www.jointsecretariat.ca/inuvialuit-game-council). The IGC appoints members to the Inuvialuit co-management organizations.

The IFA also established a co-management system for environmental management in the ISR; co-management involves a joint management system that allows for integrated resource management of certain resources and uses within the ISR by Inuvialuit organizations and the territorial and federal governments (https://www.irc.inuvialuit.com/co-management; November 5, 2019). The Inuvialuit co-management organizations include:

- Inuvialuit Environmental Impact Screening Committee (EISC)
- Inuvialuit Environmental Impact Review Board (EIRB)
- Fisheries Joint Management Committee (FJMC)
- Wildlife Management Advisory Council – Northwest Territories
- Wildlife Management Advisory Council- North Slope (Figure 2-1)

Each Inuvialuit community (e.g., Aklavik, Inuvik, Paulatuk, Sachs Harbour, Tuktoyaktuk and Ulukhaktok) has a Community Corporation which is made up of six elected directors and one chair. Each community also has a Hunter and Trapper Committee (HTC), Elder Committee and Youth Committee.

The Joint Secretariat was established as a not-for-profit coordinating organization after the IFA was finalized; it provides administrative, technical and logistical support to the IGC and Inuvialuit co-management groups (with exception of the Wildlife Management Advisory Council- North Slope) (https://www.irc.inuvialuit.com/sites/default/files/Co-Management%20Structure.pdf; November 5, 2019).



SOURCE: (https://www.irc.inuvialuit.com/sites/default/files/Co-Management%20Structure.pdf; November 5, 2019)

Figure 2-1 Co-management Structure as established in the Inuvialuit Final Agreement

2.3.2 Inuvialuit Regional Corporation

The IRC was established with the overall responsibility of managing the affairs of the Western Arctic Claims Settlement Act as outlined in the Inuvialuit Final Agreement (IFA) of 1984. The IRC represents the collective interests of the Inuvialuit in dealings with governments and the world at large. The mandate of the IRC is to continually improve the economic, social and cultural well-being of the Inuvialuit through the implementation of the IFA and other means. The corporate structure for the IRC is shown in Figure 2-2. The head office of the IRC is located in Inuvik.

The Board of the IRC is composed of the Chairpersons of the Community Corporations from the six Inuvialuit communities and a Chairperson elected by the Board Members of the Community Corporations (http://irc.inuvialuit.com/corporate-structure-0; November 5, 2019).

The IRC has four subsidiary corporations: Inuvialuit Development Corporation, Inuvialuit Investment Corporation, Inuvialuit Land Corporation and the Inuvialuit Petroleum Corporation.

Under the IFA, oil and gas operators exploring for or developing petroleum resources on Inuvialuit Lands are required to negotiate a Participation Agreement with the Inuvialuit Land Administration. Benefit agreements, including employment and training of Inuvialuit and use of Inuvialuit businesses, are discussed in Section 2.11.

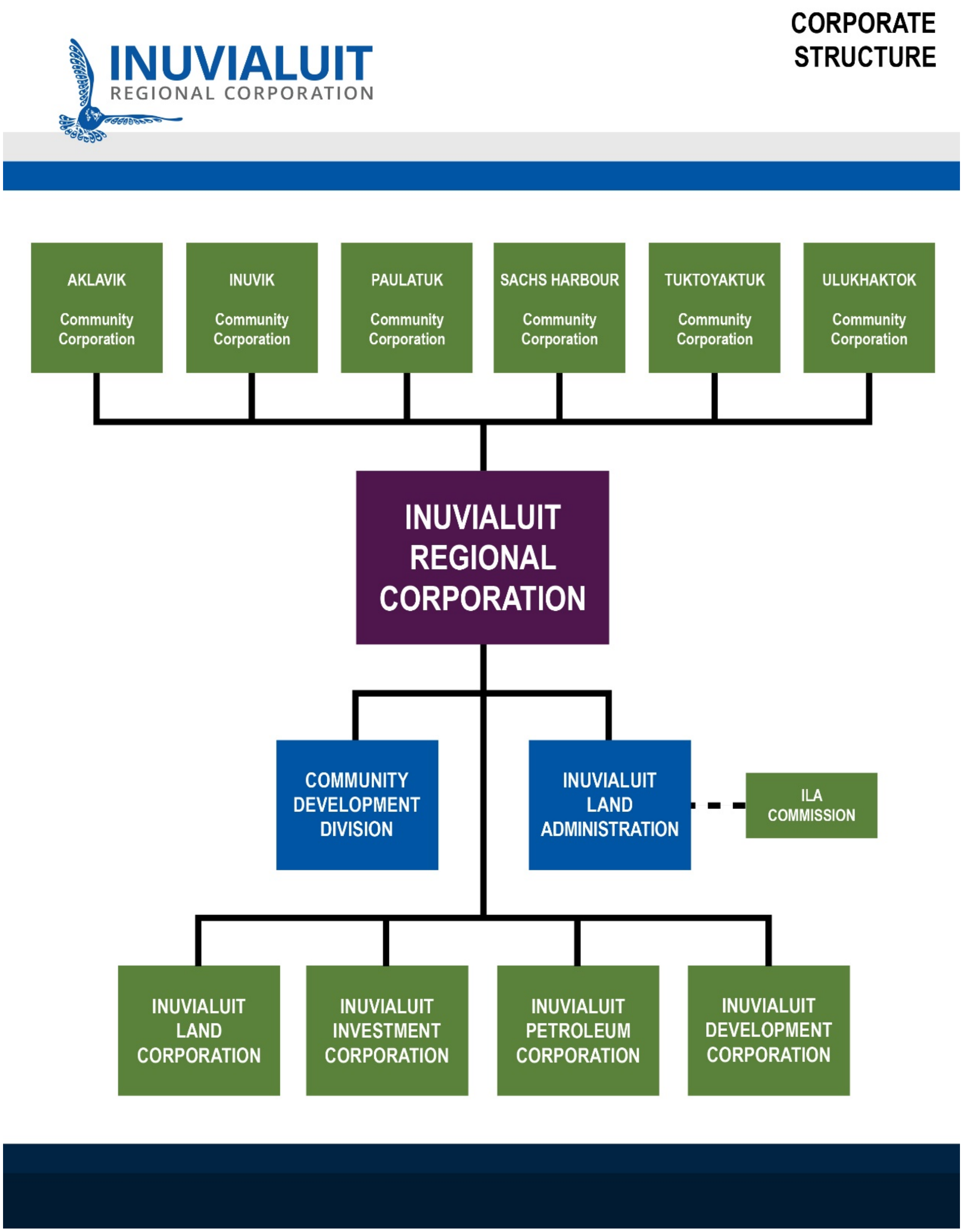
As a Co- Chair, IRC is responsible for coordinating the participation of Inuvialuit organizations in the BRSEA, including the IGC, co-management organizations, and Inuvialuit communities.

2.3.3 Inuvialuit Game Council

Under the IFA, the IGC "represents the collective Inuvialuit interest in all matters pertaining to the management of wildlife and wildlife habitat in the ISR. This responsibility gives the IGC authority for matters related to harvesting rights, renewable resource management, and conservation" (https://jointsecretariat.ca/co-management-system/inuvialuit-game-council/; November 6, 2019).

The IGC is made up of a chair and two representatives appointed by the Hunters and Trappers Committee (HTC) in each of the six ISR communities.

"The specific duties of the IGC are set out in Section 14(74) of the IFA and include appointing Inuvialuit members for all Inuvialuit co-management bodies under the IFA and assisting these bodies whenever requested; and advising government agencies through the co-management bodies or otherwise, on renewable resource policy, legislation, regulation, and on any proposed Canadian position for international purposes that affects wildlife in the ISR. The IGC also allocates Inuvialuit quotas among the six ISR communities and appoints members for any co-management body dealing with Inuvialuit fish and wildlife harvesting and environment" (https://jointsecretariat.ca/co-management-system/inuvialuit-game-council/; November 6, 2019).



SOURCE: (http://irc.inuvialuit.com/sites/default/files/Corporate%20Structure%20Final%20UPDATED.pdf; November 6, 2019).

Figure 2-2 The Corporate Structure for the IRC

2.3.4 Crown-Indigenous Relations and Northern Affairs Canada

CIRNAC is the federal department primarily responsible for relations with Indigenous communities throughout Canada and for the development of Canada's social and economic policy for the northern territories.

Under authority of the *Canada Petroleum Resources Act* (CPRA), CIRNAC maintains authority for the granting of rights to explore for and develop petroleum resources in the Beaufort Sea and other offshore areas.

As a Co- Chair of the BRSEA, CIRNAC is responsible for coordinating the participation of federal departments and agencies, including the Department of Fisheries and Oceans Canada, Environment and Climate Change Canada, Natural Resources Canada, Canadian Coast Guard, the Impact Assessment Agency of Canada and Transport Canada.

2.3.5 Canada Energy Regulator

The Canada Energy Regulator (CER), formerly known as the National Energy Board, is an independent federal Commission that exercises regulatory responsibilities for oil and gas exploration and production activities on certain frontier lands, including land-based activities and pipelines in the ISR, and offshore oil and gas activities and pipelines in the Beaufort Sea. The CER also is responsible for oil, gas, and commodity pipelines that traverse the onshore-offshore boundary. The CER operates under authority of the *Canadian Energy Regulator Act* (CERA), the *Canada Oil and Gas Operations Act* (COGOA) and the CPRA.

CER's primary responsibilities in the Beaufort Sea fall under the authority of COGOA and include regulation of exploration, development, production and transportation of oil and gas to promote conservation of the resource, environmental protection and worker safety. Primary regulatory responsibilities under CERA include the regulation of interprovincial pipelines and the export of oil and natural gas. The CER also provides technical expertise to assist CIRNAC with its responsibilities under the CPRA. Acquisition of approvals from CER does not absolve an operator from obtaining and complying with other land, water and environmental assessment requirements.

2.3.6 Government of the Northwest Territories

The Government of the Northwest Territories (GNWT) became a fully elected body in 1975. Division of the Northwest Territories (NWT) into the two territories of the NWT and Nunavut occurred in 1999.

The Northwest Territories Lands and Resources Devolution Agreement came into effect on April 1, 2014 and devolved authority to the GNWT for land and resource management on territorial lands and some other federal lands, including the ISR ((https://www.aadnc-aandc.gc.ca/eng/1390503182734/1390503256117; November 7, 2019). Within the ISR, the Inuvialuit, and the governments of Canada, the Northwest Territories and the Yukon share management responsibilities.

Since 2014, the GNWT is responsible for administering oil and gas interests within the NWT, including the Inuvialuit and Gwich'in Settlement Regions and the Sahtu and Dehcho Regions. As part of the devolution agreement (Chapter 5 of the Devolution Agreement), the GNWT, IRC and Government of Canada agreed to coordinate and cooperate in the management and administration of petroleum resources in the ISR. Unlike the rest of the land areas within the NWT, regulatory authority over land-based oil and gas activities in the ISR remains with the Canadian Energy Regulator, but under territorial legislation. The management of oil and gas resources in the Beaufort Sea currently remains the responsibility of the federal government; however, an oil and gas co-management and revenue sharing agreement for the Canadian Beaufort Sea is being negotiated with the governments of the Northwest Territories and Yukon, and the IRC (https://www.canada.ca/en/intergovernmental-affairs/news/2018/10/canada-announces-next-steps-on-future-arctic-oil-and-gas-development.html, October 4, 2018).

2.3.7 Yukon Government

The Yukon Territory Act (1898) recognized the Yukon Territory as separate and distinct from the North-West Territories (http://www.gov.yk.ca/aboutyukon/history.html; November 6, 2019).

In April 2003, the Yukon Act and Devolution Transfer Agreement came into effect and gave the Government of Yukon direct control over a much wider variety of provincial-type programs, responsibilities and powers, including control over public lands, forests, water, minerals and gas from coal on territorial lands. However, within the ISR, the Inuvialuit and the governments of Canada, the Northwest Territories and the Yukon share management responsibilities.

The 1993 Canada Yukon Oil and Gas Accord transferred the administration and control of oil and gas resources in onshore areas and in adjoining areas[16] to the Yukon Government, including the determination of revenues and management of northern benefits. The Accord also includes a commitment to a shared offshore oil and gas management regime and revenue sharing arrangement in the Beaufort Sea. As noted for the GNWT, an oil and gas co-management and revenue sharing agreement for the Canadian Beaufort Sea is being negotiated that includes the Yukon Government.

2.4 Regulatory Approvals and Protection Planning for Offshore Oil and Gas

Most offshore oil and gas activities including seismic exploration, exploration drilling and more advanced phases of development (e.g., field delineation, production, decommissioning and subsea pipelines), are required to undergo an environmental review and follow a broad range of federal, territorial and Inuvialuit legislation, regulations and guidelines for environmental protection. Use of vessels for offshore oil and gas projects is also regulated. The following is an overview of the major regulatory requirements and protection planning; the review is not intended to be a comprehensive summary of all legislation, permits and guidelines.

[16] The Yukon Act defines adjoining areas as a line following the ordinary low water mark of the northern coast of the mainland of the Yukon territory, as well as some coastal indentations such as bays or estuaries (see Act for specifics). As defined, the adjoining areas fall within the BRSEA Study Area.

2.4.1 Federal Requirements for Offshore Oil and Gas

Environmental approvals for offshore oil and gas projects are governed by Section 11 of the IFA (see Section 2.4.2), as well as by the Impact Assessment Act (IAA). Most major activities for offshore oil and gas (e.g., seismic programs, exploration drilling projects, production) are subject to an environmental screening or impact assessment that meets the legal requirements of the two processes. The IFA process can also be substituted for the IAA, with approval of the Minister of the Environment and Climate Change Canada.

Federal regulatory requirements for offshore oil and gas which are applicable within the BRSEA Study Area are summarized in Table 2-2 with a focus on the major requirements for environmental assessment, monitoring and protection. This summary is not intended to be a comprehensive review of all oil and gas regulations for the region.

Table 2-2 Federal Regulatory Requirements Applicable to the BRSEA Study Area

Regulatory Body	Act or Regulation	Requirement
Impact Assessment Agency of Canada (IAAC)	*Impact Assessment Act (IAA)*	The IAA and its regulations establish the legislative basis for the federal impact assessment process; this Act replaces the *Canadian Environmental Assessment Act* (2012). Under the IAA, an assessment is required for "designated projects", which are determined in two ways: projects designated by regulation, and Minister discretion to designate projects not included in the regulations. Of relevance to offshore oil and gas activities, activities requiring an impact assessment include: • drilling, testing and abandonment in an area set out in one or more exploration licences • construction, installation and operation of a new offshore floating or fixed platform, vessel or artificial island used for the production of oil or gas • decommissioning and abandonment of an existing offshore floating or fixed platform, vessel or artificial island used for the production of oil or gas
Environment and Climate Change Canada (ECCC)	*Canadian Environmental Protection Act (EPA)*	Requires adherence to Environment Canada measures to prevent effects of industrial development on air and water.
	Environmental Enforcement Act (EEA)	Provides a common set of principles and factors to be considered in sentencing, enforcement tools, and the regimes for fines across all of the amended acts. The EEA covers several acts and regulations, including the *Canada National Marine Conservation Areas Act, Migratory Birds Convention Act, Clean Water Act,* and *Canadian Environmental Protection Act.*
	Migratory Birds Convention Act (MBCA)	Requires adherence to Environment Canada measures to protect migratory birds and their nesting areas.
	Species at Risk Act (SARA)	Requires adherence to Environment Canada measures and recovery plans to protect SARA-listed species. The exception is aquatic species, which fall under DFO's jurisdiction.
	Wildlife Act	Describes regulations surrounding management and protection of wildlife areas, especially for species that are at risk. Regulates permits for activities that may otherwise be harmful to wildlife areas or species at risk.

Table 2-2 Federal Regulatory Requirements Applicable to the BRSEA Study Area

Regulatory Body	Act or Regulation	Requirement
Fisheries and Oceans Canada (DFO)	*Fisheries Act (2019)*	Requires actions be taken to prevent the harmful alteration, disruption, or destruction (HADD) of fish habitat, including protection and monitoring measures. Prohibits pollution of waters frequented by fish. Requires DFO authorization to catch fish for scientific purposes.
	Species at Risk Act (SARA)	Requires adherence to DFO measures and recovery plans to protect aquatic SARA-listed species.
Crown-Indigenous Relations and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC)	*Arctic Waters Pollution Prevention Act (AWPPA)*	Authorization for disposal of waste into arctic marine waters from non-ship sources, including fixed drilling platforms, caissons and artificial islands.
	Canada Petroleum Resources Act (CPRA)	CIRNAC is responsible for North of 60 (NRCan is responsible for other frontier lands). The Act authorizes the issuance by the Crown of title rights to explore for, develop and produce petroleum in areas under federal jurisdiction. The Act establishes the process by which these rights may be issued, defines the core rights that are granted by each form of licence, provides for a royalty to be imposed on production and establishes a fund to support related environmental studies. CIRNAC also must approve or waive the requirement for a benefits plan, subject to the provisions of the IFA, before the CER can consider issuing an authorization.
	Canadian Oil and Gas Operations Act (COGOA)	Establishes the requirement for a Benefits Plan and a Benefits Plan approval by the Minister, concurrent with an application for approval of a development plan or an application for an authorization of any oil and gas work or activity. The Minister can approve or waive the requirement for approval of a benefits plan.
Canada Energy Regulator (CER)	*Canadian Energy Regulator Act (CERA)*	Establishes the Canada Energy Regulator and sets out its composition, mandate and powers. The primary role of the CER is to regulate the exploitation, development and transportation of energy within federal jurisdictions.
	Canada Petroleum Resources Act (CPRA)	Manages applications for Declaration of Significant Discovery and Commercial Discovery. Authority to make, amend or revoke Declarations of Significant and Commercial Discovery on frontier lands
	Canada Oil and Gas Operations Act (COGOA)	Regulates the exploration, production, processing, and transportation of oil and gas in marine areas controlled by the federal government. The Act promotes safety, protection of the environment, the conservation of oil and gas resources, and joint production agreements. Requires environmental protection and monitoring work plans be submitted to the CER for authorization of exploration, drilling and protection activities.
Transport Canada (TC)	*Arctic Waters Pollution Prevention Act*	Requires Transport Canada's authorization for disposal of waste into arctic marine waters from ship-based sources.
	Canada Shipping Act	Principal legislation governing safety in marine transportation, and protection of the marine environment. Various regulations, including the Ballast Water and Control Management Regulations, and Vessel Traffic Services Zones Regulations have been made under the Act.

Table 2-2 Federal Regulatory Requirements Applicable to the BRSEA Study Area

Regulatory Body	Act or Regulation	Requirement
Transport Canada (TC) (cont'd)	*Marine Liability Act*	A consolidation statute that brings together statutory liability issues including the apportionment and limitation of liability, civil liability of pollution, and liability for the carriage of passengers.
	Transportation of Dangerous Goods Act and Transportation of Dangerous Goods Regulations	Mandates employer responsibility for ensuring all employees involved in the transportation and handling of dangerous goods have adequate training.

2.4.2 Inuvialuit Requirements for Offshore Oil and Gas

Oil and gas projects within the ISR are required to undergo an environmental screening or review as per Section 11 of the IFA, as well as by the IAA (see Table 2-2). Two co-management boards were established under the IFA to manage screening and reviews: the EISC and the EIRB.

The EISC conducts an environmental screening of development activities proposed for offshore areas (as well as onshore areas) within the ISR (EISC 2014). The EISC's mandate is to undertake a preliminary assessment (i.e., screening) of a proposed development and its environmental effects to determine whether a proposed development "…could have a significant negative environmental impact". If the EISC determines that significant negative environmental effects could occur, the application is referred to the EIRB for a more detailed review or another environmental impact review process that, in its opinion, adequately encompass the assessment and review function. Otherwise, the EISC can make a determination that "the project is unlikely to have a significant negative environmental impact and can proceed without environmental impact review" as per IFA 11(17) to 11(20).

For projects referred to review, the EIRB carries out a detailed environment impact assessment and public review of the project. The EIRB requires the project proponent to submit an Environmental Impact Statement (EIS) that includes a project description; information on the current state of the biophysical and human environment prior to the development; assessment of project effects and cumulative effects on the biophysical and human environment; and proposed mitigation to reduce potential negative effects on the environment (EIRB 2011). A Review Panel, appointed by the EIRB, reviews the project. If the Review Panel recommends that the proposed development should proceed, the Panel is also required to recommend terms and conditions including:

- "the ability to meet present economic, social and cultural needs while preserving the natural environment for generations to come (i.e., sustainable development goals)
- preserving the ability to continue with activities such as hunting, trapping, fishing (e.g., minimize conflicts or disruption of harvest practices and activities)
- mitigative and remedial measures
- appropriate monitoring requirements
- an estimate of the potential liability of the Developer (e.g., the Worst Case Scenario)" (EIRB 2011)

The Review Panel then forwards its decision the regulatory authorities competent to approve the proposed development (EIRB 2011).

2.4.3 Government of the Northwest Territories Requirements for Environmental Protection in Offshore Areas

The Government of the Northwest Territories has requirements for environmental protection on NWT Territorial Lands under the following Acts; requirements which are applicable to offshore areas within the BRSEA Study Area are summarized in Table 2-3.

Table 2-3 Northwest Territories Regulatory Requirements for Environmental Protection Applicable to the BRSEA Study Area

Regulatory Body	Act	Requirement
Environment and Natural Resources	*Environmental Protection Act*	Requires safeguards to prevent discharge of contaminants into the environment.
	Species at Risk (NWT]) Act[1]	Requires adherence to conservation and recovery plans for species identified as being of special concern, threatened, endangered or extirpated.
	Wildlife Act	Includes Inuvialuit HTC hunting regulations and other conservation measures applicable to wildlife including those that may range into the offshore (e.g., polar bears) Addresses co-management with the Wildlife Management Advisory Council (NWT) Requires observance of areas set aside as wildlife reserves.

2.4.4 Yukon Government Requirements for Environmental Protection in Offshore Areas

The Yukon Government has requirements for environmental protection on Yukon Territorial Lands under the following Acts; requirements which are applicable to offshore areas within the BRSEA Study Area are summarized in Table 2-4.

Table 2-4 Yukon Government Regulatory Requirements – Environmental Protection Applicable to the BRSEA Study Area

Regulatory Body	Act	Requirement
Department of Environment	*Environment Act*	Includes requirements for: • integrated resource management • waste management, reduction and recycling • release of contaminants • hazardous substances • spills
	Wildlife Act	Includes Inuvialuit HTC hunting regulations and other conservation measures applicable to wildlife on the North Slope including those that may range into the offshore (e.g., polar bears) Addresses co-management issues with the Wildlife Management Advisory Council (North Slope) Process for establishing designated habitat protection areas.

2.5 Regulatory Requirements for Waste Management in Offshore Areas

Treatment, management and disposal of non-hazardous and hazardous wastes are commonly raised as concerns in regard to offshore oil and gas operations and associated ship use. The following provides an overview of waste management regulations under federal, Inuvialuit and territorial legislation and regulations which are applicable to offshore areas within the BRSEA Study Area are summarized in; it is not intended to be a comprehensive review of all legislation and regulations. Hazardous and non-hazardous wastes that are shipped from the ISR to Alberta or British Columbia for recycling or treatment are subject to the provincial- and municipal-level waste management regulations in these provinces.

2.5.1 Federal and International Requirements

The federal government is responsible for:

- regulating the interprovincial and international movement of hazardous waste and recyclable material
- regulating offshore waste management
- supporting and coordinating waste management activities carried out by the provinces and territories

Under the *Canada Oil and Gas Operations Act*, the CER is responsible for regulating oil and gas operations in Canada's offshore areas. Where offshore disposal of drilling waste material is proposed, the CER, Environment Canada, Fisheries and Oceans Canada (DFO) and Transport Canada would determine the need for a disposal-at-sea permit.

Offshore oil and gas projects in the BRSEA Study Area are subject to the following federal acts, regulations and guidelines for waste management:

- Arctic Waters Pollution Prevention Act, 1985
- Arctic Shipping Pollution Prevention Regulations (C.R.C., c, 354)
- Arctic Waters Pollution Prevention Regulations (C.R.C., c. 353)
- Canadian Ballast Water Control and Management Regulation (SOR/2006-129)
- Canada Oil and Gas Operations Act, 1985
- Canada Oil and Gas Drilling Regulations (SOR/79-82)
- Canadian Environmental Protection Act, 1999
- Fisheries Act, 1985
- Transportation of Dangerous Goods (TDG) Act, 1992 and Regulations
- Guidelines Respecting the Selection of Chemicals Intended to be used in Conjunction with Offshore Drilling and Production Activities on Frontier Lands, January 1999
- Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands, April 2009
- Offshore Waste Treatment Guidelines, 2010

Key regulatory requirements for offshore waste management which are applicable to offshore areas within the BRSEA Study Area are summarized in Table 2-5.

Table 2-5 Summary of Regulatory Requirements for Offshore Waste Management Applicable to the BRSEA Study Area

Waste Type	Regulatory Document	Requirement
General	Guidelines Respecting the Selection of Chemicals Intended to be Used in Conjunction with Offshore Drilling and Production Activities on Frontier Lands, 2009	Operators proposing to carry out activities related to oil or gas exploration or production must obtain an authorization from the appropriate regulatory body. The operator should demonstrate they have incorporated a chemical selection process to minimize potential environmental effects of a discharge where technically feasible. The CER may conduct periodic audits to ensure compliance with these guidelines and operator-specific chemical selection systems.
Drilling mud	Offshore Waste Treatment Guidelines, 2010	Use of synthetic-based mud (SBM) or enhanced mineral oil-based mud (EMOBM) should be limited to wells where use of water-based fluids is technically impractical. The SBM or EMOBM cannot be discharged at sea. Spent and excess water-based drilling muds can be discharged on site from offshore installations without treatment.
Drill cuttings and produced sand[17]	Offshore Waste Treatment Guidelines, 2010	Oil-based drill solids cannot be discharged at sea. Drill solids from water-based muds can be discharged at sea. Drill solids from SBM or EMOBM must be treated before discharge using the best available technology. Approval is required to discharge; approval depends on the concentration of oil in the cuttings and produced sand and its aromatic content.
Produced water, deck drainage, bilge and ballast water, well treatment fluids	Offshore Waste Treatment Guidelines, 2010	Production installations that began operations after 2002 should ensure that the 30-day weighted average of oil in discharged produced water does not exceed 30 mg/L and that the 24-hour arithmetic average of oil in produced water does not exceed 60 mg/L. Produced water is required to be analyzed for heavy metals and total hydrocarbons. Well treatment fluids recovered from operations must be treated to an oil concentration of 30 mg/L or less. Well treatment fluids can be directed to the produced water discharge and treated as a component of produced water. Strongly acidic fluids recovered from well treatment operations should be treated with neutralizing agents to a pH of at least 5.0 before being discharged. Deck drainage that might be contaminated with oil needs to be treated to reduce its oil concentration to 15 mg/L or less. Deck drainage with no potential for oil contamination can be discharged directly to sea. Oil concentrations in discharged bilge and ballast water should be treated to levels of 15 mg/L or less before discharge.
Bilge and ballast water	Canadian Ballast Water Control and Management Regulation (SOR/2006-129)	Ballast water exchange should be carried out at least 200 nautical miles from shore and in water at least 2,000 m deep. Ships unable to complete a ballast water exchange in this manner should be at least 50 nautical miles from shore and in water at least 500 m deep.

17 The Offshore Waste Treatment Guidelines require the use of the best available technology for treating drill solids before discharge overboard; they do not define a standard for drill cuttings discharge.

Table 2-5 Summary of Regulatory Requirements for Offshore Waste Management Applicable to the BRSEA Study Area

Waste Type	Regulatory Document	Requirement
Waste mixing	Offshore Waste Treatment Guidelines, 2010	A proposal must be submitted to the Chief Conservation Officer to mix waste streams. The proposal should identify the points of waste discharge. Wastes should not be mixed as a means of dilution to meet specified waste concentrations.
Sewage and food wastes	Offshore Waste Treatment Guidelines, 2010	Sewage and food wastes should be macerated to a particle size of six millimetres or less before discharge. In some circumstances the Chief Conservation Officer might require additional treatment.
	MARPOL	Sewage may be discharged into the sea if the ship: has an approved sewage treatment plant is using an approved system that pulverizes and disinfects the sewage and discharges at a distance of more than three nautical miles from the nearest land is discharging sewage that has not been pulverized or disinfected at a distance of more than 12 nautical miles from the nearest land
Other waste	Offshore Waste Treatment Guidelines, 2010	Other wastes generated on offshore installations (e.g., sludge from oil-water separation systems, spent lubricants and plastic material, excess or damaged supplies of chemicals) should be reused or recycled or alternatively recovered and transferred to shore in a manner approved by the Chief Conservation Officer and disposed of in a manner approved by local regulatory authorities.
	MARPOL	Only approved substances should be incinerated. The combustion chamber gas outlet temperature should be above 850°C, and each incinerator should be certified under the International Maritime Organization.
Waste transportation	TDG Act and TDG Regulations	Waste manifests are required when transporting hazardous waste from the offshore to an onshore location and then transporting to an approved disposal or treatment facility.

The following international conventions also apply to waste management for offshore oil and gas projects, including vessel use:

- International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL)
- Basel Convention on the Control of Transboundary Movement of Hazardous Waste and Their Disposal (1989 and Organization for Economic Co-operation and Development [OECD] Council Decision, C(92)39, 1992)

2.5.2 Northwest Territories Requirements

Within the NWT, onshore waste management falls under the jurisdiction of the Government of the Northwest Territories. Management of waste from offshore operations (which is brought to shore for transport or treatment) would be addressed by the following territorial statutes and their associated regulations and guidelines:

- Environmental Protection Act, NWT 1988
- Waste Reduction and Recovery Act, NWT 2003
- Guideline for Industrial Waste Discharges in the NWT, 1998
- Waters Act, amended 2016
- Guideline for the General Management of Hazardous Waste in the NWT, 1998

2.5.3 Yukon Requirements

Within the Yukon, onshore waste management falls under the jurisdiction of the Yukon Government. Management of waste from offshore operations (which is brought to shore for transport or treatment) would be addressed by the following territorial statutes and their associated regulations and guidelines:

- Environment Act (2014)
- Solid Waste Regulations
- Special Waste Regulations

2.5.4 ISR Requirements

The Inuvialuit Land Administration is responsible for management of Inuvialuit Private Lands and may have their own requirements for waste management which meet or exceed territorial requirements. The Town of Inuvik has several bylaws that address waste and waste water management. Because of the rights of Inuvialuit under the IFA, any onshore development associated with an offshore project, including onshore waste management, should be discussed with local Inuvialuit and municipal authorities.

2.6 Consultation and Engagement

The ISR has a well established approach to consultation and engagement during the regulatory review of proposed projects, subject to the provisions of the IFA. The following is a high level overview of how consultation and engagement have been undertaken during past projects and how information is used in the regulatory review process and project design.

Consultation is defined as activities associated with the legal obligation of the Crown to consult Indigenous governments and communities and accommodate where Aboriginal rights (as defined in the Constitution Act 1982) might be affected. Engagement is defined as activities by proponents and governments to inform Indigenous people and the public about projects, obtain meaningful input and responses from these groups, involve them in planning and implementation of projects, and provide follow-up information on outcomes and results.

Under the Constitution Act 1982 and the IFA 1984 (with amendments in 1987), for projects that require regulatory review outside the prescribed Inuvialuit regulatory process (e.g., a Joint Panel Review), the federal and territorial governments are required to consult with Inuvialuit organizations (e.g., IRC, IGC, FJMC, Wildlife Management Advisory Council NWT and North Slope) and communities (e.g., Community Corporations), as early as possible in a project review to seek input on the review process (e.g., approach, timing) and the project (e.g., project design and activities, as well as alternatives). Participation by these organizations in a review process or decision does not discharge the duty of federal and territorial governments to consult.

Within the ISR, proponents are required under the IFA to formally engage Inuvialuit government institutions and community organizations (including Inuvialuit and northern residents) from the start of a project. Proponents are required to document engagement activities and outcomes with community organizations as part of the application process for a project screening (i.e., the preparation of the Project Description). While most projects in the BRSEA Study Area would follow Inuvialuit processes and requirements, some projects may require participation by the Yukon, NWT and Nunavut (e.g., transboundary effects, project components or activities outside of the ISR).

For offshore oil and gas projects (e.g., seismic exploration, offshore exploration drilling), typical engagement activities include, but are not limited to:

- meetings with the primary Inuvialuit organizations, including the IRC, IGC, FJMC and Wildlife Management Advisory Councils (NWT and North Slope)
- community-focused meetings with each of the six community based Hunters and Trappers Committees, Community Corporations, Elder and Youth committees, Hamlets and other community groups
- community open houses and meetings for Inuvialuit. Depending on the geographic scope of the project, northern residents in the Yukon, NWT and Nunavut may also be engaged
- workshops with community and stakeholder representatives
- newsletters and posters

Where a project is determined to have no significant negative environmental effects through screening by the EISC, proponents typically continue to engage with the communities prior to the start of project activities, and sometimes during the project activities. Proponents are required to document that they have shared the results of studies and the outcomes of projects once they are complete. This may be done through community meetings, as well as other forms of communications (e.g., newsletters), and updates to previously engaged regulators and Inuvialuit and community organizations.

Where a project is advanced to a review by the EIRB, proponents typically engage with communities at regular intervals, including:

- during or following the conduct of baseline field studies (this includes socio-cultural, biophysical and geotechnical field work, as well as site inspections or reconnaissance surveys)
- during and following the preparation of the environmental impact assessment
- review of environmental protection programs and mitigation
- review of follow-up and monitoring programs

Community organizations and members can also participate in the public hearings.

If the EIRB recommends that the proposed development proceed and approval is issued by the federal authority, proponents typically continue to engage with regulators, Inuvialuit organizations and community organizations on a regular basis (e.g., one to several times annually) to inform them of progress on the project and project outcomes.

2.7 Oil and Gas Development Life Cycles in the Offshore

Oil and gas development life cycles are described in detail by LTLC Consulting and Salmo Consulting Ltd. (2012) and CAPP (2017). The following is an overview of typical life cycle phase and activities. The Arctic Offshore Drilling Review (NEB 2011a) also offers additional details on lessons learned from past spill events, procedures for safe drilling and protection of the environment, and financial responsibilities and procedures for responding to spills.

Frontier oil and gas is a decadal process from the initial nomination and bid process for license areas, through exploration, development, production and decommissioning.

The *Canada Petroleum Resources Act* (1986) establishes a process for the issuance of a hierarchy of licenses or title rights from the Crown to an interest owner or operator (i.e., exploration license, significant discovery license, production license) (Harrison 2016). The Minister of CIRNAC is responsible for the administration of the Act north of 60. Of note, the issuance of an exploration license confers not only the right to explore, drill and test for petroleum resources within the license area, but also an exclusive right to eventually obtain a production license and develop the petroleum resources. However, the advancement from one license to another requires specific applications and approvals, including an assessment of environmental effects and the development of benefit plans (Harrison 2016). The Act also sets out the right of the Crown for royalties for petroleum produced from the license area.

Activities and operations undertaken under the authority of these licenses require separate approvals under the *Canada Oil and Gas Operations Act.* The CER is the authority for these approvals. As part of an application for drilling in the Canadian arctic, the owner is required to develop a Safety Plan, Environmental Protection Plan and a Contingency Plan.

Of note, the federal government is currently negotiating a Beaufort Sea oil and gas co-management and revenue sharing agreement with the governments of the Northwest Territories and Yukon and the IRC. As a result, regulatory and permitting processes may change.

2.7.1 Typical Life Cycle Phases in the Offshore

In general, the time from acquiring an Exploration License (EL) to the first exploration well being drilled is between six and eight years of the nine-year term of the Exploration License. [18]

Normally, the first work done on the license is acquisition of seismic data using a seismic exploration vessel, a sound source (e.g., air guns) and various types of acoustic receivers or streamers. Seismic surveys provide information on the underground geological formations (e.g., depth and shape) that may contain oil and gas. In the 1970s to 2000s, two-dimensional (2D) data was acquired first followed by three dimensional (3D) seismic data collection. Today, most companies would acquire 3D seismic over the areas of interest on their EL. The seismic data is usually acquired in year 2-4 of the EL.

Once a prospect is mapped using seismic information, the Operator would typically drill one or two exploration wells. During the first several decades of industry activity in the BRSEA Study Area, exploration wells were drilled with moored drillships or from sacrificial islands and bottom-founded structures (most of these exploration wells were in shallow water less than 40m deep). Today, most exploration wells in shallow water would be drilled from ground-based structures, whereas wells in deeper water (> 40) would be drilled with dynamically-positioned drillships or semi-submersibles. Wells in deep water may take two seasons to complete.

If an exploration discovery is made and is deemed to be commercially viable, the operator would apply for a Significant Discovery, and once approved by the regulatory authority, the authority would issue a Significant Discovery License (SDL) to the Operator. An SDL has an established area, applies to all zones that have been drilled and deeper zones, and currently has no timeline or fees to maintain the SDL though time.

If the exploration well is successful, most operators would drill 2-4 delineation wells that may be capped and used later as producing wells. The delineation wells and the exploration wells are used to apply for a Commercial Discovery. When approved, the regulatory authority would issue a Commercial Discovery Declaration (CDD) that covers specific zones for production.

Following the issuance of a Commercial Discovery License, if the Operator wishes to proceed to production, they must get approval to develop the discovery by submitting a Development Plan. As part of this process, they must also convert the rights conferred by the Commercial Discovery License into a Production Licence by submitting a Production Application to the regulator. If approved, the government would issue a Production License for the field. Field development and production can then proceed.

In general, in the Canadian Frontier offshore, the timelines from issuance of an Exploration License to the first production is estimated to be 25 to 30 years. There are a number of reasons for this extensive timeline, including the time it takes the Operator to apply for and receive regulatory approvals; the scope of technical work to be carried out; the capital investment and associated agreements from the Operator and partners; and the amount of time to develop the field and build facilities for a large offshore project.

[18] The text on life cycles phases in the offshore was prepared by the Engineering Panel for the KAVIK-Stantec team, with support from J. Green and J. Beckett: it includes information from LTLC Consulting and Salmo Consulting Ltd. (2012) and CAPP (2017), as well as professional experience of members of the Engineering Panel.

2.7.2 Exploration Licenses in the Offshore

The government (CIRNAC) issues a Call for Nominations to industry to nominate areas for Exploration Licenses. The results of the nomination process are used to issue a Call for Bids. CIRNAC reviews all bids and awards the lands to the highest value work bid (i.e., highest dollar value of work commitments) for each specific Exploration License (EL).

2.7.3 Seismic Exploration in the Offshore

2.7.3.1 2-D and 3D seismic programs

The EL holder or a speculative seismic contractor may undertake 2D or 3D seismic programs.

Speculative programs may be completed in conjunction with, or before a Call for Bids. Oil and gas companies often make investment decisions on the acquisition of new parcels based on this data. This type of seismic program typically involves acquisition of 2-D data over a large area or to infill existing 2-D data. This program would likely be conducted in the open water on the continental shelf or on the deep-water slope. There is a potential for seismic on ground-fast ice and pack ice or in shallow water (i.e., 3-5 meters) with ocean bottom hydrophones. 3-D regional speculative seismic programs would usually be conducted after a 2-D program or may be conducted instead of a 2-D program.

2.7.3.2 Focused 3D seismic programs

Before drilling exploration wells, or delineation wells, the Operator is likely to acquire additional highly focused 3D programs for target areas within their license area.

2.7.4 Geotechnical and Metocean Studies in the Offshore

Exploration, delineation and development wells would require a sea floor geotechnical assessment before drilling is undertaken. In deep water, there also could be work done to understand the currents throughout the water column and the stability of the sea floor using techniques that may include ocean LIDAR and Multibeam SONAR and sea floor sampling in localized areas. For deep-water wells, there may be ocean buoys deployed in the area of interest for summer seasons to better understand the currents throughout the water column for riser design.

2.7.5 Exploration Drilling in the Offshore

Exploration drilling is done to assess the potential of prospects that are identified during 2D or 3D seismic programs. Generally, in frontier basins, about 20% of identified prospects contain hydrocarbons, the rest are filled with water (which is called dry). Historically, exploration success in the Beaufort Sea was very high; more than 50% of identified prospects contained hydrocarbons in the initial round of drilling during the mid-seventies through mid-eighties. However, of the hydrocarbon discoveries in frontier areas, typically only 3-5% are economically feasible as standalone developments. Combined development of multiple discoveries have been suggested (e.g., Mackenzie Gas, Amauligak oil).

2.7.6 Delineation Drilling in the Offshore

Once a discovery is considered economic, the Operator would drill a number of additional wells, normally two to five, to fully understand the aerial extent of the field and find the gas and/or oil/water contacts. In most cases, these wells would be drilled as producing wells, and suspended until the development of the field is approved.

2.7.7 Significant Discovery Licenses in the Offshore

Once the operator has enough information to meet the requirements under CPRA of "the first well on a geological feature that has the potential for sustained development", the Operator would apply to the Regulatory Authority (the CER), for a Significant Discovery Declaration (SDD). This SDD document provides the regulator all the information necessary to prove the production, the size and the area for consideration for the declaration. Once the regulatory authority approves the SDD, the Federal Government would issue a Significant Discovery License (SDL) for the offshore areas involved with the discovery.

2.7.8 Commercial Discovery License in the Offshore

After the completion of the delineation drilling and before the operator applies for a Production License, the operator applies for a Commercial Discovery Declaration, CDD, with the Regulatory Authority. The same procedure applies as defined in the SDL application, but with the additional requirement that the Operator prove that the SDL is of commercial value to the regulator.

2.7.9 Development Plan Approval for the Offshore

Following the issuance of a Commercial Discovery License, once an operator decides that it is appropriate to develop a hydrocarbon discovery, the operator must get approval from the regulator to develop the discovery by submitting a Development Plan. As part of this process, they must also convert the rights conferred by the Commercial Discovery License into a Production Licence.

The primary purpose of submitting a Development Plan is to satisfy the CER that production of the hydrocarbons would be done in a manner that provides for safety of the workers and protection of the environment (https://www.nrcan.gc.ca/energy/energy-sources-distribution/offshore-oil-and-gas/oil-and-gas-activity/5841; November 7, 2019). The Development Plan also describes how local benefits would be generated over the life of the project, as well as outlining how the production operations would maximize the recovery of the resources.

2.7.10 Production License in the Offshore

The final step with the Regulatory Authority and the Government is to apply for a Production Declaration and obtain a Production License from the government. This license requires negotiations with the federal government involving all aspects of the development of the field including environmental assessment, drilling plans, construction and workforce requirements and royalties.

2.7.11 Field Development in the Offshore

A full-fledged development would be undertaken once the Production License has been granted. This is a large commitment by the Operator and a typical frontier field would be expected to produce hydrocarbons for 15 to 25 plus years.

2.7.12 Production in the Offshore

Production in a frontier field involves both producing and transporting the produced product. All of the production scenarios developed for the Data Synthesis and Assessment Report involve shipping the product with Arctic class tankers and supertankers.

2.7.13 Decommissioning in the Offshore

After the completion of production, the field would be decommissioned. As noted in Table 2-2, under the IAA, an impact assessment is required for decommissioning and abandonment of an existing offshore floating or fixed platform, vessel or artificial island used for the production of oil or gas. Wells would be abandoned in accordance with federal regulations. Subsea flowlines and structures may be left in place or removed from the seabed. Decommissioning is typically 20 to 40 years after the start of production, depending on the size and production from the formation.

2.8 Well Management and Control in the Offshore

The following is a brief overview of recent approaches to well management and control, as described by CAPP (2017). Additional detail on well management and control is provided in that report.

The industry's primary approach is prevention. Well control and management typically include:

- conservative design of well equipment and programs to handle the range of identifiable risks
- development of detailed procedures based on global industry experience and adherence to these procedures during drilling
- use of multiple types of barriers, redundant barriers and incorporating redundancy in well design and execution

- regular inspection and maintenance of well control and monitoring equipment according to schedules specified in the well plan
- training of drilling employees and operators in on-going testing and emergency response drills prior to and throughout the drilling program

Well control during exploration, delineation and production drilling involves selective use of drilling muds to maintain the hydrostatic pressure in the well to avoid intrusion of oil, gas or formation water into the wellbore (CAPP 2017). If ongoing well monitoring detects well flows, and measures to manage or restore hydrostatic pressure are not successful, the operator would likely activate the blowout preventer (BOP) to manage a well control event and restore the hydrostatic pressure in the well (CAPP 2017).

Drilling programs in the Beaufort Sea are required to provide contingency plans, including a Well Control Plan and an Emergency Response Plan prior to the start of a drilling program. BOPs and other well control and emergency response equipment must meet regulatory, industry and operator specific standards (CAPP 2017).

The CER's same season relief well policy for the Beaufort Sea require that operators provide an alternative response[19] to an uncontrolled well flow event; in the past, this has involved planning for a relief well. Specifically, the policy states that as part of an application for a drilling authorization, an Operator must "demonstrate how they would meet or exceed the intended outcome of our policy" (NEB 2011b). Operators must describe their well management systems, same season relief well capability (or alternatives), proof of financial security and describe their operational reporting and notification procedures (NEB 2011b; NEB 2011b c).

2.9 Drilling and Support Vessels

The following is an overview of the major types of vessels that may be used to support an offshore exploration or production project.

2.9.1 Seismic Vessels

Seismic vessels are normally involved prior to the development of a project. In rare cases, during production there may be a short, small, acquisition program of 4D seismic to assess the movement of hydrocarbons during production.

2.9.2 Drilling Ships and Platforms

Drilling ships and platforms for the Canadian Arctic have to be able to withstand a range of open water and partial ice conditions. Depending on the specific conditions within the EL or SDL, drilling might be done from an artificial island in shallow water, or a Gravity Based Structure (GBS) in water up to 40m in depth. In deeper water (> 40m up to 100s of metres), drilling would be completed by specialized floating drilling platforms or deepwater drill ships.

[19] First responses includes well control and blowout protection valves.

2.9.3 Production Platforms

Production Platforms are designed to produce oil, gas and formation water, and store oil or gas for offloading onto a tanker for transportation to markets. In some cases, the platforms can contain facilities for liquified natural gas (i.e., LNG). The amount of hydrocarbon storage on the platform would be determined by the maximum flow rates of the reservoir and the take-away capacity of the tankers. In shallower water, production platforms may also contain injection wells for the disposal of production water and drill cuttings.

2.9.4 Ice Breakers and Ice Class Vessels

Icebreakers are special purpose vessels designed to break ice floes and sheets, and widen leads in ice covered waters (https://www.marineinsight.com/naval-architecture/design-of-ice-class-ships/; November 8, 2019). They are designed to be able to break thick ice and move through broken ice using strengthened hulls with specially designed shapes to break and clear ice and strong propulsion systems to create a channel and navigate through ice-infested waters. Icebreakers are often used to extend the season for oil and gas activities (e.g., drilling). They would be required to support year-round operations over the Ice Season. Icebreakers can be used to support the following aspects of oil and gas operations:

- protecting oil and gas infrastructure and activities from ice (e.g., islands, GBS, Floating Production, Storage and Offloading (FPSO) vessels, drilling operation)
- escorting wareships and other vessels that support offshore operations
- maintaining shipping routes through ice for tankers and other vessels
- maintaining access to ports and logistical bases (primarily during the late spring and early fall transition period)
- spill response support in the event of a spill

Ice class vessels are usually intended for general purposes (e.g., cargo, fuel, passenger vessels) but have additional hull strengthening and stronger propulsion systems to safely navigate and manoeuvre in ice.

2.9.5 Wareships

Wareships are purpose-built large vessels to store large volumes of drilling materials and supplies, including fuel, for drilling in areas remote from an onshore supply base. They are an economical alternative to the use of existing ports/shore bases or construction of custom-purpose logistical bases (Williams and Harrington 1984).

Wareships are typically self-propelled and are able to mobilize/demobilize to the field without support tugs or vessels. Wareships are typically secured or anchored close to the offshore platform (e.g., GBS, FPSO) to provide a readily accessible base for supplies and services. They have storage for a wide range of consumables including fuel, drilling muds, lubricants, drilling supplies, and mechanical parts. Wareships also may provide accommodation for service and supply workers, as well as other personnel that are not considered vital to the drilling or production operations on the platform.

2.9.6 Dredging Vessels

Dredging vessels are equipped with excavation tools that are capable of scraping or sucking bottom materials from the seabed, such as sand, gravel, or muddy sediments using either mechanical methods or hydraulic methods (https://www.marineinsight.com/types-of-ships/different-types-of-dredgers-used-in-the-maritime-industry/; November 8, 2019). Use of dredge vessels in offshore oil and gas projects include:

- channel and harbour dredging
- trenching for marine pipelines
- pipe and cable laying and intervention
- bottom preparation for offshore structures (e.g., GBS, pipelines, subsea manifolds)
- excavation of glory holes for drilling
- platform and wellhead intervention
- removal of contaminants from the seabed/environmental cleanup and disposal
- decommissioning (Waring 2010).

2.10 Logistical Support for the Offshore

Past offshore oil and gas development in the Beaufort Sea has required logistical bases to provide services and supplies for offshore activities, as well as facilities for crew changes. These logistical bases typically provided marine access and docking facilities, storage warehouses, fuel tanks, maintenance shops, administrative offices, airport facilities (i.e., runways, heliports, hangars, fuel and buildings for passengers and cargo), and water treatment and waste management facilities. Most also included some form of power generation. Annual sealifts, sometimes supported by road transportation to Inuvik and subsequent barging, were used to resupply these bases, as well as the offshore structures, platforms and vessels.

Tuktoyaktuk was the primary logistical support and supply base for oil and gas development in the Beaufort Sea (Guthrie 2019, pers. comm.). At one time, Tuktoyaktuk supported five major operations (Gulf/BeauDril Nalluk Base, Dome/Canmar base, Esso/Imperial Oil base, the Northern Transportation Company Limited (NTCL) base and a Dewline Station). The airport was and is still capable of handling large aircraft such as Hercules transport airplanes and passenger jets through to small fixed-wing aircraft.

Other logistical bases that were used by industry included:

- Herschel Basin
- King Point
- McKinley Bay
- Summers Harbour
- Wise Bay

Additional details on types of services required to support exploration and development and the associated economic opportunities are provided in Section 3.4.

2.11 Benefit Agreements, Employment and Training associated with Offshore Oil and Gas

The COGOA (Section 5.2) requires the development of a benefit plan defined as "a plan for the employment of Canadians and for providing Canadian manufacturers, consultants, contractors and service companies with a full and fair opportunity to participate on a competitive basis in the supply of goods and services used in any proposed work or activity referred to in the benefits plan". The Act also states that the Minister may require that benefits plan to include provisions to "ensure that disadvantaged individuals or groups have access to training and employment opportunities and to enable such individuals or groups or corporations owned or cooperatives operated by them to participate in the supply of goods and services used in any proposed work or activity referred to in the benefits plan". The CPRA (Section 21) also references benefit plans as described in COGOA.

The IFA (Subsection 16) describes a number of measures to drive economic development within the ISR including preferential use of Inuvialuit businesses, suppliers and services.

Benefit plans for past projects in the BRSEA Study Area typically includes commitments for employment, education, and training of Inuvialuit and other northerners. It also describes how Inuvialuit-owned and northern businesses, including those owned directly by the Inuvialuit Development Corporation and Inuvialuit beneficiaries, would have fair access to provide supplies and services. The Minister of CIRNAC Canada, or a delegate, has the responsibility for reviewing and determining the acceptability of benefits plans or can waive this requirement (NEB 2011c).

2.12 Environmental Considerations

The following is an overview of typical environmental issues of concern that have been raised during past project development and approvals in the BRSEA Study Area; it is not intended to be a comprehensive summary of all issues that have been raised by the Inuvialuit, government agencies or public stakeholders.

2.12.1 Air Contaminants and Greenhouse Gases (GHGs)

Routine activities for oil and gas projects would result in the release of various contaminants of concern (COCs) including:

- sulphur dioxide (SO_2)
- nitrogen oxides (NO_X)
- CO (carbon monoxide (CO)
- particulate matter with different particle sizes (10 micron or PM_{10}, and 2.5 micron or $PM_{2.5}$) and
- volatile organic compounds (VOCs)

Routine activities also would result in the release of greenhouse gases (GHGs) including:

- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)

The emission rates from these activities would vary with the types, extent and duration of activities, and the fuel consumed by each activity.

Activities that would generate such emissions include:

- marine bathymetric and seismic survey vessels
- drilling of wells (e.g., exploration, delineation, production) and movement of drill ships
- flaring
- various activities for field development and production including subsea installations and wellheads, towing and operation of offshore platforms, and transits by and operation of floating and production storage and offloading vessels (FPSO)
- marine vessels for resupply (e.g., annual sea lifts, regular resupply from supply bases)
- aircraft
- transits by tankers into and out of the region

The quantities of fuel for each of these activities are not fully known; however, from past projects, a large fraction of petroleum is consumed in the generation of electrical power to drive the equipment on the drilling and production facilities. While the quantities emitted by specific equipment or activities cannot be estimated for the BRSEA, types of emissions can be identified using the National Pollutant Release Inventory for Offshore Platforms in the ocean region off Newfoundland and Labrador (ECCC 2018a), and the national database on GHGs (ECCC 2018b); specifically:

- Power generation is typically supplied by turbine generators, burning either diesel fuel or fuel gas. The primary emissions from the combustion of diesel or produced gas include NO_2, CO, SO_2, TSP, PM_{10} and $PM_{2.5}$, and GHGs (CO_2, CH_4, and N_2O).
- Typical emissions from the operation of vessel and helicopter engines include CO, NO_2, SO_2, TSP, PM_{10}, $PM_{2.5}$ and GHGs (CO_2, CH_4, and N_2O).
- The flare system is an essential component of the pressure relief and safety system for a wellhead. It is designed to prevent over-pressurization of equipment during process upset conditions and dispose of associated gas produced during emergency situations (i.e., blow down during a de-pressurization; see next bullet point). Air emissions during flaring include CO, NO_2, TSP, PM_{10} and $PM_{2.5}$ and GHGs (CO_2, CH_4, and N_2O). In addition, a small amount of fuel gas would be continuously used for flare pilots during the operation of the well head platform; however, the associated air and GHG emissions would be minimal compared to other operational sources.

- Blowdown events are expected to be rare. If they occur, the emissions from the blowdown events are expected to be similar to those described for flaring, short in duration, and disperse rapidly with distance from the source to well below ambient standards at onshore receptor locations.

Air emissions are discussed in more detail in association with the scenarios described in Chapter 3 (i.e., Status Quo and the three oil and gas development scenarios) and the assessment of potential effects (Chapter 8).

2.12.2 Light

Light sources during oil and gas projects are closely associated with the activities being carried out to find, produce and transport the petroleum resources in a given marine area. Sources of lighting are associated with:

- power generation
- operation of offshore structures and production vessels
- flaring
- various types of vessels for drilling, resupply, ice breaking and management, and transport of oil and gas out of the region
- operation of helicopters and other aircraft
- maintenance activities (i.e., welding)

The nature of exploration and production activities demands that operation typically be 24 hours per day, seven days per week, which means that lighting is required at night and during the Arctic winter for safety reasons. The activities require the provision of extensive safety lighting. This includes interior and exterior lighting, and lighting fixtures along all walkways, stairways, ladders, towers, and process units. Additional lighting is also installed near critical process equipment such as valve trains, pumps, and vessels. For the most part, these light sources would be emitted from the major electricity generating, drilling and processing units. As an example, the operation of an offshore structure could have up to 200 luminaires, at 150 watts of electrical power each.

These safety-oriented lighting fixtures radiate light in all directions by design. As a result, light would be visible when viewing the offshore structure or vessel from an offsite observation point during hours of darkness.

The flares can also be a source of light; the strength of the light would depend on the quantities and rates of petroleum product flared.

2.12.3 Sound Generation

2.12.3.1 In-Air Noise

In-air noise would be generated by vessels and offshore structures during seismic exploration, exploration drilling, production drilling, field development and production, as well as from supply ships as they come and go, and unload at the offshore structure or FPSO. In-air noise would also be generated by transport vessels during transits to and from the site and during loading; and aerial support (i.e., helicopters) used to support crew transfer to and from seismic vessels, drilling platforms and production platforms. Ice breaking and management activities would also generate in-air noise.

2.12.3.2 Underwater Noise

The major sources of underwater noise include the operation of vessels and icebreakers, as well as the conduct of seismic surveys, drilling operations and production operations.

Support Vessels: Underwater noise would be produced by vessels used to support all phases of oil and gas exploration and development. The noise produced is typically generated by propeller cavitation and is considered to be continuous in nature. Average source levels of vessels have been shown to range from 159 (± 9) dBrms (decibel root mean square) for small craft to as high as 201 dBrms for large vessels (PAME 2019).

Icebreakers: Icebreakers use a strengthened hull to push and ram a path through ice, run ballast through the hull to stabilize or rock the ship over and through the ice, and may have propellers or thrusters at the bow and stern to assist with maneuverability. Icebreakers produce underwater noise source levels up to 10dB (decibel) higher than vessels operating in open water. In addition to noise created by the physical breaking of the ice, underwater noise produced by icebreakers is typically associated with the bubbler system and propeller cavitation (DOSITS 2019).

- The bubbler system is used to push floating ice away from the hull of the ship by blowing pressurized air into the water just below the surface. While in operation, the bubbler system produces continuous noise. Noise levels produced by the bubbler system are variable, but median broadband source levels have been calculated to be 192 dB re 1 μPa at 1 m (Erbe and Farmer 2000).
- Noise produced by propellers is continuous but more irregular, especially when the ship is breaking through ice by backing and ramming. This results in the ship propeller switching from forward to reverse and ramming the ice repeatedly. This type of manoeuvring can result in broadband source levels up to 205 dB re 1 μPa at 1 m (Erbe and Farmer 2000).

Seismic Exploration: Seismic vessels tow air source arrays suspended behind the survey vessel on floatation devices to maintain a specified operating depth. Air source arrays currently in use would output sound source levels less than 260 dB re 1 μPa at 1 m (Gisiner 2016; International Association of Geophysical Contractors 2002). This sound level decreases with increasing distance from the source. The source emits impulsive sound that lasts approximately 0.1 seconds and is repeated every 10–15 seconds.

Drilling: Underwater noise would be produced by the in-water equipment used by drilling platforms and drill ships. A study of broadband sound pressure levels from an active drilling platform surrounded by sea ice found that drilling produced noise levels to a maximum of 124 dB re 1 μPa at a distance of 1 km from the platform and dropped to below ambient sound levels 9.4 km from the platform (Blackwell et al. 2004a). Sound source levels measured from other drilling units operating in the Beaufort Sea, Chukchi Sea and Baffin Bay ranged from 146 to 190 dBrms (PAME 2019).

Production: Production equipment (e.g., power generation, pumps, hydraulic systems) and activities, as well as ongoing operations, would also generate low levels of underwater noise.

2.12.4 Offshore Waste

As described in the Offshore Waste Treatment Guidelines 2010, offshore operators are expected to take all reasonable measures to reduce the volumes of waste materials generated by their project activities, as well as reduce the amounts of contaminants of potential concern in the waste materials. Operators are expected to:

- "Reduce amounts of waste material generated and discharged offshore
- Reduce effluent volumes to the minimum required
- Reduce the concentrations of substances of potential environmental concern in effluents through process management and effective treatment
- Reduce toxicity of effluent streams by practicing effective source control at the chemical selection phase" (NEB et al. 2010)

Types and sources of liquid waste and solid waste are summarized below for surface structures associated vessels (e.g., wareships), and subsea structure based on the Offshore Waste Treatment Guidelines (NEB et al. 2010). The locations for the discharge of waste materials from offshore structures must be detailed in the Environmental Protection Plan (EPP) for the project.

2.12.4.1 Surface Structures and Associated Vessels

- Produced water: during petroleum production, formation water is extracted along with oil and gas and injection water is brought to surface . Operators are required to treat produced water prior to discharge into the marine environment or into a disposal well. In particular, operators are required to reduce oil in water concentrations to an average of 44 mg/l over a 24 hour period and an average of 30 mg/l over a 30 day period.
- Drilling muds: these are fluids that are circulated in wells during drilling to lubricate the drill bit, clean and condition the well hole, and maintain hydrostatic pressure within the well. Under the Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands, the constituents of drilling muds are screened through a chemical management system to manage the toxicity of chemicals used in the muds. Disposal of drilling muds varies according to the chemical components:

- Water-based mud (WBM) is the preferred product for drilling of wells whenever possible. Following use, WBM can be discharged into the sea without treatment if the residual oil concentration is < 15 mg/L.
- Synthetic based mud (SBM) or enhanced mineral oil based mud (EMOBM) are used in certain applications during the drilling of exploration, delineation and production wells. Neither of these muds can be discharged into the sea. The preferred disposal method is downhole injection.
- Oil based mud (OBM) is only used in exceptional cases and must be approved for use. It cannot be discharged to the sea.
- Drilling solids: these are largely the drill cuttings produced during drilling of the well into a geological formation. Disposal of drilling solids varies depending on the types of drilling muds used.
- Where WBM are used, drilling solids may be discharged to the sea without treatment.
- Where SBM or EMOBM are used during drilling, the preferred disposal method is downhole injection. Where this is not technically possible, the operator is required to demonstrate how removal of the large majority of the drilling fluids from the cuttings would be achieved. Operators may also choose to treat the cuttings and fluids to meet requirements for disposal at sea, or an operator may choose to transfer drilling wastes to onshore facilities for further treatment. The performance target for disposal of these solids is 6.9 g/100 g oil or less on wet solids for a 48 hour average.
- OBM-containing drill cuttings cannot be discharged overboard and must be disposed through downhole injection or transported to shore for disposal at an approved facility.
- Bilge water is seawater that has seeped or leaked into an offshore structure or vessel that may be contaminated with hydrocarbons. Bilge water with a residual oil concentration less than 15 mg/L can be discharged into the sea. Treatment such as an oil-water separator may be used to reach this requirement.
- Ballast water is used to maintain the stability of an offshore structure or vessel; it is typically segregated from the bilge water and, where no contamination is present, it can be discharged without treatment or monitoring (assuming the bilge water is from the immediate locale). Bilge water in vessels coming from jurisdictions outside Canada must flush their bilge water in international waters in compliance with the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78).
- Deck drainage is water from the superstructure of offshore structures as a result of precipitation, sea spray, and on-board operations and fire drills. It must be collected and treated to have a residual oil concentration of less 15 mg/L.
- Produced sand is generated from geological formations during production. It is separated during the processing of hydrocarbons. Before disposal, residual oil concentrations must be reduced to meet requirements for disposal in the sea.
- Well treatment fluids are used in activities such as well maintenance and formation fracturing. These fluids can be treated as a component of produced water (and associated standards for discharge) or collected and treated so that residual oil concentrations are less than 30 mg/L before discharge.

- Cooling water is pumped from the sea for use in heat exchangers to remove heat from certain production processes, before being returned to the sea. To prevent biofouling and corrosion of piping and mechanical systems, biocides are typically added to the cooling water. Before use, the biocides must be screened through the operator's chemical management system to meet the requirements of the Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands.
- Desalination brine from the production of potable water may be discharged without treatment.
- Sewage and food wastes must be macerated before discharge. If biocides are used to disinfect the discharge, the biocide must be screened (as noted for cooling water).

2.12.4.2 Subsea Structures

During the installation of subsea systems (e.g., manifolds), connection of new equipment to existing subsea systems, or subsea maintenance of these systems, small discharges to the sea may be required including ethylene glycol, methanol, water, brine, residual petroleum, and other residues. These discharges need to be identified in the operator's EPP; they need to be screened through the operator's chemical management system and should be kept as small as possible.

During the operation of subsea equipment (e.g., production risers, wellheads, blowout preventers, subsea pipelines and flowlines, and associated control systems), a number of fluids are required for hydraulic systems, pressure testing, antifreeze, and purging. These liquids include ethylene glycol and methanol. These fluids must be screened through the operator's chemical management system developed and meet the requirements of the Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands.

2.13 Oil Spill Planning and Response

The following section is a high level overview of the regulatory requirements, spill response planning, spill response management, and spill response organizations. It also includes high level information on the implications of oil behaviour on spill responses in the marine environment, spill response methods, methods for shoreline cleanup and remediation, and financial responsibilities and liabilities. A detailed review of these complex topics is outside of the scope of the Data Synthesis and Assessment Report for the BRSEA. While the review focuses on offshore oil and gas activities, oil spill response approaches and methods apply equally to hydrocarbon spills from ships, barges and other human sources.

2.13.1 Regulatory Requirements

2.13.1.1 Requirements for Oil and Gas Exploration and Production Activities

For accidents and malfunctions from an authorized oil and gas exploration and production work or activity, the CER would be the lead federal regulatory agency. The roles of the CER are:

- "holds the company responsible for responding appropriately by monitoring, observing and assessing the overall effectiveness of the company's emergency response;

- participates in single or unified command and other roles within the Incident Command System (ICS) framework (or similar framework if ICS is not used);
- investigates the event, either in cooperation with the Transportation Safety Board, under the Canada Labour Code, or as per the CER or COGOA (whichever is applicable);
- inspects the pipeline or facility;
- examines the integrity of the pipeline or facility;
- requires that appropriate repair methods are being used;
- requires that an appropriate environmental remediation of contaminated areas is conducted;
- coordinates stakeholder and First Nations feedback regarding environmental clean-up and remediation through an integrated approach both during and after the emergency phase;
- confirms that a company is following its Emergency Procedures Manual commitments, plans and procedures and CER regulations, and identifies non-compliances;
- initiates enforcement actions as required;
- coordinates post-incident follow-up meetings with the company to further enforce compliance and to share knowledge obtained during the emergency; and,
- approves the restart of the pipeline" (or the facility). (https://www.cer-rec.gc.ca/sftnvrnmnt/mrgnc/rspndmrgnc/rspndmrgnc-eng.pdf; November 8, 2019)

Under the current regulations, south of 60° N latitude, a proponent is required to create a certified Response Organization (RO) with a 10,000-tonne initial capability for a marine response for certain vessels and Oil Handling Facilities (OHFs). The current regulations do not specify requirements for proponents north of 60° N latitude. However, based on past precedence, oil and gas proponents for projects within the BRSEA Study Area have been required to develop oil spill response frameworks as part of their applications for environmental approvals (i.e., as part of the information provided to the EISC and, if triggered, the EIRB). Conditions for approval have also required proponents to develop detailed oil spill response plans and have appropriate spill response capabilities and equipment in place prior to the start of and throughout the exploration program.

2.13.1.2 Requirements for Marine Shipping

Transport Canada (TC) is the lead regulatory agency for marine spills from tankers and other vessels. The Department of Fisheries and Oceans, Canadian Coast Guard (DFO-CCG) would be the federal On-Scene Commander (OSC) for a response.

Based on the 2014 revision to the Canada Shipping Act (CSA), spill response requirements for marine shipping include the following:

- TC is the lead regulatory/governance agency for all ship-source spills and the overall response regime, while Environment and Climate Change Canada (ECCC) remains the lead for land-based spills.
- DFO-CCG is the lead response agency in the case of ship-source pollution spills.

- DFO-CCG is responsible for the development of its national and regional emergency response plans.
- The industry-funded Marine Oil Spill Preparedness and Response Regime is designed to provide the industry with the capability, under the leadership of TC, to respond to and "clean up its own spills". Specifically, industry is required to maintain a 10,000-tonne response capability for marine regions south of 60° N latitude in Canada.
- The Canada Shipping Act (CSA) 2001 requires that certain vessels and OHFs have arrangements in place with a TC certified RO to provide a 10,000-tonne response capability. In addition, certain vessels must have oil pollution emergency plans on board. Certain OHFs must have emergency plans, as well as equipment and resources on-site to immediately contain and control a spill incident at the facility.
- TC is responsible for ensuring that ROs and certain OHFs meet the standards set out in the regulations, and for monitoring the thoroughness of RO and certain OHFs operations and the effectiveness of the regime. As part of its regulatory capacity, TC ensures the adequacy of the planning standards and regulations.
- The DFO-CCG is responsible for responding to spills and would fulfill the federal monitoring and/or on-scene command roles for the Government of Canada and, among other things, north of 60° N latitude, would provide the response to mystery spills and ship source spills.

With respect to advice and consultation regarding response plans and response strategies, the DFO is responsible for the Marine Advisory Boards across Canada, whereas TC is responsible for all Regional Advisory Councils and the Marine Oil Pollution Working Group of the Canadian Marine Advisory Council (CMAC).

Within the GNWT, the Departments of Environment and Natural Resources and Lands, and the Office of the Regulator of Oil and Gas Operations (OROGO) are responsible for coordinating regulatory oversight and investigation of hazardous material spills in the Northwest Territories (NWT) under their respective jurisdictions (https://www.enr.gov.nt.ca/en/services/preventing-and-managing-spills; November 8, 2019). The Yukon Department of Environment (Environmental Protection) would play a similar role. The Inuvialuit Land Administration is responsible for conducting spill investigations and monitoring spill cleanup on private lands within the ISR. While these organizations are largely responsible for spills on land or in freshwater, they would be engaged in a marine oil spill response.

In addition to individual roles, a single-window approach to hazardous spill reporting and response was established in the NWT and Nunavut, including the ISR, in the 1980s. The Northwest Territories and Nunavut Spills Working Group Agreement is intended to "provide a single-window approach to hazardous materials spill reporting and the dissemination of information pertaining to spills …. and to establish a clear division of responsibilities with respect to which agency would act as the lead agency in the event of a spill" (NT/NU SWA 2014). The Spills Working Group Agreement signatories include the Government of Nunavut; the GNWT (Departments of Environment and Natural Resources, Industry Tourism and Investment and Lands), the Inuvialuit Lands Administration, CIRNAC (formerly INAC); Environment and Climate Change Canada, Canadian Coast Guard; Transport Canada; and the National Energy Board

(NT/NU SWA 2014). The Department of National Defence (Northern Region Headquarters) and Parks Canada, while not signatories, are active participants (NW/NT SWA 2014).

2.13.2 Spill Response Planning

The typical planning and preparedness phases to develop an oil spill response capability are:

- create a long-term preparedness, management and operational strategy and implementation plan based on a realistic scenario
- develop a series of detailed specific management, operational and training plans within that framework
- implement the long-term preparedness plan to include:
  - infrastructure development to support the operations
  - acquisition and commissioning of equipment and resources
  - training and exercises
- auditing procedures to ensure that capacity and capability is in place and is maintained

The Environmental Atlas for Beaufort Sea Oil Spill Response (Dickens et al. 1987) and the more recent update, the Beaufort Regional Coastal Sensitivity Atlas (Environment Canada 2014) were developed by environment Canada to provide a synthesis of environmental information relevant to the planning and implementation of oil-spill countermeasures in coastal areas of the Beaufort Sea.

For oil spill response in the BRSEA Study Area, a primary planning goal should be to increase available options in an emergency, including mechanical recovery, where they are appropriate and effective. It is especially important to have in place a rigorous, scientifically defensible, streamlined process to rapidly assess the environmental trade-offs (Net Environmental Benefits Analysis [NEBA] or Spill Impact Mitigation Assessment [SIMA][20]), as well as processes for the necessary approvals related to the use of spill treatment agents (e.g., herders, dispersants) and in-situ burning. Planning and preparedness to provide responders with the flexibility to rapidly select and apply the most effective and environmentally beneficial strategy is crucial to ensuring to the success of any spill response, linked with the need for thorough contingency planning and drills in advance.

This planning process could include an assessment of the relative merits or expected effectiveness of the different strategies once they are applied. This process could involve a viability analysis specifically for an oil spill response strategy for the BRSEA Study Area to quantify the window of opportunities for oil spill response systems. This type of Response Viability Analysis (RVA) estimates the percentage of time that marine conditions may be favorable, marginal, or not favorable for defined oil spill response systems. The planning process would address the issue of responses to subsurface releases under ice (i.e., blowouts or sunken or leaking vessels), as well as above-ice/water facilities and ship releases at the water surface

[20] http://www.ipieca.org/resources/good-practice/response-strategy-development-using-net-environmental-benefit-analysis-neba/
http://www.ipieca.org/resources/awareness-briefing/guidelines-on-implementing-spill-impact-mitigation-assessment-sima/

and under or on top of ice. There would be additional value from comparisons with the marine operating environments of the Norwegian Barents Sea, North Sea and the Canadian East Coast to provide context to the results.

Part of the planning process could include the identification of primary response areas for protection or cleanup, based on seasonal sensitivity and vulnerability, and the creation of Geographic Response Plans (GRPs). The GRPs should be initiated by local inhabitants and involve Inuvialuit TLK holders, and other subject matter experts. The Beaufort Regional Coastal Sensitivity Atlas (Environment Canada 2014) would provide a basis for development of GRPs, but would require updating given rapid changes in the BRSEA Study Area due to climate change, associated changes in coastal areas, and other factors (e.g., changes in infrastructure).

Long-range planning (>10 years) for spill response and mitigation should factor in technology changes that currently may be in the conceptual or prototype stage but may become proven operational tools within the time frame of the strategic planning. In particular, rapid recent developments in the application of Unmanned Aerial Systems (UASs) and Unmanned Surface Vehicles (USVs) could provide new and improved tools to safely meet the challenges of a response in remote arctic environments.

2.13.3 Spill Response Management - Incident Command System

Two critical components of a spill response operation are the leadership and organization of the operations. Leadership is provided through the Unified Command (UC) concept; the current recommended organization and management practice for emergency response in Canada is based on the ICS. A critical component of the UC concept is the engagement of local communities and residents in the leadership for the decision process. The combination of a UC with the ICS enables each organization or agency to carry out their responsibilities while working cooperatively within a single management system.

A Unified Command is a command structure that is necessary to bring together the Incident Commanders who have individual jurisdictional or management responsibilities for the major agencies and organizations who are involved in a response operation, including the Responsible Party (Figure 2-3). Multiple, and potentially overlapping, jurisdictions may be associated with boundaries based on:

- geography (land ownership or land management)
- government (federal, provincial, territorial, rights)
- functions (e.g., emergency response organizations)
- statutes (legislation and regulations)

A response should have a single Incident Commander (IC) within the UC team and a representative of the industrial proponent or Responsible Party would fulfill that role. Planning for a UC should clearly define the roles and responsibilities of the major agencies and organizations which would be involved. Each agency and organization would provide IC for the UC; for example, including but not limited to, and in alphabetical order: CER, CIRNAC, DFO-CCG, HTCs, GNWT, IGC, IRC, and TC.

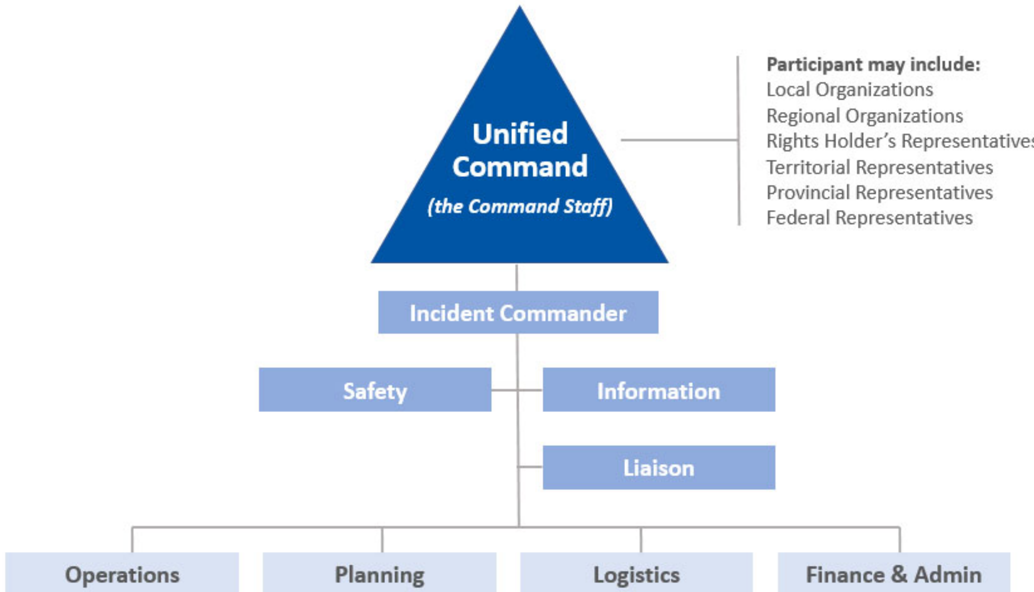


Figure 2-3 Composition of a UC, relationship between the UC and the ICS, and the components of an ICS

The ICS is a response management tool of which the key features are an organizational structure that:

- involves a single, effective, hierarchical organizational structure (Figure 2-3)
- can embrace multiple agencies and organizations
- follows standardized procedures for the coordination and functional management of personnel, equipment, and communications to maintain span-of-control
- can easily be scaled up or down depending on the nature of the incident and this scaling is effective as a response expands or contracts through time

See also: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/spills-and-environmental-emergencies/docs/intro-ics.pdf.

Effective implementation of a UC/ICS organization requires considerable planning and training. The US Oil Pollution Act of 1990 mandated that a UC/ICS system be standard practice for oil spill response. The US successfully adapted to this system, but it required practice through exercises, drills and actual spill incidents to achieve this paradigm shift in oil spill response. In Canada, several industry proponents are well versed in UC/ICS concepts and procedures; however, the level of competency of many agencies and other organizations varies depending on when these concepts were adopted. As discussed later in this report, the Government of Canada should initiate a UC/ICS system as early as possible regardless of how the oil and gas industry proceeds in the region; the UC/ICS also is of value for marine spill incidents from vessels.

2.13.4 Spill Response Organization

CER, as the lead regulatory agency for spills associated with offshore oil and gas exploration, and TC, as the lead regulatory agency for marine spills from vessels, would require that a certified oil spill RO be in place. That certified RO would be required to provide a 10,000 tonne capability for a marine Tier 1 response from pre-positioned equipment at site, most probably at Tuktoyaktuk and Inuvik. Arrangements would be made in the planning process for Tier 2 and Tier 3 level support:

- Tier 1 is defined as a response that would involve the "resources necessary to handle a local release and/or provide an initial response" (IPIECA 2015).
- Tier 2 is defined as the "shared resources necessary to supplement a Tier 1 response" which would be made available through mutual aid agreements (or similar) from other ROs in Canada and the US (North Slope of Alaska).
- Tier 3 is defined as the "global resources necessary for releases that would require substantial external support due to the incident scale, complexity, and/or potential consequences" that would be made available from international (US and global Tier 3 centers) mobilized through TC.

The RO would support the Operations Section in an ICS (Figure 2-3) and RO personnel would report to the Operations Section Chief.

A model for a certified RO is Alaska Clean Seas (ACS). This industry cooperative was established at Prudhoe Bay by industry as the Alaskan Beaufort Sea Oil Spill Response Body (ABSORB) in 1979. It has operated continuously since then to support onshore and nearshore development and production activities in the Alaskan Beaufort Sea and on the North Slope. When the organization was restructured in 1983, the objectives were to:

- develop spill response technology for the area
- acquire an appropriate inventory of the best available countermeasure equipment and materials
- maintain the equipment and materials in a high state of readiness
- provide spill response training for personnel of member companies and their contractors

ACS currently has approximately:

- a full-time staff of 91, with at least 35 on shift at any one time
- 150 trained responders available on a daily basis through the North Slope Spill Response Team (NSSRT)
- an additional 600 trained personnel who are available to ACS from Auxiliary Contract Response Teams (ACRT) (e.g., Pacific Environmental Corporation, National Response Center) and North Slope Village Response Teams (VRTs)
- 100 (inshore and river) vessels
- US$100M of equipment with an annual equipment replacement budget of US$1M

The RO for the BRSEA Study Area could be an industry cooperative, as is the case for ACS in Alaska, the Eastern Canada Response Corporation (ECRC) for Atlantic Canada or the Western Canada Marine Response Corporation (WCMRC) in British Columbia. If the program involves only one proponent, the RO may be supported by a single industrial organization; this is the case in Canada for Atlantic Emergency Response Team (ALERT), which is independently operated but affiliated with Irving Oil Ltd., and Point Tupper Marine Services Ltd. (PTMS), a subsidiary of NuStar Energy L.P.

Several existing organizations in the BRSEA Study Area could contribute to spill response planning and response. The Mackenzie Delta Spill Response Corporation (MDSRC)[21], formed in 2002, was a non-profit, cooperatively funded group made up of oil and gas companies operating within the Mackenzie River Delta and the Mackenzie Valley of the Northwest Territories (NT), Canada. The Canadian Rangers, a sub-component of the Reserve Force within the Canadian Armed Forces (CAF), provide a CAF presence in northern, coastal and isolated areas of Canada and are often engaged in disaster response and community evacuations. The local Canadian Coast Guard Auxiliary units in the ISR (e.g., Inuvik, Tuktoyaktuk, Uluhaktok) could also play a role in a spill response.

Whichever model is used, engagement of Inuvialuit communities in the RO, through involvement in the leadership and active participation on trained response teams, would be critical to promoting local understanding of spill response strategies, capabilities and trade-offs. In turn, the RO would benefit and gain understanding from Inuvialuit TLK, for example, sea ice characteristics, access and coastal sensitivities.

2.13.5 Implications of Oil Behaviour on Spill Responses in the Marine Environment

Two factors associated with the behaviour of spilled oil – the volume of recoverable oil and the oil slick thickness – strongly influence the success of a spill response. The former is related to natural fractionation and biodegradation of the oil and the latter to spreading on open water.

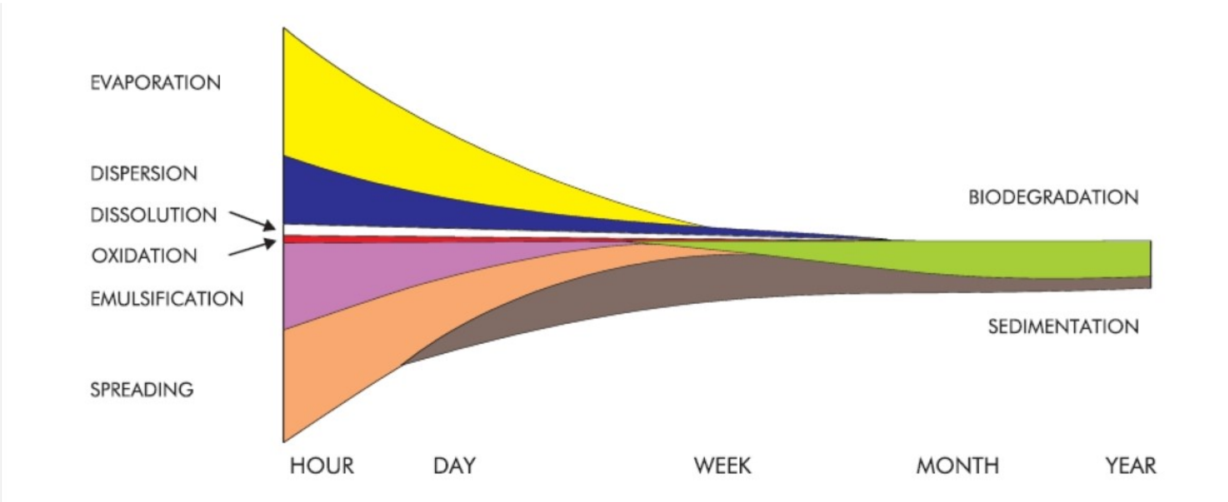
The physical properties of spilled oil begin to change immediately upon release. Collectively these processes are referred to as the weathering of the oil. Oil weathering processes over time are illustrated in Figure 2-4.

In the short term, the most important changes are evaporation into the atmosphere and, if the spill reaches water (i.e., direct contact or through the ice), dispersion and dissolution into the water column. Both of these weathering processes reduce the volume of oil that can be mechanically recovered or treated. For example, the NOAA ADIOS2 model for the weathering of North Slope crude oil[22] spilled into marine waters estimates that with a 10 knot wind speed and a water temperature of 15°C, approximately of 27% of the total oil volume would evaporate within 24 hours and 29% within 96 hours of a release (NOAA 2019; https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/response-tools/adios.html, November 8, 2019). Additionally, 1.65% of the oil volume would disperse into the water

[21] http://www.mackenziespillresponse.ca/gallery.html

[22] As very little oil has been extracted from the Canadian Beaufort Sea, North Slope Crude Oil is used as a surrogate for oil in the Beaufort Region.

column within the first 12 hours. Some increase in volume may result from emulsification as a result of wind movement and the associated wave action conditions. For North Slope crude and similar oils spilled into the marine environment, typically 30% is lost within a few days to a week by evaporation and natural dispersion, even in cold environments. The remainder is considered to be recoverable oil.



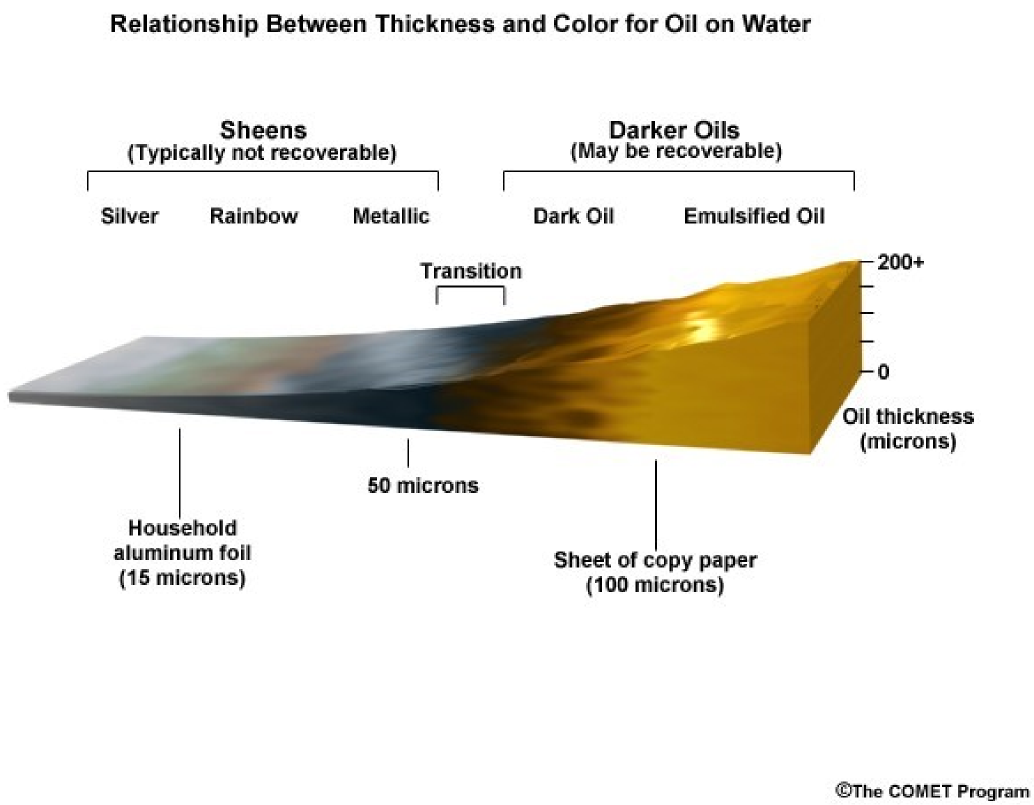
SOURCE: (https://www.itopf.org/knowledge-resources/documents-guides/fate-of-oil-spills/, November 8, 2019)

Figure 2-4 Weathering process for spilled oil over time

The light fractions that evaporate into the air and disperse into the water are potentially are the most toxic components of crude oil. The NOAA ADIOS2 model for North Slope crude oil predicts that virtually all of the benzene fraction evaporates or disperses within the first 6 hours following the release. Oil components that evaporate are also broken down by photo-oxidation (Garrett et al. 1998)

Oil components that disperse into the water column are biodegraded into carbon dioxide and water by naturally-occurring microorganisms, such as bacteria (Prince et al. 2017). Recent research has shown that biodegradation by micro-organisms indigenous to Arctic seawater is an active process for physically dispersed oil (e.g., McFarlin et al. 2014; Garneau et al. 2016).

Spreading is an important factor in dispersion and weathering and occurs rapidly immediately following the release of the oil into water (Figure 2-4). Oils similar to North Slope crude have relatively low viscosities and surface tension and, as a result, spread rapidly on open-water surfaces (Section 3.10.4; Table 3-11). Sheens less than 50 microns in thickness are too thin to be mechanically recovered, chemically dispersed or burned (Figure 2-5).



SOURCE: http://kejian1.cmatc.cn/vod/comet/emgmt/oil_aerial_surv/print.php.htm

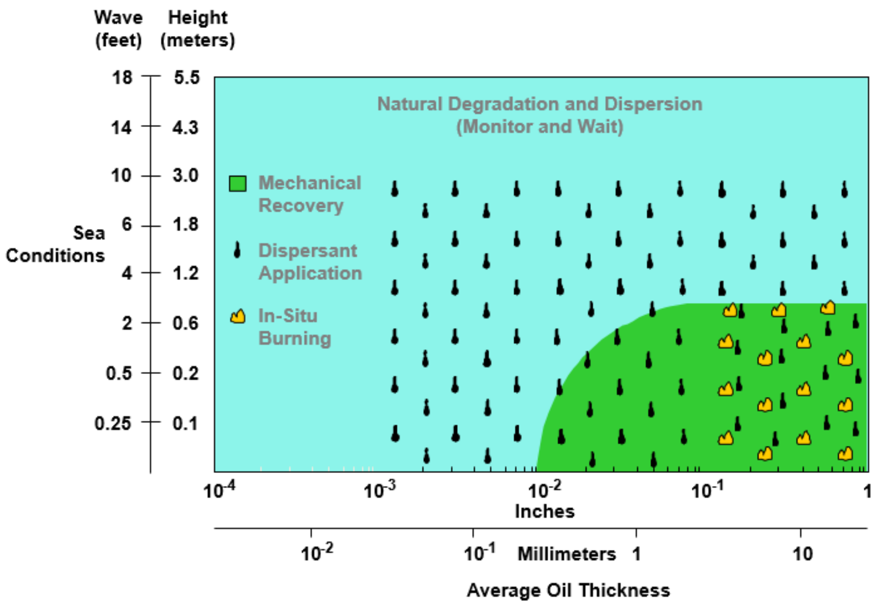
Figure 2-5 Relationship between oil slick thickness, colour and recoverability

2.13.6 Marine Spill Response and Removal Methods

In the event of an oil release, the first priorities are the safety of workers and people in the immediate vicinity of the spills, as well as stopping or reducing the source of the spill, and spill response.

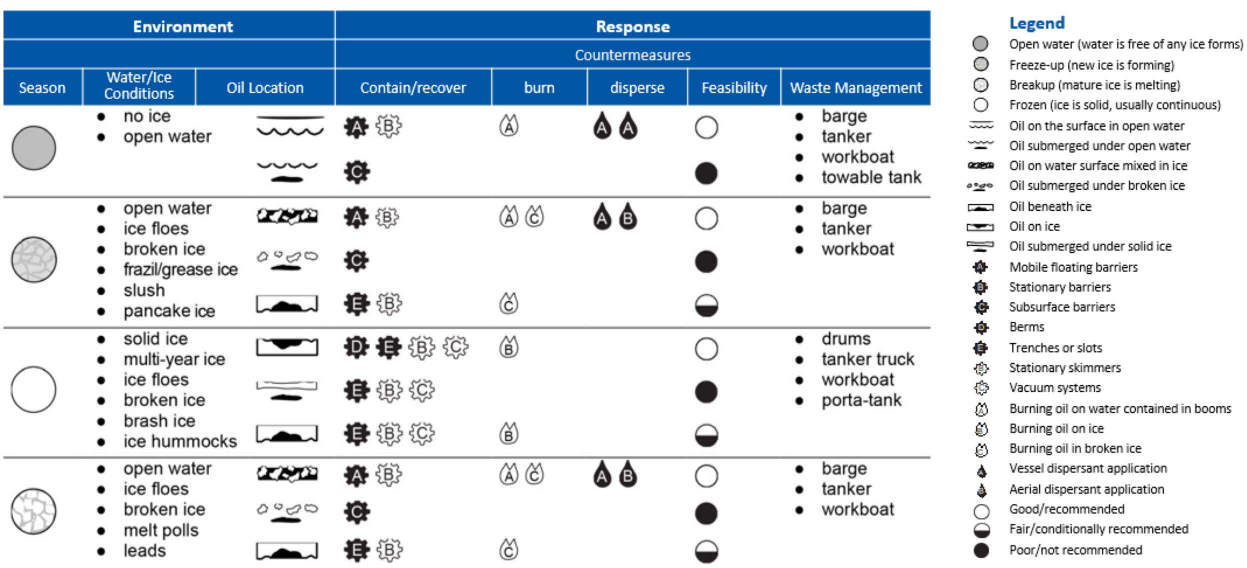
Any spill response requires detection and/or delineation followed by a trajectory analysis and transport modelling, predictions and tracking (e.g., aerial surveillance, remote sensing). The current generation of airborne detection, delineation, monitoring and tracking systems have a high potential for detecting and mapping large spills in open water and in very open ice, but less potential as the ice concentration increases (International Maritime Organization [IMO] 2017a). An important gap in technology for these components is under-ice detection and delineation; this is currently being addressed by a prototype air-deployed nuclear magnetic resonance technique (Altobelli et al. 2019) and the use of oil detection canines (dogs).

The response to an oil spill onto the surface of water or ice or onto the seabed relies on well-established principles and strategies, although different planning and response strategies apply for batch versus continuous spills (e.g., a vessel release versus a well blowout). These basic principles and strategies for mechanical containment and recovery, dispersion and controlled burning are based on windows of opportunity (e.g., sea states) and encounter rates (e.g., oil thickness) (Figure 2-6). The current best practice tactics associated with these strategies for arctic regions are described in an EPPR Field Guide (2017). The large oil release event presented in Section 3.10 are based on the four oceanographic seasons in this field guide: open water, freeze-up transition, solid ice, breakup transition (Figure 2-7).



SOURCE: from Allen 1988

Figure 2-6 Spill response options under various wind/sea conditions and oil thicknesses



SOURCE: EPPR 2017

Figure 2-7 Summary of possible response countermeasures by season and oil location

Mechanical containment and recovery are often preferred over other oil spill countermeasures because this strategy is viewed as directly removing oil from the marine environment. However, the recent experience with using mechanical recovery on an unprecedented scale in the Macondo response highlights a key drawback of mechanical containment and recovery systems when confronted by a large, rapidly spreading oil slick: namely, the encounter rate is insufficient to allow the skimmers to achieve an adequate percentage of their theoretical recovery capacity (Gregory et al. 1999). This problem in the BRSEA Study Area is amplified greatly by the presence of any substantial ice cover.

Another serious drawback in relying on mechanical recovery as a primary response strategy in the BRSEA Study Area is the difficulty in providing the necessary offshore storage to support sustained recovery operations involving large fluid volumes in remote situations. Although not necessarily the most effective strategy for dealing with very large Tier 3 incidents in remote areas, mechanical recovery has an important role to play in responding to smaller spills, especially in areas where there is sufficient infrastructure and marine resources to support the need for lightering, storage, and disposal.

Dispersants are designed to enhance natural dispersion by reducing the surface tension at the oil/water interface, making it easier for waves to create small oil droplets (generally less than 100 microns) that are rapidly diluted in the water column, such that natural levels of nutrients can sustain microbial degradation. When used appropriately, dispersants can be an effective oil spill response strategy. They are capable of quickly removing substantial quantities of oil from the sea surface by transferring it into the water column where it is broken down by natural processes (ITOPF 2014). Substantial environmental and economic benefits can be achieved, particularly when other at-sea response techniques are limited by weather conditions, distances, or the availability of resources. Rapid dilution down drift of the dispersant application can result in oil concentrations below toxicity threshold limits within very short distances However, as with other response techniques, dispersants also have their limitations and account must be taken of the characteristics of the oil being treated, sea and weather conditions and environmental sensitivities (ITOPF 2014; Paris et al. 2018).

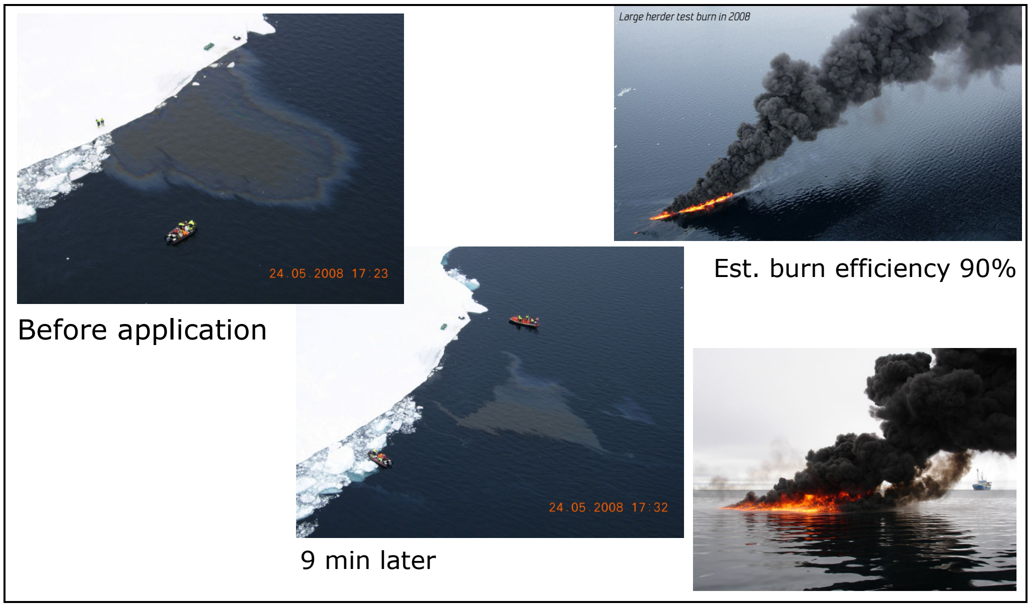
Over the past decade, a series of tank and basin tests and field experiments have proven that oil can be dispersed successfully in cold ice-covered waters. In recent studies in the laboratory at Point Barrow, Alaska, indigenous Arctic microorganisms effectively degraded both fresh and weathered oil. Most importantly, Arctic microorganism species and their counterparts in southern waters exhibited similar tolerance to dispersed oil, and the use of dispersants was not observed to increase the toxicity of the oil to these species (Gardiner et al. 2013). The substantial contribution of subsea injection of dispersants in the Macondo response in reducing environmental impacts both offshore and on the shorelines provides a new, potentially highly effective response strategy for dealing with future large oil release events from Arctic wells. NEBA/SIMA provide a means of assessing the probability and potential extent of impacts ahead of an actual incident and represents a valuable tool in assessing the environmental acceptability of using dispersants in a given scenario (IMO 2017a).

Controlled or in situ burning (ISB) in open water and snow and ice-covered environments is a safe, environmentally acceptable, and proven technique with numerous successful applications in large-scale field experiments and accidental spills over the past 40 years (Owens 2019, pers. comm.). ISB is especially suited for use on spills in ice where the ice cover itself often provides a natural barrier to maintain the necessary oil thicknesses for ignition, without the need for booms. Close pack ice (6/10 ice concentration or more) can enhance ISB by maintaining the original as-spilled thickness and preventing subsequent thinning through spreading (Buist and Dickins 1987). Recent and on-going research combines the aerial application of proven herding agents and ignitors to create a new rapid response tool for spills in open drift ice where the ice concentrations are insufficient to maintain a burnable film thickness (Photo 2-1 and Photo 2-2) (Buist et al. 2017; Potter et al. 2017; Cooper at al. 2017). Importantly, from both operational and environmental perspectives, US Federal and State agencies have developed comprehensive burn guidelines that lay out procedures to avoid health and safety risks to responders or local populations; a large body of research has demonstrated that burning can be environmentally safe in terms of smoke particulates and gases, carcinogens (PAHs), and residue aquatic toxicity (IMO 2017a).

New technologies to provide improved response capability and capacity in remote marine areas and during the transition seasons include fixed wing and rotary-wing herding/burning strategies or aerially-deployed Unmanned Surface Vehicles (USVs) (currently in the prototype test phase). Using today's technology, it is reasonable to assume that remotely-operated, aerially-deployed, ice-strengthened surface water vehicles (similar to jet skis) could safely deliver herders, ignition systems, and dispersants to remote marine areas in open water or during the transition seasons, with command-and-control data provided by Unmanned Aerial Systems (UASs). The military has similar capabilities in place today.

SOURCE: Potter et al. 2012

Photo 2-1 Burning crude oil spilled into a field of small ice cakes collected in a fire-resistant boom.



SOURCE: Photos: DF Dickins

Photo 2-2 Sequence showing before (left) and after (right) photographs during the first field test of herders under arctic conditions.

2.13.7 Shoreline Cleanup, Remediation and Restoration

Shorelines with persistent ice cover are typically protected from direct oiling in winter by a fringe of fast ice, which lessens the likelihood of substantial immediate impacts (Owens 2019, pers. comm.).

If oil is stranded on the shorelines of the Beaufort Sea coast, systematic air and ground surveys can provide information on the location and character of the oiled shorelines. The protocols for shoreline segmentation, a technique used to provide information for planners and operations that were developed for ice- and snow-free shorelines, require adaptation when ice and snow are present.

- The survey techniques are the same as used elsewhere in the world and face the same challenges for detecting and delineating subsurface oil when in ice and snow. Trained oil detection dogs have demonstrated the ability to locate oil in ice and buried in beach sediments.
- Treatment standards and end points should be based on the concept of NEBA, as it relates to the resources at risk and the potential effects of treatment actions.

2.13.8 Financial Responsibilities and Compensation

2.13.8.1 Offshore Drilling and Production

As part of the application for an authorization to undertake an offshore drilling program (e.g., exploration, delineation, production), field development or production program in the BRSEA Study Area, the applicant must demonstrate to the CER that the company is able to:

- undertake the proposed drilling program safely and in an environmentally responsible manner, as well as the ability to pay for these costs (i.e., Financial Viability)
- respond to a large oil release event and pay for all costs associated with responding to the spills, clean-up of the environment and compensation to affected parties

The Guidelines Respecting Financial Requirements (NEB et al. 2016) describe "the minimum information requirements and proof that an applicant must provide for an offshore drilling, development or production program to demonstrate to the respective Board that it is capable of acting in a responsible manner for the life of the proposed work or activity"[23]. For the BRSEA Study Area, the respective Board would be the CER.

As described in the Guidelines (NEB et al. 2016), an applicant must be able to show that they have the financial ability to "clean up the spill and debris" (such as a large oil release event); specifically, all costs associated with:

- containing each incident
- cleaning up the environment
- compensating affected third parties

This includes:

- all losses or damages incurred by any person as a result of the incident, including "loss of income, future loss of income and, with respect to any Aboriginal peoples of Canada, loss of hunting, fishing and gathering opportunities"
- "any costs and expenses reasonably incurred by any person, including a respective Board", as well as pay out all claims as appropriate

In the event an operator fails in these duties, the CER may "manage and control that work or activity and take all reasonable measures in relation to the spill and pay out claims for damages" (NEB et al. 2016), including the compensation provisions of the IFA. In such an event, the operator would be responsible to pay all such costs.

[23] The new financial requirements came into force through legislative amendments and new subordinate legislation; for the Beaufort Region the applicable acts are the COGOA and the CPRA.

Based on the polluter pay principle. the legislation sets out three components of financial requirements, with unlimited liability for an operator who is at fault for an incident. The following is a summary of these requirements as described by NEB et al. (2016):

- ***Absolute Liability***: An operator undertaking a drilling, development or production program for petroleum resources (including other authorized activities) is liable for the loss or damage that they may cause as a result of an incident in accordance with COGOA. The COGOA and the Inuvialuit Final Agreement further state that “operators are liable, regardless of negligence or fault, for losses or damages up to certain limits. This is known as absolute liability” (NEB et al. 2016). In 2015, amendments to COGOA (Section 26) increased absolute liability for operators to $1 billion.
- ***Financial Responsibility***: The Applicant for a drilling, development or production program must provide proof of financial responsibility (e.g., Letter of Credit, Bank Letter of Guarantee. Indemnity Bond, pooled industrial fund) to conduct the program as described in the application, as well as proof that they can maintain this responsibility for the duration of the program and, in certain circumstances, for a longer period (as the CER may direct).
- ***Financial Resources***: The Applicant must also “provide proof that it has the financial resources necessary to pay the absolute liability limit applicable to the work or activity”, as well proof of financial resources for the duration program and, in certain circumstances for a longer period (as the CER may direct). The Regulations set out the acceptable forms of financial resources.

2.13.8.2 Vessels

There are many differences in financial responsibilities and liabilities between spill incidents from vessels versus marine oil and gas facilities or rigs, including the assignment of liability and access to compensation. Canada has signed International Conventions that relate to compensation for a release of oil from a ship. These conventions provide uniform rules and criteria relating to compensation claims for the owners of ships, and for those affected by an oil spill in countries that have signed the appropriate convention.

3 SCENARIOS FOR THE STRATEGIC ENVIRONMENTAL ASSESSMENT

3.1 Purpose and Use of Scenarios

The development of scenarios for offshore oil and gas activities is a key foundational task for the Data Synthesis and Assessment Report. The scenarios are the basis for assessing how various types of existing and future (hypothetical) development might affect the physical, biological, socio-cultural and economic VCs of the BRSEA Study Area, including traditional use and wildlife harvesting. Scenarios such as these provide a framework to explore and evaluate plausible futures for the region and can help guide decision makers and organizations to make informed management choices (GeoAdaptative 2016).

- The scenarios are hypothetical and based on an understanding of the geology of the region, historical exploration and development activity, and current assumptions regarding how climate change could influence future exploration and development (see Chapter 6). The scenarios are not predictions of actual future projects or proposed projects.

As described in the Terms of Reference (Appendix A), five (5) hypothetical scenarios were developed; specifically:

- "one (1) status quo
- at a minimum, three (3) Scenarios of varying levels of development activity – 'low', 'medium' and 'high'[24]; and
- one (1) 'worst case scenario[25] or most severe potential outcome that can reasonably be projected"

The three oil and gas development scenarios reflect a range of oil and gas activities and outcomes that could result in different types and intensities of impacts to biophysical, socio-cultural and economic VCs, taking into account the location and extent of oil and gas activities, and the seasonal timing and duration of these activities.

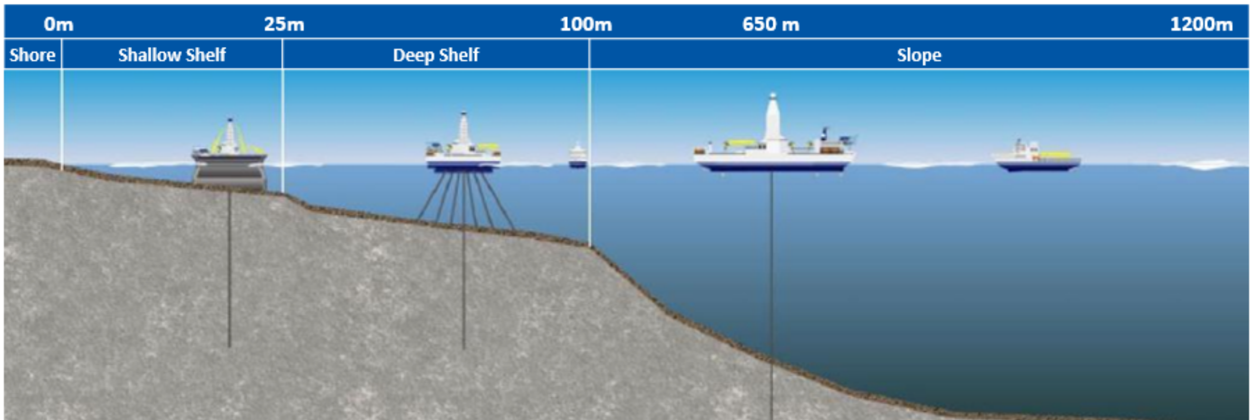
Where possible, specific elements within the three oil and gas development scenarios were deliberately selected to each include different types of infrastructure, activities and geographic locations (within the Canadian Beaufort Sea). Of note, attention was given to:

- Location of offshore development relative to landfast and pack ice, as well as the outflow from the Mackenzie River. These geographic locations reflect different ecological conditions and timing of biological and oceanographic events, as well as different levels and types of traditional use.

[24] For the purpose of the BRSEA and the Data Synthesis and Assessment Report, development intensity was assessed using Scenario 2 (Export of Natural Gas and Condensate) as low intensity, Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf) as medium intensity, and Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope) as high intensity (see Section3.5).

[25] The worst case scenario will be referred to in this report as a "large oil release event".

- Location of the project relative to the shallow shelf, deep shelf and deep slope of the continental shelf within the Beaufort Sea (Figure 3-1).
- Intensity of activities for offshore oil and gas development with respect to location, season and duration
- Different types of shipping support and vessel use, including ice-breaking
- Inclusion of different phases for offshore developments from seismic exploration and exploration drilling, through to field delineation; drilling of production wells; development of offshore infrastructure; production operations, decommissioning, and rehabilitation or restoration of disturbed sites.



Factors	Shallow Shelf	Deep Shelf	Slope
Water Depth	• 0m – 25m	• 25m – 100m	• 100m – 1,200m
Ice	• Land-fast, first-year ice • Limited multi-year ice	• Multi-year ice intrusions	• Multi-year ice present
Type of Offshore Drilling Rig	• Bottom-founded and moored drilling	• Moored drilling	• Dynamically positioned drilling

SOURCE: from CAPP 2011

Figure 3-1 Typical Drilling Depths and Associated Drilling Platforms in the Beaufort Sea

The inclusion of these different aspects for development were intentionally considered to facilitate the assessment of a range of potential adverse effects and/or benefits to different VCs (Chapter 4, Methodology).

For the Status Quo and the three oil and gas development scenarios, it is assumed that oil and gas proponents and operators would fully comply with environmental protection and management measures such as:

- government regulations and guidelines (e.g., federal, territorial and Inuvialuit guidelines for environmental protection, waste management)
- seasonal restrictions on aircraft flying altitudes (Notice to Pilots [NOTAMS])
- Inuvialuit and community guidelines to reduce effects on specific species and resource use (e.g., Beluga Whale Management Zones) and Community Conservation Plans
- industry best practices

Regulatory requirements, guidelines, mitigation measures and environmental protection measures for the Status Quo and the three oil and gas development scenarios were discussed in Chapter 2.

3.2 Process for Development and Finalization of Scenarios

The five scenarios were developed by a core team within the KAVIK-Stantec team. The core team included:

- An Engineering Panel that included: Jim Guthrie, John Hogg, Ed Owens, Mike Paulin and Peter Poos. These individuals have substantial experience in and knowledge of Arctic offshore oil and gas projects, including approaches to offshore development for oil and gas, logistical support and oil spill planning and response.
- A Scenario Team that included Jeffrey Green (KAVIK-Stantec) and Janine Beckett (Advisian) who have experience with development of scenarios for SEAs.

The Engineering Panel and the Scenario Team worked closely with the Co-Chairs to develop scenarios that would address existing and future uses (in absence of oil and gas development), different types and intensities of oil and gas development, and Large Oil Release Event. The process for development and finalization of the five scenarios involved the following steps (Table 3-1).

Table 3-1 Process for Development, Refinement and Approval of the Five Scenarios for the Data Synthesis and Assessment Report.

Date Range	Activity
Prior to 2019	Co-chair organizations conceptualize and discuss scoping for scenarios
March 26, 2019	Project initiation call with IRC
April 1, 2019	Project initiation call with CIRNAC
Late March – early April 2019	The Engineering Panel, in collaboration with the Scenario Team scoped out a suite of possible scenarios for consideration by IRC and CIRNAC.
Mid- to late April, 2019	Review of the suite of possible scenarios by IRC and CIRNAC.
April 24, 2019	Approach for scenarios and other documents (TLK and Climate Change) reviewed with IRC, IGC and CIRNAC. IRC and CIRNAC provided direction on the selection of the three oil and gas development scenarios (mid-water gas, mid-water oil and deepwater oil), as well as the approach to the Status Quo and Large Oil Release Event.
Late April to early May 2019	Engineering Panel and scenario team develop detailed descriptions of the Status Quo and the three oil and gas development scenarios. The scenario team and Ed Owens develop a first approach to Large Oil Release Event.
Early May 2019	Review of scenario descriptions by IRC, IGC and CIRNAC.
May 14, 2019	Teleconference with the IRC, CIRNAC and Advisory Committee to review scenario descriptions, as well as approach to TLK and Climate Change predictions. There was a request from an Advisory Team member to consider land-based gas extraction with offshore loading facility as a scenario. IRC and CIRNAC agreed to this change.
Mid-May to early-June 2019	Engineering Panel and scenario team revised scenario descriptions for Status Quo, three oil and gas development scenarios (Export of Natural Gas and Condensates, Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf, Large Scale Development of Exploration Licenses (EL) on the Continental Slope).

Table 3-1 Process for Development, Refinement and Approval of the Five Scenarios for the Data Synthesis and Assessment Report.

Date Range	Activity
June 12, 2019	Met with some members of the Advisory Committee, CIRNAC and CAPP to review specific details of scenarios with respect to how the oil and gas industry would most likely approach development.
Mid-June 2019	Approach for large oil release event modified to reflect four seasonal periods and locations relative to offshore currents and Mackenzie River plume. Description modified for review by IRC, IGC and CIRNAC
June 17, 2019	Teleconference with IRC and CIRNAC to review revised scenario descriptions (i.e., Status Quo; Export of Natural Gas and Condensates; Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf; Large Scale Development of Exploration Licenses (EL) on the Continental Slope; and Large Oil Release Event).
July 8 2019	Teleconference with IRC and CIRNAC to refine the revised scenario descriptions (e.g., review of estimate of quantities and timing)
July 30, 2019	Teleconference with IRC and CIRNAC to further refine the revised scenario descriptions (e.g., review of estimate of quantities and timing)
August 27, 2019	Teleconference with CIRNAC to finalize and approve scenario descriptions. Scenarios approved by CIRNAC for the assessment.
September 3, 2019	Separate teleconference calls with the biophysical and socio-cultural and economic assessment teams to initiate assessment of scenarios.
September 9, 2019	Teleconference with IRC to finalize and approve scenario descriptions. IRC confirmed that the scenarios are appropriate for assessment.

With the exception of some of the estimates of quantity and duration of certain activities in the Status Quo scenario (references are provided), estimates for volumes and quantities, frequency and duration and phasing of activities in the three oil and gas development scenarios were largely based on historical precedence and the professional judgement of the Engineering Panel.

3.3 Assumptions and Limitations

The scenarios for the Data Synthesis and Assessment Report were developed to reflect realistic predictions of current and future human activities (e.g., Status Quo), as well as descriptions of realistic oil and gas developments (the three oil and gas development scenarios) and a hypothetical large oil release event. None of the scenarios are site-specific and most only provide a rough approximation of timing and duration within the period of 2020-2050.

The lack of site-specific and time-specific information for specific activities and phases was deliberate. This is because the focus of a strategic assessment is not on specific project effects, but rather:

- identification of potential impacts of importance to VCs (i.e., potentially significant adverse or positive changes)
- an understanding of how impacts may result in effects to VCs (e.g., pathways)

- determining the potential range of impact characteristics (i.e., how important is this effect to the long-term sustainability of a Valued Component)
- describing potential types of mitigation measures and environmental protection

As discussed in Section 1.3, quantitative modeling for the scenarios or the assessment of environmental effects was outside the scope of this report. As an example, economic forecasting was not completed for the scenarios to estimate potential benefits such as jobs and training, local business benefits, and royalty and tax revenues for the Inuvialuit and other northerners, including Nunavut and the Yukon.

3.4 Hypothetical Onshore Supply and Service Bases and Administrative Centres

Each of the proposed scenarios for offshore oil and gas development in the Beaufort Sea would require logistical bases to provide services and supplies for offshore activities, and facilities for crew changes, as well as administrative and business support. For the Data Synthesis and Assessment Report, it has been assumed a major portion of the supplies and services for offshore development would be provided through annual sealifts and a combination of wareships and offshore supply bases. However, additional logistical support is likely to be required onshore; this would typically include marine access and docking facilities, storage warehouses, fuel tanks, maintenance shops, administrative offices, airport facilities (i.e., runways, heliports, hangars, fuel and buildings for passengers and cargo), and water treatment and waste management facilities. Most onshore facilities would also include some form of power generation.

Given the existing infrastructure (see below), Tuktoyaktuk would likely be used as a base during the Open Water Season, while a second coastal facility might be required to extend the marine resupply season as long as is necessary (Section 3.4.2). Offshore support would also be required (Section 3.4.3). Inuvik would likely remain the centre for administrative and business support (Section 3.4.4). In the case of onshore gas development, logistical bases would likely be developed for each major land-based producing field (however, given the marine focus of the Data Synthesis and Assessment Report, the effects of these logistical bases are not be assessed in the BRSEA).

The Inuvialuit, through the IRC, have identified the need to generate business and employment benefits for Inuvialuit beneficiaries and other northerners as part of any offshore activity and development. To provide specific opportunities during offshore development, it was assumed supply and services activities and infrastructure would be roughly allocated equally between the offshore and onshore bases. It is also assumed that project proponents for offshore developments and governments (federal and territorial), would provide training for Inuvialuit residents to help them secure long-term employment in diverse job areas throughout the industry, as well as direct and indirect business opportunities.

The following describes how Tuktoyaktuk and an additional logistics base might be used to support offshore development. Inuvik is assumed to be the administrative and business centre for oil and gas development in the region. These proposed uses are hypothetical for use in the scenarios; if an actual development were to proceed, specific details are likely to be the similar although the locations may differ with the specific need of the project.

3.4.1 Tuktoyaktuk

For each of the three oil and gas development scenarios (see Sections 3.7 to 3.9), Tuktoyaktuk is assumed to be the primary logistical support and supply base for oil and gas development in the Beaufort Sea, as it was during oil and gas exploration and development during the 1970s to 1990s.

Tuktoyaktuk provides a good base for logistical supplies and service given its proximity to the open ocean, as well as the presence of existing infrastructure. The 2017 completion of an all-weather road to Tuktoyaktuk now makes it easier to support year-round operations than it was in the past since transportation of supplies, equipment and construction materials to the community are no longer completely dependent on sea or river routes and air. In addition, there are still many community members who worked previously in oil and gas exploration, as well as companies and services with industry experience.

Tuktoyaktuk Harbour is the only existing harbour on the Canadian Beaufort Sea coast and has served as the main trans-shipment location for barged goods coming down the Mackenzie River and then along the Arctic coast for 75 years or more (Photo 3-1) (KAVIK-AXYS Inc. 2010). The harbour is open to vessel traffic from approximately mid-June to mid-October. Once ice forms across the harbour, ship tracks can obstruct over ice travel by residents for hunting and recreation. There are concerns that coastal erosion along the Tuktoyaktuk peninsula associated with climate change could threaten the viability of the harbour and community (Johnson et al. 2003).

NOTE: Nalluk Base in foreground, Canmar Base background, NTCL across from Canmar, and Dewline site across from NTCL

SOURCE: Jim Guthrie

Photo 3-1 Tuktoyaktuk base operations in 1985

While the main harbour area has water depths greater than 20 m, the Tuktoyaktuk Channel entry to the harbour only allows for vessels with drafts of up to 4 m (KAVIK-AXYS Inc. 2010). While dredging could be used to deepen the channel, past proposals for dredging have raised concerns regarding disturbance of fish habitat and fish harvesting. The new Class 2 shallow draft ice strengthened supply vessels, presently available in Canada, would be able to access the harbour fully loaded. Class 2 vessels are able to make constant progress through 2 feet/0.6m of ice.

The land and facilities previously owned by Gulf/BeauDril (Nalluk Base) could be upgraded as a base camp to meet some of the needs of future oil and gas development (Photo 3-1). The old Dome/Canmar base, currently owned by E. Gruben's Transport Ltd., could also be developed. The Nalluk Base and Canmar Base still have tank farms that could be used for storage of jet fuel, diesel and gasoline. While upgrades or new facilities could be built without interfering with the infrastructure of the community, the community government and residents should be consulted on preferred locations for future facilities.

The Tuktoyaktuk runway has been used extensively in the past by the oil industry, with as many as 10 crew changes per week using large jet aircraft (Photo 3-2). Other aircraft, including Hercules Transport, executive jets, and a wide variety of non-jet aircraft have used this runway on a regular basis. It is assumed that the runway surface and navigational aids would need to be upgraded to support future oil and gas development. For example, changing conditions in the region (e.g., increased fog in the area, caused by climate change), would necessitate advanced navigational aids to improve landing capabilities. For the purpose of the BRSEA, we have assumed the following types of air traffic in and out of the Tuktoyaktuk base:

- Helicopter traffic: During exploration, construction and development of offshore infrastructure and field development, the volume of helicopter traffic would be very high (e.g., an average of 12 helicopter round trips offshore per day). During operations, helicopter flights would be in the range of 2 to 4 per day to support crew changes, delivery of perishable foods, and small freight (e.g., emergency parts).
- Fixed wing traffic: During exploration, construction and development of offshore infrastructure, it is assumed there would be an average of 3 to 4 large jet round trips weekly from the south to support crew changes and deliver materials and supplies for offshore activities. During operations, it is assumed that flights would drop to 1-2 flights per week. There would also be round trips by smaller fixed wing aircraft to bring employees to work from various communities in the ISR.

It is assumed that all air traffic would follow guidelines to avoid environmentally sensitive time periods and specific sites (e.g., minimum flight altitudes, flight corridors to avoid environmentally sensitive areas).

To accommodate the higher volumes of air traffic associated with offshore development, the existing Tuktoyaktuk Air Terminal would need to be expanded or replaced, and a separate oil industry air terminal for fixed and rotary wing aircraft and helicopter hangar would need to be built. It is assumed that these new facilities would be located on the opposite side of the runway from the present air terminal, to reduce traffic congestion and noise effects on the community. Helicopter search and rescue services would need to be provided by the Coast Guard or commercial helicopter operators.

NOTE: all aircraft were operated by Inuvialuit businesses partners
SOURCE: Jim Guthrie

Photo 3-2 Aircraft at Tuktoyaktuk Airport on a crew change day

It is assumed that Tuktoyaktuk would be the main supply base for helicopter portable supplies like food and emergency provision of equipment and materials. Emergency response equipment and personnel would also likely be located in Tuktoyaktuk. Vessel traffic in and out of the harbour to service the offshore industry would likely be in the range of 1-2 vessel transits per day, since major stores of drilling materials and supplies would be located at the major supply base further east along the coast (see below).

As described for air traffic, vessel traffic would comply with guidelines and shipping routes to reduce or avoid environmentally sensitive areas and time periods (e.g., bird or whale migrations).

Business opportunities associated with the Tuktoyaktuk Base include:

- ownership and/or management of the Tuktoyaktuk Operations Base (e.g., Tuktoyaktuk Community Corporation)
- air services by Canadian North, Aklak Air, Canadian Helicopters or other operators (e.g., either owned by or partnered with IDC)
- drilling support, including provision of drilling crews and equipment (e.g., through IDC)
- offshore supply vessels (e.g., through an Inuvialuit-owned company or another supplier)
- dry docking facilities to facilitate vessel inspections, as well as repair and maintenance (Photo 3-3)
- support services for the base camps (e.g., catering, laundry, cleaning, maintenance)
- transportation services (e.g., bringing employees to and from work at the base, employees arriving or leaving by helicopter or fixed wing aircraft)
- personnel for the air terminal, warehouses and yards, as well as equipment operators and truck drivers

- Health, Safety, Security and Environment (HSSE) personnel (e.g., safety training and equipment, offshore survival)
- training and staffing for an oil spill cooperative
- Environmental Monitors (e.g., Wildlife Monitors, Marine Mammal Observers [MMOs], compliance monitoring, environmental monitoring)

SOURCE: Jim Guthrie

Photo 3-3 Drydocking an icebreaker in Tuktoyaktuk Harbour

Project proponents would have to negotiate benefit agreements with the IRC. These agreements would set specific targets for full-time and part-time employment of Inuvialuit beneficiaries and residents, and typically include written agreements with the proponent/operators as to the intent, commitment, plan and budget for various types of training and direct employment, as well as use of local businesses and services. Types of jobs include, but are not limited to:

- drilling crews
- marine crews (e.g., deckhands, engineers, mates and captains)
- aviation crews and maintenance
- accounting and administrative staff
- supply chain management
- logistic planners
- trades workers (electricians, mechanics, welders)
- communications and information technology personnel
- catering

- HSSE personnel
- environmental monitors
- oil spill and emergency response personnel

3.4.2 Additional Year-Round Logistical Support Base

Offshore oil and gas development may require an additional logistical support base that can provide year-round supplies and services; these bases would need to provide:

- a protected, deep draft harbour (i.e., entry and harbour area 10-20 m deep) to provide safe anchorages for vessels (e.g., ice breakers, wareships, tugs, spill response vessels) during summer storms and winter ice that is within a reasonable operational distance of the offshore development (i.e., within 100-200 nautical miles (NM) of offshore operations)
- office facilities for administrative and logistical support
- fuel storage using tankers or land-based storage tanks
- warehouses and yards for storage of consumables (e.g., drilling muds, cement, casings), HSSE equipment, replacement parts, machinery and other equipment (this could include land-based facilities and barges)
- offloading from supply ships, as well as loading of wareships
- drydocking capabilities to allow vessel maintenance and repair, as well as inspection
- equipment maintenance facilities
- airport facilities to support STOL (short takeoff and landing aircraft) and helicopters
- camp facilities for personnel at the base, as well as during crew changes (between offshore facilities and the base, as well as from ISR communities and the south)
- storage of oil spill and emergency response equipment
- housing for emergency response personnel (including training and drills)

Several options for year-round logistical support bases exist in the BRSEA Study Area (KAVIK-AXYS Inc. 2010; Figure 4):

- Herschel Basin
- King Point
- McKinley Bay
- Summers Harbour
- Wise Bay

Each of these five locations have been used in the past as locations for logistical support bases for one or more offshore oil and gas projects. Some have been used for overwintering of vessels and drilling platforms.

For the purpose of the scenarios considered for the BRSEA, Herschel Basin and King Point were not included as possible sites for logistical bases in the scenarios as they are located within or close to Qikiqtaruk Territorial Park (Herschel Island) and Ivvavik National Park and close to the Tarium Niryutait Marine Protected Area (most notably Niaqunnaq Marine Protected Area [Shallow Bay]). In addition, the Yukon North Slope Order (2010) withdrew use of all of the Yukon North Slope outside of the protected areas (i.e., Ivvavik National Park on the west to the Yukon and Northwest Territories border in the east, and from Vuntut National Park and Old Crow Flats Special Management Area on the south to the Beaufort Sea coastline on the north) (http://www.gov.yk.ca/legislation/regs/mo2010_009.pdf; November 6, 2019).

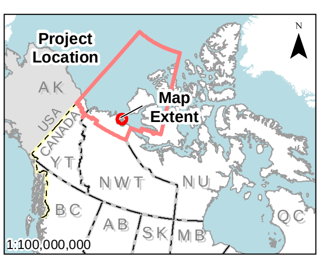
While McKinley Bay provides a protected harbour and close access to deep water, the approach has a maximum depth of 9 metres and would require maintenance dredging. It also does not provide the same level of protection as Summers Harbour. It was not considered further for the BRSEA oil and gas scenarios.

For the BRSEA scenarios, Summers Harbour and Wise Bay were considered as suitable locations for a year-round deep-water operation base which could accommodate deep draft vessels (>10 metres of draft) (Figure 3-2). Both are outside the influence of the Mackenzie River and would not require large-scale dredging to maintain the harbour. Of these two locations, given that Summers Harbour provides better protection from storms and sea ice than Wise Bay, it was chosen as the second hypothetical location for a supply and service base for the oil and gas scenarios for the BRSEA.

For the purpose of the three oil and gas development scenarios for the BRSEA, we have assumed that:

- an operations base has been developed in Summers Harbour to support offshore operations by one to several operators
- engineering studies have been completed to assess ice issues and identify appropriate locations for marine and land-based facilities
- required environmental approvals have been obtained, including the development and approval of an environmental management plan to mitigate impacts on the biophysical environment
- the dock design may not require dredging of the seabed (i.e., the dock could extend out to 150 meters from shore where water depths are greater than 10m)

In the past, BeauDril's drilling rigs *Kulluk* and *Molikpak*, and BeauDril's 4 Class 4 Icebreakers went in and out of Summers Harbour without concern (their drafts were less than 10 meters) (Photo 3-4). Year-round offshore oil and gas development would likely require Class 5 or Class 6 Icebreakers and, with recent modern designs, it is assumed they would remain in the range of 10 meters draft.



Study Area Boundary

0 1 2 3 4 km
1:125,000 (at original document size of 11x17)

KAVIK-STANTEC
INUVIALUIT REGIONAL CORPORATION

Project Location
Beaufort Sea, Northwest Territories, Canada

Project Number 123513135
Prepared by LTRUDELL on 20191104
Discipline Review by SJONES on 20191104

Client/Project
Inuvialuit Regional Corporation
Beaufort Region SEA

Figure No.
3-2

Title
Location of Summers Harbour and Wise Bay

Notes
1. Coordinate System: NAD 1983 UTM Zone 10N
2. Data Sources: Natural Resources Canada

NOTE: BeauDril's drilling rig *Kulluk* in foreground with BeauDril's Class 4 Icebreaker/supply vessels and the drill rig *Molikpak* in background.
SOURCE: Jim Guthrie

Photo 3-4 Summers Harbour during Fall 1986

For the three oil and gas development scenarios for BRSEA, it is assumed that Summers Harbour would provide similar business and employment opportunities, as discussed for Tuktoyaktuk.

3.4.3 Offshore Supply and Support

Based on current operations in other offshore oil and gas areas in the world, it is assumed that an offshore development in the Beaufort Sea would be supported by a bottom-founded or floating supply base or ice-strengthened wareships moored close to the development location. Resupply of wareships would occur by replacing the existing vessel with a fully supplied vessel, or by transferring supplies by a supply vessel or barges.

For exploration programs and operations during winter, it is assumed an ice-strengthened wareship would be moored near the offshore activity. It is assumed that some ice breaker support would be required to protect the wareship overwinter. During the transition periods in spring and fall, a wareship could be temporarily relocated to avoid large ice floes from the Polar Pack.

3.4.4 Inuvik as the Administrative and Business Centre

Inuvik is the commercial and administrative centre for the Canadian Beaufort Region; it is the third largest community in the Northwest Territories (https://www.inuvik.ca/en/doing-business/Doing-Business-Here-Why-Inuvik.asp; November 8, 2019). It is the major transportation hub in the region with three airline companies servicing the Inuvik Airport, as well as a direct connection to the south of Canada by the Dempster Highway and, recently, a direct connection to Tuktoyaktuk by the new Inuvik to Tuktoyaktuk Highway. Major companies and services in Inuvik include transportation, construction, public administration, supplies and a range of services for both residents and industry.

Based on past oil and gas projects in the region, Inuvik typically served as the business and administrative centre for industry projects. Most major operators maintained administrative offices in Inuvik, given the proximity to government offices for federal, territorial and Inuvialuit agencies and organizations.

3.5 Potential Effects of Climate Change on Oil and Gas Development and Other Human Activities

Climate change is expected to result in changes to open water, sea ice and weather conditions that would influence how, when and where certain human activities, including oil and gas activities, might occur. These changes in human activities need to be considered when assessing adverse effects and benefits to VCs over a period of 30 years (i.e., 2020-2050). To provide assessors with consistent guidance on how various activities might change, a summary of changes to human activities was developed using Stantec (2013a), information on climate change in this report (Chapter 6), and the professional judgement of the engineering panel and climate change team for this report.

Potential effects of climate change on oil and gas activities and other human activities were reviewed by Stantec (2013a) in support of the Beaufort Regional Environmental Assessment Climate Change Working Group. Potential effects of climate change on the oil and gas industry are summarized in Table 3-2; these predicted effects are largely based on the Stantec (2013a), and the professional opinion of the KAVIK-Stantec climate change team and Engineering Panel. Detailed references are provided in Stantec (2013a).

Some changes would result in benefits to construction and operational activities such as longer open water periods and shorter Ice Seasons. Other changes may result in adverse effects such as extreme weather events (e.g., storm surges, increased fog) and coastal erosion.

Table 3-2 Potential Effects of Climate Change on Industrial and Human Activities in the BRSEA Study Area

Environmental Change[26]	Potential Change in Industrial and Human Activities		
	2020-2030	2030-2040	2040-2050
Earlier Open Water • Would benefit start date for seismic, drilling, and some aspects of production. • Timing of traditional fishing and hunting trips may shift with earlier Open Water Season	• Activities such as seismic exploration and drilling might start by early July.	• Activities such as seismic exploration and drilling might start in late June or early July.	• Activities such as seismic exploration and drilling might start in late June.
Later Open Water: • Would benefit later end date for seismic, drilling, and some aspects of production. • Extend traditional use of nearshore	• Activities such as exploration drilling might extend to mid-November.	• Activities such as exploration drilling might extend 3-10 days later than in 2020, depending on interannual freeze-up timing.	• Activities such as exploration drilling might extend 7-14 days later than in 2020, depending on interannual freeze-up timing.
Longer Open Water Season: • Longer vessel operating season • Reduced need for ice management • Longer Open Water Season beneficial to spill response.	• Open Water Season for vessel transits in southern Beaufort Sea ranging from 50 days in areas offshore to 85 days nearshore.	• Open Water Season for vessel transits in southern Beaufort Sea ranging from 65 days in areas offshore to 100 days nearshore.	• Open Water Season for vessel transits in southern Beaufort Sea ranging from 80 days in areas offshore to 120 days nearshore. • By 2050, there would be a 50-60% chance of ice-free conditions in early fall throughout the southern Beaufort Sea.

[26] For detailed information on these projected changes, see Chapter 6 and Appendix C.

Table 3-2 Potential Effects of Climate Change on Industrial and Human Activities in the BRSEA Study Area

Environmental Change[26]	Potential Change in Industrial and Human Activities		
	2020-2030	**2030-2040**	**2040-2050**
Thinner or Reduced Ice Cover (including less multiyear year and more first year ice) and later freeze-up: • Timing of snow machine travel over sea ice by Inuvialuit and other users may be delayed and impacted by sea ice lead formation / decreased landfast ice extent and duration.	• Ice breaking period (i.e., mid-fall transition through to mid-spring transition) ranging from 225 – 275 days, (longer in waters offshore of the Continental Shelf). • Earlier entry and later egress by support vessels that do not overwinter in the region.	• Ice breaking period (i.e., mid-fall transition through to mid-spring transition) in range of 210-260 days, with thin ice appearing and persisting later into the fall. • Earlier entry and later egress by support vessels that do not overwinter in the region.	• Ice breaking period (i.e., mid-fall transition through to mid-spring transition) in range of 195-245 days, with thin ice appearing and persisting later into the fall. • Earlier entry and later egress by support vessels that do not overwinter in the region.
Increased Ice Velocities: • Ice speed can affect movements of vessels, as well as ice management for offshore platforms (e.g., ice breaker support). • Increased ice speed would also enhance the movement of oil trapped in ice (Scenario 5).	• Winter mean ice velocities have increased from 2 -5 cm/s over the past 35 years. This trend is expected to continue (5-6 cm/s in 2020-3030) or even accelerate.	• Expected to continue to increase; with speeds of 6-7 cm/s based on continuation of existing trend. Increased dominance of first-year sea ice in the region expected to exhibit increased dynamic sea ice activity (motion, dynamic thickening, and possibly winter sea ice lead formation).	• Expected to continue to increase; with speeds of 7-8 cm/s based on continuation of existing trend. Increased dominance of first-year sea ice in the region expected to exhibit increased dynamic sea ice activity (motion, dynamic thickening, and possibly winter sea ice lead formation).
Increased Precipitation: • Increased likelihood of early winter and spring freezing rain events. Could affect aircraft use.	• +0.92 mm/year increase projected for Tuktoyaktuk.	• +9.2 mm/year mean increase in combined precipitation projected for Tuktoyaktuk by 2040.	• Combined precipitation is expected to increase by +32.1 mm at Tuktoyaktuk by 2050.

Table 3-2 Potential Effects of Climate Change on Industrial and Human Activities in the BRSEA Study Area

Environmental Change[26]	Potential Change in Industrial and Human Activities		
	2020-2030	**2030-2040**	**2040-2050**
Increased Fog / Low Visibility Days: • Increased fog / reduced visibility would have implications for aerial and maritime operations (e.g., delays in travel); it could also affect oil spill response.	• Maximum probability of fog during August over open water. • Average probability of fog days during the Open Water Season of 25%, with peak occurrences between 1000 – 1800 UTC (Coordinated Universal Time).	• Maximum probability during August over open water. • Average probability of fog days during Open Water Season of 25%, with peak occurrences between 1000 – 1800 UTC. Uncertainty due to lowered visibility from intense precipitation events, particularly blowing snow.	• Maximum probability during August – Mid-September over open water. • Average probability of fog days during the above-noted Open Water Season of 25%, with peak occurrences between 1000 – 1800 UTC. Uncertainty due to lowered visibility from intense precipitation events, particularly blowing snow.
Increased Air Temperatures	• Mean temperatures over the Beaufort Sea expected to increase by 3 - 5°C between September and February, and 1 – 2°C between March – August.	• Mean temperatures over the Beaufort Sea expected to increase by 4 - 7°C between September and February, and 1.2 – 3.5°C between March – August.	• Mean temperatures over the Beaufort Sea expected to increase by 5 - 9°C between September and February, and 1.5 – 5°C between March – August.
Increased Ocean Waves: • Traditional fishing and maritime activities in small craft would be impacted by increased wave action. • Could limit oil spill response capabilities, but would also increase dispersion of an oil spill	• Beaufort Sea mean significant wave height (Hs) increasing by 0.1 – 0.25 m relative to 1980 – 1999 • States with Mean significant wave height (Hs) >2 m (> 3m) are expected to increase in frequency by 0 – 2 days (0 – 1 days) in September, and by 2 – 6 days (0 – 0.5 days) in October. • Hs over 4.0 m would restrict support vessel movements	• Beaufort Sea mean significant wave height (Hs) increasing by 0.25 – 1.0 m relative to 1980 – 1999 • States with Hs >2 m (> 3m) are expected to increase in frequency by 0 – 2 days (1 – 2 days) in September, and by 2 – 6 days (0 – 1 days) in October. • Hs over 4.0 m would restrict support vessel movements	• Beaufort Sea mean significant wave height (Hs) increasing by 0.5 – 1.5 m relative to 1980 – 1999. • Increased occurrence of easterly-driven waves relative to westerly winds and waves. • States with Hs >2 m (> 3m) are expected to increase in frequency by 2 – 4 days (0 – 0.5 days) in September, and by 2 – 6 days (0 – 1 days) in October. • Hs over 4.0 m would restrict support vessel movements.

Table 3-2 Potential Effects of Climate Change on Industrial and Human Activities in the BRSEA Study Area

Environmental Change[26]	Potential Change in Industrial and Human Activities		
	2020-2030	**2030-2040**	**2040-2050**
Increased Winds/Storm Surges: • Likely to affect vessel and aircraft movements at wind speeds above 56 - 63km/hr. • Damage or loss of coastal infrastructure	• Current (2020) median wind speed of 11.00 km/hr at Tuktoyaktuk. • Mean wind direction of 175° (S) and median of 140° (ESE) at Tuktoyaktuk; ESE and WNW at Pelly Island[27]. • June – October Open Water Season, mean storm frequency ranges from 3.1 (June) to 4.5 (October) storms per month • Increased likelihood of damaging storm surges >2.0m above mean sea level at Tuktoyaktuk due to existing storm climatology interacting with increasingly longer Open Water Seasons, persisting until late October. • Likely to affect vessel and aircraft movements at wind speeds above 56 - 63km/hr.	• Increase in wind speed by a median of 2.5% / maximum of 3.5% for the BRSEA Study Area, relative to 2020. • Minimal change in storm frequencies; however increased likelihood of damaging storm surges >2.0 m above mean sea level at Tuktoyaktuk due to existing storm climatology interacting with increasingly longer Open Water Seasons, persisting until early November.	• Increase in wind speed by a median of 5% to maximum of 6.5% for the BRSEA Study Area, relative to 2020. • Minimal change in storm frequencies; however increased likelihood of damaging storm surges >2.0 m above mean sea level at Tuktoyaktuk due to existing storm climatology interacting with increasingly longer Open Water Seasons, persisting until early-mid November.
Sea Level Rise	• Sea level rise at Tuktoyaktuk increasing at rate of +75 mm ± 50mm	• +150mm ± 100mm mean increase would likely require changes in coastal infrastructure	• +300mm ± 200mm mean increase would likely require changes in coastal infrastructure

[27] Meteorological data from Pelly Island (just west of Tuktoyaktuk) is included as it is believed to better represent the marine wind environment in the offshore Canadian Beaufort Sea (Fissel et al. 2009).

Table 3-2 Potential Effects of Climate Change on Industrial and Human Activities in the BRSEA Study Area

Environmental Change[26]	Potential Change in Industrial and Human Activities		
	2020-2030	2030-2040	2040-2050
Reduced Permafrost	• Increased need for dredging to support vessel traffic into Tuktoyaktuk Harbour and manage coastal erosion. • Require changes in oil and gas supporting coastal infrastructure. • Also, would impact current infrastructure (roads, buildings, power stations, schools, etc.). • Socio/economic impact and potential for additional coastal habitat impacts.	• Increased need for dredging to support vessel traffic into Tuktoyaktuk Harbour and manage coastal erosion. • Increased intensity of ongoing mitigation efforts to protect critical community and oil and gas infrastructure from permafrost changes, coastal erosion, and thermokarst failure.	• Increased need for dredging to support vessel traffic into Tuktoyaktuk Harbour and manage coastal erosion. • Increased intensity of ongoing mitigation efforts to protect critical community and oil and gas infrastructure from advanced permafrost changes, extensive coastal erosion, and widespread thermokarst failure.

3.6 Scenario 1 – Status Quo

The purpose of the scenario is discussed first, followed by a general description of the activities considered in the scenario. This is followed by two tables: one that quantifies the volume/quantity, duration and frequency of these activities, and a second table that describes the range of years (during 2020-2050) and seasons over which the activities are likely to occur. Where available, references are provided to support the quantities, duration, frequency and seasonality of current activities. Other estimates are based on the professional experience and knowledge of the Engineering Panel and the Scenario Team.

3.6.1 Overview: Scenario 1 (Status Quo)

The purpose of the Status Quo Scenario is to describe existing human use activities, other than oil and gas activities, that are likely to occur in the BRSEA Study Area over a time frame similar to that for the development scenarios (e.g., 2020-2050). The Status Quo Scenario provides the basis for considering potential effects on biophysical and socio-economic VCs in the absence of oil and gas activity over the 30-year time frame. However, it is assumed in each of the three oil and gas development scenarios that these activities would be occurring within the same temporal scope as the development scenario (i.e., the assessment of environmental effects for each of the development scenarios assumes that the activities described below are also occurring; the cumulative effects of these activities are discussed for each Valued Component.

Types of human activities that currently occur in the ISR and are considered in the Status Quo scenario include:

- ***Commercial shipping*** is expected to increase within the region in response to increased development in the Canadian Arctic and longer Open Water Seasons that open up the Northwest Passage as a viable transport option for shipping to global markets.
- ***Cruise ship tourism*** has been increasing in the region over the past decade and is expected to increase as changing sea ice conditions and longer Open Water Season allow for access by different types of vessels and higher frequency of visits by cruise ship and tourism operators.
- ***Regional boat traffic and snowmobile traffic*** associated with traditional harvesting activities and personal use is expected to continue into the future. Traditional harvesting activities may increase slightly with population growth. Of note, traditional harvesting activities are a major component of the local economy in the ISR (Usher et al. 2003). Traditional harvesting not only provides a substantial volume of food for local residents, but also is an important basis of the cultural and social fabric of the Inuvialuit. While harvesting activity and associated boat or snowmobile travel does occur offshore (e.g., polar bear hunts, inter-island travel), most of these activities and travel occurs within 5 km of shore.

- ***Ship-based resupply and export*** for communities and mine-exploration sites is expected to continue and increase in frequency as resource development projects proceed (e.g., in association with the Grays Bay Port and Road in Nunavut). This include inbound ship transits to supply communities and developments with fuel, equipment and consumables, as well as outbound transits to carry products and certain types of solid waste.
- ***Renewable energy*** - while solar power is being used in several communities (e.g., Inuvik), no wind turbines are operational in the region. In the past, land-based wind turbines have been installed but none are currently operational. No offshore installations have been proposed. However, in the future, communities in the ISR might consider wind energy or other renewable energy projects as an alternate energy source, based on the experience of Kozebue, Alaska (this community has 19 operating land-based turbines) (https://www.rcinet.ca/eye-on-the-arctic/2018/06/26/wind-renewable-inuvik-canada-alaska-power-arctic/; November 8, 2019).
- ***Scientific research*** is currently ongoing in the region and is expected to increase in frequency as arctic environments and communities shift with the influence of climate change; this includes offshore cruises and sampling (including use of underwater remotely operated vehicles and mooring arrays), as well as coastal/shoreline research and surveys.
- ***Military vessels and exercises*** would continue and may increase in frequency as changing sea ice conditions open up access. These exercises can include ships, as well as submarines from Canada and other participating countries (e.g., Operation Nanook) https://nunatsiaq.com/stories/article/redesigned-operation-nanook-gets-underway-in-the-canadian-arctic/; November 11, 2019).
- ***Lower-level aircraft overflights*** (i.e., under 1000 metres) are expected to continue and potentially increase slightly, given opportunities for tourism, renewable energy and possibly mining exploration. While there are aircraft overflights at higher altitudes (e.g., commercial aircraft travelling the Great Circle route between Europe, North America and Asia), these flights would not be a major source of impacts to the biophysical or socio-cultural environment.

Existing and future conservation and protected areas would influence the distribution and intensity of human use in some portions of the region. Within the BRSEA Study Area, there are two existing marine protected areas to consider (Figure 3-3, from https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/anguniaqvia-niqiqyuam/index-eng.html):

- Tarium Niryutait Marine Protected Area made up Niaqunnaq Marine Protected Area (Shallow Bay), Okeevik Marine Protected Area (East Mackenzie Bay), and Kittigaryuit Marine Protected Area (Kugmallit Bay)
- Anguniaqvia Niqiqyuam Marine Protected Area (west side of Darnley Bay)

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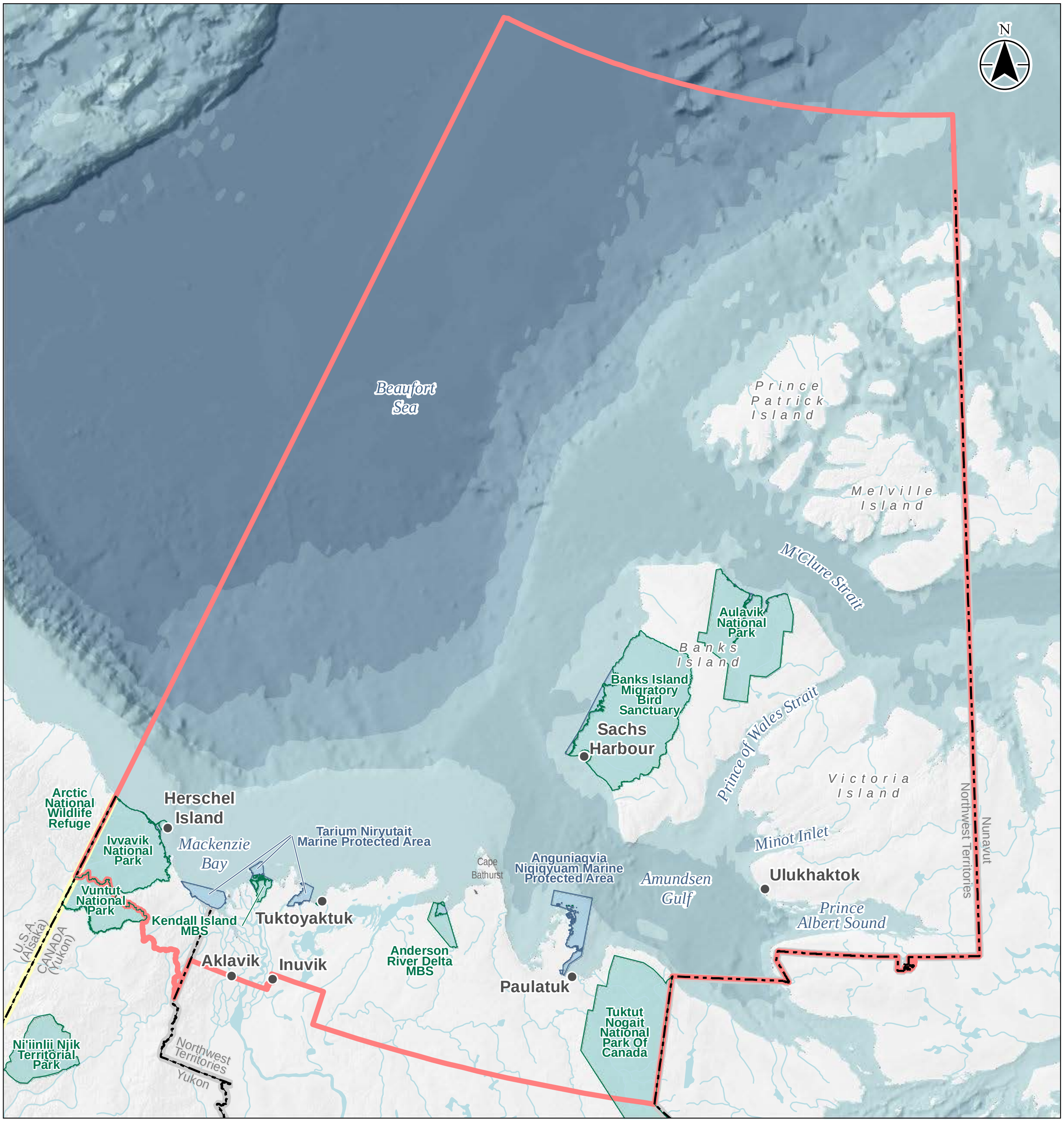
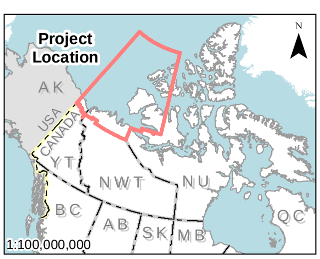




- Community
- International Boundary
- Territorial Boundary
- Watercourse
- Waterbody
- Marine Protected Area
- Terrestrial Protected Area
- Study Area

Bathymetry Depth (m)

- < 200
- 200 - 1000
- 1000 - 2000
- 2000 - 3000
- > 3000

0 50 100 150 200 250 300 km

1:8,000,000 (at original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Natural Resources Canada

KAVIK-STANTEC INUVIALUIT REGIONAL CORPORATION

Project Location
Beaufort Sea, Northwest Territories, Canada

Project Number 123513135
Prepared by LTRUDELL on 201900815
Discipline Review by NLAWSON on 20190815

Client/Project
Inuvialuit Regional Corporation
Beaufort Region SEA

Figure No.
3-3

Title
Location of Marine and Land-based Protected Areas in the BRSEA Study Area

There are also a number of restrictions on land-based development, including several land-based protected areas that would prohibit or restrict development of land sites along the coast; these include: Ivvavik National Park, Qikiqtaruk Territorial Park (Herschel Island) Heritage Area; Anderson River Delta Migratory Bird Sanctuary, Kendall Island Migratory Bird Sanctuary, and Banks Island Migratory Bird Sanctuary. There are two additional protected areas: Tuktut Nogait National Park and Aulavik National Park (on M'Clure Strait) that are unlikely to interact with offshore oil and gas activities (i.e., do not extend to the coast). As noted earlier, the *Yukon North Slope Order* (2010) withdrew use of all of the Yukon North Slope outside of the protected areas (http://www.gov.yk.ca/legislation/regs/mo2010_009.pdf; November 6, 2019).

Lastly, DFO also has authority to prohibit certain activities within specific spatial locations and/or seasons, as well as implement specific measures for protection of individual species, regulation of shipping lanes and/or vessel speeds.

Commercial fishing is not considered in the BRSEA as such activities are not allowed under the current Canadian federal moratorium that prohibits the issuance of new commercial fishing licenses in a large portion of the Canadian Beaufort Sea.

3.6.2 Quantification of Activities: Scenario 1 (Status Quo)

Assumptions on the potential specifications (e.g., footprint sizes, volumes and quantities) for activities, as well as the frequency and duration of some activities are summarized in Table 3-3.

Table 3-3 Quantification of Activities: Scenario 1 (Status Quo)

Activity	Footprint (Area)	Number or Volume	Frequency or Duration
Commercial shipping[1]	Transit across Beaufort Sea to Northwest Passage	30 in 2020 increasing to 120 in 2050; assume 750 km per transit	Less than two days (35 hours) per transit; two transits a week increasing to eight transits per week
Cruise ship tourism	Cruises across Arctic Islands with stops at some communities	Assume 10 cruises annually for 2020-2050; assume 850 km per transit with one to two stops within the ISR	Less than two days (40 hours) per transit, spread over late open water period
Ship-based resupply: sealifts annually to each of Sachs Harbour (Sachs Harbour), Ulukhaktok (Holman) and Paulatuk from Tuktoyaktuk[2,3]	Transit between Tuktoyaktuk, Ulukhaktok and Sachs Harbour	One sealift to each coastal community each year. Assume 850 km transit per sealift.	Less than two days (40 hours) per sealift, twice per year
Ship-based resupply: sealifts to two hypothetical mines (these would most likely be east of the ISR in Nunavut))	Transit across Beaufort Sea through Amundson Gulf	One sealift to each location each year (850 km per one-way transit; 1700 km roundtrip per sealift)	Less than two days (40 hours) per sealift; two per year (one to each location). Approximately four days total for each one-way transit.

Table 3-3 Quantification of Activities: Scenario 1 (Status Quo)

Activity	Footprint (Area)	Number or Volume	Frequency or Duration
Renewable energy (e.g., offshore wind). No current use.[4]	Assume one offshore wind platform within 5 km of shore	Assume disturbed area up to 20 ha with permanent base of 1 ha	One installation (assume 4 months total) and permanent presence during operations
Regional boat traffic to support traditional harvesting activities and local travel[2]	Along the entire coastal region within 5 km of shore, but greatest concentration near communities	Average round-trip distance of 57 km (Parrott 2019, pers. comm.	Assume 30 trips per day for all communities for duration of Open Water Season
Regional snowmobile use on ice for traditional harvesting and travel	Along the entire coastal region within 3 km of shore, but greatest concentration near communities	Average round-trip distance of 59 km (Parrott 2019, pers. comm.)	Assume 30 trips per day for all communities for duration of the late fall transition through to early spring transition period
Scientific research vessels[1,3,5,6]	Multiple transects across Beaufort Sea from mid- to deep water	Assume a total length of transits of 1000 km per cruise in Beaufort Sea	Less than two days (45 hours) per transit, three transits per season. Approximately six days total per season
Military vessels: surveillance and security cruises[1,3, 7]	Multiple transects across Beaufort Sea from mid- to deep water offshore; can involve ships and submarines	Assume total length of transits of 1000 km per cruise	Less than two days (45 hours) per cruise per month during open water and transition seasons (for total of 6 months)
Low level aircraft overflights[8]	Multiple flights t between Inuvik and Tuktoyaktuk, and out to the other Inuvialuit communities	Assume average length of flight path per flight of 200 km	Average of one flight per day throughout the year (365 days)
Conservation and protected areas[9]	Existing protected areas are shown in Figure 3-3. No industrial activity west of Mackenzie Delta (*Yukon North Slope Order* [2010])	Assume no additional areas added.	Once areas established, they are permanent

SOURCES:
[1] Environment and Natural Resources 2015a
[2] Arctic Council 2009
[3] Engler and Pelot 2013
[4] Muir, M. A. K. 2016
[5] DFO 2017
[6] Government of Canada 2016
[7] Raegehr and Jackett 2018
[8] Environment and Natural Resources 2015b
[9] Beaufort Sea Partnership 2019a,b

3.6.3 Timeline and Phasing: Scenario 1 (Status Quo)

Timing of activities from the start of the BRSEA in 2020 (i.e., year or years during which an activity is likely to occur) and the season(s) of activity are summarized in Table 3-4.

Table 3-4 Timing and Phasing of Activities: Scenario 1 (Status Quo)

Activity	Year beginning in 2020	Seasonal Timing
Commercial shipping	All	late spring transition to early fall transition
Cruise ship tourism	All	late Open Water Season with focus on mid-August to mid-September
Ship-based resupply: sealifts annually to each of Sachs Harbour, Ulukhaktok and Paulatuk from Tuktoyaktuk	All	open water
Ship-based resupply: sealifts to two hypothetical mines (e.g., Bathurst Inlet and Grays Bay)	5-30	open water
Renewable energy (e.g., offshore wind). No current use.	10 - 30	year round
Regional boat traffic for traditional harvesting and travel	All	open water
Regional snowmobile use on ice for traditional harvesting and travel	All	Ice Season (winter)
Scientific research vessels	All	late spring transition to early fall transition
Military vessels: surveillance and security cruises	All	late spring transition to early fall transition
Low level aircraft overflights	All	year round
Conservation and protected areas	All	year round

3.6.4 Biophysical, Socio-cultural and Economic Considerations: Scenario 1 (Status Quo)

This scenario is intended to assess potential effects associated with existing human use and project activities, other than oil and gas activities, that are likely to occur in the BRSEA Study Area over a time frame similar to that for the development scenarios (e.g., 30 years). The Status Quo scenario includes traditional and other human uses in nearshore areas (i.e., within 5 km from shore) (e.g., harvesting, travel by boat or skidoo, recreation, coastal research, local aircraft overflights, tourism), as well uses in moderate to deep water areas that are well offshore from the coastline (e.g., cruise ships, transits by cargo vessels and tankers, cruises by research vessels and the military).

Given the diverse range of current and future activities and uses that are considered, this scenario provides an opportunity to assess potential effects of existing human use and project activities, other than oil and gas activities, on:

- social, cultural and economic aspects such as traditional harvesting activities (e.g., fishing, hunting of birds and marine mammals), associated travel, cultural vitality, recreational and tourism uses, community services and infrastructure, demographics, public health, employment, and opportunities for local businesses and the broader economy
- biophysical components such as air quality, in-air noise, light, marine water quality, ice (e.g., nearshore/landfast ice, first year and multi-year pack ice, shear zones and leads), coastal processes, coastal habitats, lower trophic levels, marine fish and habitat, migratory birds, seabirds, marine mammals (e.g., ringed seals), polar bear and caribou

The VCs for the Human and Biophysical Environment and associated indicators that were considered for this scenario are described in detail in Chapter 8.

3.7 Scenario 2 –Export of Natural Gas and Condensates

The purpose of the scenario is discussed first, followed by a general description of the activities considered in the scenario. This is followed by two tables: one which quantifies the volume/quantity, duration and frequency of these activities, and a second table that describes the range of years (during 2020-2050) and seasons over which the activities are likely to occur. As this is a hypothetical scenario, estimates are based on the professional experience and knowledge of the Engineering Panel and the Scenario team.

3.7.1 Overview: Scenario 2 (Export of Natural Gas and Condensates)

The purpose of this hypothetical scenario is to assess potential environmental effects associated with the development of infrastructure and subsea pipelines in the nearshore for export of natural gas and condensate from existing land-based reserves on the Mackenzie Delta (e.g., Mackenzie Gas Pipeline fields) and additional discovered gas on the delta. It is assumed that a major portion of the development in this scenario would occur on land; however, because the focus of the Data Synthesis and Assessment Report is on the Canadian Beaufort Sea (i.e., marine areas within the ISR), the assessment of effects focuses on offshore infrastructure, pipelines and loading platforms. While offshore gas fields might eventually be accessed through such a development, development of production wells in offshore reserves is not considered in this scenario; their effects would be similar to effects described for the offshore wells in Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf. This scenario represents a low level of development activity.

It is assumed that all of the anchor gas fields are located on or in proximity to the Mackenzie River Delta. These fields would each involve drilling of land-based production and injection wells; as well as construction of on-site infrastructure (e.g., gathering systems, administration buildings, maintenance and support/services depots and warehouses, landing strip, aircraft hangers); and the construction/operation of a collection pipeline to transport natural gas from the anchor fields to a central processing facility (similar to what was proposed for the Mackenzie Gas Project; Imperial Oil Ventures Limited 2005). A processing facility for treatment (purification), refrigeration and liquefaction of natural gas (referred to as a train) would be located onshore in a location within a reasonable distance from the site for the offshore loading facility. The LNG train, assumed to be in the range of 5 million tonnes per annum (MTPA), would separate the natural gas, condensates, natural gas liquids and produced water and purify the natural gas before liquefaction. Storage for LNG and condensate would be onshore.

The LNG and condensate would be shipped offshore via subsea pipelines, while the natural gas liquids (NGLs) and produced water would be reinjected into the reservoir. It is assumed that a small quantity of processed natural gas and NGLs would be used locally to fuel a Gas to Liquids plant for production of syn-diesel and syn-jet for local and regional consumption.

As discussed in Section 3.4, supplies and services would be provided from a logistics base in Tuktoyaktuk, with administrative and business support from Inuvik. An annual sealift would also bring supplies and consumables for storage on the on the GBS. Inuvik would serve as the administrative and business centre.

The marine component of this scenario that is assessed for the BRSEA includes:

- construction and operation of a twin subsea pipeline system; with one subsea cryogenic pipeline for LNG and a separate liquids pipeline for condensate
- installation and operation of an offshore GBS loading facility, 15-20 km offshore of the Mackenzie Delta; LNG and condensate would be loaded onto carriers/tankers from the GBS
- decommissioning of the GBS and pipelines at the end of the project, and removal of the GBS

Assumptions about the potential specifications (e.g., footprint sizes, volumes and quantities) for the different marine activities, as well as the frequency and duration of these activities and the timing of activities from the start of the BRSEA in 2020 (i.e., year or years during which an activity is likely to occur) and the season(s) of activity are summarized below.

As noted in Section 3.6, it is assumed that other human activities (as described in the Status Quo scenario) would be occurring over the same 30-year duration as the activities described for the export of natural gas and condensates.

3.7.2 Scenario Details: Scenario 2 (Export of Natural Gas and Condensates)

3.7.2.1 Subsea Pipeline

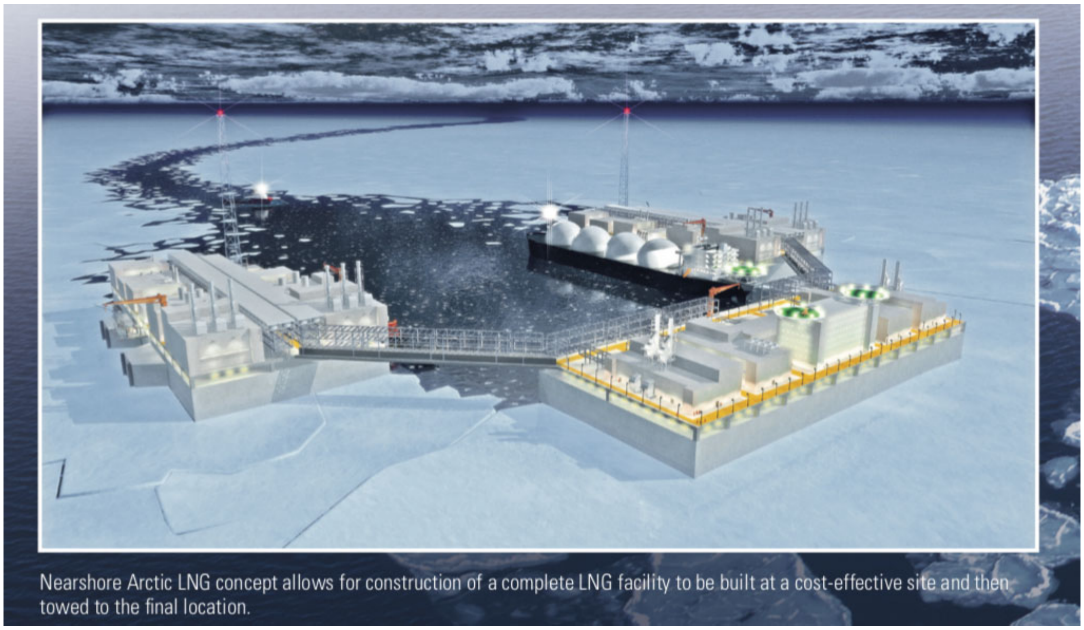
- The processing facility and the land terminus of the two pipelines would be located west of Tuktoyaktuk.
- A subsea cryogenic pipeline for LNG and a subsea liquids pipeline for condensate would be constructed between the onshore gas processing facility and the GBS loading facility.
- Each pipeline would be 15-20 km in length.

- The nearshore portion of both pipelines within the ground fast ice zone would be installed using directional drilling out to a water depth of 5 meters (i.e., assume about 1 km of horizontal directional drilling).
- The remainder of the pipeline length in the scour zone (i.e., ~ 14-19 km) would be installed in an open cut trench of sufficient depth to protect the pipelines from ice scour, then backfilled with sand, gravel and excavated seabed materials.
- At project closure, the pipelines would be capped below grade and filled with appropriate amounts of seawater, ballast or inert gases.

3.7.2.2 Loading Platform, LNG Carriers and Condensate Tankers

- A GBS offshore loading platform would be positioned approximately 15-20 km northwest of Tuktoyaktuk in less than 10 meters of water (Figure 3-4).
- The GBS loading platform would be built outside Canada and towed to site during the Open Water Season. Some dredging of the seabed would be required to provide a stable platform for the GBS.
- The GBS platform would be used to load the LNG carriers and condensate tankers (both assumed to be dual-action[28], ice class vessels) for year-round transport to global markets.
- At project closure, the GBS loading platform would be refloated and towed westward out of the Beaufort Sea. Following capping of the dual pipeline system (as per regulations for such decommissioning), the disturbed bottom would be left to recover naturally through ice scour and sediment transport.
- It is assumed that the LNG carriers would be dual-action and have a capacity of 170,000 cubic meters.
- Assuming one gas train with a production capacity of 5 MTPA (i.e., 1270 cubic meters per hour) and a LNG carrier capacity of 170,000 cubic metres, sufficient LNG would be processed to fill a LNG carrier about once every 5-6 days (i.e., 134 hours). Filling of a condensate tanker would require ~24 hours but loading would occur in sync with LNG carrier loading (once every five days).
- For the purpose of this hypothetical scenario, it is assumed a LNG carrier would be loaded once every 5 days, with a similar period for the condensate tanker (once every five days).

[28] Dual-action vessels are a type of icebreaking ship designed with a typical bow for running in open water and thin ice, but with a stern design that provides greater ice protection and some icebreaking capabilities; in heavy ice conditions, the vessel turns and advances stern-first to provide icebreaking capabilities.



SOURCE: https://www.kvaerner.com/Global/images/Products/Concrete/Concrete%20GBS%20LNG%20Solutions.pdf

Figure 3-4 Example of an Arctic Offshore Loading concept for Mackenzie LNG

3.7.3 Quantification of Activities: Export of Natural Gas and Condensates

Assumptions on the potential specifications (e.g., footprint sizes, volumes and quantities) for different activities, as well as the frequency and duration of these activities are summarized in Table 3-5.

Table 3-5 Quantification of Activities: Scenario 2 (Export of Natural Gas and Condensates)

Activity	Footprint (Area)	Number or Volume	Frequency or Duration
Towing of the GBS loading facility to the project site	NA	One round trip by towing vessels (GBSs towed only one way in); 350 km towing distance with GBS and 350 km transit on exit	Less than one day (20 hours) for towing within the Beaufort Sea and less than a half day (10 hours) for the same season transit of the towing ship out of the Beaufort Sea
Installation of GBS loading facility	~2 ha prepared for GBS installation (e.g., dredging)	NA	Once at program start; positioning and installation would require 28 days
Installation of dual pipelines	1 km of directional drilling in the ground fast ice zone for each pipeline 14-19 km of trenching to accommodate the dual pipelines in the scour zone	2 parallel pipelines	Once during project construction

Table 3-5 Quantification of Activities: Scenario 2 (Export of Natural Gas and Condensates)

Activity	Footprint (Area)	Number or Volume	Frequency or Duration
Carrier/tanker loading at the GBS loading facility	NA	Assuming LNG carrier capacity of ~ 170,000 cubic metres, would require ~ 134 hours to fill. Condensate tanker assumed to be similar (~ 24 hours to load).	One LNG carrier every 5 days One Condensate tanker every 5 days. Assume carrier/tankers would convoy together during Ice Season.
Icebreaking around GBS loading facility	Assume circular transit of ~ 2km around GBS	NA	One day per week for 5 months over 27 years (production only), for a total of 20 days each year
Dual-action carrier/tanker transport of gas westward	350 km distance one-way transit in Canadian Beaufort Sea; 700 km total	One return carrier/tanker transit every five days	Less than a half day (10 hours) per transit for a total of less than one day (20 hours) per trip in and out of the Beaufort Sea
Icebreaking by dual-action carrier/tanker	Assume 700 km per round trip	One return carrier/tanker transit every five days	Icebreaking capacity would be used during late fall transition through Ice Season to early spring transition (5 months, for a total of 150 days)
Annual sealift	350 km transit distance in Canadian Beaufort Sea (one way); round trip by resupply vessels; 700 km transit in total for 25 years of production	2 per year	20 days of ship time per round trip
Local ship resupply of GBS loading facility	Tuktoyaktuk: 25 km (one way) and Summers Harbour 350 km (one way)	2 trips by supply ship per year from each of Tuktoyaktuk and Summers Harbour (total of 4) during open water for 27 years of production	Tuktoyaktuk: less than a half day (1 hour) per one-way transit Summers Harbour: less than one day (15 hours) per one-way transit
Local air resupply of GBS loading facility	Tuktoyaktuk: 25 km (one way) and Summers Harbour 350 km (one way)	1 weekly trip by large helicopter from each of Tuktoyaktuk and Summers Harbour year round for 27 years of production	Tuktoyaktuk: less than a half day (15 minutes) per one-way transit Summers Harbour: less than a half day (1.5 hours) per one-way transit
Crew change and helicopter resupply for GBS Loading Facility	Tuktoyaktuk: 25 km (one way) and Summers Harbour 350 km (one way)	2 per week year-round from Tuktoyaktuk, and one per week year-round from Summers Harbour over 27 years of production	Tuktoyaktuk: less than a half day (15 minutes) per one-way transit Summers Harbour: less than a half day (1.5 hours) per one-way transit

Table 3-5 Quantification of Activities: Scenario 2 (Export of Natural Gas and Condensates)

Activity	Footprint (Area)	Number or Volume	Frequency or Duration
Air emissions from GBS Loading Facility, support vessels and aircraft (t CO2e/year):	NA	121,000	Over a one year period (365 days)
Removal of GBS loading facility	Would expose ~2 ha of disturbed sea bottom	One round trip by towing vessels (GBSs towed only one way out); total of 700 km	Less than a half day (10 hours) for ship inbound transit and less than one day (20 hours) for towing
Capping and filling of subsea portions of the pipelines	Minimal disturbance ~1 ha around capping ends of pipeline	NA	Once, Assume 14 days of underwater work.

3.7.4 Timeline and Phasing: Scenario 2 (Export of Natural Gas and Condensates)

Timing of activities from the start of the BRSEA in 2020 (i.e., year or years during which an activity is likely to occur) and the season(s) of activity are summarized in Table 3-6.

Table 3-6 Timing and Phasing of Activities: Scenario 2 (Export of Natural Gas and Condensates)

Activity	Year[29]	Seasonal Timing
Towing of the GBS loading facility to the project site	1	Summer (open water)
Installation of GBS loading facility	1-2	Summer (open water)
Installation of dual pipelines	2	Summer (open water)
Carrier/tanker loading at the GBS loading facility	3-30	Year round
Icebreaking around GBS loading facility	3-30	Fall Transition to Spring Transition
Dual-action carrier/tanker transport of gas westward	3 - 30	Year round
Icebreaking by dual-action carrier/tanker	3-30	fall transition to spring transition
Annual sealift	3 - 30	summer (open water)
Local ship resupply of GBS loading facility	3 - 30	summer (open water)
Local air resupply of GBS loading facility	2-30	year-round
Crews changes and helicopter resupply for GBS loading facility	2 – 30	year round
Air emissions from GBS Loading Facility	3 - 30	year round
Air emissions from support vessels and carrier/tankers	3 - 30	year round
Removal of GBS loading facility	30	summer (open water)
Capping and filling of subsea portions of the pipelines	30	summer (open water)

[29] As noted in Section 3.7.1, this scenario assumes that all of the anchor gas fields, associated infrastructure, a central processing facility, a plant for refrigeration and liquefaction of natural gas, and storage for LNG and condensate would be located on land; as these area are outside the BRSEA Study Area, they are also outside the scope of this assessment. Some of these facilities would likely be developed in advance of or in parallel with offshore activities and operations.

3.7.5 Biophysical, Socio-cultural and Economic Considerations: Scenario 2 (Export of Natural Gas and Condensates)

This scenario is intended to assess potential effects associated with offshore hydrocarbon development in nearshore (shallow water) and mid-depth marine habitats. The inclusion of areas affected by grounded landfast ice in shallow water and ice scour in nearby deeper water would provide an opportunity to assess different socio-cultural and economic effects on traditional harvesting and other human activities (e.g., recreation and tourism), as well as effects on different marine fauna and flora. Specifically, nearshore areas are used by the Inuvialuit for harvesting and other activities and associated transport during all seasons of the year, but with greater use occurring during the Ice Season, late spring transition, open water and early fall transition periods. Year-round shipping also provides an opportunity to assess potential effects of icebreaking and open water shipping activities on fish, birds and marine mammals

The location of this scenario also allows assessment of effects on different migratory bird species, assemblages of fish and benthic species and marine mammals (e.g., ringed seals) than for the oil and gas development scenarios in deeper water on the continental shelf and slope. The use of leads for early and late season carrier/tanker and support vessel access also provides an opportunity to assess effects of conflicts with travel and harvesting activities and marine mammal migratory movements and habitat use.

The offshore aspects of this potential development also provide an opportunity to examine potential effects on communities (e.g., changes demographics, impacts on cultural vitality, increased pressures on community services and infrastructure, changes in public health), opportunities for employment (offshore as well as in Tuktoyaktuk and Inuvik), and economic benefits (e.g., opportunities for local businesses and the broader region).

3.8 Scenario 3 -Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

The purpose of the scenario is discussed first, followed by a general description of the activities considered in the scenario. This is followed by two tables: one which quantifies the volume/quantity, duration and frequency of these activities, and a second table that describes the range of years (during 2020-2050) and seasons over which the activities are likely to occur. As this is a hypothetical scenario, estimates are based on the professional experience and knowledge of the Engineering Panel and the Scenario team.

3.8.1 Overview: Scenario 3 (Large Scale Oil Development on the Continental Shelf)

The purpose of this scenario is to examine potential effects associated with the hypothetical development and production of oil reserves from existing Significant Discovery Licenses (SDLs) (i.e., resources are known and delineated) in moderate depth water (< 40 metres) on the continental shelf. It is assumed that exploration drilling or appraisal drilling would not be required as the hydrocarbon resources are known. This hypothetical scenario involves the positioning and use of an offshore GBS located on the continental shelf. Following field development, operations are assumed to be year-round. This scenario represents a moderate to high level of development activity.

For the purpose of the Data Synthesis and Assessment Report, the oil development would involve two or more previously discovered oil reserves located approximately 80 km offshore in less than 40m water. The reservoirs are multiple tertiary-aged, semi-consolidated sandstones with 700+ million barrels of recoverable high-quality oil over an area of ~4,500 to 5,500 hectares at a depth of 2800 to 3300 metres below the seabed. The operational life of the reservoirs would be 30 years or more (i.e., after 2050); as a result, the assessment focuses on the first 30 years of exploration and production between 2020 and 2050. While there could be potential for additional nearby fields to be developed once the anchor field (described here) is operational; these additional developments are not considered in this scenario or the assessment.

Decommissioning would occur after 2050, outside the temporal boundaries for the BRSEA. For the Data Synthesis and Assessment Report, potential effects of decommissioning activities are based on environmental conditions in 2050, even though it is likely that these activities would occur at a later date. Decommissioning would involve plugging all wells and abandoning them below the seabed (as per CER regulations), and removal of the production GBS platform (i.e., the platform would be towed out of the Beaufort Sea).

As discussed in Section 3.4, supplies and services would be provided from land-based facilities in Tuktoyaktuk, as well as a wareship. The existing facilities in Tuktoyaktuk would be re-purposed with appropriate remediation (if required). Summers Harbour would be used for additional logistical support. An annual sealift would also bring supplies and consumables for storage on the wareship. Inuvik would serve as the administrative and business centre.

For the purpose of the BRSEA, this hypothetical scenario includes:

- 3D seismic surveys to delineate the field within the lease area (open water acquisition, one summer season)
- one GBS platform, manufactured outside of the Beaufort Sea, for use during production, would be towed into position using an icebreaker and ice-strengthened tug
- development would take place with all wells being drilled from the GBS; this would include producing oil wells, reinjection wells for natural gas[30] and water injection to maintain reservoir pressure, and waste disposal wells
- all wellheads would be within the GBS and above the waterline; this allows for drilling of all wells from the GBS, as well as removing the requirement to bring in additional vessels and equipment to service or repair wellheads
- production wells would be directionally drilled from the GBS to avoid the need for a subsea pipeline

[30] While natural gas could be exported (as discussed in Scenario 2), this scenario assumes that appropriate facilities for such export do not exist in the ISR; hence natural gas is reinjected to improve oil recovery.

- once operations begin, production would be year-round; dual-action Class 3 ice breaking carriers would be used to take product out of the Beaufort Sea via an Alaska route during all seasons
- the exploration, field development and operational phases would be supported by a wareship moored next to the production GBS, with additional support from the Tuktoyaktuk Base (open water only) and Summers Harbour (year-round) (see Section 3.4)

Assumptions about the potential specifications for the different marine activities (e.g., footprint sizes, volumes and quantities), the frequency and duration of these activities, and the timing of activities from the start of the BRSEA in 2020 (i.e., year or years during which an activity is likely to occur) and the season(s) of activity are summarized below.

As noted in Section 3.6, it is assumed that other human activities (as described in the Status Quo scenario) would be occurring over the same 30-year duration as the activities described for Large Scale Oil Development within Significant Discovery Licenses.

3.8.2 Scenario Details: Scenario 3 (Large Scale Oil Development on the Continental Shelf)

3.8.2.1 Seismic Program

- There would be one season of 3-D data acquisition within a 60,000 ha footprint.
- Seismic data acquisition would require approximately eight weeks during mid-July to mid-September.

3.8.2.2 Field Development and Construction

- A GBS for drilling and oil production would be located to access two or more fields that are currently held under Significant Discovery Licenses. The GBS would include oil offloading facilities. An example of an offshore GBS in arctic waters (eastern Russia) is shown in Figure 3-5.
- Construction of the production GBS would be completed outside of Canada and floated to location during the Open Water Season.
- The production GBS would have a footprint of ~ 2 ha.
- A wareship would be moored next to the GBS to provide a base for supplies and logistical support.
- The production GBS would have approximately 50 well slots inside the GBS.
- Oil wells, gas and water injection wells and waste disposal wells would be drilled from the GBS.
- The production GBS would have a dry oil storage capability of ~1 million barrels.

SOURCE: https://www.fircroft.com/blogs/engineering-feat-of-the-month-berkut-oil-rig-62352216030; November 11, 2019

Figure 3-5 An example of a GBS Platform in Arctic Waters, Berkut Oil Production Platform, Sea of Okhotsk, Russia

3.8.2.3 Production

- There would be year-round production with ice-breaking, Polar Class 3, dual-action tankers for oil transport.
- The extracted hydrocarbons would be a mix of oil, gas, and produced water.
- The oil would be separated from the gas and produced water onboard the production GBS.
- Waste materials, drill cuttings and oil field solids would be re -injected into shales (above the primary reservoir) through a disposal well.
- Natural gas produced water and sea water (treated with biocides) would be reinjected to maintain reservoir pressure.
- Produced oil would be stored in internal (dry) GBS storage tanks.
- Based on an assumed GBS storage capacity of approximately 150,000m³, tankers would be loaded once every week.
- Domestic wastewater would be treated on the production GBS; appropriately treated grey water could be used in cuttings slurry or injected into the disposal well.
- Air emissions would be generated through processing and from diesel electric generators and vessels.

3.8.2.4 Offshore and Onshore Support

- Support would include use of a wareship moored next to the GBS, combined with Tuktoyaktuk Base (open water only) and Summers Harbour (year-round).
- Resupply via annual sea lift to the wareship, as well as from Tuktoyaktuk and Summers Harbour.
- Ship transport from Tuktoyaktuk and Summers Harbour supply bases to the wareship would only occur in late spring transition, Open Water and early Fall Transition Seasons. All resupply during winter would be by air (i.e., helicopter).
- Crew changes would be made primarily from the Tuktoyaktuk Base using helicopters.
- Icebreakers would be used during the Winter and Spring Transition Season to protect the GBS platform, wareship and other vessels.

3.8.3 Quantification of Activities: Scenario 3 (Large Scale Oil Development on the Continental Shelf)

Assumptions about the potential specifications (e.g., footprint sizes, volumes and quantities) for different activities, as well as the frequency and duration of these activities are summarized in Table 3-7.

Table 3-7 Quantification of Activities: Scenario 3 (Large Scale Oil Development on the Continental Shelf)

Activity	Footprint (Area)	Number or Volume	Frequency or Duration
3D seismic program	60,000 ha	1 open water program	8 weeks, for a total of 56 days
GBS towing to the Beaufort Sea	NA	350 km towing distance in across the western Canadian Beaufort Sea, with tow vessel transit out (350 km)	Less than one day (20 hours) for tow transit in; less than one day (15 hours) for same-season transit out by the tow ship
Installation of the GBS platform	~2 ha per GBS		Once at program start; 28 days
Transit of wareship into the Beaufort Sea at program start		350 km one-way transit in across the western Canadian Beaufort Sea	Once at start
Drilling of production wells	NA	50 in total	Initial development wells 10 per year for 2 years Continuous drilling and abandoning of wells as produced
Water and gas Injection Wells	NA	10-20	Used to conserve natural gas and NGL's and water injection for pressure maintenance

Table 3-7 Quantification of Activities: Scenario 3 (Large Scale Oil Development on the Continental Shelf)

Activity	Footprint (Area)	Number or Volume	Frequency or Duration
Drill cuttings(re-injected into formation)	NA	800 cubic metres per well, 50,000 m^3 in total volume	Disposal wells would be drilled as required for disposal of cuttings and waste
Oil production	NA	700+ million barrels of recoverable high-quality oil	Year-round production for 21 years (365 days per year)
Abandonment of depleted produced wells	NA	Would occur within the production GBS	Year-round as required
Air emissions from production GBS, support vessels and aircraft (t CO2e/year)	NA	194,000	Over a one year period (365 days)
Icebreaking around GBS and wareship	Assume circular transit of ~ 2km around GBS, wareship and other vessels	NA	One day per week for 5 months over 21 years (production only), for a total of 20 days each year
Tanker transport of oil westward (assume no eastward transportation in this scenario)	350 km distance in Canadian Beaufort Sea; total of 700 km of transit per trip over 21 years of production	One tanker every week, year-round (i.e., one inbound and one outbound)	Less than one day (15 hours) per one-way transit; less than one and a half days (30 hours) in total
Icebreaking by tankers during transits	Assume 700 km per round trip	Once return tanker transit every five days	Icebreaking capacity would be used from late fall transition through Ice Season to early spring transition (5 months, for a total of 150 days)
Annual sealift	350 km transit distance in Canadian Beaufort Sea (one way); assume 700 km total for each round trip for each platform	2 per year over 21 years of production; one to each of the production GBS and wareship;	Less than one day (15 hours) per one way transit
Local ship resupply of production GBS and supply wareship	Tuktoyaktuk: 40 km (one way) and Summers Harbour 350 km (one way)	2 trips by supply ship per year from each of Tuktoyaktuk and Summers Harbour (total of 4) during open water for 21 years of production	Tuktoyaktuk: less than half a day (3.5 hours) per one-way transit Summers Harbour: less than one day (15 hours) per one-way transit
Local air resupply of production GBS and wareship	Tuktoyaktuk: 40 km (one way) and Summers Harbour 350 km (one way)	1 weekly trip by large helicopter from each of Tuktoyaktuk and Summers Harbour year-round or 21 years of production	Tuktoyaktuk: less than a half day (20 minutes) per one-way transit Summers Harbour: less than a half day (1.5 hours) per one-way transit

Table 3-7 Quantification of Activities: Scenario 3 (Large Scale Oil Development on the Continental Shelf)

Activity	Footprint (Area)	Number or Volume	Frequency or Duration
Crews change and helicopter resupply for drill platform	Tuktoyaktuk: 40 km (one way); Summers Harbour 350 km (one way)	2 per week year-round from Tuktoyaktuk, and one per week year-round from Summers Harbour over 21 years of production	Tuktoyaktuk: less than a half day (20 minutes) per one-way transit Summers Harbour: less than a half day (1.5 hours) per one-way transit
Removal of GBS platform	NA	350 km towing distance in Beaufort Sea; 700 km for tow ship for GBS platform	Less than one day (15 hours) per one way transit in; less than one day (20 hours) for tow transit out
Transit of wareship out of the Beaufort Sea at program end		350 km one-way transit in across the western Canadian Beaufort Sea	Less than one day (20 hours) for tow transit out
Well capping and site cleanup	Disturbed area would be within the GBS footprint	All wells	Once

3.8.4 Timeline and Phasing: Scenario 3 (Large Scale Oil Development on the Continental Shelf)

Timing of activities from the start of the BRSEA in 2020 (i.e., year or years during which an activity is likely to occur) and the season(s) of activity are summarized in Table 3-8.

Table 3-8 Timing and Phasing of Activities: Scenario 3 (Large Scale Oil Development on the Continental Shelf)

Activity	Year	Seasonal Timing
3D seismic program	2	open water
GBS towing to the Beaufort Sea	5	open water
Installation of the GBS platform	5	open water
Transit of wareship into the Beaufort Sea at program start	5	open water
Drilling of production wells	5-7	year-round
Drill water and gas injection wells	5-7	year-round
Drill cuttings (re-injected into formation)	5-7	year-round
Oil production	8-29	year-round
Drilling of additional production, injection and disposal wells to fully produce the asset	8-29	year-round
Abandonment of depleted produced wells	14-29	year-round
Air emissions from production GBS (processing and diesel power)	8-30	year-round
Air emissions from wareship	5-30	open water and fall transition
Air Emissions from sealift vessels and tankers	5-30	late fall transition to spring transition
Icebreaking around GBS and wareship	5-30	fall transition to spring transition

Table 3-8 Timing and Phasing of Activities: Scenario 3 (Large Scale Oil Development on the Continental Shelf)

Activity	Year	Seasonal Timing
Tanker transport of oil westward (assume no eastward transportation in this scenario)	8-29	year-round
Icebreaking by tankers during transits	5-29	fall transition to spring transition
Annual sealift	5-29	early open water
Local ship resupply of production GBS and supply wareship	5-29	open water
Local air resupply of production GBS and wareship	5-29	year-round
Crews changes and helicopter resupply for drill platform	5-30	year-round
Removal of GBS platform	30	open water
Transit of wareship out of the Beaufort Sea at program end	30	open water
Well capping and site cleanup	30	open water

3.8.5 Biophysical, Socio-cultural and Economic Considerations: Scenario 3 (Large Scale Oil Development on the Continental Shelf)

The primary purpose of this scenario is to examine potential effects on the biophysical and human environment associated with activities in mid-water depths, as well as the transition ice zone. Depending on the ice conditions and winter weather, this could include different combinations of landfast ice and pack ice (new ice and possibly multi-year ice). Given that oil development in this scenario is assumed to be 80 km offshore, limited traditional harvesting is likely to occur in the immediate vicinity of the oil development. The primary interactions with traditional and local use would be during vessel movements in and out of the logistical bases, as well as aircraft overflights.

This location and scope of this scenario provides an opportunity to examine potential effects on key aspects such as:

- effects on ice associated with ice breaking and positioning of the GBS platform, and associated biological effects
- disturbance of benthic habitats by the GBS platform
- habitat use by migratory birds and marine fish
- migration of bowhead whales and beluga whales and use of offshore feeding areas
- Use of ice and open water habitats by polar bear

The scenario also provides an opportunity to examine potential effects on communities (e.g., changes demographics, increased pressures on community services and infrastructure, impacts on cultural vitality, changes in public health), opportunities for employment (offshore as well as in Tuktoyaktuk and Inuvik), and economic benefits (e.g., opportunities for local businesses and the broader region).

3.9 Scenario 4 - Large Scale Oil Development within Exploration Licenses (EL) on the Continental Slope

The purpose of the scenario is discussed first, followed by a general description of the activities considered in the scenario. This is followed by two tables: one that quantifies the volume/quantity, duration and frequency of these activities, and a second table that describes the range of years (during 2020-2050) and seasons over which the activities are likely to occur. As this is a hypothetical scenario, estimates are based on the professional experience and knowledge of the Engineering Panel and the Scenario Team.

3.9.1 Overview: Scenario 4 (Large Scale Oil Development on the Continental Slope)

The purpose of this hypothetical scenario is to assess potential environmental effects associated with exploration and hydrocarbon development within Exploration Licenses (ELs) located in deep water (>100 m to 1200 m) in an area on the slope of the continental shelf approximately 100 km northwest of Tuktoyaktuk. In addition, the scenario assumes that tankers would exit the Beaufort Sea westward through Alaska (year-round) and eastward through Amundsen Gulf and the Northwest Passage (only during the Open Water to early-Fall Transition seasons). Given the scale, duration and sequencing of development in the offshore location, and inclusion of shipping westward and eastward, this scenario represents a high level of development activity.

For the purpose of the Data Synthesis and Assessment Report, development in this area would be oil with gas being reinjected for conservation and reservoir pressure. For this hypothetical scenario, the field is assumed to be 40,000 to 60,000 ha, with 2 billion barrels of recoverable oil potential (as of yet undiscovered). Once wells have been drilled, it is assumed that production operations would be year-round. The scenario would involve establishment of a single FPSO vessel on the continental slope for processing and loading of oil onto dual-action tankers.

While the full life cycle of this hypothetical scenario is likely to be on the order of 50+ years (i.e., 5-10 year for seismic exploration and exploration drilling followed by 3-5 years for field development and an operational life of the reserve in the order of 30 years), for the purpose of the BRSEA, the scenario is assessed over the period of 2020-2050. Decommissioning would likely occur after 2050 and involve sealing all wells and capping them below the seabed, and as removal of the subsea manifolds, riser systems, and gathering flowlines. Potential effects of decommissioning activities is assessed based on environmental conditions in 2050, even though it is likely that these activities would occur at a later date.

Assumptions on the potential specifications for the different marine activities (e.g., footprint sizes, volumes and quantities), the frequency and duration of these activities, the timing of activities from the start of the BRSEA in 2020 (i.e., year or years during which an activity is likely to occur) and the season(s) of activity are summarized below.

As discussed in Section 3.4, supplies and services would be provided from land-based facilities in Tuktoyaktuk, as well as one or more wareships. Inuvik would provide most of the administrative and business support. The scenario assumes that existing facilities in Tuktoyaktuk would be re-purposed with appropriate coastal resiliency protection and remediation (if required). Summers Harbour would be used for additional logistical support. An annual sealift would also bring supplies and consumables for storage on the wareship. Inuvik would serve as the administrative and business centre.

As noted in Section 3.6, it is assumed that other human activities (as described in the Status Quo scenario) would be occurring over the same 30-year duration as the activities described for Large Scale Development of Exploration Licenses.

3.9.2 Scenario Details: Scenario 4 (Large Scale Oil Development on the Continental Slope)

3.9.2.1 Seismic Program

- A 3-D seismic program would be conducted within one Open Water Season (90 to 120 days in duration) to delineate the oil reserves within the EL.
- The survey would be conducted over an area of 80,000 to 120,000 ha within the EL.
- A seismic vessel would be contracted specifically for the survey and would include a full crew complement.

3.9.2.2 Exploration Drilling

- It is assumed that a minimum of two exploration wells would be drilled after reissuance of exploration licenses (project start).
- Each well would require two years to complete drilling and evaluation.
- Drilling would occur from a dynamically positioned Arctic class drillship. One well would be completed and evaluated before beginning drilling of the second exploration well (total duration of four years).
- Ice class vessels would be used to provide support and supplies to the drillships, as well as protection from ice.
- Reservoir evaluation would be completed through closed chamber testing of each well (i.e., no drill stem testing [DST]).
- Drill cuttings would be treated to meet standards for disposal and dispersed overboard in the vicinity of the drilling (due to the cost of drilling wells in deep water, disposal wells for cuttings and produced water are not economic),
- The scenario assumes that commercial quantities of oil are discovered that justify subsequent field development.

3.9.2.3 Delineation Drilling

- Two delineation wells would be completed three to five years after discovery (i.e., year 7 onward after project start).
- Each well would require two years to complete drilling and evaluation.
- Drilling would occur from a dynamically positioned Arctic class drillship. One well would be completed and evaluated, before beginning drilling of the second delineation well (total duration of four years).
- Ice class vessels, including a wareship, would be used to provide support and supplies to the drillships.
- The delineation wells would be completed as future development wells.
- Drill cuttings would be treated to meet standards for disposal and dispersed overboard in the vicinity of the drilling.

3.9.2.4 Field Development Drilling and Construction

- The initial production and injection wells would be drilled seven to twelve years after discovery (year 12 after project start onward).
- Drilling would occur from a dynamically positioned Arctic class drillship. Each well would be completed before beginning the next well.
- The production and injection wells would be grouped within manifolds on the sea bottom, with directional drilling of six to eight wellbores per subsea manifold.
- At completion, up to 50 production and injection wells would be drilled and operated.
- Subsea infrastructure would include the six subsea manifolds. As the manifolds are completed, pipeline bundles from the manifold would be connected to a riser that moves produced fluids to the moored FPSO.

3.9.2.5 Production

- Construction of the FPSO would occur outside North America. An example of a FPSO, currently under consideration for harsh environment operations, is illustrated in Figure 3-6 and Figure 3-7. The field depicted is located in the Flemish Pass 400 km offshore of Newfoundland in 1,200 metres of water.
- The FPSO would transit to the Beaufort Sea for the production phase of the project.
- The ice class FPSO would include processing facilities for the hydrocarbons and storage and offloading capabilities.
- The FPSO would be turret moored and designed to disconnect and sail away under its own power in the event of an emergency.
- One or more wareships would be moored next to or close to the FPSO to provide supplies of consumables and logistical support. The wareship would be resupplied by sea lift and from onshore bases.

- Start-up of production is assumed to occur 12 to 15 years after discovery; oil production and associated shipping (see below) is assumed to be year round
- Oil, gas and water would be produced from the production wells.
- Natural gas would be returned to the reservoir via gas injection wells to maintain reservoir pressure.
- Water injection wells would use produced water and sea water; sea water would be treated with biocide to prevent contamination of the reservoir.
- For the purpose of Data Synthesis and Assessment Report, it is assumed that add-on fields would be developed in later stages of production (years 20-30). These would require sub-sea completions with tie backs to the FPSO.
- Waste streams include produced water, natural gas, and produced solids (e.g., drill cuttings, sand).
- Drill cuttings would be treated to meet standards for disposal and dispersed overboard in the vicinity of the drilling.
- Air emissions would be generated by diesel electric generators on the FPSO.

SOURCE: Equinor (http://atlanticcanadaoffshore.ca/wp-content/uploads/2019/04/EHS_Outreach_Presentation.pdf; November 11, 2019)

Figure 3-6 Artist's rendering of proposed Bay du Nord FPSO

SOURCE: Equinor (https://www.cbc.ca/news/canada/newfoundland-labrador/equinor-update-noia-1.5316476; (November 11, 2019)

Figure 3-7 Artist's rendering of proposed Bay du Nord FPSO, with subsea manifolds pipeline bundles and riser

3.9.2.6 Offloading and Transport

- Produced oil would be stored on the FPSO and offloaded to double acting tankers for transport to global markets via Alaska (year-round) or eastward through Amundsen Gulf and the Northwest Passage (open water to mid-fall transition)[31]. The addition of shipping eastward during the Open Water Season was intentional to differentiate this scenario from Scenario 4; this shipping route offers an opportunity to look at biophysical and socio-cultural effects over a larger area.
- Based on an assumed FPSO storage capacity ranging between 143,000m³ and 191,000m³, tankers would be loaded every five to six days.

3.9.2.7 Offshore and Onshore Support

- Wareships would be used for storage and operations to support offshore drilling and production activities.
- Additional logistical support and supplies would be provided through the Tuktoyaktuk Base (open water only) and Summer Harbour (year-round).

[31] Only tanker transport of oil is included in this scenario, an alternate approach would be to construct a subsea oil pipeline to Prudhoe Bay to hook up with the Trans-Alaska Pipeline Systems (TAPS); this latter option is not assessed.

- Ship transport from supply base to the FPSO and wareships would only occur in late Spring Transition, Open Water and early Fall Transition Seasons. All resupply during winter would be by air (i.e., helicopter).
- Three to four supply and support vessels/icebreakers would be used for ice management, resupply to the drill ship and FPSO, and on-site support in the case of an accident or malfunction at sea.
- Crews transfers via helicopter would mobilize out of Tuktoyaktuk or Inuvik.
- Resupply via annual sea lift, as well as from Tuktoyaktuk, via all season road to the Dempster Highway.
- Icebreakers would be used to extend the shipping season and support year-round production

3.9.3 Quantification of Activities: Scenario 4 (Large Scale Oil Development on the Continental Slope)

Assumptions on the potential specifications (e.g., footprint sizes, volumes and quantities) for different activities, as well as the frequency and duration of these activities are summarized in Table 3-9.

Table 3-9 Quantification of Activities: Scenario 4 (Large Scale Oil Development on the Continental Slope)

Activity	Footprint (Area)	Number or Volume	Frequency or Duration
3D seismic program	100,000 ha	One season	120 days
Drillship transit to/from the Beaufort Sea	350 km transit within Canadian Beaufort Sea (one way)	Two transits per year for a total of 700 km	One day per year (i.e., not overwintered in Summers Harbour) for eight years (four for exploration and four for delineation)
Exploration drilling	1 ha per well	2	Drilling for 5 months (150 days; open water) over two years per well
Delineation drilling	1 ha per well	2	Drilling for 5 months (150 days; open water) over two years per well
Transit of FPSO into Beaufort Sea (assume self-driven)	350 km transit within Canadian Beaufort Sea (one way)	One transit into the development area	One inbound transit; approximately 15 days
Anchoring of FPSO at continental slope site and mooring of one or more wareships close to the FPSO	Up to 20 ha disturbance on seafloor; floating area of 2 ha	NA	Occurs once; 45 days for installation and anchoring. Wareships might move short distances during drilling and operations
Drilling of production and injection wells	2 ha per manifold with 8-10 directionally drilled production and injection wells per manifold	50	Drilling for 5 months (150 days; open water) during production phase

Table 3-9 Quantification of Activities: Scenario 4 (Large Scale Oil Development on the Continental Slope)

Activity	Footprint (Area)	Number or Volume	Frequency or Duration
Drill cutting volumes	2 ha disturbed area per manifold (8-10 weeks per manifold, six manifolds)	Approximately 700 cubic metres per well; 50 well in total	Deposition of cuttings, overboard, after treatment for 5 months (150 days; open water) during exploration drilling and production phase
Oil Production	NA	2 billion barrels recoverable high-quality oil	~ 20 years, 365 days per year
Drilling and abandonment of production and injection wells as they are depleted	NA, within existing disturbed area	NA	As field production requires.
Subsea tie-in of satellite field(s)	10 ha disturbed area satellite field	Assume 2 satellite fields	One day per satellite field
Air emissions from drillships, FPSO, support vessels and aircraft (t CO_2e/year)	NA	290,000	Over a one year period (365 days)
Icebreaking around drillships and FPSO	Assume circular transit of ~ 2km around FPSO or vessel	NA	One day per week for 5 months over 18 years (production only), for a total of 20 days each year
Tanker transport of oil westward	350 km distance in Canadian Beaufort Sea	One tanker return movement every 5-6 days); total of 700 km of transit	Less than one day (15 hours) per one-way transit; less than one and a half days (30 hours) per round trip
Tanker transport of oil eastward	450 km distance in Canadian Beaufort Sea	One tanker movement per month from June to October; total of 900 km of transit (inbound and outbound)	Approximately one day (22.5 hours) per one-way transit; Approximately two days (45 hours) per round trip
Icebreaking by tankers during transits	Assume 700 km per round trip for westward trips only	One tanker movement every 5-6 return days); total of 700 km of transit	Icebreaking capacity would be used late fall transition through Ice Season to early spring transition (5 months, for a total of 140 days)
Annual sealift	350 km transit distance in Canadian Beaufort Sea (one way); one round trip by resupply vessels per year; 700 km in total for 24 years of production	2 per year; one to drill platform and one to FPSO (total transit distance of 1400 km)	Less than one day (20 hours) of ship time per round trip; less than two days (40 hours) total ship time
Local ship resupply of drillships	Tuktoyaktuk: 100 km (one way) and Summers Harbour 350 km (one way)	2 trips by supply ship per year from each of Tuktoyaktuk and Summers Harbour (total of 4) for 12 years of drilling	Tuktoyaktuk: less than a half day (4.5 hours) per one-way transit Summers Harbour: less than one day (15 hours) per one-way transit

Table 3-9 Quantification of Activities: Scenario 4 (Large Scale Oil Development on the Continental Slope)

Activity	Footprint (Area)	Number or Volume	Frequency or Duration
Local air resupply of drillship	Tuktoyaktuk: 100 km (one way) and Summers Harbour 350 km (one way)	1 weekly trip by large helicopter from each of Tuktoyaktuk and Summers Harbour for 12 years of drilling	Tuktoyaktuk: less than a half day (30 minutes) per one-way transit Summers Harbour: less than a half day (1.5 hours) per one-way transit
Crew change and helicopter resupply for drill ship	Tuktoyaktuk: 100 km (one way) and; Summers Harbour 350 km (one way)	2 per week year-round from Tuktoyaktuk, and one per week year-round from Summers Harbour for 12 years of drilling	Tuktoyaktuk: less than a half day (30 minutes) per one-way transit Summers Harbour: less than a half day (1.5 hours) per one-way transit
Local ship resupply of FPSO	Tuktoyaktuk: 100 km (one way) and Summers Harbour 350 km (one way)	2 trips by supply ship per year from each of Tuktoyaktuk and Summers Harbour (total of 4) during open water for 18 years of production	Tuktoyaktuk: less than a half day (4.5 hours) per one-way transit Summers Harbour: less than one day (15 hours) per one-way transit
Local air resupply of FPSO	Tuktoyaktuk: 100 km (one way) and Summers Harbour 350 km (one way)	1 weekly trip by large helicopter from each of Tuktoyaktuk and Summers Harbour year round for 18 years of production	Tuktoyaktuk: less than a half day (30 minutes) per one-way transit Summers Harbour: less than a half day (1.5 hours) per one-way transit
Crew change and helicopter resupply for FPSO	Tuktoyaktuk: 100 km (one way); Summers Harbour 350 km (one way)	2 per week year-round from Tuktoyaktuk, and one per week year-round from Summers Harbour for 18 years of production	Tuktoyaktuk: less than a half day (30 minutes) per one-way transit Summers Harbour: less than a half day (1.5 hours) per one-way transit
Removal of FPSO	NA	350 km distance in Beaufort Sea (total transit of 700 km)	Less than one day (15 hours) per one-way transit; less than one and a half days (30 hours) per round trip
Well capping and site cleanup	Disturbed area would be within the ~ 20 ha disturbed footprint for 6 manifolds and anchoring	All wells	Once

3.9.4 Timeline and Phasing: Scenario 4 (Large Scale Oil Development on the Continental Slope)

Timing of activities from the start of the BRSEA in 2020 (i.e., year or years during which an activity is likely to occur) and the season(s) of activity are summarized in Table 3-10.

Table 3-10 Timing and Phasing of Activities: Scenario 4 (Large Scale Oil Development on the Continental Slope)

Activity	Year from Project Start	Seasonal Timing
3D seismic program	1 - 3	open water
Drill ships transit to the Beaufort Sea	4 - 12	late spring transition
Exploration drilling	4 -8	late spring transition to early fall transition
Delineation drilling	7 - 11	late spring transition to early fall transition
Transit and commissioning of FPSO into Beaufort Sea (assume self-driven)	12	late spring transition to early fall transition
Anchoring of FPSO at continental slope site and mooring of one or more wareships close to the FPSO	12	open water to early fall transition
Drilling of production and injection wells	12 -15	late spring transition to early fall transition
Treating and open water disposal of well cuttings	12-15	year-round
Oil production	12 - 30[32]	year round
Drilling and abandonment of production and injection wells as they are depleted	20 - 30	year round
Subsea tie-in of satellite field(s)	20-30	late spring transition to early fall
Air emissions from drillships (extraction and diesel power)	4 - 30	late spring transition to early fall transition
Air emissions from FPSO (processing and diesel power)	12 - 30	year round
Air emissions from vessels	1 - 30	year round
Icebreaking around drillships and FPSO	4 - 30	fall transition to spring transition
Tanker transport of oil westward	12 - 30	year round
Tanker transport of oil eastward	12 - 30	open water
Icebreaking by tankers during transits	12-30	fall transition to spring transition
Annual sealift	12 - 30	open water
Local ship resupply of drillships	4 - 12	late spring transition to early fall transition
Local air resupply of drillship	4-12	year-round
Crews changes and helicopter resupply for drillships	4 - 12	year-round
Local ship resupply of FPSO	12-30	late spring transition to early fall transition
Local air resupply of FPSO	12-30	year-round
Crews changes and helicopter resupply for FPSO	12 30	year round
Removal of FPSO	30	open water
Well Capping and site cleanup	30+	late spring transition to early fall transition

[32] Production for a development of this size would likely extend beyond 30 years; however, given that the temporal scope of the assessment is 30 years, the assessment assumed production would cease in year 30.

3.9.5 Biophysical, Socio-cultural and Economic Considerations: Scenario 4 (Large Scale Oil Development on the Continental Slope)

The primary purpose of this hypothetical scenario is to examine potential effects on the biophysical environment associated with activities in deep water and the pack ice zone. The inclusion of ship transits westward and eastward from the hypothetical development also provide an opportunity to assess effects of shipping on a broader range of biophysical components and human socio-cultural uses. This scenario provides an opportunity to examine potential effects on key aspects such as:

- marine mammals such as bowhead, polar bear, migratory bird species (eiders) and offshore assemblages of fish and benthic species
- specific focus on use of leads for early and late season vessel access and potential for conflicts with marine mammals, polar bear and caribou (e.g., Dolphin and Union caribou herd)
- conflicts between year-round shipping and travel on ice by local communities (e.g., inter-island travel)

Given that oil development in this scenario is assumed to be 100 km offshore, very limited traditional harvesting is likely to occur in the immediate vicinity of the oil development. Hunting of polar bear might occur in the general vicinity. However, ship resupply from Tuktoyaktuk and Summers Harbour, as well as air flights from these locations would cross marine and coastal areas used by harvesters.

The scenario also provides an opportunity to examine potential effects and benefits on communities (e.g., changes in demographics, increased pressures on community services and infrastructure, impacts on cultural vitality, changes in public health), opportunities for employment (offshore as well as in Tuktoyaktuk and Inuvik), and economic benefits (e.g., opportunities for local businesses and the broader region).

3.10 Scenario 5 – Large Oil Release Event

3.10.1 Background: Scenario 5 (Large Oil Release Event)

The Terms of Reference for the Data Synthesis and Assessment Report required that at "one (1) 'worst case Scenario', or most severe potential outcome that can reasonably be projected" be assessed. The concept of a Worst-Case Scenario was included in the Inuvialuit Final Agreement (paragraph 13(11)(b)). Specifically, it states that "*the EIRB must prepare an estimate of the potential liability of the Developer, determined on a worst-case scenario, taking into consideration the balance between economic factors, including the ability of the Developer to pay, and environmental factors*." In subsequent impact assessment for offshore exploration drilling programs (e.g., Gulf's Kulluk program; Devon Energy's Paktoa Drilling program), the concept of a Worst Case Scenario was used to assess potential effects of different types of releases of hydrocarbons (but most typically a large oil spill). The Worst Case Scenario was also used to estimate the financial liability of the proponent in the event a release did occur.

Scientific studies and monitoring have documented that the effects of exposure to large releases of crude oil on marine species and habitats are adverse, and that human uses can be negatively affected (ITOPF 2014). However, the extent and significance of these effects would depend on many factors (Kingston 2002), including:

- the type and amount of crude oil
- the sensitivity and vulnerability of the receptor to crude oil exposure
- seasonal and environmental conditions (e.g., open water versus ice cover)
- physical conditions such as ocean currents, wind speed and direction, and sea states
- biological conditions such as shoreline type or marine habitat type

While effects of exposure to crude oil are adverse and may be significant, the probability of a large to very large oil release from a new and modern offshore oil development are unlikely (Section 2.13). Nonetheless, effects of a potential oil spill in the Beaufort Sea on marine ecosystems and human uses are of high concern to the Inuvialuit, community residents, government agencies and a broad range of public stakeholders in Canada and internationally. As a result, it is important that potential effects of a large oil release be considered in the Data Synthesis and Assessment Report.

3.10.2 Approach to Assessing a Large Oil Release Event: Scenario 5 (Large Oil Release Event)

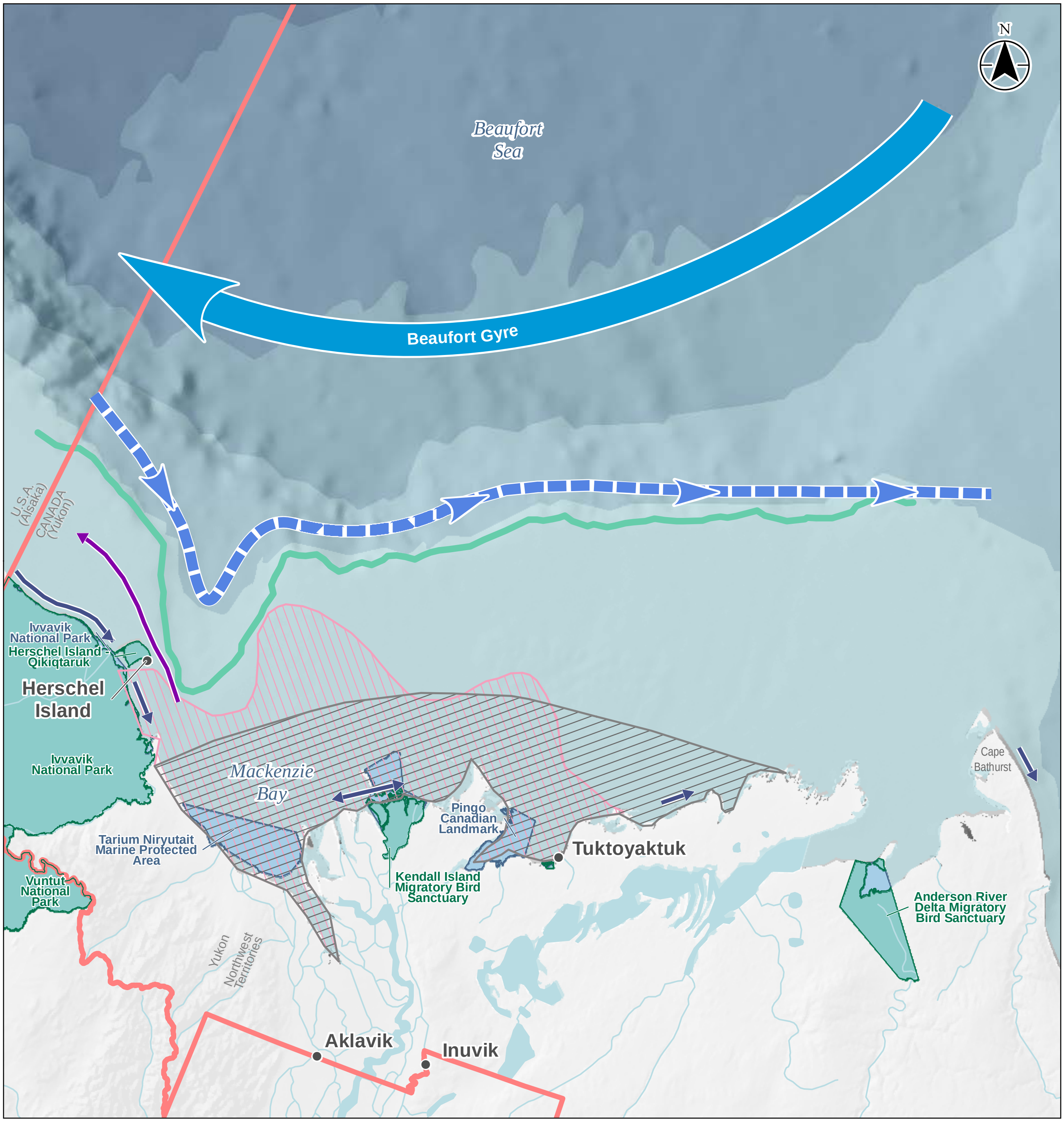
Rather than assess a specific spill location and volume for a large oil release event for the Data Synthesis and Assessment Report, a qualitative approach was used that allows the assessment team to look at a wide range of potential effects on the biophysical environment and socio-cultural and economic values and factors. This approach facilitates an examination of a range of potential outcomes based on oil spills occurring under different combinations of conditions related to:

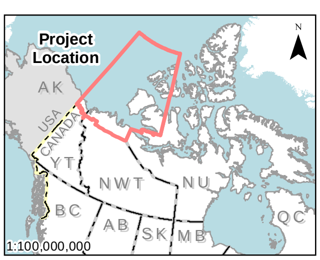
- season (ice, spring transition, open water and fall transition)
- location relative to the Mackenzie Plume (as discussed in Section 3.10.3, the plume has a year-round influence on how oil might move and be transported in the Beaufort Sea) (Figure 3-8)
- movement of oil by ocean currents in the Beaufort Sea (e.g., Beaufort Gyre, shelf break jet) (Figure 3-8)
- a surface release versus a subsea release

Combinations of these factors were then be used to qualitatively describe how each of the following factors would be affected and what the general range of outcomes might be; specifically:

- spill extent (i.e., the movement or trajectory of released oil) and shoreline oiling
- oil dispersion in the water column
- spill response capabilities and effectiveness by season

S:\1232\projects\123513135\figures\reports\SEA\fig_123513135_SEA_3-8_Major currents and bathymetry in relation to the plume of the Mackenzie River.mxd Revised: 2020-07-28 By: ltrudell





Community
Watercourse
Waterbody
Marine Protected Area
Terrestrial Protected Area
Bathymetry Depth (m)
< 200
200 - 1000
1000 - 2000
2000 - 3000
> 3000

Study Area Boundary
Mackenzie Shelf edge
Beaufort Gyre
Shelfbreak Jet (Predominant flow direction shown but can reverse with wind.)
Outer-shelf Current
Inner-shelf Current
Mackenzie Plume (West Wind)
Mackenzie Plume (East Wind)

0 25 50 75 100 km
1:3,000,000 (at original document size of 11x17)

KAVIK-STANTEC
INUVIALUIT REGIONAL CORPORATION

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Natural Resources Canada, Imperial Oil Resources Ventures Limited (2013)

Project Location
Beaufort Sea,
Northwest Territories,
Canada

Project Number 123513135
Prepared by LTRUDELL on 20191031
Discipline Review by SJONES on 20191031

Client/Project
Inuvialuit Regional Corporation
Beaufort Region SEA

Figure No.
3-8

Title
Major currents and bathymetry in relation to the plume of the Mackenzie River

For the purpose of the Data Synthesis and Assessment Report, it is assumed that other human activities would continue in the region (Section 3.6), but outside of the area affected by the oil spill. Human activities within the zone of influence of the spill and the spill response measures would be restricted or prohibited until the spill response measures and follow-up have achieved the operational target criteria.

3.10.3 Effects of Timing and Location on the Extent of Oiling, Oil Transport, and Shoreline Oiling: Scenario 5 (Large Oil Release Event)

The volume of oil released is not the only factor in determining the potential effects on the environment. While a large release of oil (e.g., hundreds to thousands of cubic meters) is likely to have a greater potential impact than a relatively small release (e.g., several or tens of cubic meters), other factors in the Canadian Beaufort Sea are as or more important than volume; specifically:

- the timing of a release (with respect to the oceanographic seasons) (EPPR 2017:Figure 2-6, this report)
- the location of a release (with respect to the shorelines and the Mackenzie River plume)

Timing is considered in terms of the four oceanographic seasons described earlier (EPPR 2017): ice, spring transition (break-up), open water and fall transition (freeze up).

Location is described relative to the location of the Mackenzie River plume which dominates the inshore water properties over the southern Beaufort Sea shelf (Mulligan and Perrie 2019). The area where the buoyant (warmer and less dense) river flow meets the dense (colder and saline) Arctic Ocean waters is a convergence zone where surface currents move toward each other and meet before mixing in the water column.

Similar processes have been observed off of other river deltas that flow into marine environments, For example, following the Deepwater Horizon oil spill, which occurred in the Gulf of Mexico outside the river plume of the Mississippi River, the effects of river flow on oil transport within the continental shelf was a major factor in the natural protection of the Mississippi River Delta wetlands and reducing oil movement and associated biological effects (Kourafalou and Androulidakis 2013). Similar effects of convergence zones constraining oil slick movement had been reported from other earlier oil spills outside the plume in that coastal region (Murray 1982).

The Mackenzie River plume convergence zone (“density front”) is a year-round, dynamic feature that provides a natural constraint to oil slick movements; there are several relatively constant characteristics which include:

- the majority of the freshwater flows into a coastal “V” cone shape and the outflow is confined by the Yukon coast and the northern extension of the delta (Garry-Pelly Islands) (Figure 3-8, based on original in Imperial Oil Resources Ventures Limited (2013))

- the wind regime is predominantly easterly and strong east winds cause upwelling and offshore surface water flow that move the convergence zone toward the west and farther offshore (Figure 3-8). The less frequent strong west winds can cause the convergence zone to move eastward along the Tuktoyaktuk Peninsula
- in terms of the coastal circulation, the relatively weak coastal and offshore coastal currents favour "front" formation and integrity

The geographic location of the edge of the plume and the intensity of the density gradients where the two water bodies converge is variable, depending on river flow and winds, but can extend several hundred kilometers from shore. The significance of this for oil transport and fate is that:

- oil released on the continental shelf within the Mackenzie River plume would be largely contained in that zone and seaward or alongshore spreading would be limited
- landward transport of oil released in deeper water outside of the plume would be limited, even under the influence of onshore winds

3.10.4 Scenario Details: Scenario 5 (Large Oil Release Event)

When considered together, the seasonal timing of an oil release and its location (relative to the Mackenzie plume) have the following implications for a large oil release event:

3.10.4.1 Scenarios during the Winter Ice Season

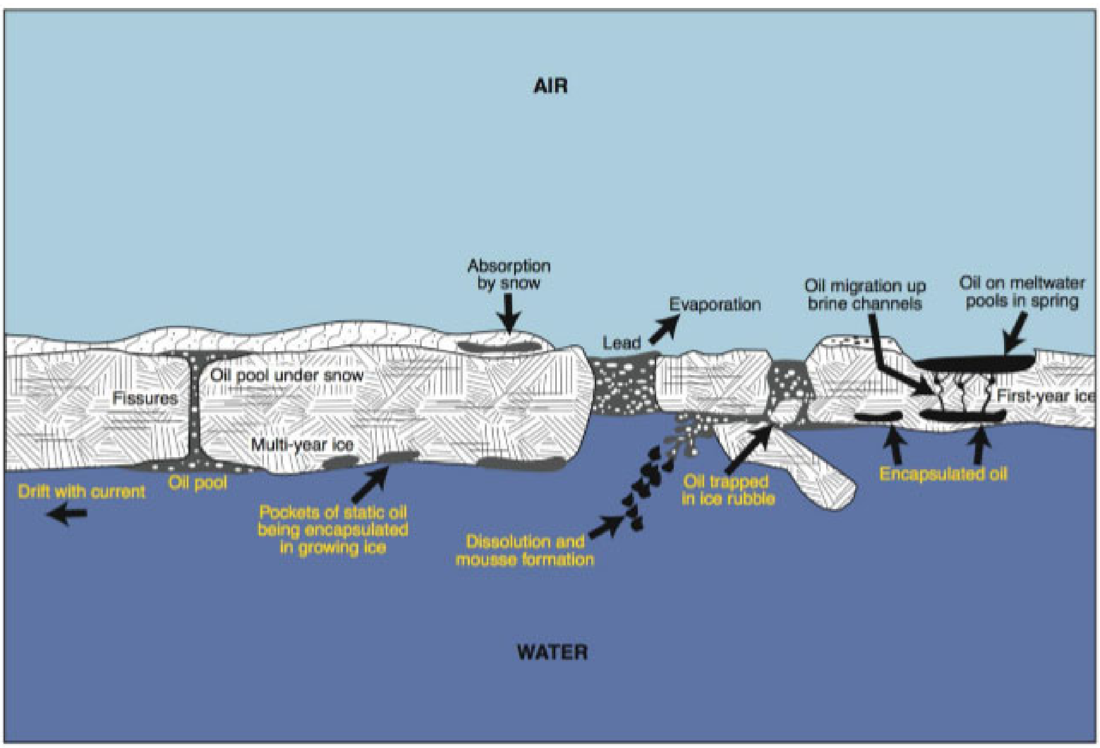
- **Oil on the ice surface from an above-ice source** (either an above-surface GBS platform or artificial island inside the plume, or an ice-breaking vessel outside the plume):
  - has very limited spreading potential (Table 3-11 and Figure 3-9)
  - may mix with snow, which would further minimize spreading
  - is essentially stationary after the initial release (although the ice itself may move)
  - can be readily detected day or night by aerial-borne sensors
  - can be removed mechanically or burned
  - does not disperse into the water column (only pathway into the water column is at leads)
- **Oil under the ice from a seabed release** (deep water well, pipeline within the plume):
  - has limited spreading potential
  - may surface in any leads or cracks
  - partially disperses into the water column as the oil rises to the surface
  - can be detected and delineated under ice by aerially deployed nuclear magnetic resonance (NMR) technology and canines
  - can be readily detected in leads day or night by aerial-borne sensors
  - can be removed mechanically or burned by ice slotting techniques

Table 3-11 Comparison of predicted final thicknesses and areas covered by a 1600 m^3 (10,000 bbl) batch crude oil spill.

	Open Water	Under Solid Mid-Winter Ice	On Smooth Ice	
			Ice	Snow
Final avg. oil thickness (mm)	0.016	40 to 90+	3	40
Final area (ha)	10,000	7 to 70*	50	4
SOURCE: SL Ross et al. 2010				

NOTES:

* The maximum pool depth under ice depends on the depth of the under-ice depressions, which grow deeper as the ice grows over winter
* The range of areas reflects the variable processes of oil spreading under ice. The final contaminated area depends on both the available volume of under-ice depressions and how they fill with oil: a point source subsea release of oil beneath undeformed fast (static) first-year ice may flow outward under the ice by only filling interconnected under-ice depressions (after Wilkinson et al. 2007), but a point source subsea release beneath a moving undeformed ice sheet may result in all the available under-ice depressions filling, depending on the flow rate, ice velocity and gas volumes



SOURCE: from Dickins 2011: derived from original sketch by A. Allen, ABSORB 1981

Figure 3-9 Schematic showing the range of oil and ice combinations from a spill under or on the ice.

3.10.4.2 Scenarios during the Spring Transition (ice breakup) Season:

- **Oil on broken ice surfaces or in leads from an above-ice source** (either an above-surface platform or artificial island inside the plume, or an ice-breaking vessel outside the plume):
  - has very limited spreading potential on ice surfaces: may collect in surface depressions, absorb into snow, be buried by snow, enter brine channels or may flow onto open water surfaces in leads or adjacent open waters
  - has limited spreading on water potential due to presence of ice, depending on the ice concentration
  - floats on water, unless the oil density is greater than that of the water: a situation that only would occur if the spilled oil (a) is originally denser than the water, (b) has become denser due to mixing with coarse sands or larger size material (that is, greater than 1 mm diameter), or (c) is a residue from a controlled burn
  - oil on the ice or on water drifts with the ice fields; highly unpredictable with many potential detailed localized scenarios as ice breaks up, surface waters refreeze, and floes affected by local winds
  - can be readily detected day or night by aerial-borne sensors
  - can be mechanically removed where ice conditions allow vessel operations
  - can be concentrated by herders and burned
  - can be chemically dispersed on open water
  - does not disperse into the water column except during very rare periods of partial open water with strong winds and high wave-energy activity; the oil would refloat once the energy levels return to normal
- **Oil from a seabed release** (deep water well, pipeline within the plume):
  - has limited spreading potential if under ice
  - would surface in open water areas but would have limited spreading potential in open water due to presence of ice, depending on the ice concentration
  - partially disperses into the water column as the oil rises to the surface
  - can be readily detected on water day or night by aerial-borne sensors
  - can be detected and delineated under ice by aerially deployed NMR technology and canines
  - can be removed mechanically on the ice or on water where ice conditions allow vessel operations
  - can be chemically dispersed on open water
  - can be concentrated on open water by herders and burned

3.10.4.3 Scenarios during the Open Water Season:

- **Oil released outside the Mackenzie River plume:**
  - Would spread rapidly as uncontained slicks transported by surface currents and winds
  - Would not disperse into the water column except for temporary submergence by turbulent wave action
  - Would affect shorelines outside of the plume area; limited potential for oiling of the delta wetlands and adjacent coastal regions that are used for traditional harvesting
  - Natural dispersion potentially effective for >3m wave heights
  - Aerial-deployed dispersants effective <3 m waves
  - Aerial-deployed herders and controlled burning or mechanical recovery effective for waves <1.25m
  - Limited shoreline cleanup as few wetlands or sensitive coastal resources at risk
- **Oil released within the Mackenzie River plume:**
  - Would spread rapidly and would be contained within the plume convergence zone
  - Floats on water, unless the oil density is greater than that of the water: a situation that only would occur if the spilled oil (a) is originally denser than the water, (b) has become denser due to mixing with coarse sands or larger size material (that is, greater than 1 mm diameter), or (c) is a residue from a controlled burn
  - Would not disperse into the water column except for temporary submergence by turbulent wave action
  - Could result in widespread shoreline oiling of the delta wetlands and adjacent coastal areas that are used for traditional harvesting
  - Natural dispersion potentially effective for >3m wave heights
  - Aerial-deployed dispersants effective <3 m waves
  - Aerial-deployed herders and controlled burning or mechanical recovery effective for waves <1.25m
  - Shoreline operations would be constrained by access and cleanup activities would be limited due to the fragility of many of the shoreline types

3.10.4.4 Scenarios during the Fall Transition (ice freeze up) Season:

- **Oil on broken ice surfaces or in leads from an above-ice source** (either an above-surface platform or artificial island inside the plume, or an ice-breaking vessel outside the plume):
  - has very limited spreading potential on ice surfaces: may collect in surface depressions, absorb into snow, be buried by snow, enter brine channels or may flow onto open water surfaces in leads or adjacent open waters

  - floats on water, unless the oil density is greater than that of the water: a situation that only would occur if the spilled oil (a) is originally denser than the water, (b) has become denser due to mixing with coarse sands or larger size material (that is, greater than 1 mm diameter), or (c) is a residue from a controlled burn
  - has limited spreading on water potential due to presence of ice, depending on the ice concentration
  - oil on open water or on ice drifts with the newly-forming ice fields; highly unpredictable with many potential detailed localized open water and ice scenarios as surface waters freeze, ice potentially breaks up under strong wind and wave action, and waters refreeze
  - can be readily detected day or night by aerial-borne sensors
  - can be mechanically removed from water where ice conditions allow vessel operations
  - can be concentrated by herders and burned
  - can be chemically dispersed on open water
  - does not disperse into the water column except during periods of open or partial-open water with strong winds and high wave-energy activity; the oil would refloat once the energy levels return to normal
- **Oil from a seabed release** (deep water well, pipeline) within the plume:
  - has limited spreading potential if under ice
  - would surface in open water areas but would have limited spreading potential in open water due to presence of ice, depending on the ice concentration
  - partially disperses into the water column as the oil rises to the surface
  - can be readily detected on water day or night by aerial-borne sensors
  - can be detected and delineated under ice by aerially deployed NMR technology and canines
  - can be removed mechanically on the ice or on water where ice conditions allow vessel operations
  - can be chemically dispersed on open water
  - can be concentrated on open water by herders and burned

3.10.5 Summary of Potential Outcomes: Scenario 5 (Large Oil Release Event)

3.10.5.1 Spill Extent and Shoreline Oiling

The likely spill extent and shoreline oiling for each of the combinations of season and location are summarized in Table 3-12.

3.10.5.2 Oil Dispersion into the Water Column

The likely dispersion of oil into the water column under different combinations of season and location are summarized in Table 3-13.

Table 3-12 Likely Extent of Spill and Shoreline oiling by Season: Scenario 5 (Large Oil Release Event)

Season	Platform or Tanker Spill within the Plume (Surface Release)	Platform Outside the Plume (Sub-sea Release)	Tanker Spill Outside the Plume (Surface Release)
Ice	• On ice surface • Limited spreading • Stationary	• Under ice surface • Limited spreading	• On or under ice surface • Limited spreading • On-ice oil stationary
Spring Transition	• On ice surface and in leads • Limited spreading • Mobile drifting ice fields	• On ice surface and in leads • Limited spreading • Mobile drifting ice fields	• On ice surface and in leads • Limited spreading • Mobile drifting ice fields
Open Water	• Rapid spreading and dispersion • Contained in the nearshore zone • Widespread shoreline oiling	• Rapid spreading and dispersion • Uncontained, free drifting, widespread distribution	• Rapid spreading and dispersion • Uncontained, free drifting, widespread distribution
Fall Transition	• On ice surface and in leads • Limited spreading • Mobile drifting ice fields	• On ice surface and in leads • Limited spreading • Mobile drifting ice fields	• On ice surface and in leads • Limited spreading • Mobile drifting ice fields

Legend

- Scenario with the potential least areal extent; very low potential for shoreline oiling
- Limited spreading due to containment within broken ice conditions; very low potential for shoreline oiling
- Scenario with the potential greatest uncontained areal extent; some potential for shoreline oiling
- Scenario with the potential greatest contained areal extent; high potential for shoreline oiling

Table 3-13 Likely Dispersion of Oil into Water Column by Season: Scenario 5 (Large Oil Release Event)

Season	Platform or Tanker Spill within the Plume (Surface Release)	Platform Outside the Plume (Sub-sea Release)	Tanker Incident Outside the Plume (Surface Release)
Ice	• Oil primarily on ice surface • Little to no dispersion to water column	• Partial dispersion to water column as oil rises to surface	• Oil primarily on ice surface or in leads • Little to no dispersion to water column
Spring Transition	• Oil primarily on ice surface or in leads • Little to no dispersion to water column	• Partial dispersion to water column as oil rises to surface	• Oil primarily on ice surface or in leads • Little to no dispersion to water column
Open Water	• Oil primarily on water surface • Little to no direct dispersion to water column, some near-surface dispersion at density fronts and due to wave turbulence at sea and shoreline breaking wave zone	• Partial dispersion to water column as oil rises to surface	• Oil primarily on water surface • Little to no direct dispersion to water column; some near-surface mixing due to wave turbulence
Fall Transition	• Oil primarily on ice surface or in leads • Little to no dispersion to water column except during partial open-water high-energy wave events	• Partial dispersion to water column as oil rises to surface	• Oil primarily on ice surface or in leads • Little to no dispersion to water column except during partial open-water high-energy wave events

Legend
• Little to no dispersion to the water column
• Some temporary near-surface dispersion and mixing due to wave turbulence
• Not used
• Dispersion greatest as oil rises to the sea surface

3.10.5.3 Spill Response Capability and Effectiveness: Scenario 5 (Large Oil Release Event)

The focus of oil response strategies is to first protect human life and then recover or eliminate released oil. The light fractions of an oil naturally attenuate by evaporation into the atmosphere or dispersion into the water column and are not recoverable. Recovery by mechanical systems, booms and skimmers, or elimination through controlled burning or chemical dispersion address the oil that remains (i.e., the recoverable oil).

Experience on the North Slope of Alaska and elsewhere in the Arctic has shown that exploration or development activities can be conducted safely in open-water or winter conditions and, if properly planned and executed, during the transition seasons (Section 2.13). No major releases of oil have occurred in the Beaufort Sea in the approximately 40 years of offshore oil and gas exploration between 1970 and 2010 (Owens and Dickins 2015). Owens and Dickins (2015) in a report for the Arctic Council, state that "the record of Arctic drilling over more than four decades is excellent with no significant spill events caused by loss of well containment". For the North Slope of Alaska, where oil has been produced for over 40 years onshore and offshore, all spills were onshore (Nuka Research and Planning Group 2013); 10 spills >500 bbl and 2 >1,000 bbl. No spills have occurred offshore.

Within the ISR, currently available oil spill response equipment includes three Canadian Coast Guard (CCG) caches designed to recover up to 1,000 tonnes of oil in total and one private cache: specifically[33]:

- CCG has an Arctic Community Pack (ACP) of equipment designed for small near-shore spills (up to one tonne of oil) in Ulukhaktok
- a CCG Rapid Air Deployable (RAT) with 120 pallets of equipment located at Hay River that would serve the ISR region
- one of three CCG "Delta-1000" large equipment caches is located in Tuktoyaktuk
- the Mackenzie Delta Spill Response Corporation (MDSRC) has a total of 20 mobile containers that contain oil spill response equipment for its members stored in Inuvik

In addition to the spill response equipment, the ISR region is serviced by the Transport Canada MART program (Marine Aerial Reconnaissance Teams). This involves surveillance overflights for oil releases using a Dash-7 surveillance aircraft that is stationed in Iqaluit during the Arctic shipping season (July to October).

In recent years, several important improvements have enhanced previous response capabilities based on aerial strategies; in particular, under-ice detection by Nuclear Magnetic Resonance (NMR) technology and concentration of released oil with herders (released from aircraft and without vessel support). The IMO (2017a) recently stated that "Logistics limitations and sparse infrastructure …. may preclude mechanical containment and recovery, and favour response strategies built around air support".

[33] https://nac-o.wildapricot.org/resources/Documents/Governance/CCG-English.pdf pages 14, 15 and 16
https://www.tc.gc.ca/media/documents/mosprr/TC-Tanker-E-P2.pdf pages 39 and 40
http://www.mackenziespillresponse.ca/home.html

In addition, as discussed in Section 2.13.6, new technologies will continue to provide improved spill response capability and capacity to meet operational challenges in remote marine areas and during the transition seasons. For example, considering current advances in response technology it is likely that in the future that remotely-operated, aerially-deployed, ice-strengthened surface water vehicles (similar to jet skis) would be able to safely deliver herders, ignition systems, and dispersants to remote marine areas in open water or during the transition seasons, with command-and-control data provided by Unmanned Aerial Systems (UASs) (Section 2.13.6). Similar delivery system capabilities currently exist in the military today.

Based on current capabilities and anticipated advances in technology (as discussed above), the capability and effectiveness of oil spill response measures under different combinations of season and location within the BRSEA Study Area were evaluated (Table 3-14).

As described in Table 3-13, (see also Section 2.13.6), the percentage of time that meteorological and oceanographic conditions may be favorable, marginal, or not favorable for defined oil spill response systems is an important consideration in the assessment of environmental effects in the BRSEA. Accordingly, a range of potential outcomes with respect to spill response capabilities and effectiveness were considered in assessing potential effects on VCs as a result of a large oil release event.

There are clearly logistical, operational and seasonal challenges associated with working in a remote and harsh environment such as the Beaufort Sea. However, given recent advances in technology (e.g., remote detection of oil and aerial or remote vehicle application of chemical treatments), combined with past and current knowledge of spill response in arctic waters, it is the opinion of the spill response specialist for the KAVIK-Stantec team (Ed Owens) that, if an oil release was to occur in the BRSEA Study Area, a spill could be detected and a substantial quantity of the recoverable oil could be removed (e.g., mechanical means or in-situ burning) or cleaned (e.g., dispersants, herders). However, to do so successfully, substantial amounts of spill response equipment and an organized system for local and outside spill responders would need to be in place. As part of any proposed exploration or production project, industry would need to work with the federal and territorial government and Inuvialuit organization to ensure that adequate and season-specific response equipment, process, and personnel are in place prior to the start of such projects.

Table 3-14 Effectiveness of Oil Spill Response Measures: Scenario 5 (Large Oil Release Event)

Season	Platform or Tanker Spill within the Plume (Surface Release)	Platform Outside the Plume (Sub-sea Release)	Tanker Incident Outside the Plume (Surface Release)
Ice	• Effective by physical removal and controlled burning on ice	• Surface oil detection by aerial sensors and under-ice detection by NMR and canines • Slotting for oil under ice and physical removal and controlled burning on ice	• Effective by physical removal and controlled burning on ice and in leads or for oil under ice by slotting then physical removal and controlled burning on ice
Spring Transition	• Mechanical removal where ice conditions permit • Aerial herders with controlled burning	• Mechanical removal where ice conditions permit • Aerial herders with controlled burning	• Mechanical removal where ice conditions permit • Aerial herders with controlled burning
Open Water	• Natural dispersion effective for >3 m wave heights • Aerial-deployed dispersants effective <3 m waves • Aerial-deployed herders and controlled burning or mechanical recovery effective for waves <1.25 m • Limited shoreline cleanup	• Natural dispersion effective for >3 m wave heights • Aerial-deployed dispersants effective <3 m waves • Aerial-deployed herders and controlled burning or mechanical recovery effective for waves <1.25 m	• Natural dispersion effective for >3 m wave heights • Aerial-deployed dispersants effective <3 m waves • Aerial-deployed herders and controlled burning or mechanical recovery effective for waves <1.25 m
Fall Transition	• Mechanical removal where ice conditions permit • Aerial herders with controlled burning	• Mechanical removal where ice conditions permit • Aerial herders with controlled burning	• Mechanical removal where ice conditions permit • Aerial herders with controlled burning
Legend			
• Effective mitigation possible			
• At sea, open-water mitigation can be effective using aerial response strategies			
• Mechanical removal where ice conditions permit • Aerial herders with controlled burning for oil on water			
• Limited effectiveness for response capability due to proximity to shorelines. • Difficult or limited cleanup on oiled tundra shorelines			

3.10.6 Potential Toxic Effects of Oil

Potential toxic effects of oil for each of the combinations of season and location are summarized in Table 3-15. Effects from oil spills are often referred to as acute or chronic. Here, acute effects refer to those that develop immediately (e.g., within minutes, hours or days) after an exposure while chronic effects are those that develop following prolonged exposure (lasting months or years) or a persistent effect following a short-term exposure. In general, low molecular weight compounds such as benzene, toluene, ethylbenzene, and xylenes (collectively referred to as BTEX), naphthalene, and some short-chain alkanes are more likely to cause acutely lethal effects and represent the more soluble and more volatile components of spilled oil (NRC 2005). The higher molecular weight compounds such as alkylated PAHs are more likely to cause sub-lethal chronic effects (such as internal and external lesions, developmental abnormalities in early life stages, and behavioral changes in feeding and breeding) and represent the more persistent, less soluble and less volatile components of oil. Asphaltenes and resins are typically not biologically available and thus non-toxic. However, asphaltenes and resins may adhere to surfaces and be slow to degrade, and thus act as reservoirs for the slow release of other more toxic constituents such as PAHs (Lee et al. 2015).

Table 3-15 Likely Toxic Effects of Oil Release by Season and Location (does not include physical effects of oiling)

Season	Within Plume (Surface)	Outside Plume (Subsea)	Tanker (Outside Plume, Surface)
Ice	• Limited potential for toxic effects from oil on ice surface	• Increased likelihood of acute toxic effects due to greater dispersion to water column as oil rises to surface • Reduced evaporation increases persistence of acutely toxic constituents • Residual components (including PAHs) may exhibit chronic, sublethal toxicity to aquatic organisms (e.g., internal and external lesions, developmental abnormalities in early life stages, and behavioral changes in feeding and breeding)	• Limited potential for toxic effects from oil on ice surface
Spring Transition	• Limited potential for toxic effects from oil on ice surface • Likelihood of toxic effects to nearshore habitats and associated species – benthic species, near-shore shellfish, near-shore fish. Extent of potential effects limited	• Increased likelihood of acute toxic effects due to greater dispersion to water column as oil rises to surface • Residual components may exhibit chronic, sublethal toxicity to aquatic organisms	• Limited potential for toxic effects from oil on ice surface
Open Water	• Greater surface spreading and higher temperature leads to higher evaporation which tends to reduce the acute toxicity of the oil • Higher TSS increases likelihood of oil-particulate aggregate formation and settlement to sea floor • Effects to nearshore habitats and associated species due to aggregate settlement and high potential for shoreline oiling.	• Increased likelihood of acute toxic effects due to greater dispersion to water column as oil rises to surface Once on surface, evaporation would reduce the acute toxicity of the remaining oil • Residual components may exhibit chronic, sublethal toxicity to aquatic organisms	• Greater surface spreading and higher temperature leads to higher evaporation which tends to reduce the acute toxicity of the oil • Likelihood of toxic effects to nearshore habitats and associated species – benthic species, near-shore shellfish, near-shore fish. Extent of potential effects limited

Table 3-15 Likely Toxic Effects of Oil Release by Season and Location (does not include physical effects of oiling)

Season	Within Plume (Surface)	Outside Plume (Subsea)	Tanker (Outside Plume, Surface)
Fall Transition	• Limited potential for toxic effects from oil on ice surface • Likelihood of toxic effects to nearshore habitats and associated species – benthic species, near-shore shellfish, near-shore fish. Extent of potential effects limited	• Increased likelihood of acute toxic effects due to greater dispersion to water column as oil rises to surface • Residual components may exhibit chronic, sublethal toxicity to aquatic organisms	• Limited potential for toxic effects from oil on ice surface
Legend			
• Least potential for toxic effects due to effectiveness of spill response and limited potential for spreading, dispersion, or potential for shoreline oiling			
• Limited potential for toxic effects due to limited potential for spreading, dispersion, or potential for shoreline oiling			
• Potential for toxic effects due to potential for spreading, dispersion, or shoreline oiling			
• Greatest potential for toxic effects due to high potential for shoreline oiling to affect near-shore sediment-dependent communities			

4 METHODOLOGY FOR THE ASSESSMENT OF EFFECTS

The purpose of the BRSEA is to "assess potential effects, including activity-specific and cumulative effects, on the human and environmental systems of the BRSEA Study Area (as monitored through the VCs), of alternative strategic initiatives, plans or programs (collectively "Scenarios"), associated with potential offshore oil and gas activities in the BRSEA Study Area" (Appendix A, Terms of Reference).

The inclusion of TLK with western science is a fundamental principle for the BRSEA. In describing existing and past conditions, assessing potential environmental effects (i.e., effects of routine activities and cumulative effects), and developing recommendations on knowledge gaps and future needs, the assessors considered TLK (through the TLK Database, Chapter 5), community input (from community meetings for BRSEA), and western science (e.g., published papers, reports).

To support the descriptions of existing conditions (Chapter 7) and the assessment of effects (Chapter 8 and Appendix D), the assessment team used information from recent citations for TLK and western science, as well as information from past oil and gas projects in the BRSEA Study Area and information compendia (e.g., Beaufort Environmental Monitoring Program [BEMP]; Beaufort Region Environmental Assessment and Monitoring program [BREAM], and Beaufort Region Environmental Assessment [BREA]).

While the BRSEA follows a similar set of steps as a project-based environmental and social impact assessment (ESIA) (e.g., issues identification, scoping, assessment of effects, identification of mitigation, assessment of residual effects; assessment of cumulative effects and identification of monitoring and follow-up actions), its objective is to describe the range of potential effects that might occur in the region as a result of specific potential activities (as described in the scenarios) with the intent of informing future needs for policy and regulations, management direction, community and Inuvialuit engagement, and filling of important knowledge gaps. The latter includes TLK, western science and engineering (e.g., adaptation to climate change, spill response methods).

Given the use of hypothetical scenarios with minimal site-specific information, the discussion of effects (environmental effects, residual effects, cumulative effects), is largely qualitative and not site-specific, with a focus on describing mechanisms through which effects might occur and the range of outcomes that might be possible. Similarly, discussions of mitigation measures, benefits plans, compensation and monitoring are described as high level approaches and programs, as opposed to site-specific measures.

4.1 Effects of Routine Activities

The following steps are addressed for each Valued Component (Section 4.1.1.1) for each of the five scenarios (Chapter 3).

4.1.1 Scoping

4.1.1.1 Identification of Valued Components

Valued Components (VCs) are defined as components of the biophysical environment and the social, cultural and economic systems that represent broad indicators of the health or wellbeing for these systems as well as regional environmental change. VCs were selected based on engagement with communities (during 2016, 2017 and 2018), review of previous work (e.g., the Beaufort Regional Environmental Assessment, previous assessments), engagement with experts (e.g., FJMC), and discussion among IRC, IGC and CIRNAC.

For the purpose of the Data Synthesis and Assessment Report, VCs within Physical, Biological and Human disciplines (as identified in the draft Table of Contents in the Terms of Reference; Appendix A of this report) were used to as a framework for the assessment (Table 4-1):

Table 4-1 Valued Components selected by the IRC and CIRNAC for use in the BRSEA.

Physical Environment	Biological Environment	Human Environment (Socio-Cultural and Economic Aspects)
• Atmospheric Environment • Climate and Weather • Oceanography • Sea Ice • Coastal Dynamics and Sea Floor Geology • Coastal Habitat	• Rare and Endangered Species and Communities • Marine Lower Trophic Levels • Marine Fish and Habitat • Migratory Birds • Seabirds • Marine Mammals • Polar Bear • Caribou • Invasive Species	• Economy • Demographics • Infrastructure • Traditional Activities • Cultural Vitality • Public Health

For each VC, the assessor identified and discussed the appropriate indicators, based on TLK, community input, western science and professional judgement[34]. The assessor also provided justification for the selection of the indicators and identified knowledge gaps.

[34] Professional judgement is defined as applying technical knowledge, skills and experience informed by professional standards, laws and ethical principle, to develop an opinion or decision about potential outcomes, adverse effects and benefits for the technical areas for which that individual is qualified.

4.1.1.2 Issue Identification

The discussion of environmental effects for each VC begins with an identification of the issues for that VC with respect to the specific scenario. Issues were identified using:

- TLK (from the TLK inventory; Section 5.3)
- input from the Inuvialuit communities during early community engagement activities under the BRSEA
- western science
- professional judgement of the assessor for that VC

4.1.1.3 Spatial Boundaries

The BRSEA Study Area for the Data Synthesis and Assessment Report is defined as the marine areas of the ISR (i.e., the Canadian Beaufort Sea up to the ordinary highwater mark of the coastlines within the ISR) (Figure 1-1). The regional study areas, specific to each VC and scenario, are identified, taking into account the spatial extent of likely effects of routine activities and cumulative effects associated with each scenario. In general, the assessor for each VC identified a single regional study area for that VC for use in all scenarios.

4.1.1.4 Temporal Boundaries

As noted in Section 1.6, the terms of reference for the Data Synthesis and Assessment Report required that the assessment focus on the 30-year period between 2020-2050. Given the likely needs and timelines for community engagement, regulatory applications and approvals, project planning and engineering, associated permitting, construction and field development, a likely production period of 20-40 years, and decommissioning, the full life cycle of typical types of oil or gas projects in the Beaufort Sea would be longer than 30 years (e.g., 40 to 60 years or even longer).

For all scenarios, the assessment of effects focuses on the period from 2020-2050. Where a specific phase or activity is likely to go beyond this period (e.g., ongoing production, decommissioning), the potential environmental effects of that activity or phase have been described using predictions and professional opinions about the biophysical and sociocultural and economic characteristics as of 2050.

4.1.2 Environmental Setting

An understanding of the existing status of each identified VC within the study region is provided in Chapter 7, taking into account TLK, western science and professional opinion. A single state of knowledge is provided for each VC and is used to support the assessment of each of the five scenarios.

The State of Knowledge chapter is intended to provide readers with an overview of information on existing conditions in the BRSEA Study Area with a strong focus on the VCs selected for the BRSEA (Section 4.1.1.1) and the TLK and western science information for those VCs that is pertinent to the assessment of potential activity-specific effects and cumulative effects. The environmental context is not intended to be a comprehensive statement of all knowledge for a VC, but rather focuses on the aspects of baseline conditions that are likely to be affected by one or more activities in one or more scenarios. This typically includes information on existing conditions and trends such as physical characteristics and processes; chemical constituents and contaminants; population status; geographic distributions and seasonal timing (including movements of biological species, important habitats across different life stages, seasonal use of marine areas by humans (including traditional uses); and environmental and human health.

The State of Knowledge chapter also includes a discussion of important data gaps for the physical, biological and human environment VCs.

4.1.3 Describing Potential Effects from Routine Activities

The most likely environmental effects that could result from the activities in a scenario are described for each VC. Where a potential interaction may exist, but the potential effects are not considered further, a rationale is provided. For the three oil and gas development scenarios, it was also assumed that activities described in the Status Quo scenario were also occurring over the same temporal duration.

The description of each environmental effect for a VC in each scenario begins with an overview of the mechanism(s) through which an effect might occur (e.g., pathways) and the parameters that can be used to characterize the important environmental effects on a VC. The selection of these parameters took into consideration information from TLK, community engagement, published sources for western science, and professional judgement.

Next, the range of possible outcomes (effects) to the VC are described, taking into account potential for different spatial and temporal overlaps between the VC and industrial activities in the scenario. For example, since shipping is defined as an activity without a specific location, a shipping route might avoid an important habitat area for a species, or it could intersect a portion of a seasonally important area[35]. The discussion would acknowledge this range of potential outcomes.

Residual environmental effects (i.e., effects remaining following application of best practices and mitigation) were described in terms of likely adverse effects or benefits that might occur throughout the 30 year period, taking into account environmental regulations and guidelines and typical industry best practices and mitigation measures. For example, if cuttings are to be disposed overboard, it is assumed they are treated to meet the current regulations and standards for such disposal (Section 2.5). The description of adverse effects and benefits (i.e., effects) also took into account various types of general and VC-specific mitigation measures and environmental management measures (Section 4.1.4). Site-specific effects and quantification of effects of routine activities are not addressed given that the scenario activities are not site-specific.

[35] However, given that there are specific spatial and temporal restrictions on industrial activity in marine and coastal areas, it is assumed that industrial activity would not occur in those areas during exclusion windows for sensitive periods.

The most likely environmental effects to a VC in each scenario were described, as appropriate, using the characterization terms and framework shown in Table 4-2. Each assessor defined the effect characterization terms for their VC as part of the scoping task for that VC.

Table 4-2 Example of the Table for Characterization of Residual Environmental Effects for VCs[36]

Characterization	Description	Parameter Categories
Direction	The long-term trend of the residual effect	**Positive**—an increase in … **Adverse**—a decrease in … **Neutral**—no net change in …
Magnitude	The amount of change in parameters or the VC relative to existing conditions	Typically expressed qualitatively as: • **Negligible**—no measurable change … • **Low**—a measurable change but … • **Moderate**—measurable change but less than high … • **High**—measurable change of [provide dimension]…
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint** —residual effects are restricted to the footprint of the activity **Local** —residual effects extend into the local area Regional – residual effects extend into the regional area **Extra-regional**: residual effects extend beyond the regional area
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**— **Multiple irregular event** (no set schedule) **Multiple regular event**—… **Continuous**—residual effect occurs continuously
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to …(e.g., construction phase) **Medium-term**—residual effect extends through …(e.g., operation phase) **Long-term**—residual effect extends…(e.g., beyond closure) **Permanent**—measurable parameter unlikely to recover to existing conditions
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over some time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., significantly modified from natural conditions) or such human activity is still occurring

[36] This is a template for the effects characterization table; tables specific to each VC are provided in the detailed assessment in Appendix D.

4.1.4 Mitigation Measures and Planning Considerations

As noted in Section 4.1.3, the types of mitigation measures and environmental management measures that would likely be used to address effects of specific activities or groups of activities on a VC were identified so that residual effects could be discussed. TLK and western science were used as sources of information. As site-specific information or quantification of site-specific environmental effects was not the intent of the BRSEA, the description of mitigation measures and environmental management measures focuses on the measure or methods and how these might be used to reduce an effect or improve benefits. Given this, a range of types and intensities of mitigation and environmental management measures might be employed given the severity of the potential environmental and residual effects. Mitigation measures are described further in Chapter 8.

4.1.5 Summary of Effects of Routine Activities

A standardized tabular summary was developed to provide a concise overview of how industrial and human activities might affect a specific VC during different seasons and in different locations. The outline for that table is shown in Table 4-3. Assessors for each VC completed a similar table as part of their assessment (Chapter 8).

Each assessor defined the four terms in the legend - Least Effect, Moderate Effect, High Effect and Greatest Effect – based on published information on environmental effects (including impact assessments for previous projects in the region and previous regional assessments), TLK and professional judgement. Potential effects were then summarized for each of the four seasons for each of Scenarios 1 through 4 (a different summary table was used for the Large Oil release Event). The summaries provided in these tables are based on the maximum residual effects characterization, and do not include consideration for how climate change could alter residual effects predictions. Additional details on the effects (including references to TLK and western science) and justification for the rankings and conclusions are provided in the text of the BRSEA.

Table 4-3 Example of the Summary Table for Potential Effects of Development Scenarios on VCs

Season	Scenario 1: Status Quo	Scenario 2: Natural Gas Export in Mid-Water	Scenario 3: Oil Development in Mid-Water on Continental Shelf	Scenario 4 Oil Development in Deep Water on Continental Slope
Ice	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend
Spring Transition	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend
Open Water	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend
Fall Transition	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend
Cumulative Effects	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend	• Max of 25 words – shade cell as per effects legend
Legend				
• Least effect: Definition of Least effect for specific VC to be inserted here				
• Moderate effect: Definition of Moderate effect for specific VC to be inserted here				
• High effect: – Definition of High effect for specific VC to be inserted here				
• Greatest effect: Definition of Greatest effect for specific VC to be inserted here				

4.1.6 Cumulative Effects

Cumulative effects on a VC were considered for the Status Quo and the three oil and gas development scenarios. Cumulative effects are defined for the BRSEA as effects of routine activities in the scenario in combination with effects of other human activities in the region over the 30 year duration of the scenarios. For the Status Quo scenario, the cumulative effects assessment considered how all of the human activities for Status Quo might cumulatively affect a VC. For the three oil and gas development scenarios (Scenarios 2 to 4), cumulative effects included the activities described for each individual scenario as well as the activities for the Status Quo scenario. Cumulative effects were not assessed for multiple oil and gas development scenarios (e.g., cumulative effects of Scenario 2 and 3).

Cumulative effects were not described for a large oil release event because it is not a routine activity and:

- There are differences in the probability of the effects of routine activities occurring versus the probability of effects from an accidental oil spill event; specifically effects from routine activities are expected to occur if a scenario proceeds as described, whereas accidents and malfunctions are unlikely to occur.
- Effects from a large oil release event would overshadow effects from routine activities and cumulative effects.
- In the event of a spill, management measures to protect sensitive species would be employed that may prohibit or restrict other industrial actions and human activities and later routine effects on some VCs.

The potential range of cumulative effects was described based on the potential for different spatial and temporal overlaps between the VC and multiple human activities, as well as the longevity of these effects on the VC. Where possible, cumulative effects were described using the same effects characterization criteria as described in Table 4-2. Site-specific effects and quantification of cumulative effects were not addressed given that the scenario activities are not site-specific.

The characterization of cumulative effects focuses on the impacts from the full suite of activities in the Status Quo and the single oil and gas development scenario activities (as noted, the activities in the Status Quo scenario were also considered as part of the three oil and gas development scenarios). Following the characterization of potential cumulative effects for each of Scenarios 1 – 4, the potential influence of climate change on the prediction of cumulative effects was also discussed for each VC.

4.1.7 Potential Effects of Climate Change on Predicted Project Effects

Once the residual effects of routine activities on a VC were discussed, the effect that climate change (as described in Chapter 6) might have on the VC and on the potential residual effects and cumulative effects for that VC under each scenario were described, taking into account:

- How climate change might influence or change the VC; this might include changes in spatial distribution, seasonal timing, use of areas/habitats or resources by ecosystem component or humans, population status or health of ecosystem component or humans, harvesting success, or cultural practices.
- How climate change might alter the pathways and the characteristics of potential environmental and residual effects on a VC for a scenario or specific group of activities as a result of changes in the spatial or temporal overlap between a VC and activities in a scenario. The latter could result from changes in the VC and/or changes in industrial or human activity.

Since there is limited published information on effects of climate change on industrial and human activities and associated effects on specific VCs, this assessment relied heavily on TLK and the professional judgement of the assessors and the climate change team.

4.1.8 Follow-up and Monitoring

The last step of the assessment for each VC for each scenario is to describe potential needs for follow-up and monitoring programs at a high level. Given the regional focus of the Data Synthesis and Assessment Report, by necessity, the description of recommended programs is at a high level with a focus on what might be done (as opposed to when and where).

Follow-up is defined as a program for:

- verifying the accuracy of the environmental assessment of a project
- filling knowledge gaps where needed to increase confidence in the residual effects characterizations and conclusions
- determining the effectiveness of any measures taken to mitigate the potential adverse environmental effects of a given scenario

Follow-up programs would also include recommendations for adaptive monitoring programs.

Monitoring primarily relates to compliance monitoring (i.e., were the mitigation measures implemented?) and are typically implemented during specific activities and during specific time periods for a project. While the scenarios described here are hypothetical, recommendations for compliance monitoring programs were provided for some VCs for the Status Quo (e.g., wind energy projects; geophysical surveys) and three oil and gas development scenarios. Some monitoring is required under existing legislation (e.g., monitoring of chemicals of concern in water discharges).

4.2 Large Oil Release Event

The approach for assessing the effects of a large oil release event is described in Section 3.10. A range of potential effects on the VCs was considered based on potential outcomes of exposure to an oil spill occurring under different combinations of conditions related to (Section 3.10.3):

- timing or season (ice, spring transition, open water and fall transition) (EPPR 2017)
- location relative to the Mackenzie Plume
- movement of oil by ocean currents in the Beaufort Sea (e.g., Beaufort Gyre, shelf break jet)
- surface release from a platform or tanker versus a subsea release (e.g., from a subsea well blowout)[37]

The types of effects from oil releases and exposures to oil are described based on published literature and professional opinion. This review is high level with a focus on the major effects in arctic conditions. Following this high-level assessment, information in Table 3-12 and Table 3-13 on shoreline oiling and seasonal water column dispersion was then used to determine how a VC might interact with released oil given potential spatial and temporal overlaps between the VC and released and dispersed oil. Two major aspects were considered:

- The range of potential effects that an unmitigated large release of crude oil may have on the natural and human environment on the VC taking into account the season, location (relative to the Mackenzie Plume) and the type of release (surface versus sub-sea)
- The potential and timing for the recovery of the biophysical and human environment following a large release of crude oil

In determining the range of potential environmental effects and recovery from an oil release, the effectiveness of oil spill response measures by season, location and type of release were considered (Table 3-14).

A tabular summary was developed to provide a concise overview of how released oil could affect a VC during different seasons and in different locations (Table 4-4). Each assessor defined the four terms in the legend - Least Effect, Moderate Effect, High Effect and Greatest Effect – based on published information, observations from oil releases in arctic conditions, TLK and professional judgement. Potential effects were then described for each of the four seasons and multi-year effects for each of the three combinations of locations (relative to the Mackenzie Plume) and the type of release (surface versus subsea). Additional details and justification for rankings and conclusions are provided.

[37] A subsea release was not assessed for locations within the plume since it was assumed that, in shallow water, oil released from a subsea location would rapidly rise to the surface. While dispersion and mixing with the water column would occur, this would be minor compared to a subsea release in deep water.

Table 4-4 Template for the Summary Table for Effects of a Large Oil Release Event on a Valued Component

Season	Platform or Tanker Spill within the Plume (Surface Release)	Platform Outside the Plume (Sub-sea Release)	Tanker Incident Outside the Plume (Surface Release)
Ice	• Max of 25 words – shade cell with appropriate colour as per effects legend	• Max of 25 words – shade cell with appropriate colour as per effects legend	• Max of 25 words – shade cell with appropriate colour as per effects legend
Spring Transition	• Max of 25 words – shade cell with appropriate colour as per effects legend	• Max of 25 words – shade cell with appropriate colour as per effects legend	• Max of 25 words – shade cell with appropriate colour as per effects legend
Open Water	• Max of 25 words – shade cell with appropriate colour as per effects legend	• Max of 25 words – shade cell with appropriate colour as per effects legend	• Max of 25 words – shade cell with appropriate colour as per effects legend
Fall Transition	• Max of 25 words – shade cell with appropriate colour as per effects legend	• Max of 25 words – shade cell with appropriate colour as per effects legend	• Max of 25 words – shade cell with appropriate colour as per effects legend
Longer-term/ Multi-year	• Max of 25 words – shade cell with appropriate colour as per effects legend	• Max of 25 words – shade cell with appropriate colour as per effects legend	• Max of 25 words – shade cell with appropriate colour as per effects legend
Legend			
• Least effect – No to minor alterations to travel routes, harvesting locations, harvesting season and/or camps			
• Moderate effect - Moderate alterations to travel routes, harvesting locations, harvesting season and/or camps			
• High effect - Major alterations to travel routes, harvesting locations, harvesting season and/or camps			
• Greatest effect – Severe alterations to travel routes, harvesting locations, harvesting season and/or camps			

4.3 Information Gaps and Recommendations

Once the assessment of the potential environmental effects of the five scenarios was complete, each assessor identified knowledge gaps and uncertainties that would make it difficult to predict environmental consequences of potential interactions with project activities and recommended types of information that could be collected to address these gaps and uncertainties. Knowledge gaps included both TLK and western science.

5 TRADITIONAL AND LOCAL KNOWLEDGE

5.1 Introduction

Inuvialuit have lived in the Western Arctic since time immemorial. From generations of living on the land, Inuvialuit have developed intricate knowledge systems about the interrelationship between the land, waters, plants, animals, and climate upon which traditional uses depends. This knowledge has been passed on through oral traditions, cultural teachings and participating in traditional practices. Inuvialuit continue to carry out traditional land use activities throughout the ISR including traditional harvesting, travel on the land and cultural activities. Many Inuvialuit continue to depend on country foods for sustenance, hunting and trapping as part of a traditional economy. Through observations and direct experience over the past 60+ years (i.e., oil and gas activities began in the ISR in the 1950s), Inuvialuit land users also have an intimate understanding of how oil and gas development in the BRSEA Study Area has affected and may affect the biophysical and socio-cultural environment of the ISR.

The TLK Framework was developed to provide a structure for the meaningful and respectful inclusion of Inuvialuit TLK in the Data Synthesis and Assessment Report for the BRSEA. The Terms of Reference for the report (Appendix A) requires that the assessment of each scenario fully considers community and Inuvialuit perspectives. The TLK Framework included an inventory of selected reports with Inuvialuit knowledge and observations, along with guidance on the use of information and citations and corroboration of the use of TLK. Together these components facilitated the use of TLK on an equivalent basis to western science in both the state of knowledge and assessment of effects for most VCs[38].

The intention of the TLK Framework was to use TLK as a knowledge system equal to western science that provided valid, reliable observations about natural phenomena and environmental conditions that could meaningfully contribute to the conclusions of the report. The full BRSEA program, including this Data Synthesis and Assessment Report, was an important opportunity to braid TLK and western science to inform the future management of the BRSEA Study Area. Toward that end, the TLK Framework was a methodological approach to consider, from an Inuvialuit perspective, interrelationships between environmental, social, cultural and economic conditions; traditional use and harvesting of wildlife and other natural resources; and decision-making by Inuvialuit[39]. The resulting framework was intended to facilitate effective use of two major knowledge sources in the Data Synthesis and Assessment Report: TLK and western science.

[38] TLK was not available for several VCs, including oceanography and marine lower trophic levels

[39] These themes were provided by the Co-Chairs and were developed through community engagement activities in each of the six ISR communities (Table 1-1, Community Engagement Activities for the BRSEA).

5.2 Scope and Limitations

The TLK sources for consideration in the Data Synthesis and Assessment Report were identified and confirmed through consultation with the Co-Chairs, and their support teams; these sources are listed in Appendix B. The TLK sources were selected to provide specific TLK about traditional activities and land use; local knowledge about environmental conditions, habitat and wildlife[40] resources, and local perceptions of past and anticipated impacts and concerns regarding onshore, nearshore and deep-water development projects across the BRSEA Study Area.

Limitations in using TLK in the Data Synthesis and Assessment Report include:

- While eight TLK studies were completed specifically for use in the BRSEA that did take into account oil and gas development and oil releases, the studies were completed prior to the development of the Status Quo, the three oil and gas development scenarios and the large oil release scenario. As a result, the TLK studies did not specifically focus on the scenarios described in Chapter 3.
- Some of the TLK sources were completed for other studies or projects in other contexts and may not consider the full suite of activities included in the five scenarios. As a result, the level of detail and applicability of specific TLK for the BRSEA varied across different sources and was also affected by the context in which the information was gathered (e.g., project-specific versus area-specific).
- TLK from development projects was often associated with the particular location, timelines and activities for the project, and how the project might affect specific communities, traditional use, habitats and wildlife. Where possible, this information was generalized in the TLK Inventory to facilitate application to the scenarios.
- TLK is a living knowledge source that will continue to evolve and expand in relation to observations on effects of climate change, effects from human activities, monitoring success, etc. The TLK sources used in this assessment represent a snapshot in time for Inuvialuit TLK.

5.3 Methodology

The TLK Framework includes three main components:

- a TLK Inventory that summarizes key information from applicable TLK sources categorized by VCs and scenarios
- guidance to assessors for the review, identification, and inclusion of relevant TLK
- corroboration of TLK use by the Inuvialuit members of the TLK Team

[40] With respect to the TLK inventory, wildlife was a broad encompassing term for marine and anadromous fish, migratory birds, seabirds, land mammals, and marine mammals.

5.3.1 Traditional and Local Knowledge Inventory

5.3.1.1 Development of the Inventory

The TLK Inventory was compiled by TLK facilitators with experience in the use of TLK in environmental assessments and regulatory applications. Information was reviewed and summarized from TLK sources, with a focus on the BRSEA Study Area. The Inventory represents a substantial body of TLK, summarized according to VC categories, and cross-referenced by traditionally used species, human environment, baseline conditions, anticipated effects, and proposed mitigation measures.

The TLK Inventory contains information on specific TLK about activities and resources, as well as baseline and development-specific information, including:

- species harvested, harvesting methods and locations of harvest
- species diversity, distribution and abundance
- preferred habitat and migration patterns
- changes in animal behaviour
- changes in environmental conditions, including weather
- traditional habitation sites
- traditional trails and travel routes
- culturally important areas
- traditional activities or practices
- potential effects of development on wildlife, habitat, traditional and traditional activities

TLK was grouped by specific categories relating to:

- physical environment (e.g., sea ice, atmosphere)
- biological environment (e.g., marine fish and habitat, migratory birds)
- species (e.g., polar bear, arctic char)
- human use (e.g., traditional activity, economy)
- recommended approaches for future activity (e.g., mitigation and management, research gaps)

For each TLK source, the inventory also provides the following (where adequate details were provided):

- data source reference
- where possible, the source community in the ISR for the TLK
- existing conditions and trends
- anticipated effects of industrial or other human activities
- recommended mitigation measures for effects from industrial activity
- geospatial reference, including GIS, maps figures and tables

Assessors were also provided with an abstract for each of the TLK sources in the inventory, the source context, and the type of information within the source.

The summarizing of TLK in this manner was intended to assist the assessors for each VC to identify and use relevant TLK in describing the existing status of the VC and the assessment of activity-specific and cumulative effects for the scenarios (Section 5.3.2.1: Application of TLK Inventory).

For the description of existing conditions and potential effects on VCs, assessors used information contained within the TLK Inventory along with input from three local Inuvialuit knowledge holders. While each assessor was not able to directly review all of the original sources, the three Inuvialuit members of our TLK team were engaged in a review of the TLK used in this report (particularly Chapters 7 and 8) to corroborate that appropriate TLK was referenced and that it was interpreted and used in an appropriate manner.

5.3.2 Guidance to the Assessors

5.3.2.1 Application of TLK Inventory

TLK was used to inform the elements of the assessment as follows:

- scoping
  - identifying species of importance, including harvested species for consideration as VCs
  - determining spatial and temporal boundaries of the assessment for each VC
- defining existing conditions
  - observation of air quality, weather patterns, climate, sea states and ice, water quality and coastal processes and erosion
  - population status and trends, habitat use and condition, and movement and migration patterns and observed changes in these parameters over time
  - use of the land by people (travel routes, seasonal activities, known landforms) and observed changes in these parameters over time
- effects assessment (i.e., adverse effects and benefits)
  - characterizing the temporal and spatial scope of an effect on a VC
  - cultural considerations for resource or land use
  - change in ability of the Inuvialuit to undertake traditional activities or experiences of being on the land
  - impacts of development on fish, various wildlife, habitat, human health, culture and the economy
- monitoring and follow-up
  - follow-up to confirm potential project effects (e.g., effects of water and air quality on traditional use)
  - development of monitoring programs based on traditional use

During the preparation of the report, assessors worked with TLK facilitators to confirm the applicability and context of TLK for each VC. Table 5-1 contains guidance, provided to the assessors, regarding the use of TLK in the assessment.

Table 5-1 Use of TLK- Guidelines for Assessors

Topic, Section	TLK Considerations
Defining Objectives, Goals	Including an "Inuvialuit" perspective in objectives and goals. For example, access to Inuvialuit traditional use areas would not be impeded; or criteria developed in collaboration with Inuvialuit groups would be considered in site and species selection.
Scope Definition	TLK is an essential element in defining issues of concern for the Inuvialuit communities. Consideration of TLK may result in the inclusion of additional targeted species or contribute to definition of spatial and temporal boundaries, or measurable parameters. For example, Inuvialuit may identify species or uses of interest that may or may not align with those of interest to physical, biological or socio-cultural and economic disciplines (consider using these species or uses as possible indicators).
Environmental Conditions	Include TLK as baseline or point of reference. For example, Inuvialuit people may identify timing of spring breakup, high flow for local watercourse, reduction of multiyear ice, wildlife population fluctuations, etc. Include reference to these and comment on how they do or do not align with scientific data. Describe why.
Assessments	Include TLK in identifying specific effects on the physical and biological environment and in identifying approaches for mitigation, including seasonal windows for activities and avoidance of high use habitat or hot spot. Consider specific effects on Inuvialuit people, their ability to continue an activity, the species used by the communities, specific criteria linked to Inuvialuit use or other activities or resources
Developing Recommendations (e.g., mitigation, design, monitoring, reclamation)	Consider applicable TLK in the development of proposed mitigation, environmental management plans, design of monitoring follow-up programs, communication of findings to communities, etc. Explain how TLK influenced the recommendations. Focus on particular species for indicator species or examples, as appropriate.
Specific TLK references, examples	Specific types of TLK to be considered may include: • species harvested • how and where species are harvested • changes in population status or trend, migration and other patterns • changes in habitat and climate over time including trends and other patterns • how species are used (prepared), parts of species used • types of activities (harvesting, use of trails, landmarks) that may be affected by, or affect the activity proposed • how TLK, traditional activities or uses have been considered and accommodated in the State of Knowledge and assessment • importance of inter-relationships between all species and natural ecosystems, maintaining natural balance (worldview) • how access to, or use of, camps, travel routes, fishing and other harvesting sites, etc. may change, positively or adversely (note: do not suggest alternate areas since Inuvialuit communities have rights to an area that cannot arbitrarily be used by others) • location of conservation areas or sensitive areas that should be considered when development projects are proposed. • descriptions of habitat requirements (e.g., land cover types, habitat associations, seasonal foraging strategies)

Table 5-1 Use of TLK- Guidelines for Assessors

Topic, Section	TLK Considerations
Specific TLK references, examples (cont'd)	• indicator species for assessing effectiveness (monitoring applications) • timing of activities (e.g., data collection, planting, monitoring, etc.) • types of habitat (or conditions) that may benefit traditionally harvested species or enhance the ability to practice traditional activities • how TLK might support decision-making processes, recommendations in addressing data gaps, decisions for recommended research and monitoring (e.g., locations, timing and methods), communication of results, feedback cycles, etc.

The goals of this approach were to include TLK as an equivalent source of knowledge to western science and use TLK in a manner that contributes meaningfully and substantively to the state of knowledge and assessment of adverse effects and benefits. Accordingly, TLK has been braided with western science throughout the report, rather than bracketed off as stand-alone sections. TLK and western science were cited in the same way (Table 5-2).

Table 5-2 Referencing and Citing TLK Sources

Section	Instruction
Referencing, acknowledging TLK	• It is important that each use of Inuvialuit TLK is acknowledged. Where TLK is attributed to a particular Inuvialuit community, that needs to be acknowledged and referenced. Avoid aggregating TLK and, as appropriate and applicable, include all details provided. • If it makes sense to aggregate general information (e.g., many Inuvialuit groups identified the coast as an important place to harvest fish) be sure to reference each TLK report. It is acceptable to aggregate general information but avoid aggregating specifics. Specifics demonstrate due diligence, respect and understanding. • The same TLK may lend itself to different sections of a report and can be included in multiple locations (e.g., purpose, methods, site selection). The information should be applied in the context of the specific section and tracked through numbered citations so that when an update to the TLK Inventory is provided it can be applied to the corresponding sections of the report.
Limitations on use of TLK	Limitations on the use of TLK should be specified where applicable. These may include: • not all of the sources used in the TLK inventory asked specific questions about mitigation measures, wildlife and habitat compensation, monitoring programs or effects specific to the project activity being considered • information was not used if it was not possible to confirm species or location (acknowledge in the report)
Citing TLK	Cite all references back to the TLK report from which they originated. Provide page numbers in each citation so that it can be referenced back to the specific section(s) it applies to.

5.3.3 Corroboration of TLK Use by the Inuvialuit Members of the TLK Team

The TLK team included three Inuvialuit beneficiaries: James Pokiak, Doug Esagok and Trevor Lucas. These individuals are active harvesters. The Inuvialuit TLK team members are resident in different regions of the ISR and thus bring different perspectives on all facets of the BRSEA. They each have extensive knowledge of local wildlife, habitat and climate change based on personal experience, as well as from information passed on to them by Elders and other local knowledge holders. They have personal experience working on oil and gas development projects and scientific research programs, as well as personal and acquired knowledge of the benefits and impacts of past oil and gas development projects.

The assessors for different VCs discussed the use of TLK in various report sections with the TLK facilitators. In addition, the TLK facilitators reviewed Chapters 7 and 8 with the Inuvialuit Members of the TLK Team to confirm that local knowledge of relevance to the subject matter had been appropriately interpreted and used in the correct context.

6 CLIMATE CHANGE PROJECTIONS

6.1 Purpose

As described in Chapters 7 and 8, Inuvialuit TLK and western science have documented substantial changes in climate and associated changes in the physical and biological environment within the BRSEA Study Area over the past several decades. In turn, changes in the physical environment (e.g., ocean conditions, sea states, ice, open water, weather) and the distribution and abundance of biota have altered traditional use, cultural vitality, public health and the local and regional economy, and adversely affected infrastructure and services within the BRSEA study area. Climate change has also directly affected traditional uses and human safety (e.g., timing and routes for travel on ice).

The purpose of this section is forward looking. The assessment of potential environmental effects of industrial and human use over the next 30 years requires a consistent approach for consideration of climate change. Specifically, there was a desire to choose a single climate change emissions scenario from a series of greenhouse gas concentration trajectories called Representative Concentration Pathways (RCPs) adopted by the Intergovernmental Panel on Climate Change (IPCC) for its fifth Assessment Report (AR5) (IPCC 2013). This selection process is detailed in Sections 6.3.1 and 6.3.2.

Once a RCP was chosen, we selected key physical, oceanographic and coastal variables deemed most important for physical and biological processes in BRSEA Study Area (Section 6.3.3). The associated projected changes for these key physical, oceanographic and coastal variables under the chosen RCP were then characterized (summarized in Section 6.4 and developed in detail in Appendix C). These changes were used to inform the types and seasonal timing of activities and choice of equipment for the Status Quo and the three oil and gas scenario (e.g., effects of longer Open Water Seasons and increased potential for storm impacts) (Section 3.5). These changes were also used in Chapter 8 and the detail assessment of effect (Appendix D) to describe how climate change might modify the:

- Distribution, seasonal movements and populations of marine species (e.g., the effects of a longer Open Water Season and changes in sea-ice on the distribution and activities of a species), as well as socioeconomic and cultural conditions (e.g., how changes in sea ice might affects the timing and location of harvesting).
- Effect pathways or mechanisms for each valued environmental or social component (e.g., how climate might change the magnitude, duration or geographic scope of effects on a biological species, traditional use, or socio-economic values). For example, if a longer open water period allows longer industrial activities, as well as longer occupancy of the area by a marine species, effects may occur over a larger geographic area for a longer period of time.

6.2 Scope and Limitations

The projections for key physical, oceanographic and coastal variables are based on a review of current forecasts and information for the chosen RCP (see Sections 6.3.3 and 6.3.4); only limited reanalysis of data on climate change was completed to support the Data Synthesis and Assessment Report.

The effects of climate change the assessment of environmental effects was based on TLK, western science and professional judgement. Predictive modelling of the effects of climate change on specific VCs was outside the scope of this assessment.

6.3 Methodology

6.3.1 Selection of a Climate Change Scenario for BRSEA

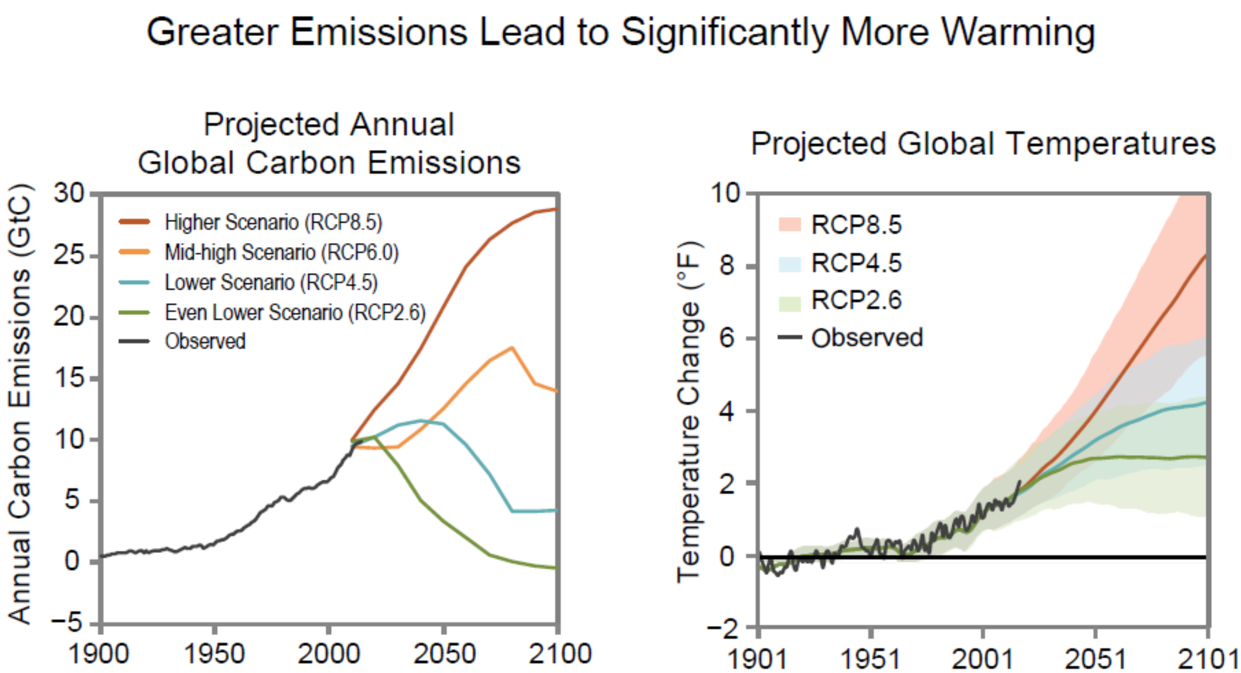
KAVIK-Stantec worked collaboratively with IRC, IGC and CIRNAC to review potential climate change scenarios (Section 6.3.2) and select a preferred (most realistic) trajectory for use in the Data Synthesis and Assessment Report (Section 6.3.3). The key steps in selecting the preferred trajectory were:

- options for climate change scenarios were researched and developed by KAVIK-Stantec
- these options were presented to the IRC, IGC and CIRNAC for discussion and consideration
- the IRC, IGC and CIRNAC evaluated the options and selected the climate change scenarios that seemed most realistic for the BRSEA Study Area based on available TLK, review of past trends in key variables presented, and expert advice and recommendations.

6.3.2 Review of Representative Concentration Trajectories

The key consideration in determining the environmental impacts of climate change is choosing a climate scenario for context. Given the uncertainties in future human behaviour regarding national and global fossil fuel use, and within and across climate prediction models, the approach generally taken is to present a range of models with different emission scenario assumptions, called RCPs (Figure 6-1). The number behind each RCP represents a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6.0, and 8.5 W/m^2, respectively). The RCPs are consistent with a wide range of possible changes in future human greenhouse gas (GHG) emissions and aim to represent their atmospheric concentrations. Assumptions differ substantially among the RCPs since they depend on the timing and degree to which national and international policies are expected to help curb global GHG emissions. For example, RCP 2.6 assumes that global annual GHG emissions peak between 2010–2020, with emissions declining substantially thereafter. Emissions in RCP 4.5 peak around 2040, then decline; RCP 6 emissions peak around 2080; and in RCP 8.5, emissions continue to rise throughout the 21st century.

To choose a single IPCC scenario that would form the basis for the BRSEA, current data for GHGs, air temperature and Arctic sea-ice were compared with the predictions these models have made for these variables beginning in 2005.

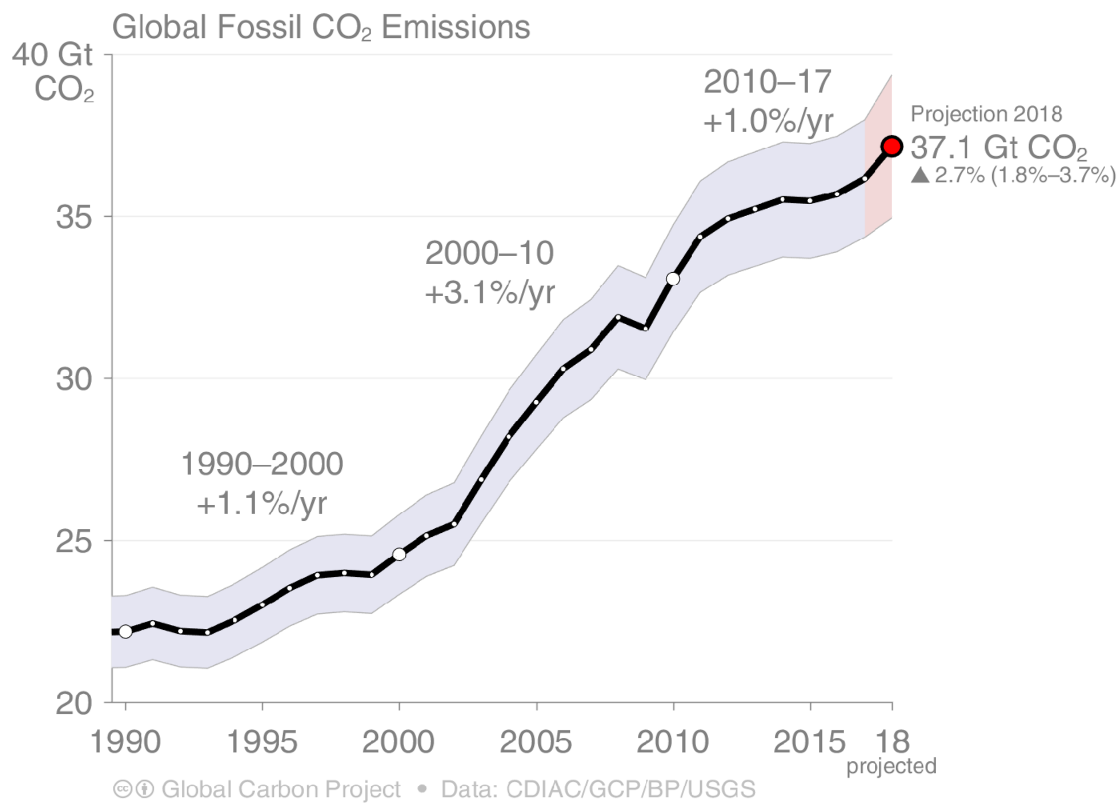


SOURCE: USGCRP 2017: Climate Science Special Report: Fourth National Climate Assessment, Volume I

Figure 6-1 Annual historical and range of plausible future carbon emissions and projected global temperatures.

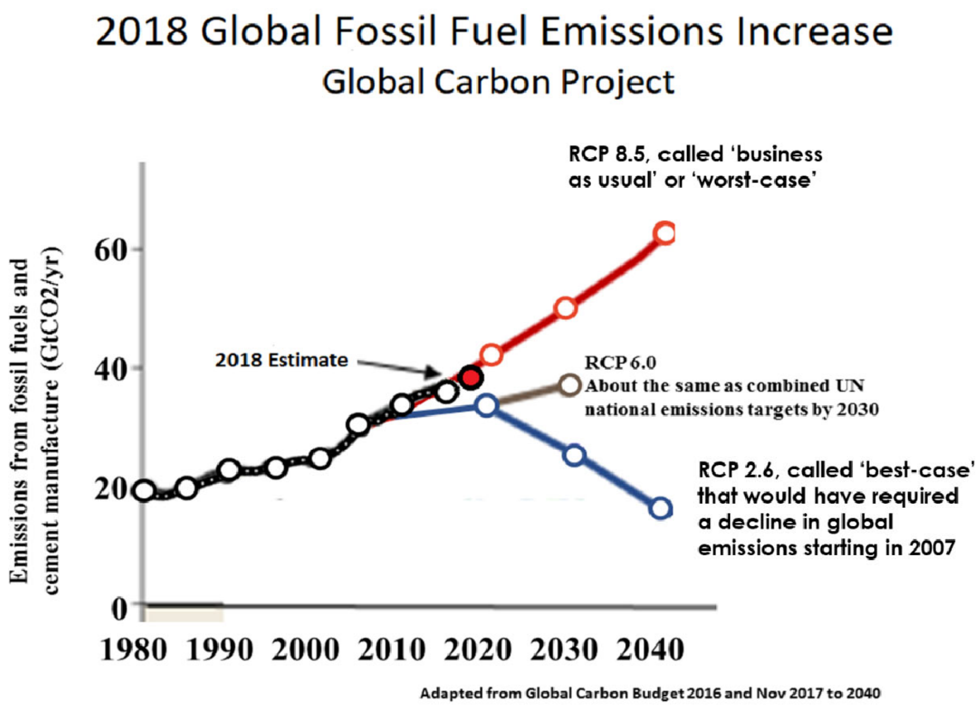
6.3.2.1 Greenhouse Gas Emissions

On the broadest scale, global fossil fuel emissions for 2018 show 37.1 ± 2 Gigatons of Carbon Dioxide ($GtCO_2$), 2.7% higher than 2017 (Figure 6-2). Overlaying this information with the RCP scenarios shows that global actual emissions are tracking closer to RCP8.5, compared to the other RCPs (Figure 6-3).



SOURCE: CDIAC (2019); Le Quéré et al 2018a; Global Carbon Budget 2018

Figure 6-2 Global fossil CO_2 emissions from 1990-2018. Estimates for 2015, 2016 and 2017 are preliminary; 2018 is a projection based on partial data.

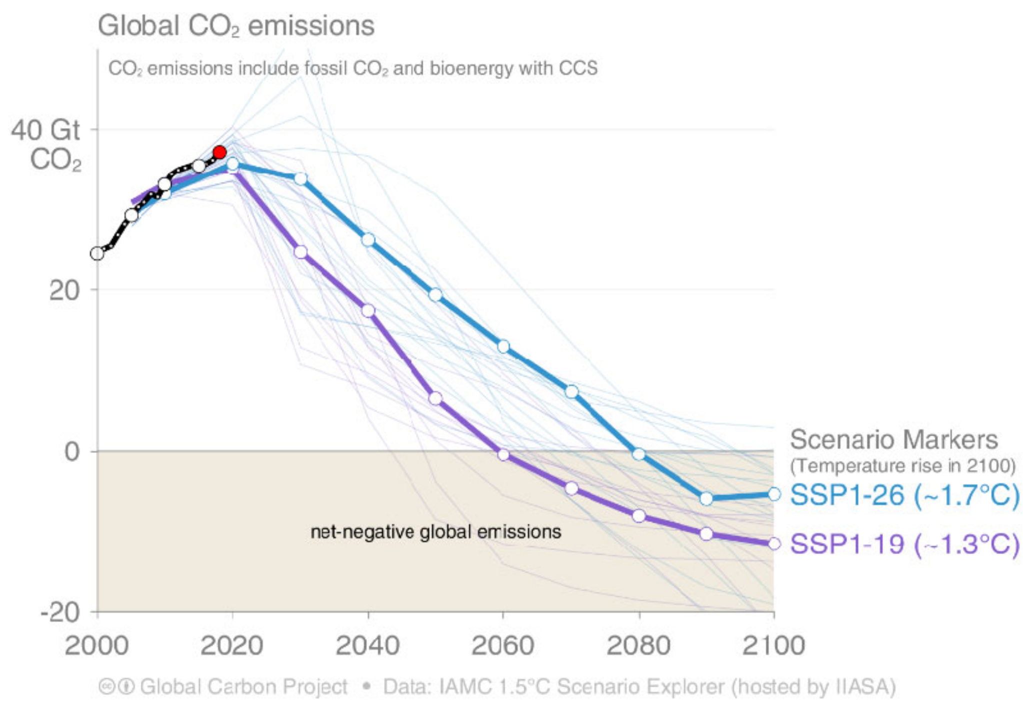


SOURCE: adapted from: Le Quéré et al 2018b and Boden, T. A., Marland, G., and Andres, R. J.: Global, Regional, and National Fossil-Fuel CO2 Emissions, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A., doi 10.3334/CDIAC/00001_V2017, 2017; available at: http://cdiac.ess-dive.lbl.gov/trends/emis/overview_2014.html

Figure 6-3 Historical and current global fossil fuel emissions relative to three RCP predictions that started in 2007.

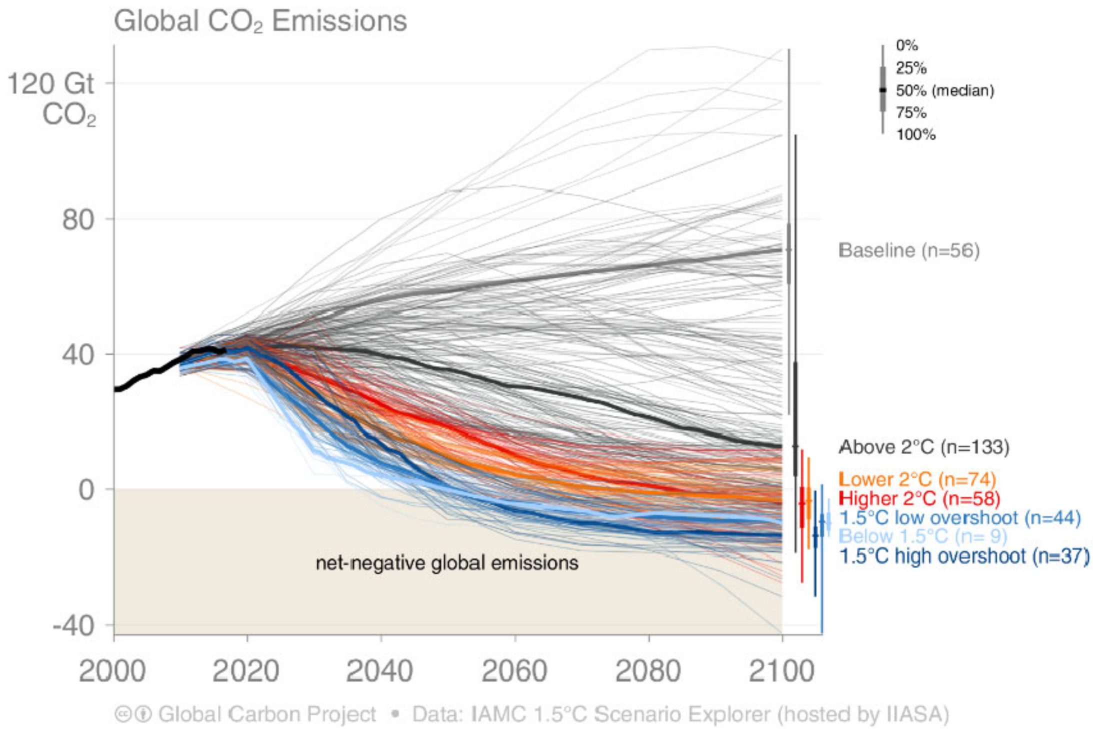
6.3.2.2 Air Temperature

The 2015 Paris Climate Accord called for global measures to be taken to limit average global air temperature rise to no more than 1.5°C by 2100. To reach this ambitious goal, immediate actions would have been necessary that would result in a rapid decline of global CO_2 emissions (blue and purple lines in Figure 6-4, Figure 6-5 and Figure 6-6). Unfortunately, this has not occurred in the 4+ years since the agreement, and so instead of following the trajectories that would have led us to that no more than 1.5°C temperature rise goal by 2100, current data show emissions are continuing to rise (black line in Figure 6-4, Figure 6-5 and Figure 6-6). Furthermore, the IPCC Special Report on “Global Warming of 1.5°C” presented new and more detailed global emission scenarios and necessary intermediate steps, noting that reaching the 1.5°C scenario by 2100 would require halving emissions by ~2030, achieving net-zero by ~2050, and be negative thereafter (Figure 6-5). However, current conditions appear to be more on track with an increase of 3-5°C, which is more consistent with predictions made under RCP 6.0 or 8.5 (Figure 6-6).



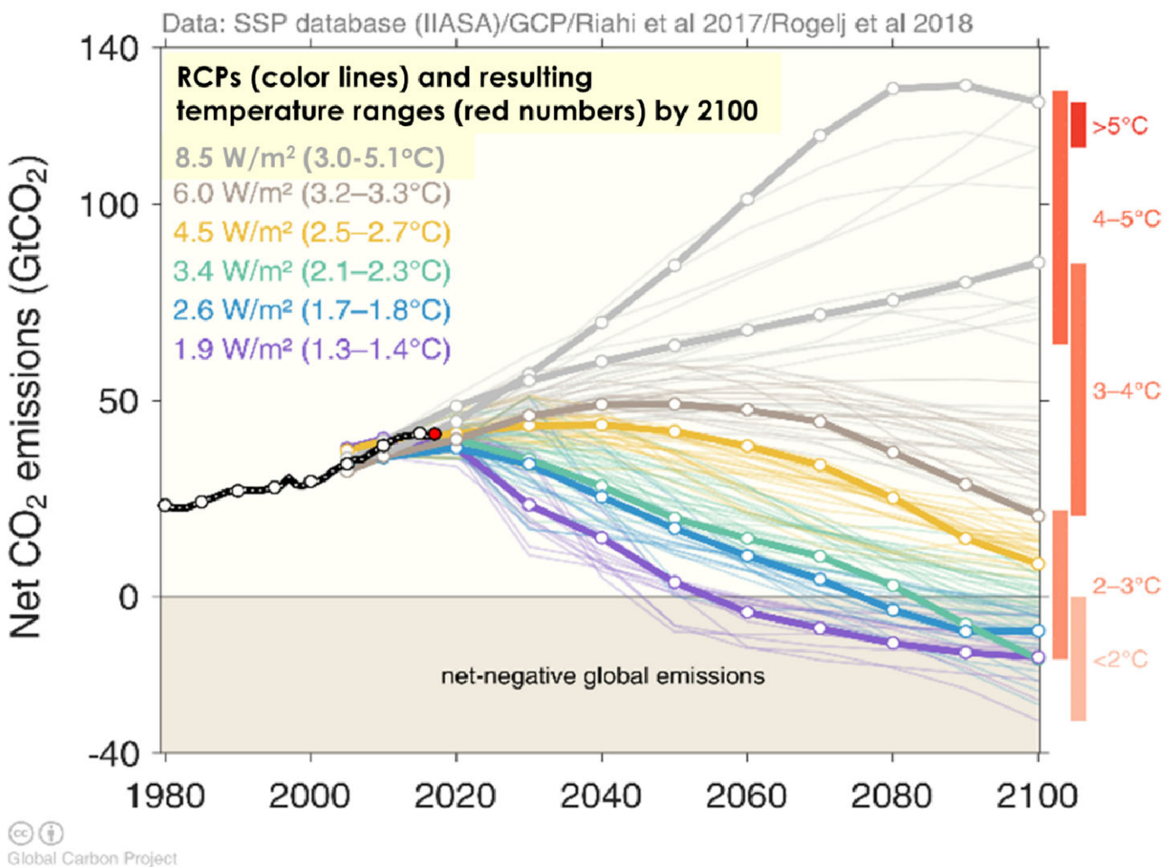
SOURCE: Huppmann et al. 2018; IPCC 2018; Jackson et al 2018; Global Carbon Budget 2018

Figure 6-4 Shared Socioeconomic Pathways (SSP) analyses for keeping with a 1.5°C target increase by 2100 compared to current observations (in black. Red dot is the 2018 preliminary estimate).



SOURCE: Huppmann et al. 2018; IPCC 2018; Jackson et al 2018; Global Carbon Budget 2018

Figure 6-5 The Shared Socioeconomic Pathways (SSPs) lead to a broad range in baselines (grey), with more aggressive mitigation leading to lower temperature outcomes (grouped by colours).

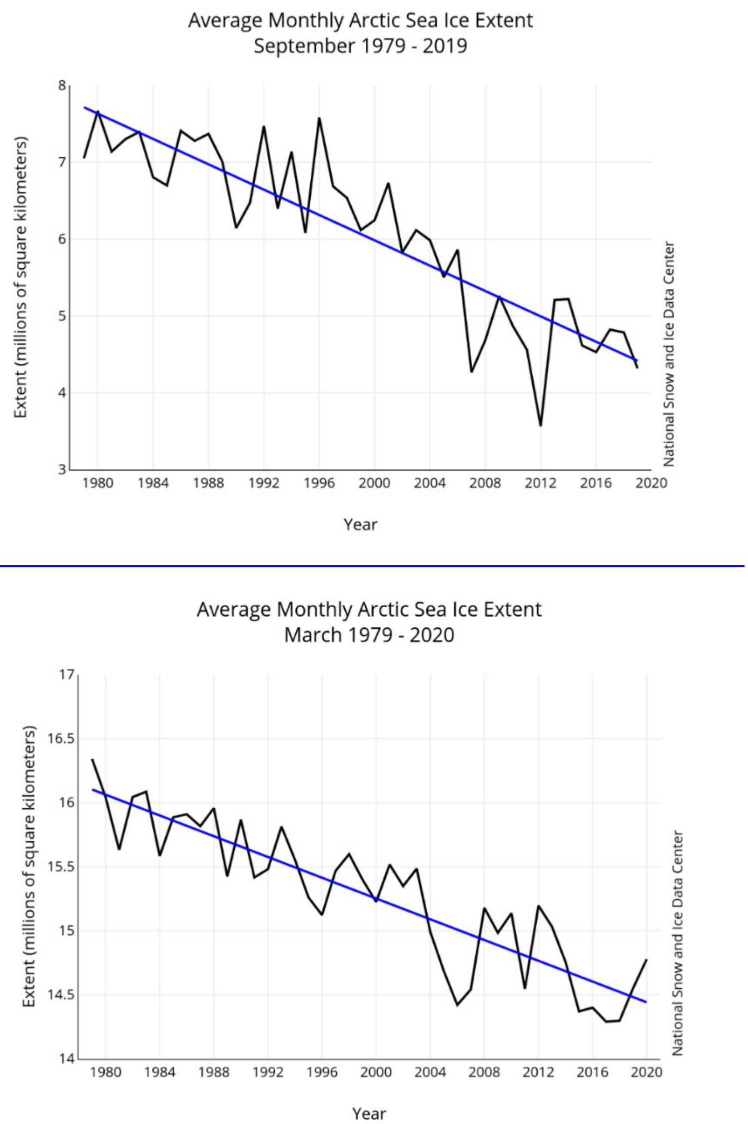


SOURCE : adapted from Riahi et al. 2017; Rogelj et al. 2018; IIASA SSP Database; Huppmann et al. 2018; Le Quéré et al. 2018

Figure 6-6 Set of quantified RCPs based on the output of six Integrated Assessment Models (AIM/CGE, GCAM, IMAGE, MESSAGE, REMIND, WITCH). Net emissions include those from land-use change and bioenergy with CCS. Black line shows actual values to date.

6.3.2.3 Arctic Sea-Ice

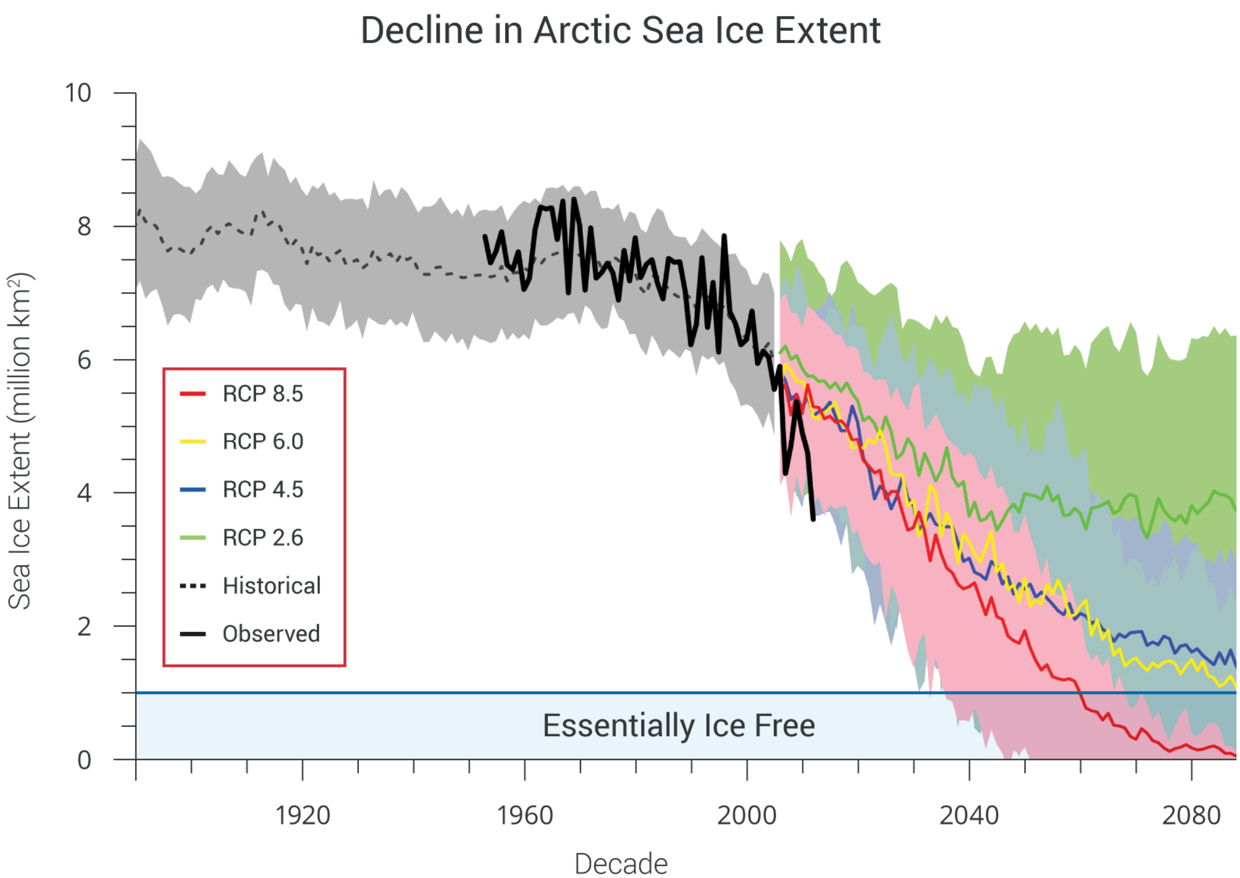
Sea-ice conditions are highly relevant to the Arctic overall and to the Beaufort Sea in particular; they are strongly linked to both GHGs and air temperature. Winter and summer sea-ice extent and thickness has been declining since the satellite record began in 1979 (Figure 6-7).



SOURCE: National Snow and Ice Data Center

Figure 6-7 Change in average March Arctic sea ice extent from 1979 – 2019 (top), Change in average September Arctic sea ice extent from 1979 – 2018 (bottom).

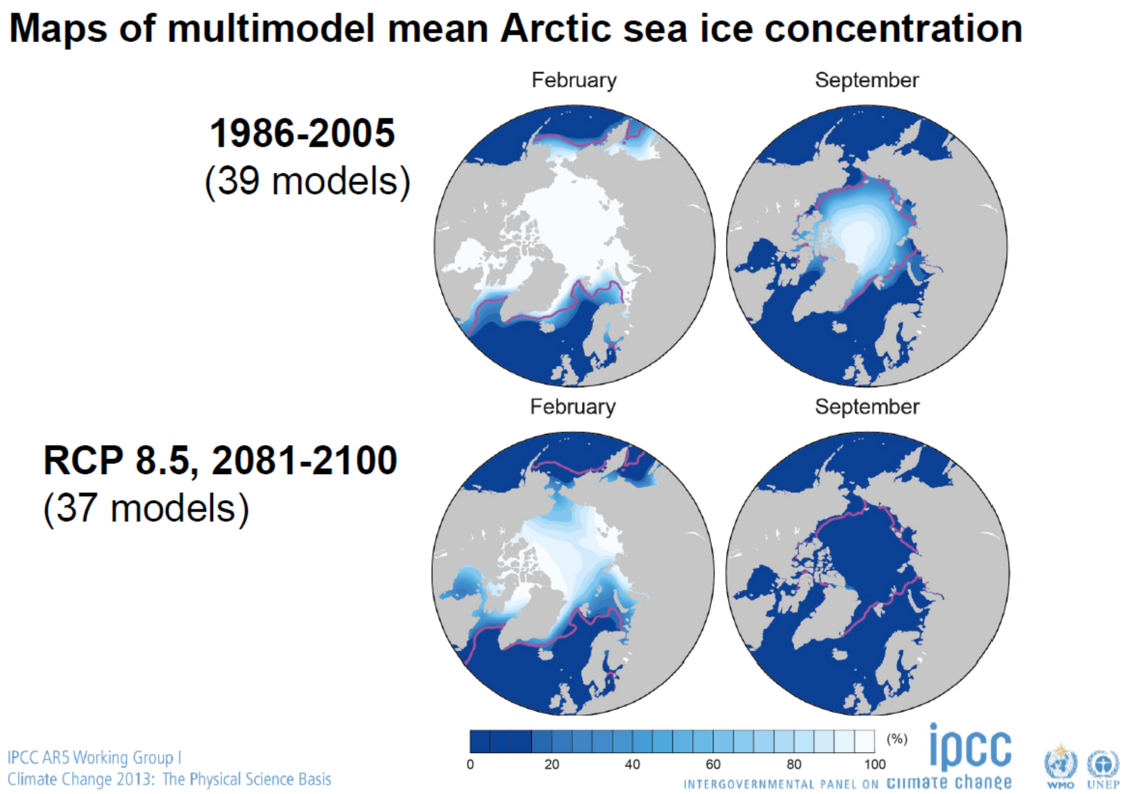
Projections for year-round reductions in Arctic sea ice extent range from 43% for RCP 2.6 to 94% for RCP 8.5 in September, and from 8% for RCP 2.6 to 34% for RCP 8.5 in February. Current sea-ice observations seem to be most in line with RCP 8.5 (black line in Figure 6-8). Under that scenario, a nearly ice-free summer Arctic Ocean (defined as sea ice extent < 10^6 km^2) for at least five consecutive years in September is likely to occur before mid-century (Figure 6-8 and Figure 6-9).



SOURCE: adapted from Stroeve et al. 2012

NOTE: Colored lines for RCP scenarios are model averages (CMIP5) and lighter shades of the line colors denote ranges among models for each scenario. Dotted gray line and gray shading denotes average and range of the historical simulations through 2005. The thick black line shows observed data for 1953-2012.

Figure 6-8 Model simulations of Arctic sea ice extent for September (1900-2100) based on observed concentrations of heat-trapping gases and particles (through 2005) and four scenarios.



SOURCE IPCC 2013

Figure 6-9 Spatial sea ice extent and concentration historically (1986-2005) and for the 2081-2100 period for RCP 8.5.

6.3.2.4 Emission Scenario for the BRSEA

Given that emissions reductions are gaining traction in some major industrial countries, it might be reasonable to expect that emissions would level off somewhere between RCP 6.0 and RCP 8.5. However, global emissions have continued to rise. Indeed, Gillingham and Nordhaus (Christensen et al 2018) noted that "*our results indicate that there is a greater than 35% probability that emissions concentrations will exceed those assumed in RCP 8.5.*" In addition, the BRSEA Study Area is located in the region of the globe that is experiencing the most rapid and severe changes, substantially above the global average (Serreze and Barry 2011). This is called the arctic amplification effect; it is due to atmospheric circulation transporting and concentrating heat at the poles, where warming is also additionally intensified because of the loss of sea ice, which helps reflect solar radiation (cooling) when present. Given the sensitivity of the BRSEA Study Area and the uncertainty in GHG reductions, RCP 8.5 was chosen as the most robust climate prediction for use in the Beaufort Region (Riahi et al. 2011). However, in choosing this projection for the BRSEA, there remains a range of variability that requires further scientific investigation by the broader scientific community (e.g., Swart et al. 2015). Beyond this are the "unknown unknowns" present in this complex coupled adaptive system of the atmosphere with the ocean, the cryosphere and terrestrial components of the earth. Given this, predictions for atmospheric, oceanographic, and coastal predictions over the next 30 years (2020-2050) under the RCP 8.5 also include measures of variability and uncertainty where possible and appropriate.

6.3.3 Selection of Physical Attributes

Climate change is one of the primary factors in predicting future consequences of both natural changes and anthropogenic effects on VCs. To help frame these effects for the Data Synthesis and Assessment Report (Chapter 8), projected changes in the atmospheric, oceanographic and coastal variables deemed most important for physical and biological processes in the BRSEA Study Area are summarized below (Table 6-1).

Table 6-1 Key physical parameters investigated during this study

Variable	Metric	Rationale/Impact
Air temperature (means, maxima, variability)	Change in air temperature relative to climate normals	Influences melting of sea ice and snow, timing and length of seasons, open water, thawing permafrost.
Precipitation (rain, fog and snow)	Change in amounts of rain and snow relative to climate normals	May enhance melting of sea ice and access for shipping; negatively affect offshore operations and coastal infrastructure; increase rates of coastal erosion; reduced snow cover on ice can influence ice algal and under ice phytoplankton blooms.
Frost-free days	Probability of frost-free days	Influences accumulation and duration of snow cover, as well as timing and length of seasons.
Wind (direction, speed, variability, frequency of extreme events)	Changes in wind speed, wind direction, storminess and storm frequency relative to climate normals	Influences storm surge, waves, sea ice extent and location, with effects on shipping, offshore operations and coastal infrastructure; and rates of coastal erosion. Compounded by impacts of storm surges, water column structure, upwelling events, and fate of Mackenzie plume.
Sea level rise (including frequency and severity of storm surges)	Changes in relative mean sea levels (m), probabilities of storm surges >1.5m and > 2.0m	Implications for coastal communities, infrastructure, marine operations, coastal ecology, and erosion rates; increased likelihood of damaging storm surges; increased likelihood of permafrost thaw through inundation
Ocean temperature and heat content (including bottom water temperature)	Water Temperature	Influences dissolved oxygen and sea ice extent. In turn, each of these parameters have impacts on the food web and coastal communities.
Sea ice (extent, thickness, type, timing, including landfast ice)	Areal extent (m^2), thickness (m), stage of development (age), changes in seasonal timing (days)	Influences the duration of the offshore exploration Open Water Season, navigability, and fetch; timing of breakup of pack and landfast sea ice near coastal communities; effects of sea ice on seasonal ocean physical attributes; ecological and coastal processes; and weather; decreased sea ice extent and duration increase probability of coastal erosion and exposure to storm surges

Table 6-1 Key physical parameters investigated during this study

Variable	Metric	Rationale/Impact
Glacial ice (ice islands: frequency of occurrence and dimensions)	Numbers and frequency of occurrence of marine glacial ice in the Beaufort Sea	The presence of massive marine glacial ice features can have a major impact on offshore oil and gas, shipping and other activities.
Waves (height, direction, speed, variability, frequency of extreme events)	Mean and maximum significant wave (H_S) height (m), peak period (T_P), mean direction	Impacts on small craft, shipping activities, offshore operations, and coastal infrastructure; physical forcing on remaining sea ice cover; and rates of coastal erosion, compounded by increased likelihood of storm surges,
Currents and water column structure (physical and chemical)	Salinity Mixed layer depth pH and alkalinity Dissolved oxygen	Impacts density and, in turn, ocean ventilation and mixed layer depth. These parameters then can impact the food web (e.g., primary production, crustaceans), coastal communities, and impact overall health of the Beaufort, including through transportation of nutrients and contaminants
Permafrost conditions	Extent of permafrost (km^2) Permafrost quality including temperature (°C) and active layer thickness (m)	Permafrost sediment holds enormous amounts of carbon (carbon dioxide and methane) which would otherwise be in the atmosphere. Extent and quality can impact ground stability – public safety and infrastructure hazard (e.g., land-based logistical centres). Active (freeze/thaw) layer thickness affects construction projects – depth of foundations, insulation characteristics. Drainage and erosion can be altered, thereby further altering ground conditions and altering ecosystems. Some metals and contaminants held by permafrost sediment may be released during thaw
Freshwater runoff from Makenzie River (timing, volume and water quality)	Discharge volume (m^3), changes in baseflow (m^3), sediment volume (kg), freshet timing, water quality ($N0_3$)	Freshwater input into Beaufort Sea prior to and following landfast ice breakup; thermodynamics (relatively warm water); discharge of sediments and contaminants; and freshwater impacts on coastal ocean attributes, sedimentation in the harbours and estuaries, flooding, freshwater influence at the ocean interface
Coastal exposure and erosion	Changes in coastlines Loss of land (hectares)	Impacts to important cultural and historical sites and coastal communities (housing) and ways of life. Changes in coastlines requires special provision for nearshore infrastructure and areas where offshore pipelines or cables make landfall, as well as impacts of sediment discharge from erosion on the ocean environments, ecosystems and infilling harbours/bays

Some of these physical attributes, including those involving physical and chemical oceanographic variables and coastal erosion/permafrost variables, are not addressed by IPCC model results. For these variables, results from scientific papers and reports that describe current trends and predictions of future conditions were reviewed and documented in relation to the underlying physical mechanisms. Much of this review was based on the BREA Climate Change Report in Relation to Oil and Gas Activities in the Beaufort Sea (Stantec 2013a), the 2016 Regional Climate Change Adaptation Strategy (IRC 2016) which outlines TLK specific to climate change, and updates from scientific literature available since 2013.

6.3.4 Use of down-scaled IPCC Model results

Trends and RCP 8.5 scenario projections for climate variables presented in this report were assessed from the IPCC's Fifth Assessment Report (Church et al. 2013), the Canada's Changing Climate Report (Bush and Lemmen 2019), and academic journal publications, published in 2014 or later. Preference was given to literature employing data from the Coupled Model Intercomparison Project (CMIP5), with regionally downscaled results for the southern Beaufort Sea. The Climate Change Hazards Information Portal (CCHIP) database was also used via the Risk Sciences International (RSI) data portal (RSI 2018). CCHIP provides visualized historical and projected climate data and analysis for both active and inactive weather monitoring stations in Canada (RSI 2018).

For example, precipitation data were obtained from the Government of Canada Database on Climate Normals for 1981-2010 for Sachs Harbour and Tuktoyaktuk. These data are supplemented with information and conclusions from the literature and the most recent IPCC reports and climate projections, and further supplemented with current climate projections for the Beaufort Sea. The projections of future climate are based on model initiation with the four selected weather monitoring stations (Tuktoyaktuk A, Ulukhaktok A, Sachs Harbour A, Mould Bay A) and were produced from runs of 40 different Global Climate Models (GCMs) (RSI 2018). This dataset is a shorter and more recent period of data and was selected to initiate the climate models because the observed changes in the North are happening faster there than at other non-polar locations. These more recent data are more reflective of the current conditions than data from 1981-2010 and the accuracy of the model runs is likely to benefit from the more recent data, as a starting point.

Projections for future climate intensity-duration-frequency (IDF) information are based on bias-corrected results from nine Global Circulation Models that simulate future climate conditions; these were obtained from information published by the Institute for Catastrophic Loss Reduction, at Western University, London, Ontario (ICLR 2018).

Studies using Global Climate Model output for the Arctic were assessed for physical attributes where regionally downscaled results were unavailable. For variables where limited information was found using CMIP5 data (e.g., Mackenzie River Discharge), studies following an AR4 climate scenarios using CMIP3 data were employed. Specifically, the scenario used by the Center for Climate System Research - Special Report on Emissions Scenarios (CCSR-SRES-A1FI) is equivalent to the RCP8.5 scenario of the IPCC Assessment Report 5 (AR5) (Riahi et al. 2011). Projections specific to coastal communities and geographic sites in the southern Beaufort Sea and Amundsen Gulf are presented, along with author interpretations of Arctic-wide and regional scale projections for physical attributes shown in Table 6-1.

6.3.5 Assessing Uncertainties in IPCC Model Results

To include measures of variability and uncertainty in predictions of the chosen variables where possible and appropriate, the same calibrated uncertainty language as in the IPCC's Fifth Assessment Report (e.g., Church et al. 2013) is used. Specifically, where possible, the predicted conditions under RCP 8.5 are laid out at the end of each decade (2030, 2040, 2050), and the uncertainties for each variable are described according to:

- IPCC levels of confidence: very low, low, medium, high, very high
- IPCC likelihood: exceptionally unlikely (<1%), extremely unlikely (<5%), very unlikely (<10%), unlikely (<33%), about as likely as not (33–66%), likely (>66%), very likely (>90%), extremely likely (>95%) to virtually certain (>99%)

Where information is not available at this decadal scale, the closest possible estimate is used.

To estimate the level of uncertainty, the model results under RCP 8.5 derived for recent past and present conditions are compared with observed conditions, as presented in papers available in the scientific literature. In addition, differences in the many different models operated under the IPCC studies provide a measure of the potential variability inherent in the model outputs for the particular variable being examined. When model results are not available for a particular variable, scientific papers that provide analyses of existing trends and the natural variability around these trends are examined, as well as consideration of the projected future changes in the variables based on analysis of relevant physical mechanisms and their potential responses to climate change. From this review, an assessment of the variability and uncertainties is made based on the results and conclusions of these papers.

6.4 Summary of Projections for Key Physical Attributes

The physical environment in the BRSEA region has been undergoing substantial changes, most of which are predicted to continue over the 30-year time frame investigated for this study. The main current trends and future projections are summarized in Table 6-2. Full details and information on spatial heterogeneity or each of these variables can be found in Appendix C.

Table 6-2 Summary of Current Trends and Future Projections of Key Physical Attributes

Physical Attribute	Metric	Unit	Current Trend	Future Projection (2020-2050)
Air temperature (means, maxima, variability)	Mean	°C	Annual mean daily temperature of –10.0°C, increasing at a rate of +0.07 °C/year over the past 30 years at Tuktoyaktuk	Expected to increase by 5.2°C by 2050
	Maxima	°C	Annual mean daily maximum temperature of –6.4°C, increasing at a rate of +0.06 °C/year over the past 30 years at Tuktoyaktuk	Expected to increase by 4.7°C by 2050
	Variability	°C	Standard Deviation of 15.3°C at Tuktoyaktuk	Expected to increase but projections on the magnitude of the variability were not available
Precipitation (rain and snow)	Rain	mm/yr	+0.92 mm/year at Tuktoyaktuk	Expected to continue to increase but no projections available as to magnitude. Combined precipitation is projected to increase by +19.2 % by 2050 at Tuktoyaktuk
	Snow	mm/yr	+0.60 mm/year at Tuktoyaktuk	Expected to continue to increase but no projections available as to magnitude. Combined precipitation is projected to increase by +19.2 % by 2050 at Tuktoyaktuk
Frost-free days	Days <0°C	days/yr	67 days/year at Tuktoyaktuk, 38 days/year at Sachs Harbour	+39 frost-free days/year by 2050 at Tuktoyaktuk +49 frost-free days/year by 2050 at Sachs Harbour
Wind (direction, speed, variability, frequency of extreme events)	Direction (mean/median)	degrees	Mean wind direction of 175° and median of 140° (ESE) at Tuktoyaktuk; ESE and WNW at Pelly Island	Limited projections available for wind direction; may be more reversals of the surface wind direction as the climate warms, sea ice thins, and the locations of the maximum Sea Level Pressure (SLP) changes
	Speed (mean/ median)	km/h	Current wind speed at Tuktoyaktuk has a mean of 11.68 km/h, and median of 11.00 km/h. Past mean trends are variable with a slight decrease of -0.12 m/s/decade in recent data	Winds speeds are projected to increase over the next 30 years by a median of 5% to a maximum of 6.5% for the Beaufort Sea region

Table 6-2 Summary of Current Trends and Future Projections of Key Physical Attributes

Physical Attribute	Metric	Unit	Current Trend	Future Projection (2020-2050)
Wind (direction, speed, variability, frequency of extreme events) (cont'd)	Variability		Variability in wind speed is equal to 11.68 ± 11.19 km/h at Tuktoyaktuk Variability in wind direction: 175 ± 105° at Tuktoyaktuk	Complex interactions between climate warming, locations of maximum SLPs, and changes to direction; example: the collapse of the Beaufort High in 2017, with change in direction of surface winds, and this may be more frequent in future
	Frequency of extreme events (>2SD)	Frequency of Change (FOC) – numbers per month	During the Open Water Season of June through October, the current mean storm frequency for the Beaufort Sea region ranges from 3.1 (June) to 4.5 (October) storms per month	Projected change in storm track density per month per unit area is -0.9 to 0.9 for the Beaufort Sea region for the 2080s, but were not identified for the 2050s
Sea level rise (including frequency and severity of storm surges)	Mean sea level rise (at Tuktoyaktuk, NWT)	mm yr-	+1.9 ± (2.0)	+300mm ± 200mm mean increase by 2050
	Frequency of Storm Surges >1.5m at Tuktoyaktuk	Exceedance Probability (0 – 1.0)	0.39	Increased likelihood
	Frequency of Storm Surges >2m at Tuktoyaktuk	Exceedance Probability (0 – 1.0)	0.04	Increased likelihood
Ocean temperature and heat content (including inferences on bottom temperature)	Near-Bottom Temperatures	˚C	None	Expected to increase marginally, but this is very uncertain
	Summer Mixed Layer Temperature	˚C	-0.03 ˚C/year	Uncertain as this recent trend likely due to changes in the freshwater distribution.
	Summer Sea Surface Temperature (SST)	˚C	>0.05 ˚C /yr in the Southern Beaufort -0.03 ˚C /yr south of Banks Island	Mean SST of 3-4 ˚C 50%-70% of SST observations in excess of the 1976-2005 maxima.

Table 6-2 Summary of Current Trends and Future Projections of Key Physical Attributes

Physical Attribute	Metric	Unit	Current Trend	Future Projection (2020-2050)
Sea ice (extent, thickness, type, timing, including landfast ice)	Ice Thickness	m	Decreasing as multi-year ice transitions to first year ice; Largest reductions are in deep offshore waters of Canada Basin; reduction rate only 0.1 m/decade on slope and shelf	If current trend continues, ice thickness reduction of 0.3 m by 2050 from present values on continental slope and shelf, with larger reductions in the much deeper water of the Canada Basin
	Timing of Ice Freeze-up	weeks	Large inter-annual variability, statistically later by 0.15 weeks/yr in most areas; change larger at 0.2 weeks/year off Banks Island	Current trend expected to continue, 2050 freeze-up in coastal areas may be delayed by 4.5 weeks from present conditions
	Timing of Break-up	weeks	Large inter-annual variability, with no significant trend in most areas, except Amundsen Mouth at 0.2 weeks/yr	Possibility of earlier break-up, but magnitude is uncertain.
	Open Water Duration	weeks	Increasing by 0.15 – 0.20 weeks/yr except no significant trend in Amundsen	Current trend expected to continue; increased open water duration of 4.5 to 6 weeks from present conditions; 50 to >60% chance of ice-free conditions in late summer and early fall by 2050
	Ice Motion	cm/s	Winter mean ice speeds on shelf have increased from 2 to 5 cm/s in last 35 years	Expected to continue to increase but no projections available as to magnitude
	Landfast Ice Duration	days	Reductions of 2-3 days/yr, varying according to sub-region	Expected to continue to increase at or near present levels resulting in reductions of 60-90 days from present conditions
Glacial ice (ice islands and Icebergs)	Numbers of Marine Glacial Ice features	Numbers	Increasing due to ablation of glacial ice in the Canadian Arctic Archipelago and northern Greenland	No projections are available but increases expected to continue through to 2050

Table 6-2 Summary of Current Trends and Future Projections of Key Physical Attributes

Physical Attribute	Metric	Unit	Current Trend	Future Projection (2020-2050)
Waves (height, direction, speed, variability, frequency of extreme events)	Duration of the Open Water Wave Season	days	Increasing due to increased duration of open water	Highly certain that increases would continue through to 2050 and beyond
	Mean Significant Wave Height (H_S)	M	Increasing by 3 – 8% from 1970-2013	Increases of 0.5 – 1.5 m in years 2046-2065 relative to 1980-1999.
	Mean Direction	Degrees clockwise from North	Increased occurrence of easterly winds and waves relative to westerly winds and waves	No projections available for 2050 period, but models for later periods suggest north-easterly waves (45 degrees) would be dominant
	Peak Period (T_P)	S	Increasing as winds and waves increase	Projected to increase to 6-7 s by 2081-2100
Currents and water column structure (physical and chemical)	Near-Bottom Salinity	Practical Salinity Unit (PSU)	None	Uncertain
	Summer Mixed Layer Salinity	PSU	-0.04 PSU/yr	Uncertain – salinification of up to 1.5 PSU in the regional model, freshening of < 1 PSU in the global model.
	Summer Mixed Layer Depth	M	0.11 m/yr (when ice-free)	Increases by 3-8 m
	pH and Alkalinity	pH/ Saturation Level	Fastest rate of acidification in Canada	Increased acidity and under saturation (<1) of carbonate expected
	Dissolved Oxygen	T_{mol}	-73 T_{mol}/decade (mean vertically integrated value)	Continued decrease, but the models have had poor skill with this parameter.
Permafrost conditions	Extent of permafrost	Degrees North	Continuous permafrost in Mackenzie Valley 67.5 degrees N, advancing at average of 3 km N per year Subsea permafrost northern extent decreasing -2 km N over the past 10000 years	Predictions for RPC8.5 indicate faster northern encroachment of discontinuous permafrost, possibly up to 9 km per year average, which would mean to the Beaufort coast before 2050. Subsea permafrost northern extent moving shoreward < 0.1 km by 2050.

Table 6-2 Summary of Current Trends and Future Projections of Key Physical Attributes

Physical Attribute	Metric	Unit	Current Trend	Future Projection (2020-2050)
Permafrost conditions (cont'd)	Permafrost temperature	°C	Variable, generally increasing at 0.9 °C per decade in south and faster in north	Increasing trend expected. As permafrost temperatures approach 0°C, permafrost is no longer viable.
	Active layer thickness (m)	M	Variable	For few RPC 8.5 projections available present day = 0.54 m, 2050 = 0.6 m, 2080 = 0.73 m
Freshwater runoff from Mackenzie River (timing, volume and water quality)	Mean discharge	m^3/sec	10,000	11,800 ± 1600 (10-20% increase over baseline)
	Maximum discharge	m^3/sec	22,000	25960 ± 2000 (10-20% increase over baseline)
	Sediment discharge	kg/sec	1715	1870 (<10% increase over baseline)
	Freshet Timing	days / decade	+2.7	7 – 28 days earlier
	Month of maximum river volumes	Month	June	May (by 2050)
	Water quality (NO_3)	mmol/m^3	N/A	−2.3 ± 1
Coastal exposure and erosion	Erosion	m/year	1-2 m per year average in Mackenzie Delta area, up to 40 m/year reported in extreme cases (e.g. Pelly Island) Average 1.2 m/year on Herschel Island. Up to 9 m per year along Yukon Coast	Coastal exposure and erosion were not variables considered in the RPC8.5 climate models; as a result, there are no projections for coastal exposure from those sources. However, at current average rates coastal retreat would be 30-60 m by 2050 at susceptible locations and hundred of metres or more at particularly exposed locations.

7 STATE OF KNOWLEDGE

7.1 Purpose

The purpose of the State of Knowledge section is to provide readers with an overview of information on existing and changing conditions in the BRSEA Study Area centred on the VCs selected for the BRSEA (Terms of Reference [Appendix A, this report] and Section 4.1.1.1) with a strong focus on the information required to support the assessment of potential activity-specific effects and cumulative effects.

7.1.1 Limitations

Information from TLK and western scientific sources in this section is intended to support the assessment of effects (Chapter 8); it is not intended to be a comprehensive synthesis of all information for all VCs. Information presented here largely relates to:

- cultural importance of the VC to the Inuvialuit
- conservation status or importance of the VC to federal and territorial governments, the Inuvialuit and, in some cases, international interests and organizations.
- where pertinent, trends in physical parameters, biological populations, human populations, cultural vitality, services and infrastructure, public health and the economy
- the spatial and temporal distribution of the VC within the BRSEA Study Area, including key habitats or “hot spots” for biota, communities, important harvesting areas, travel routes and other areas of importance
- potential trends in biological and human VCs as a result of climate change

As noted in Section 3.1, a large volume of TLK and western science has been collected and compiled on the biophysical environment, socio-cultural aspects (including traditional use) and economic impacts. While assessors for the Valued Components did use and cite a large number of primary sources for western science, they also had to rely heavily on existing compendiums and syntheses of technical information (western science). Assessors also relied on the TLK Inventory (Chapter 5) to identify TLK references; the inventory included TLK studies completed for the BRSEA, as well as Inuvialuit and industry-funded studies that the IRC felt were most useful to the BRSEA.

7.1.2 Use of Traditional Knowledge

As described in Section 5.1, the Data Synthesis and Assessment for the BRSEA is an important opportunity to braid TLK and western science to better inform the report and future management directions for the BRSEA. TLK was used in the preparation of the State of Knowledge (this Chapter) as a knowledge system equal to western science that provides valid, verified and reliable observations about environmental conditions and trends that meaningfully contribute to defining existing and changing conditions in the BRSEA Study Area. TLK also was used to define the VCs and, as appropriate, indicator groups or species for the VC, as well as the extent of the study area.

The State of Knowledge provided in this chapter is based on TLK and western science. Both sources of information are cited in describing the existing status and past trends in the physical, biological and human environment.

For the physical environment, TLK was especially useful in describing changes and trends in:

- weather (e.g., seasonal temperatures, snow fall, rain fall, fog, wind), visible air emissions (e.g., haze), light emissions and in-air noise
- physical oceanography, including sea ice formation and break-up, sea ice characteristics, seasonal distribution and movements of sea ice, human safety associated with these changes, formation of open water areas and polynyas, currents, upwellings, wave patterns, and coastal processes and erosion
- some aspects of chemical oceanography such as seasonal changes in sediment plumes and water clarity
- coastal and estuarine habitats

For the biological environment, TLK provided a wealth of information on:

- occurrence of various species of marine and anadromous fish, birds, marine mammals and other wildlife that occur within the BRSEA Study Area
- locations of preferred habitat, including seasonal use of habitat, seasonal movements and migration patterns
- feeding habitats and predator-prey relationships,
- recent and longer-term changes in abundance, seasonal distributions, movements and migrations, including changes in response to climate change
- changes in the occurrence and distribution of new species within the BRSEA Study Area, often in response to climate change
- changes in animal health and behaviour, including the physical appearance of these species, the internal appearance of fish and wildlife, taste of harvested species, and response of species to natural phenomena

TLK by nature provides strong insight to and information on traditional harvesting activities and cultural vitality, as well as the adequacy of and issues associated with public health, food security, local infrastructure and economic benefits. For the human environment, applications of TLK include:

- land use and occupancy, including:
  - sites used by the Inuvialuit from different communities for seasonal camps (e.g., whaling camps, fishing camps) and longer-term living or housing, as well as traditional and long term activities around these sites
  - sites and areas of importance for cultural values, as well as the seasonality of use (if seasonal), types of activities, and inter-relationships with traditional harvesting
  - location of traditional trails and travel routes to access traditional camps, cultural sites as well as the mode of travel and seasonality of use
- the practice of traditional harvesting, including seasons for harvesting, species on which the harvest is focused (including preference for certain age classes or sex of animal), and uses of harvested species
- inter-relationships between traditional activities and wage incomes

TLK also provides insight on how climate change has and is continuing to affect traditional and cultural uses such as seasonal shifts in harvesting patterns, species quantities and health, accessibility to harvesting sites, and harvesting success.

The methods employed to identify and use TLK during the preparation of the Data Synthesis and Assessment Report are described in Chapter 5. Additional information on the sources of TLK used in this study are provided in Appendix B.

7.2 Physical Environment

The Physical Environment includes the atmospheric environment (including air quality, greenhouse gases, airborne noise and light emissions), climate and weather, oceanography (including circulation patterns, currents, waves, temperature and water quality), sea ice, coastal dynamics, and coastal habitats.

7.2.1 Atmospheric Environment

7.2.1.1 Air Quality and Greenhouse Gases

Air pollution can affect ecosystems and health by degrading the quality of the ambient air. Some air contaminants, in addition to Greenhouse Gases (GHGs), can also affect the atmospheric radiation balance and contribute to Arctic climate warming (Arnold et al. 2016). The severity of the effects depends on the type and amounts of air pollution that occur, the sensitivity of the individuals experiencing the pollution, and the duration of exposure.

The Inuvialuit are concerned about changes in water quality and air quality and how it could affect fish, wildlife and the land. A TLK holder explained that “water is so important to everything that lives; …everything depends on it…everything is interconnected and so water and air quality [are] so important …" (KAVIK-AXYS Inc. 2004a: 4-8).

Most air contaminants are released to the atmosphere after combustion of fuels in diesel or gasoline engines. Examples of emission sources in the Arctic include marine vessels (e.g., local traffic, resupply to the ISR, transiting through Arctic Ocean), aircraft (e.g., local charters and scheduled flights, scheduled flights to south), power production (e.g., diesel power generation), or land-based transportation (e.g., commercial and personal road vehicles, skidoos, all-terrain vehicles). Many of the common air contaminants released through combustion are regulated either by the Federal or provincial governments. The Federal Government, through the Canadian Council of Ministers of the Environment (CCME) has adopted concentration standards (known as the Canadian Ambient Air Quality Standards or CAAQS) for some common air contaminants, including ground level ozone (O_3), particulate smaller than 2.5 microns ($PM_{2.5}$), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2). Canadian provinces have adopted their own air quality regulations for air contaminants, such as hydrogen sulphide (H_2S), carbon monoxide (CO), volatile organic compounds (VOCs), and Oxides of Nitrogen (NO_x - which include NO_2 as well as nitrous oxide or NO), in addition to the pollutants addressed by the CCME CAAQS.

The GNWT has developed *Guidelines for Ambient Air Quality Standards in the Northwest Territories* (Department of Environment and Natural Resources 2014). The Government of Yukon commonly uses air pollution regulations set by either the British Columbia or Alberta governments when reviewing the potential effects of air pollution from projects in the Yukon.

There are no provincial or federal regulations on GHG emissions, though many jurisdictions in Canada have set GHG emission reduction targets. For example, the Federal government and the Government of the Northwest Territories have committed to a 30% reduction in GHG emissions by 2030, compared to 2005 emission levels (GNWT 2018a).

Some quantities of air contaminant emissions are available for the Canadian Arctic through the National Pollution Release Inventory (NPRI); however, the NPRI only reports emissions from large emitters and therefore does not typically include mobile sources such as marine vessels. Table 7-1 summarizes annual emissions reported through the NPRI for 2017 from Yukon and the Northwest Territories.

Table 7-1 Emissions of Air Contaminants and GHGs in the North – 201

Territory	Total Air Emissions Reported to NPRI in 2017 (tonnes)							GHG Emissions Reported in National Inventory Report for 2015 (tonnes)		
	CO	NO_x	SO_2	VOCs	TSP	PM_{10}	$PM_{2.5}$	CO_2	CH_4	N_2O
Northwest Territories	1,165	5,458	254	339	257	269	294	1,370,000	680	90
Yukon	232	554	0	34	32	34	34	221,000	280	20
SOURCE: ECCC 2017										

The majority of the current exposure of coastal arctic communities to air pollution is associated with marine traffic exhaust emissions (WWF-Canada 2017). Vessel traffic in the north is recorded through reporting requirements found in the Northern Canada Vessel Traffic Services Zone Regulations (NORDREG) as part of the Canada Shipping Act, 2001. Vessel traffic has been increasing in the Arctic and in the BRSEA Study Area over the past two decades. This increase is largely driven by receding Arctic sea ice cover (Pizzolato et al. 2016) and is anticipated to increase air pollution emissions; however changes to fuels with lower sulphur content may mitigate emissions of some air contaminants (Azzara and Rutherford 2015).

Environment and Climate Change Canada (ECCC) has developed a Marine Emissions Inventory Tool (MEIT) to track vessel movement and marine vessel air pollution emissions (ECCC 2019a). In 2015, the majority of emissions in the BRSEA Study Area originated from Coast Guard icebreakers, warships, and tugboats, except for SO_2 where the majority of emissions originated from bulk carriers and cruise ships (Table 7-2).

Table 7-2 Marine Vessel Air and GHG Emissions – BRSEA Study Area 2015

Estimated Emissions to Atmosphere from Marine Vessel Traffic in BRSEA Study Area in 2015 (tonnes)									
CO	**NO_X**	**SO_2**	**VOCs**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**CO_2**	**CH_4**	**N_2O**
17.5	198	19.5	0	5.79	5.56	5.11	10,022	0.16	0.43
SOURCE: ECCC 2017									

Since most air contaminants are generated from combustion, their effect on air quality is usually largest near the source of emission and decreases with distance through dispersion downwind (i.e., mixing with the ambient air). However, some air contaminants, such as ground level ozone, aerosol particles (e.g., black carbon or sulphates), or polycyclic aromatic hydrocarbons (PAHs) can be transported to the Arctic region from emission sources far outside the Arctic, including Europe, Asia and the mid-latitudes of North America. In addition to its potential effect on air quality, black carbon is also of interest due to its ability to absorb light and significantly reduce the surface albedo in the Arctic, particularly during the summer (Arnold et al. 2016) and contribute to more rapid melting of snow and loss of sea ice.

The Arctic atmosphere is a relatively stable air mass (i.e., it suppresses mixing and dispersion of pollutants), so understanding vertical transport in the Arctic is one of the key uncertainties in assessing the impacts of extra-arctic air contaminants on the near surface atmosphere (i.e., the troposphere) in the Arctic (Arnold et al. 2016).

Long term surface observations provide the main source of information on seasonal cycles and long-term trends in air contaminants in Canada. The National Air Pollution Surveillance (NAPS) program was established in 1969 to provide accurate and long-term ambient air quality data of a uniform standard across Canada. There are 286 sites across Canada, including 20 in the territories; 9 of which are still operational as of 2017. The only NAPS site in the BRSEA Study Area that was operational as of 2017 is located in Inuvik, Northwest Territories.

Maximum air concentrations in 2016 for NO_X, $PM_{2.5}$, SO_2, and ozone are summarized in Table 7-3. The measured air contaminants are well below the applicable threshold values in the Ambient Air Quality Standards. This suggests that air quality is generally good most of the time. Air pollution concentrations are typically highest during the winter, likely due to increased heating and power generation.

Table 7-3 Ambient Air Quality Measurements in Inuvik in 2016

Contaminant	Ambient Air Quality Standard	Averaging Period (hours)	Maximum Air Concentration (ppb)
NO_X	400 ppb	1 hour	32.0
	17 ppb	annual	2.9
O_3	62 ppb	8 hours	45.0
$PM_{2.5}$	27 µg/m^3	24 hours	2.0
SO_2	172 ppb	1 hour	1.4
	11 ppb	annual	0.1

Given the relatively low emissions of $PM_{2.5}$, the presence of $PM_{2.5}$ in the air is likely due to transboundary effects from secondary formation and long-range transport of direct releases from areas outside of the Arctic (e.g., Asia, North America, Europe) (Arnold et al. 2016). Ambient ozone concentrations are also likely due to long range transport from other areas outside the Arctic, as there would not be much ozone formation due to the small quantities of local emissions of ozone precursors.

7.2.1.2 Airborne Noise

Noise is unwanted sound, and excessive noise may lead to nuisance complaints, sleep disturbance for people, or changes in behaviour and habitat use for animals. During consultation for the BRSEA (Section 1.5) and based on the TLK Inventory, concerns about the potential for noise effects on the marine ecosystem focused mainly on the effects of underwater noise (SCCP 2016: 40); underwater noise and effects on marine mammals are addressed in Appendix D, Section D.3.5.1.5. However, effects may also arise from airborne noise (also known as In-Air Noise) generated by human activities in the Arctic. For example, communities have raised concerns that airborne noise from vessels may alter caribou crossings of ice or water or affect their use of coastal habitat (IGC 2020, pers. comm.).

Information on airborne noise in the marine environment in the Arctic region is limited. Anthropogenic activities in the BRSEA Study Area are mainly related to shipping and marine traffic associated with Coast Guard, military, bulk transport and, more recently, cruise ship activities. The predominant noise sources from marine activity include engine operation noise through the hull, from the combustion exhaust stack or from fog horns. Noise associated with human activity along the coast may also occur from snowmobiles, motorboats, non-industrial machinery, and rifle-fire.

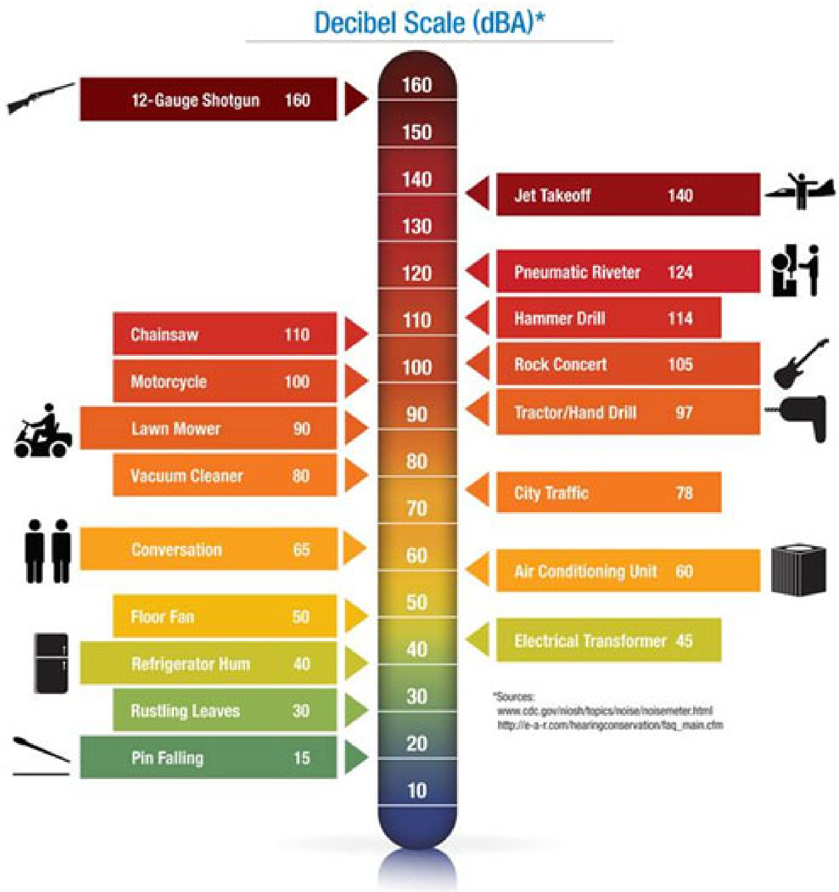
The Ulukhaktok Community Working Group is concerned that marine traffic in this area can have a negative impact on polar bear denning and on a critical community harvesting area. Specifically, “the Community Working Group is concerned that ships will destroy polar bear dens in multi-year ice, that the noise from ship traffic will disturb denning bears and that ship tracks will pose dangers to hunters in the area” (OCCP 2016: 40).

Marine traffic volumes have increased over the last two decades, increasing potential for noise exposure in marine areas (Pizzolato et al. 2016). However, the airborne acoustics environment in the BRSEA Study Area is still considered to be dominated by natural sounds from weather (winds, waves, precipitation), marine life (e.g., marine birds, polar bears, walrus) and the cracking of ice when strongly influenced by winds, ocean currents or other forces. Airborne noise from human activities is expected to be highest during the summer when ice cover is reduced, and marine vessel activities are at their highest. Sea ice tends to diminish the sounds from natural wave motions and accommodates snow cover, which dampens sound propagation.

The Sachs Harbour and Ulukhaktok Community Working Groups are concerned that Prince of Wales Strait, which is part of the Northwest Passage, could be used for year-round shipping by domestic and foreign ships and tankers. They are also concerned about Canada's ability to prevent foreign tankers from using the Passage. “Ship traffic would affect the habitat of marine mammals like seals and polar bears; the noise could disturb the social organization of seals; and open water shipping channels would be dangerous to people travelling on the ice. If tanker traffic were allowed, it could potentially result in environmentally devastating oil spills” (SCCP 2016: 57).

Noise levels measured for the purposes of estimating an effect on the environment are typically described by the sound pressure level (SPL). The SPLs are measured in decibels (denoted dB) and are typically reported as 1-hour average values. For human effects, dB SPLs are weighted by the particular sensitivity of the human ear to certain sound frequencies, otherwise known as A-weighting (dBA). A summary of typical SPLs for different activities or settings is provided in Figure 7-1. Ambient noise in the BRSEA Study Area has been reported (measurements of SPLs) in the range of 37-40 dBA in the absence of industrial or other human activity, and these are consistent with rural or wilderness areas in most places in North America (Blackwell and Greene 2005).

Noise levels are sensitive to meteorological conditions, and so noise levels of 50 dBA or more are common even in the absence of human activity due to sustained high winds in the marine environment (Greene et al. 2008).



SOURCE: 3M, 2019

Figure 7-1 Reference of Noise Sources and Associated Noise Levels

7.2.1.3 Artificial Light

Outdoor lighting is critical for public safety in general, and to help complete outdoor tasks safely for workers. Outdoor lighting also has unique and specific functions for marine traffic related to navigation. However, inappropriately designed lighting or excessive lighting can cause effects ranging from a minor nuisance to a disruptive environmental effect (CIE 2017). The attributes that are commonly used to describe obtrusive lighting are light trespass, glare, and sky glow (CIE 2017).

Light trespass is the unintended lighting of the ground or buildings outside of a facility. Facility lighting can be problematic when lights from the facility shine in through the windows of nearby residential homes at levels that can potentially disrupt sleep, or distract from normal levels of lighting, or if they excessively illuminate areas that disrupt ecological function. Light Trespass is typically measured in lux, or the amount light per unit area.

Glare occurs when intense contrast occurs between a light and the surrounding environment. A common example of glare is the oncoming high-beam headlights that provide ample light to the high beam user but can momentarily disable drivers of oncoming traffic. Glare is commonly measured in candela, or the brightness of a light fixture, and is usually reported relative to the brightness of the surroundings.

Sky Glow is the cumulative illumination of the sky or clouds by lights either emitting upward or reflected upward by the ground or other surfaces, plus the emission from photochemical activity in the atmosphere. Sky Glow is often reported by brightness of a patch of the night sky overhead and uses a scale for brightness of stars in the sky. An alternative approach to quantifying Sky Glow for industrial activity. is to take the ratio of the upward (i.e., light pointed towards the sky and also reflected from the ground) light divided by the total light emitted (CIE 2017). This ratio is called the Upward Flux Ratio (UFR).

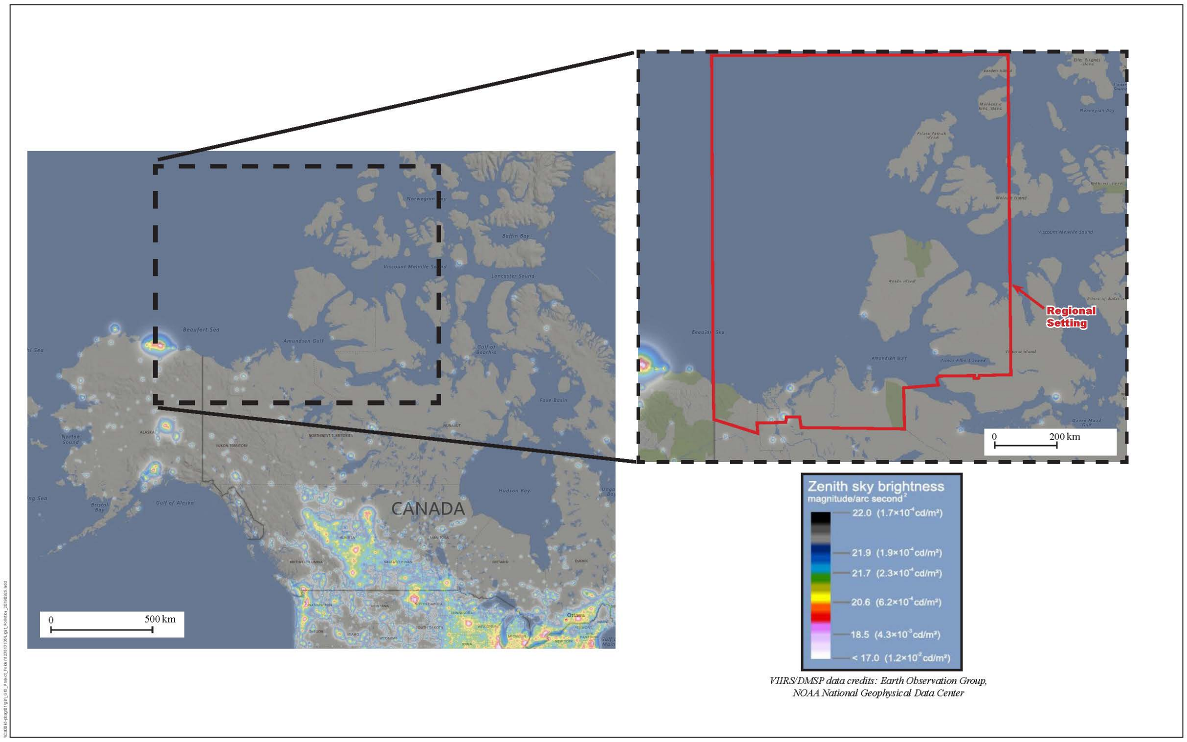
The effect of obtrusive light on people and ecosystems is an area of active research (Gaston et al. 2015). There are documented effects on discomfort or sleep disturbance in people; however, the lighting thresholds required to create an effect and the reversibility of the effects are not well understood outside of a laboratory environment (US DOE 2010). Similarly, for wildlife, documented changes in behaviour, sleep patterns, and foraging are not necessarily associated with permanent or long-term negative effects (Rich and Longcore 2005). Lighted structures can attract birds and bats and lead to mortality due to collisions (e.g., Jones and Francis 2003; Rodriguez et al. 2015). The International Commission on Illumination (CIE) has developed exposure thresholds for light trespass, glare, and sky glow for the purposes of limiting obtrusive light. The exposure thresholds depend on the environmental setting; sparsely populated rural areas are subject to lower thresholds than suburban or urban areas. The objective of the CIE guidelines is to keep dark areas dark and reduce further light pollution in areas that are already exposed to some obtrusive light.

The BRSEA Study Area is considered a wilderness or intrinsically dark environmental setting and is expected to be subject to the lowest thresholds for obtrusive light. Table 7-4 summarizes the guideline thresholds for a uninhabited rural area (CIE 2017).

Table 7-4 CIE Guidelines for Wilderness Area

Exposure Pathway	Measurement Units	Threshold for Relatively Uninhabited Rural Area
Light Trespass	Lux	0.1
Glare	Candela	0
Sky Glow	Upward Flux Ratio (UFR)	2

Measurements of night-time lighting are rare for the Arctic region. Light trespass and glare in offshore areas is primarily associated with marine vessel traffic, but localized effects also occur on land from property and street lighting. Sky glow measurements have been made via satellite observation and are available through online tools (Falchi et al. 2016). Sky glow measurements for the BRSEA Study Area confirm few human sources of light and an intrinsically dark night sky (Figure 7-2).



SOURCE: NOAA National Geophysical Data Center

Figure 7-2 Sky Glow in the BRSEA Study Area

7.2.2 Climate and Weather

Global climate is changing primarily as a result of the increased loading of greenhouse gases in the atmosphere. Warming in the Arctic over the past 100 years has occurred at a rate of about double that over the rest of the globe. This amplification appears to be related to the presence of sea ice and snow (AMAP 2017). Many TLK holders from coastal Inuvialuit communities have spoken of profound changes in climate and sea ice conditions, starting in the late 1980s. As noted in Section 3.5, these changes have negatively affected Inuvialuit travel and harvesting activities on sea ice. TLK holders report a general trend in weather patterns towards periods of more rain and wind. “Prevailing winds previously blew from the northwest, but now are more forceful and blow from the east. High water levels make it difficult to distinguish where the banks of rivers are located. Strong winds are causing arid conditions in the Delta, and fewer blizzards have been observed in winter." (IMG Golder and Golder Associates 2011a: 18). TLK holders also noted warmer temperatures in recent years, more rain, and more thunderstorms (IMG Golder and Golder Associates 2011b: 13).

TLK holders from the Hamlet of Tuktoyaktuk have observed substantial changes in weather patterns and ice conditions over the last few decades (Slavik 2010:9) that influence how industrial contractors conduct their activities. Changes include warmer winter temperatures, more open water in winter, thinner ice, and shorter winter seasons. (Devon Canada Corporation. 2004b:18-34):

The changing climate and weather in the southern BRSEA Study Area is affecting the ability of the Inuvialuit to read the weather and the sea ice. TLK holders agree that, not only has their climate become warmer and the Beaufort Sea increasingly ice free over the last twenty or thirty years, but the weather has become increasingly unpredictable. Formerly, Inuvialuit could use TLK to forecast the weather, but such techniques are now less reliable as the Beaufort Sea has become increasingly ice free over the past 30 years (Joint Secretariat 2015: 172).

Several TLK holder have spoken about their experience with the changing weather and climate over the course of their lives. One TLK holder said: "We started to have open water problems probably about mid-’80s, I guess…. When we started to have problems with the open water or ice conditions not freezing anymore, [it was] not every year for a while. Now it’s every year. It doesn’t freeze anymore out there…. It’s a weather problem. So much wind, not cold enough, so much mild weather, winter like this” (Joint Secretariat 2015: 162-163).

Sea ice mobility and related dynamic processes that lead to the formation of rubble ice and pressure ridges have been directly affected by the changing weather and climate in conjunction with the much-declined multi-year pack ice in the BRSEA Study Area. Delayed regional freeze-up in the southern BRSEA Study Area is resulting in younger sea ice types (e.g., grey, thin first-year ice) being present later into the winter months throughout many parts of the southern BRSEA Study Area (Galley et al., 2016). The presence of younger sea ice types can be prolonged by episodic wind-forced openings (sea ice leads) in the thin sea ice cover which rapidly refreezes as new sea ice. A shift in wind direction (e.g., from easterlies to westerlies) may cause open sea ice leads to converge, thereby closing and causing the sea ice to pile up in pressure ridges, and rubble ice along coastal areas. This causes a dynamic thickening of ice in some locations, which is different from having thicker (and older) sea-ice.

The presence of increased local ice pile-ups, and dynamically thickened sea ice has been noted by Inuvialuit hunters in the region: A TLK holder stated "It’s climate change, I’m pretty sure, making everything change here. And it’s hard for polar bears to survive in the winter because the ice is so thick, and the seals, I’m pretty sure we’re losing millions and millions of seals because of the thickness of the ice. And I’m pretty sure they’re having a hard time keeping those breathing holes open all year round, like right from October until the ice goes…. because of ice piling up. And climate change, I’m pretty sure makes it difficult for seals to keep their breathing holes open all year — six, seven months. That’s the one big change in the ice that I see today, even though I haven’t had a chance to go out there yet this year. But I would see with my two eyes that things are way different from the day I was born." (Joint Secretariat 2015: 194).

7.2.2.1 Air Temperature

Air temperature is an important indicator of climate conditions in the North. Air temperatures in the region typically range between lows near -28°C in the winter and highs near 12°C in the summer (ECCC 2019a), although locations of specific extremes exceed these. Air temperatures have been measured within the ISR at Tuktoyaktuk, Ulukhaktok, Sachs Harbour and Mould Bay, with records at some locations stretching from 1948 to 2018. The datasets from Tuktoyaktuk and Sachs Harbour are more complete for air temperature, and presented here. Further, these data are likely to be reasonably representative of air temperature in the region.

For example, as shown in Table 7-5, the lowest average daily minimum temperature at Sachs Harbour is -32.1°C, occurring in February and the highest average daily temperature is 6.6°C, occurring in July. Extreme temperatures at Sachs Harbour range between -52.2°C in January and 24.2°C in July. Figure 7-3 shows a profile of the minimum and maximum daily temperatures experienced at the Sachs Harbour A weather station for over a 30-year timespan (1984 – 2013).

At Tuktoyaktuk, the air temperatures in the region typically range between lows near -31°C in the winter and highs near 15°C in the summer (Table 7-5). Climate normals indicate that the lowest average daily minimum temperature at Tuktoyaktuk is -30.6°C, occurring in February and the highest average daily temperature is 15.1°C, occurring in July. Extreme temperatures at Tuktoyaktuk range between -48.9°C in January and 29.4°C in July. Figure 7-4 shows the minimum and maximum daily temperatures experienced at the Tuktoyaktuk A weather station over the past 30-years (1985-2014).

Historical mean temperature data at the Tuktoyaktuk A weather station are shown in Figure 7-5; the data show a statistically significant increasing trend in mean annual temperature within the timespan of the dataset of +0.06ºC per year.

Several changes in weather, water, and ice were identified by TLK holders including warmer temperatures in recent years, earlier break up of ice and later freeze up of ice (IMG Golder and Golder Associates 2011c: 21). It was also noted that rain and thunderstorms were becoming more common, currents have changed, and shore water levels are higher and appear to be eroding some of the banks. Local observations have noted that there is ‘‘Increased average air temperatures (increase of 0.7-1.2°C per decade from 1981-2010), and there are “significantly increased winter air temperatures” (IRC 2016).

Table 7-5 Climate Normals - Sachs Harbour and Tuktoyaktuk Weather Stations

Sachs Harbour A Weather Station – 1981 to 2010 Climate Normals

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average (°C)	-28	-28.3	-26.7	-18.3	-7.6	3.1	6.6	3.7	-1.2	-10.7	-20.5	-25.1	-12.8
Daily Maximum (°C)	-24.4	-24.5	-23.1	-14.6	-4.6	6.1	10	6.5	1.2	-7.7	-17.1	-21.5	-9.5
Daily Minimum (°C)	-31.7	-32.1	-30.3	-22	-10.5	0.1	3.1	0.9	-3.4	-13.7	-23.9	-28.5	-16
Extreme Maximum (°C)	-4.4	-4.5	-4	2.2	10	20.5	24.2	21.5	15.6	4.4	1.7	-4	-
Date (yyyy/dd)	1974/02	1989/05	1988/13	1960/25	1994/25	1977/21	1982/06	2000/01	1957/06	1969/11	1970/01	1983/24	-
Extreme Minimum (°C)	-52.2	-50.2	-48.4	-48	-26.7	-16.5	-5	-11	-22.8	-35.5	-42.8	-45	-
Date (yyyy/dd)	1975/10	1985/15	1979/04	1997/01	1958/03	1978/05	2002/31	1995/28	1975/30	1996/28	1972/20	1957/23	-

Tuktoyaktuk A Weather Station – 1981 to 2010 Climate Normals

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average (°C)	-26.6	-26.4	-25.1	-15.7	-4.7	6.4	11	8.9	3.3	-7.4	-20.7	-23.8	-10.1
Daily Maximum (°C)	-23	-22.4	-21.1	-11.3	-1.1	11	15.1	12.3	5.8	-4.7	-17.3	-20.1	-6.4
Daily Minimum (°C)	-30.4	-30.6	-29.2	-20.1	-8.2	1.7	6.9	5.4	0.7	-9.9	-24	-27.5	-13.8
Extreme Maximum (°C)	0.6	0.7	-0.5	4.8	20.9	28.2	29.4	27.6	20.9	17.4	2.2	0.8	-
Date (yyyy/dd)	1974/04	1982/04	1988/11	1989/25	1985/31	1982/28	1973/26	1989/08	2006/08	2008/02	1976/10	1992/02	-
Extreme Minimum (°C)	-48.9	-46.6	-45.5	-42.8	-28.9	-8.9	-1.7	-2.5	-12.8	-28.5	-40.1	-46.7	-
Date (yyyy/dd)	1975/13	1985/19	1979/10	1971/01	1992/03	2000/04	1974/05	1985/26	1974/27	1983/27	1988/19	1974/30	-

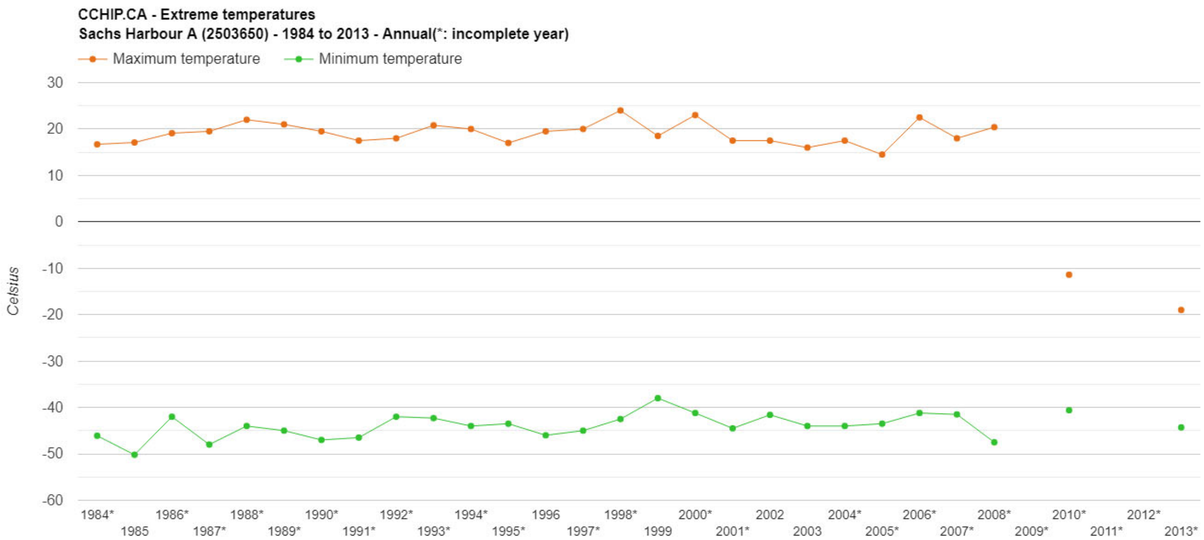


Figure 7-3 Annual extreme daily maximum and minimum temperatures at the Sachs Harbour A weather station from 1984-2013

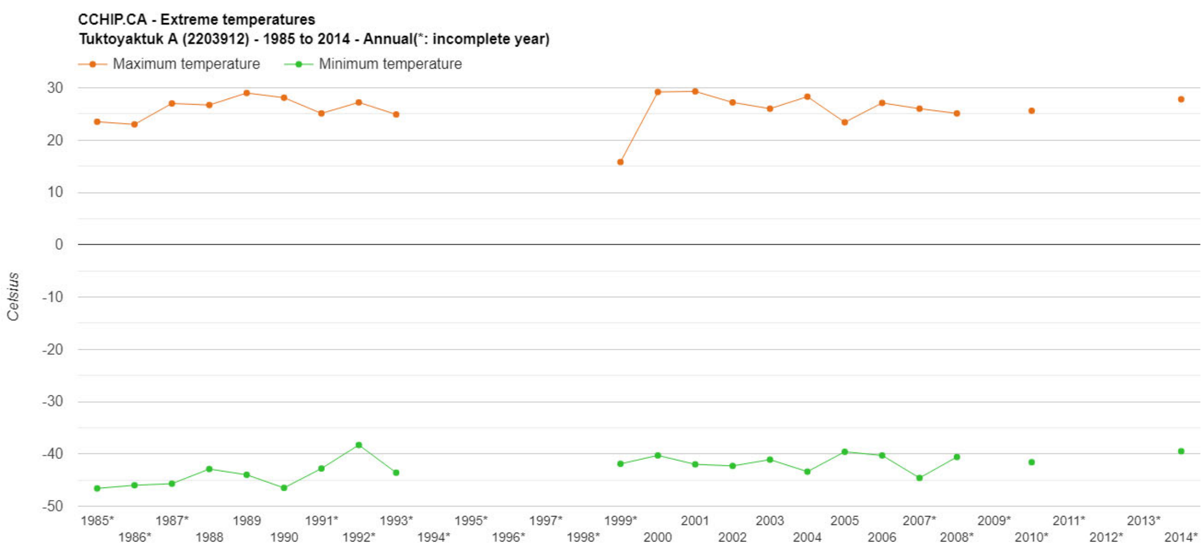


Figure 7-4 Annual extreme daily maximum and minimum temperatures at the Tuktoyaktuk A weather station from 1985-2014

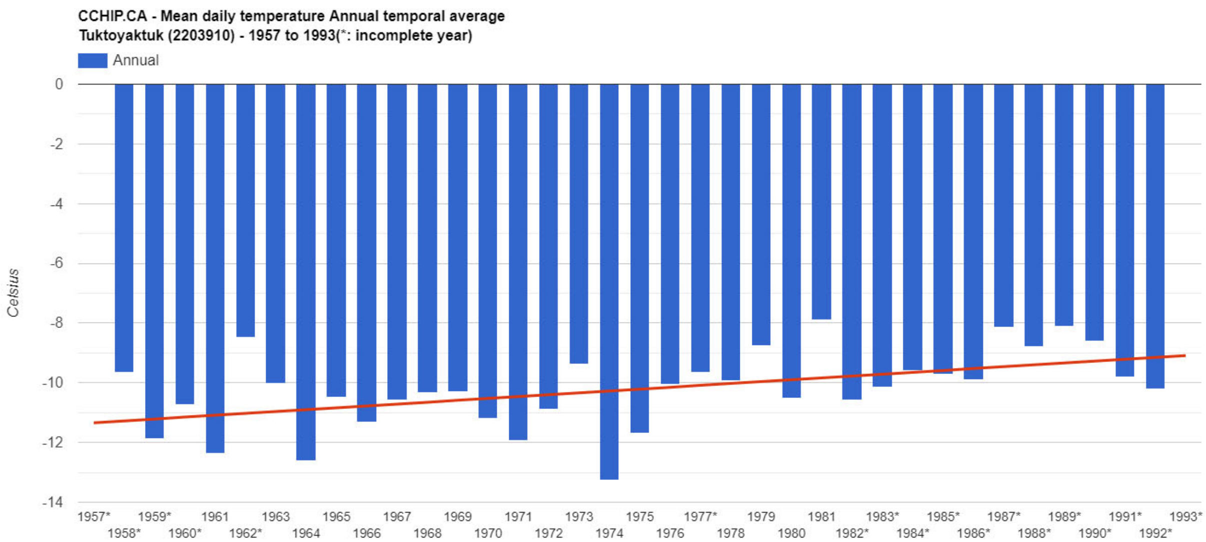


Figure 7-5 Historical mean daily temperature as annual temporal average for the Tuktoyaktuk (ID: 2203910) from 1957 to 1993. Red line shows linear trend line.

7.2.2.2 Frost-free Days

The frost-free season In the BRSEA Study Area begins on the first day in spring when temperatures remain above freezing. It ends on the first day in autumn when freezing temperatures return. A frost-free day is defined as a day when the air temperature stays above 0ºC. As a specific region warms over time, such as the BRSEA Study Area, the frost-free season would likely be extended (i.e., there would be more days with no frost). In the mid to lower latitudes, the increase is important as it relates to the length of the growing season.

Frost data were accessed from the Climate Change Hazards Information Portal (CCHIP) and historical frost profiles were plotted for the Tuktoyaktuk A and Sachs Harbour A weather stations[41] (Figure 7-6 and Figure 7-7). These plots present the percent probability of frost occurring on any given day throughout the year. The frost profile for the Tuktoyaktuk and Sachs Harbour weather stations show that there are differences between the probability of frost occurring during the summer months at each location.

Sachs Harbour (latitude of 72.00°N) has a generally higher daily probability of frost than Tuktoyaktuk (latitude of 69.45°N) (Figure 7-6 and Figure 7-7). TLK holders said that ice break-up is happening earlier and freeze-up has been occurring later in the past three or four years (IMG Golder and Golder Associates 2014: 7).

[41] These two locations were chosen since they represent a coastal community on the mainland in the south of the BRSEA Study Area and a location on one of the Arctic Islands in the north of the BRSEA Study Area.

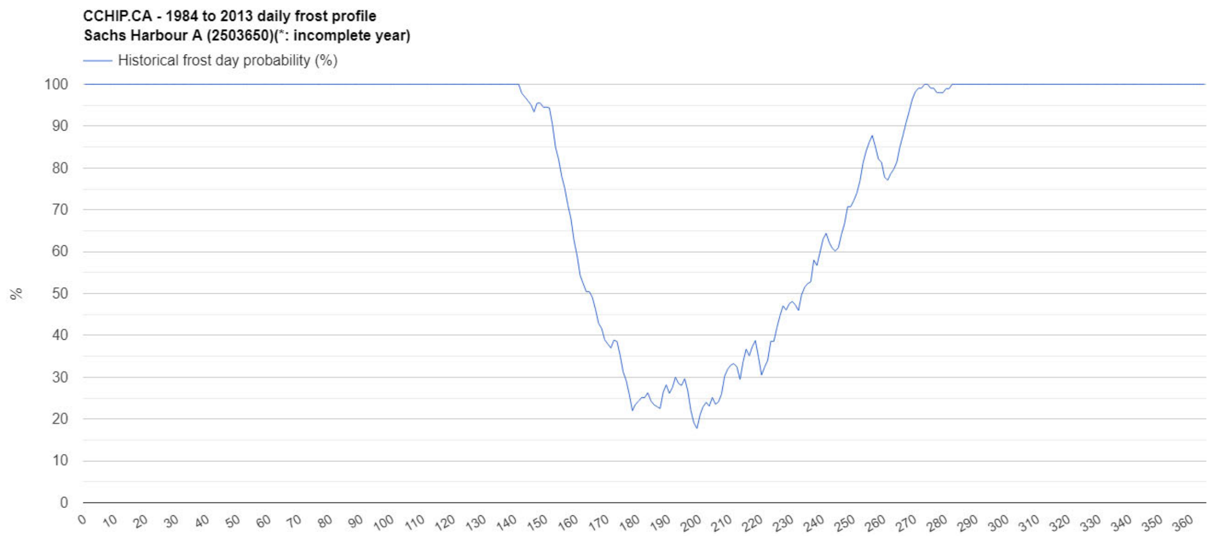


Figure 7-6 Daily frost profile for the Sachs Harbour A weather station from 1985 to 2014, expressed as % probability of frost on any given day of the year.

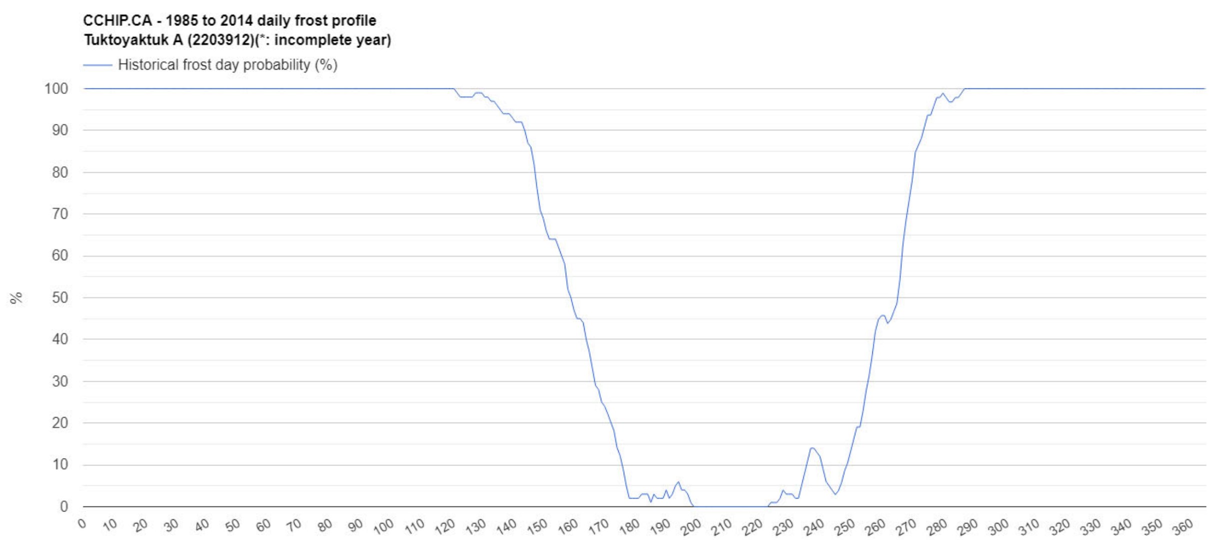


Figure 7-7 Daily frost profile for the Tuktoyaktuk A weather station from 1985 to 2014, expressed as % probability of frost on any given day of the year.

7.2.2.3 Precipitation

Precipitation in the Arctic is lower than over most regions at lower latitudes. The average annual precipitation at Sachs Harbour was 151.5 mm, for the 30-year climate normal period of 1981 – 2010 (Table 7-6; ECCC 2019a). The annual average total rainfall over the 1981 – 2010 period was 58.3 mm, with most rain falling in the July-August-September timeframe. The annual average total snowfall for the same period was 97.7 cm (ECCC 2019a). At Tuktoyaktuk A, the annual precipitation was 160.7 mm, with 74.9 mm rain and 103.1 cm of snow. The data are similar at both stations, and the maximum snow fell in October at both locations.

Data on precipitation are available for a longer period of record at Tuktoyaktuk A and are shown in Figure 7-8 and Figure 7-9. There is considerable variation in the data on both rainfall and snowfall, with a slight increase in total annual precipitation from 1970 to 2014 (0.53 mm/year). Rainfall also has increased a small amount (0.28 mm/year). Snowfall has steadily increased from about 70 to 110 cm per year, with a trend of a 1.16 cm/year increase (see red trend line in Figure 7-10). As shown by the blue bars, the year-to-year variability is high (RSI 2018). TLK holders reported a general weather trend toward periods of more rain and wind (IMG Golder and Golder Associates 2011a: 18). They also noted that there are “more thunderstorms, wetter and colder summers (in certain places, such as Tuktoyaktuk), and less snow” (IRC 2016).

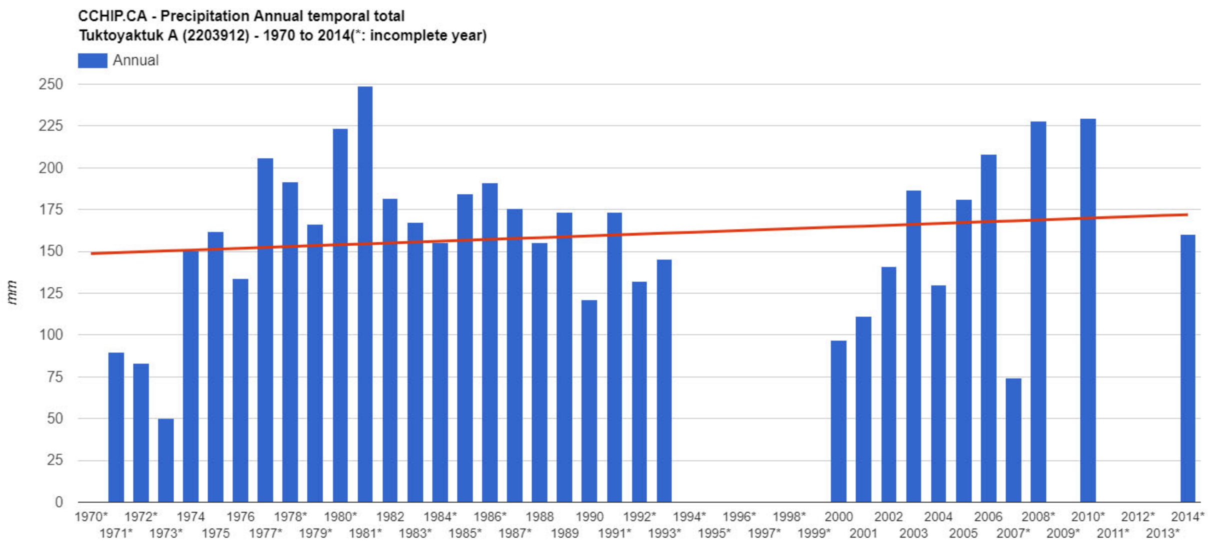
Table 7-6 Climate Normals (1981 – 2010): Precipitation - Sachs Harbour and Tuktoyaktuk A Weather Stations

Sachs Harbour Weather Station – 1981 to 2010 Climate Normals

Precipitation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	0	0	0	0	0.1	5.1	16.7	24.7	11.2	0.5	0	0	58.3
Snowfall (cm)	5.2	7	7.7	12.4	9.3	2.4	0.9	4.1	10.9	20.2	9.4	8.3	97.9
Precipitation (mm)	4.9	6.6	7.1	12.1	9.1	7.5	17.6	28.9	22	20	9	7	151.5
Snow Depth at Month-end (cm)	15	15	18	16	9	0	0	0	3	10	12	14	9

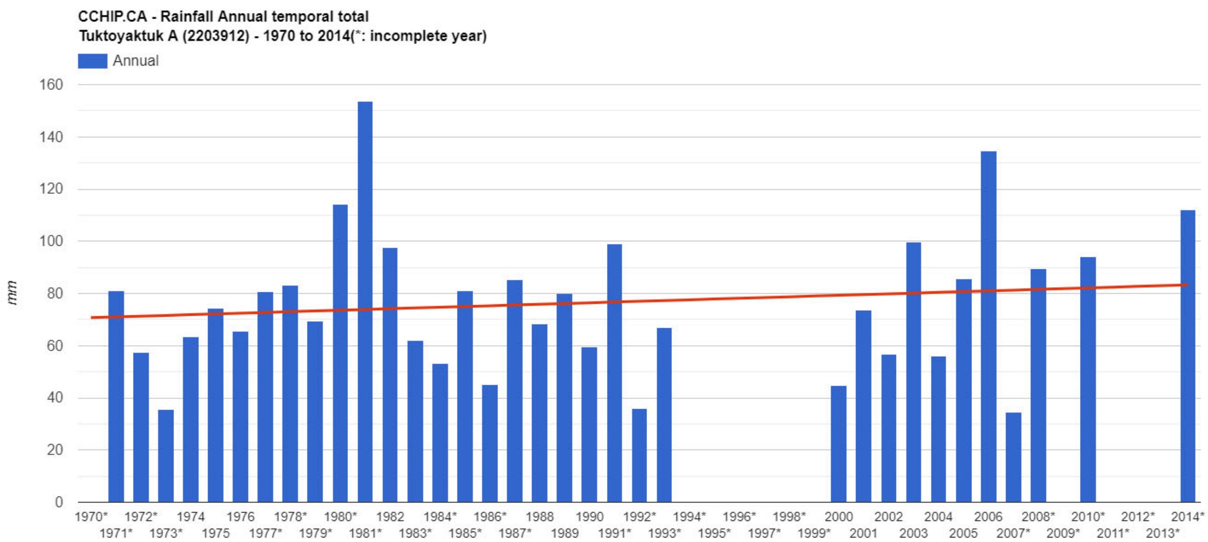
Tuktoyaktuk A Weather Station – 1981 to 2010 Climate Normals

Precipitation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	0	0	0	0	1.4	9.7	22.2	24.4	15.5	1.3	0	0.3	74.9
Snowfall (cm)	13.4	10.2	9	9.4	6.2	1.3	0.1	1.2	8.9	20.1	12.1	11.2	103.1
Precipitation (mm)	10.5	8.9	7.2	8.3	6.8	11	22.3	25.7	23.3	18.4	9.6	8.7	160.7
Avg Snow Depth (cm)	25	28	34	35	18	1	0	0	0	6	13	18	15
Median Snow Depth (cm)	25	28	34	36	19	0	0	0	0	5	13	17	15
Snow Depth-Month-end (cm)	28	31	36	31	5	0	0	0	1	10	15	20	15



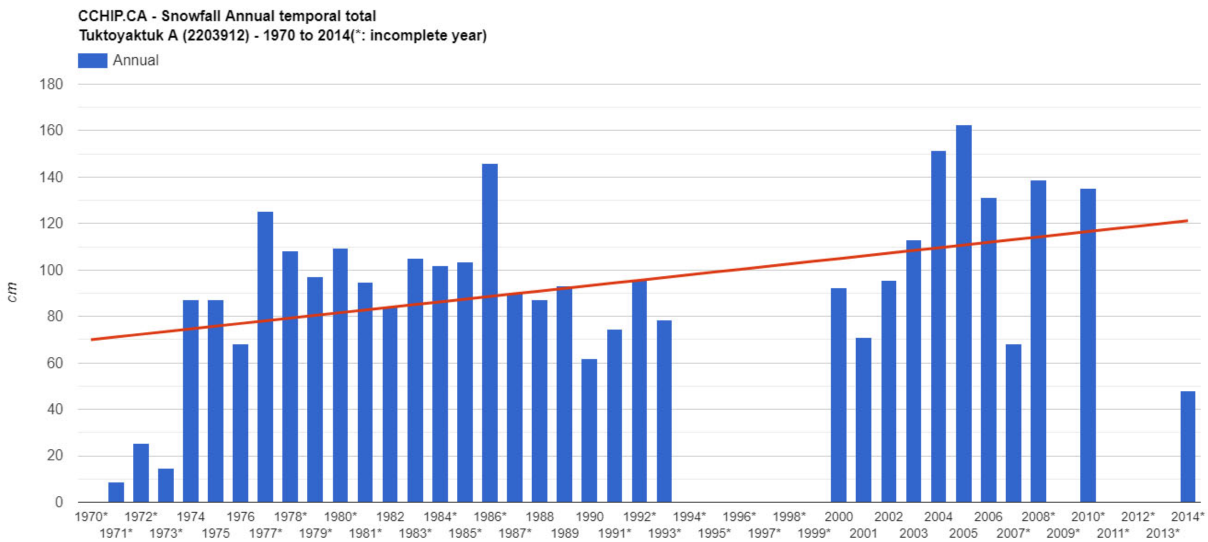
NOTE: Redline indicates statistically significant linear trendline

Figure 7-8 Historical annual total precipitation at the Tuktoyaktuk A weather station from 1970 to 2014.



NOTE: Redline indicates statistically significant linear trendline

Figure 7-9 Historical annual total rainfall at the Tuktoyaktuk A weather station from 1970 to 2014.



NOTE: Redline indicates statistically significant linear trendline

Figure 7-10 Historical annual total snowfall at the Tuktoyaktuk A weather station from 1970 to 2014.

7.2.2.4 Wind

7.2.2.4.1 Winds

Wang et al. (2015) studied historical changes in surface windspeed and wind direction in the Beaufort-Chukchi-Bering Seas over the period 1971 – 2013 (Wang et al. 2015). Two periods were studied: 1970 – 1991 and 1992 – 2013. They found that the mean windspeed over the two periods had increased north of Alaska but decreased in the region off the Canadian coast. In the area just west of the Canadian coast, the mean wind direction rotated clockwise, with the anticyclonic center displaced northeastward. The increases are not large, being 0.1 to 0.3 % per year from the climatological mean. The changes in local wind speeds alone cannot explain the trends in wave action and suggests that the role of swells generated by non-local winds is also important in wave generation.

TLK holders stated that "stronger northwest winds are another observed change and referred to the northwest wind as a "bad wind" because it can reach up to 110 kilometers per hour (km/h) and last from two to three days." Other TLK holders said that the south winds that normally occur in January are now occurring in April and seem to be arriving later each year" (IMG Golder and Golder Associates 2011b:13).

TLK holders indicated that low tides forecast east winds and high tides forecast strong west winds in the summer and potential rain. One TLK holder said that Ulukhaktok once had a consistent east wind for almost a month. It was further noted that 30 years ago, the winds were strong and then died down until about 5 years ago when the wind speeds increased again. (IMG Golder and Golder Associates 2011d:15).

Similarly, it was noted that in some areas of sea ice, over which hunters have travelled, the sea ice is no longer stable. The risks of travel are changing because the weather is less predictable and there is an increase in the frequency, duration, and intensity of strong winds and severe storms. Previously, Inuvialuit hunters relied on local knowledge to look at the weather and plan their trip. With climate changing, they are unable to read signs in the weather like they used to because the weather and seasonal changes no longer follow regular patterns (AMAP 2017).

Zhang et al. (2016) studied variation of surface winds and mesoscale climatology in the Chukchi–Beaufort Coastal Areas and adjacent Arctic Slope region. The surface winds are driven mainly by the prevailing synoptic weather patterns including the Beaufort high and the Aleutian low-pressure systems, and the winds are influenced by local terrain features on land. The surface winds have a strong seasonality with stronger winds during the colder seasons. In summer, winds are generally calm to weak. Sea breezes are prominent in June-September and may extend to 50 km offshore at 1-3 m/s in late afternoon. In July, the area’s regional scale winds are strongly influenced by the anticyclonic flow, related to the position of the Beaufort high, and the onshore winds are strongest right at the shoreline. The sea breezes along the Beaufort coast in July are relatively weak at about 2 m/s. The synoptic winds may, on occasion, add to the sea breezes and can double the windspeed in the region. The increased onshore winds may influence and strengthen upwelling that may, in turn, affect ice local distribution. (Zhang et al. 2016).

Trends in windspeed metrics for the BRSEA Study Area are shown in Table 7-7. The metric U10 is the windspeed measured at 10 m height. The data trends are presented for the average, and the 90th and 99th percentiles. The trends in average windspeed, the 90th and the 99th percentiles are different in the two periods 1996-2006 and 2007-2015. When taken together, the trends are slightly negative for average windspeed (-0.12 m/s/decade), slightly positive for the 90th percentile and a bit more positive for the 99th percentile (0.28 m/s/decade).

The climate normals for winds at the Sachs Harbour and Tuktoyaktuk weather stations from Environment and Climate Change Canada (ECCC 2019a) for the period 1981 to 2010 are presented in Table 7-8.

Table 7-7 Trends – windspeed (m/s/decade) – BRSEA Study Area

Metric	U10avg			U10_90			U10_99		
Timeframe	1996-2006	2007-2015	1996-2015	1996-2006	2007-2015	1996-2015	1996-2006	2007-2015	1996-2015
Trend (m/s/decade)	1.67	-1.48	-0.12	2.56	-1.05	0.04	2.64	-1.43	0.28
SOURCE: From Liu et al. 2016									

Table 7-8 Climate Normals for the Sachs Harbour and Tuktoyaktuk Weather Stations, NWT – 1981-2010

Sachs Harbour Weather Station – 1981 to 2010 Climate Normals

Winds	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Max Hourly Speed (km/h)	80	97	72	89	76	71	77	68	72	80	84	87	97
Date (yyyy/dd)	1957/17	1965/25	1971/08	1960/05	1957/04	1962/05	1964/11	1956/21	1962/04	2005/22	1965/12	1981/19	1965/25
Direction Max Hourly Speed	NW	N	SE	NE	SE	SE	N	NE	NW	SE	SE	SE	N
Max Gust Speed (km/h)	113	77	70	79	64	58	72	100	71	85	105	84	113
Date (yyyy/dd)	1973/28	1973/09	1977/25	1972/30	1973/08	1972/28	1974/28	1974/11	1974/03	1973/03	1972/29	1971/04	1973/28
Direction of Max Gust	E	N	SE	SE	SE	SE	S	S	NW	E	NW	NE	E

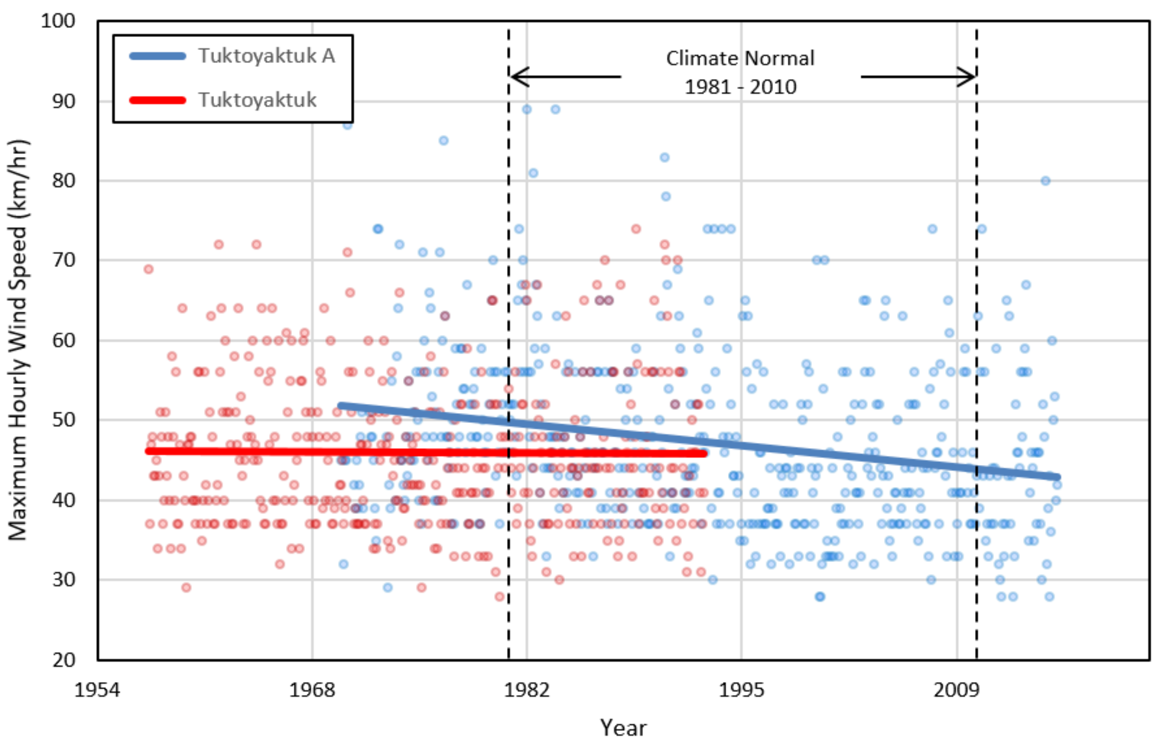
Sachs Harbour Weather Station – 1981 to 2010 Climate Normals

Winds	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Max Hourly Speed (km/h)	78	89	63	59	67	54	81	74	87	69	85	89	89
Date (yyyy/dd)	1991/26	1982/13	1996/27	1979/22	1978/01	1996/04	1982/27	1972/20	1970/14	1991/23	1976/29	1983/24	1982/13
Direction of Max Hourly	NW	W	NW	NW	NE	NW	NW	W	W	W	NW	NW	W

TLK holders have observed the unpredictability of the increasingly thin ice, the lack of stabilizing multi-year and grounded ice, and unpredictable, stronger and/or more easterly winds in some areas (such as Ulukhaktok) have greatly increased the dangers associated with ice travel. Further, it was observed that climate change effects such as warmer temperatures, thinner ice and winds that break up or seriously rubble the ice are affecting Inuvialuit polar bear harvesting activities and the knowledge they gain from it. (Joint Secretariat 2015: 44).

The maximum hourly windspeeds in Tuktoyaktuk tend to occur in the winter months and are lower in the summer months. Meteorological data from Pelly Island (just west of Tuktoyaktuk) may better represent the marine wind environment in the BRSEA Study Area (Fissel et al. 2009), and were included in the analysis presented in this study.

The variability in maximum hourly windspeeds at Tuktoyaktuk over the period 1954-2017 are shown in Figure 7-11. The means values are also shown, and indicate a slight but significant (P<0.001) negative trend from 1968 to 2012 for Tuktoyaktuk A.



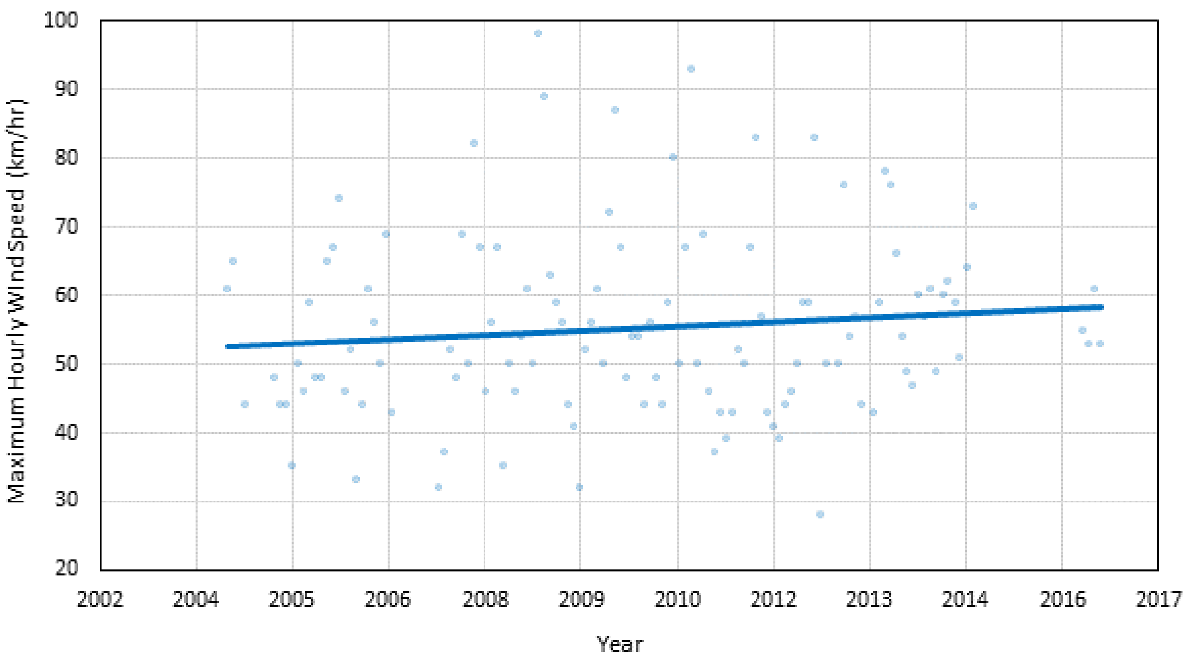
SOURCE: ECCC 2019b[42]

Figure 7-11 Wind variability at Tuktoyaktuk for 1954-2017 represented by maximum hourly wind speeds recorded monthly - trends: red line = -0.008 km/hour/year; blue line = -0.194 km/hour/year

[42] Tuktoyaktuk and Tuktoyaktuk A in this figure refer to two different weather stations

Maximum hourly wind speeds at Pelly Island (Figure 7-12) show a slightly increasing trend for this shorter and more recent dataset (0.504 km/hour/year or 0.140 m/s/y (i.e., over the past decade or so). Comparing these results with those from Tuktoyaktuk A suggests there is small-scale spatial variability in the windspeed trends; however, the Pelly Island data set presented here extends over a considerably shorter timespan, which is likely to affect the trend.

TLK holders explained that during spring, high winds may push ice into Franklin Bay and trap the whales; however, it was noted that beluga whales are intelligent animals and do not generally get trapped (IMG Golder and Golder Associates 2011b: 7-8). They also said that beluga whales are typically hunted closer to the beach unless the weather is good, at which time hunters may go out to Darnley Bay. They also said that beluga whales are not often harvested on the west side of Franklin Bay, a beluga harvesting area, since it takes too much gas and too much time to get there. TLK holders also noted that there are "more windstorms and more funnel winds" in the region (IRC 2016).



SOURCE: ECCC 2019b

Figure 7-12 Wind variability at Pelly Island for 2004-2016 represented by maximum hourly wind speeds recorded monthly – trend = 0.504 km/hour/year

Wind roses were produced using the statistical modelling software, R (version 3.5.2), and the “openair” extension package and were based on ECCC historical hourly wind data (ECCC 2019b). The wind statistics were based on hourly data for the following periods: Tuktoyaktuk: 1970-2015; Ulukhaktok: 1987-2014; Mould Bay: 1953-1996; and Pelly Island: 2004-2016.

Wind roses for the Tuktoyaktuk A and Pelly Island weather stations are presented in Figure 7-13 and Figure 7-15 (annual) and in Figure 7-14 and Figure 7-16 (the four seasons). To complement this, annual wind roses for the Ulukhaktok A (to the east of Tuktoyaktuk) and Mould Bay A (to the north) are presented in Figure 7-17 and Figure 7-18. The wind roses illustrate the variability in the windspeeds, and the strong easterly and northwesterly components in all seasons, and a north-easterly component in late spring and early summer (months 4 to 7). The annual wind roses for Mould Bay are different from the wind roses of Pelly Island and Tuktoyaktuk in that data from Mould Bay have a weaker easterly component, a strong northerly and northwesterly component, and a strong southerly component.

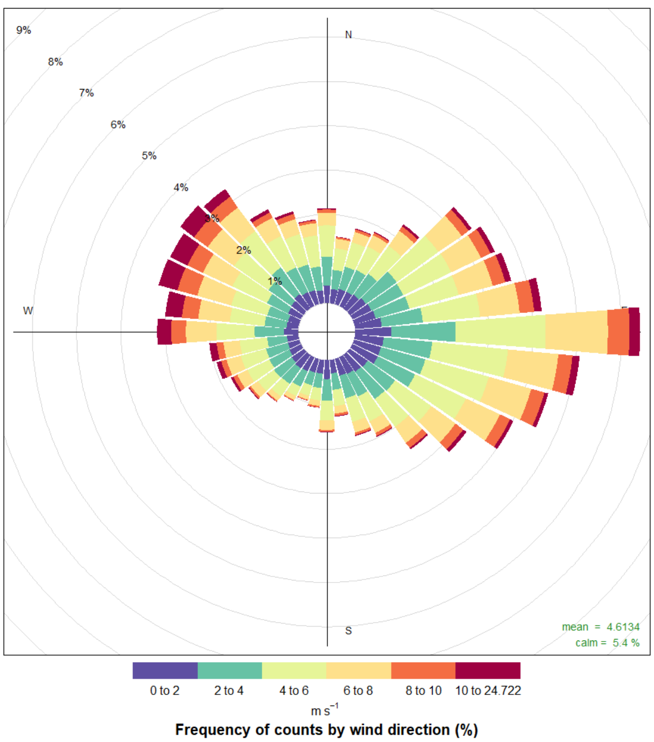


Figure 7-13 Annual wind rose for Tuktoyaktuk A hourly wind data comprising 63 years from 1954-2017

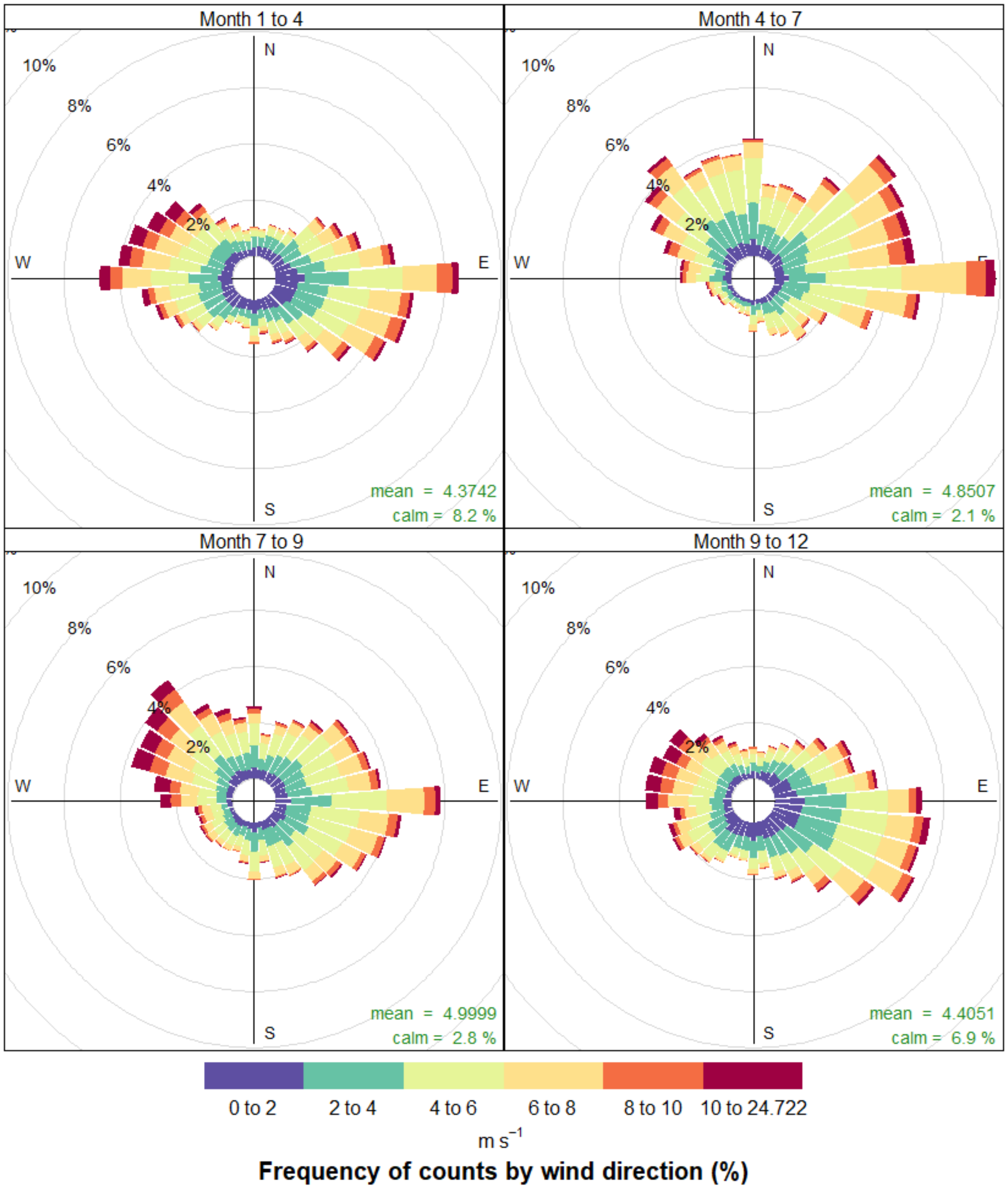


Figure 7-14 Seasonal wind roses for Tuktoyaktuk A hourly wind data comprising 63 years from 1954 – 2017, grouped quarterly.

TLK holders noted stronger and more frequent winds have been blowing from the east over the last 10 years. They explained that, typically, the direction of wind is north-west in the Tuktoyaktuk region, and that the new east winds may be drying up the lakes around the Tuktoyaktuk Peninsula (IMG Golder and Golder Associates 2011e: 12).

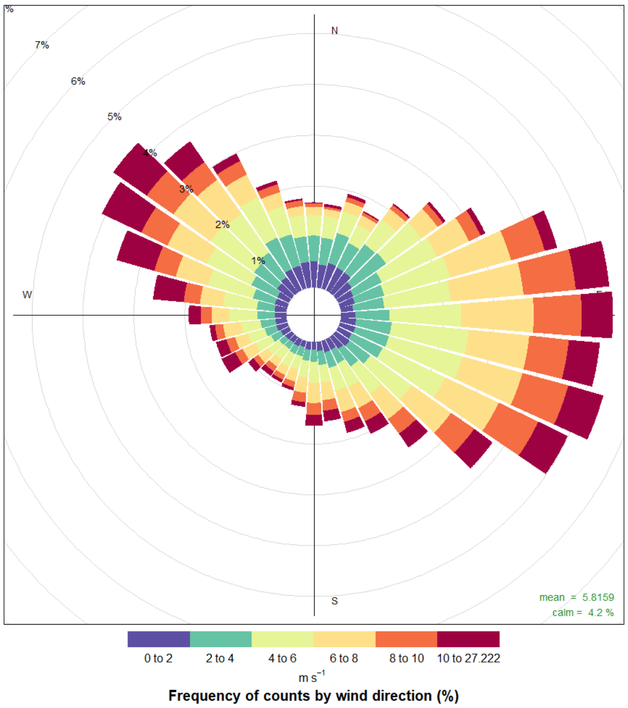


Figure 7-15 Annual wind rose for Pelly Island hourly wind data comprising 12 years from 2004 – 2016.

Regarding the thickness of the ice, local experts said that, because of warmer temperatures and the increase in wind speeds, the ice does not get as thick as it once did. One of the TLK holders said, "If it's windy, then the ice is going to float away while it's young, can't stay there and thicken." Multi-year ice was noted to still exist in the Prince of Wales Strait (IMG Golder and Golder Associates 2011d: 15-16).

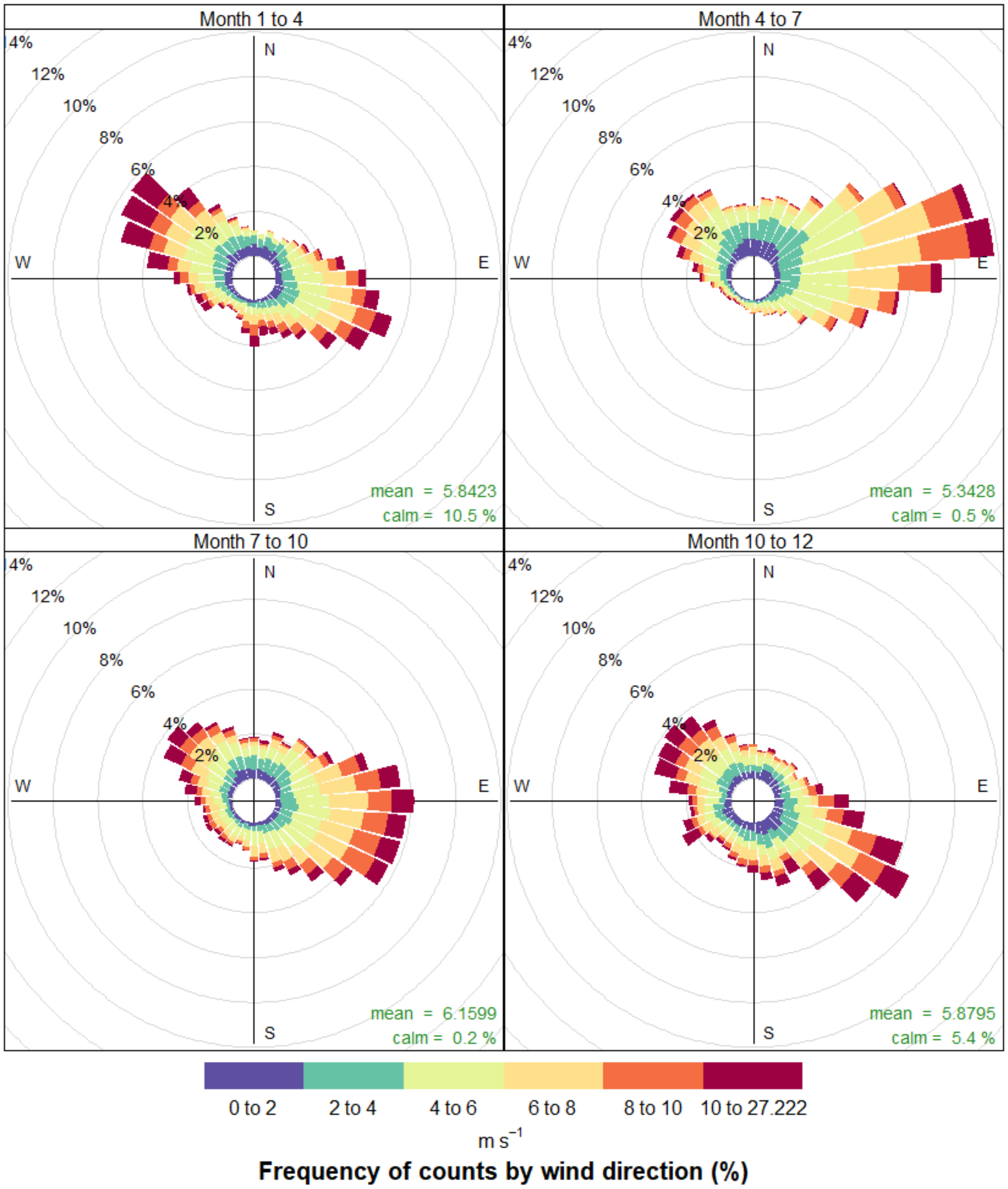


Figure 7-16 Seasonal wind roses for Pelly Island hourly wind data comprising 12 years from 2004 – 2016, grouped quarterly.

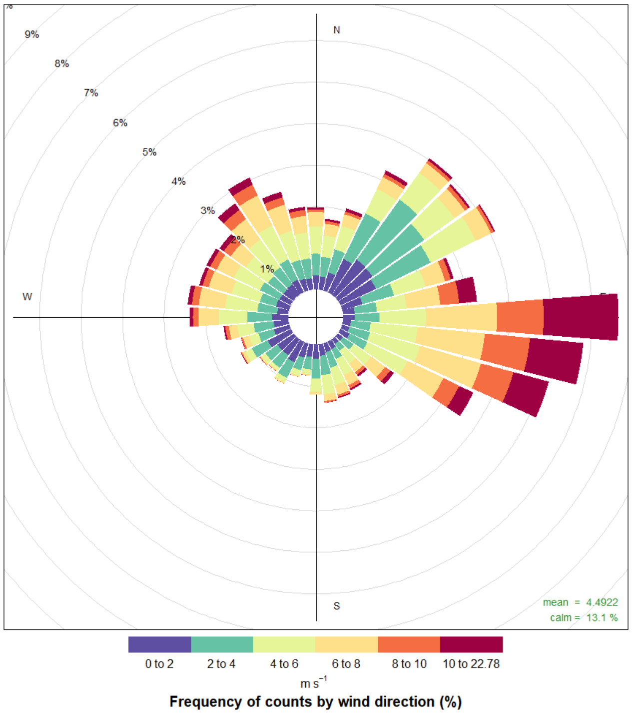


Figure 7-17 Annual wind rose for Ulukhaktok A hourly wind data comprising 27 years from 1987 – 2014.

A TLK holder commented that "The biggest change that I've noticed is the ice. The ice is getting a lot and lot thinner that what it used to be. We used to get what called multi-year ice which came to 10 to 20 feet thick. Now we're lucky if it's four or five feet thick.. As soon as there's a strong wind it breaks up right away" (Slavik 2010: 50).

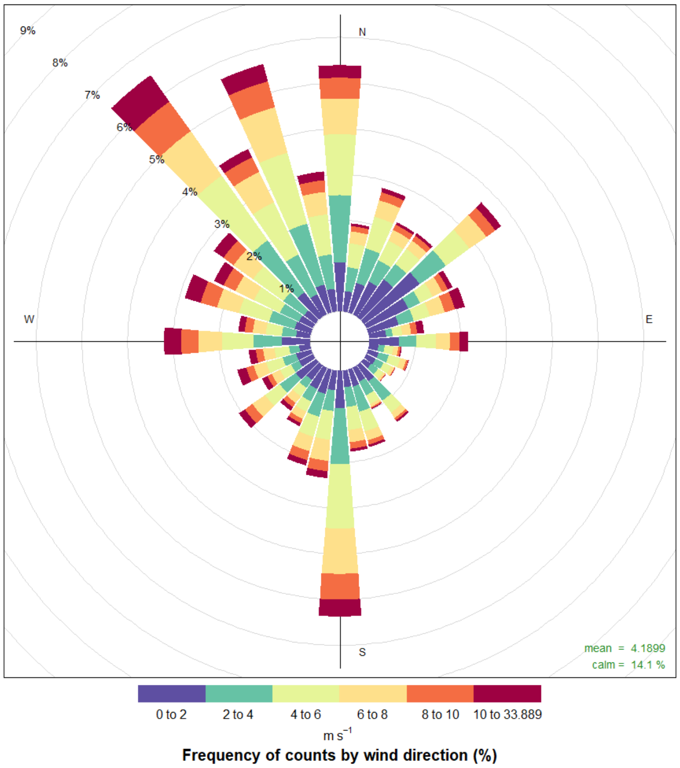


Figure 7-18 Annual wind rose for Mould Bay A hourly wind data comprising 49 years from 1948-1997

A hunter from Ulukhaktok summarized many of the climate changes he had observed over the previous twenty years. He noted that, formerly, when it was extremely cold, the steamy breath ("smoke") of dog teams and fellow travelers obscured those following along behind while moving across the ice. This phenomenon no longer occurs, due to warmer winter temperatures.

> "[Now] weather are almost going to zero degrees. Yellowknife, it's supposed to be over minus sixty this time of year. Yesterday, it was only minus six. I couldn't believe it. Right here a long time ago, when the weather get real cold, when you're travelling, you can't see the person travelling behind you, about probably 25 yards. Smoke in between us, right there, from the cold weather. From your breathing and dogs breathing, when you're travelling, so much smoke coming out of the dogs on the trail [that] you can't see your partner travelling behind you or in front of you, 25 yards to 50 yards. Now, we don't get that kind of weather no more; and it used to be good weather, no wind for a long time. Sometimes 32 weeks, no wind. Right now, the windy days, bad weather days, way more than the good weather. It's very different today. That's why we don't have ice anymore out here." (Joint Secretariat 2015: 162-163).

Table 7-9 shows mean, maximum and standard deviations based on hourly historical data for wind data at four stations within the BRSEA Study Area (ECCC 2019b).

Table 7-9 Summary of mean, maximum and standard deviations for wind data at stations considered in this study (m/s).

	Tuktoyaktuk A (1970-2015)			Pelly Island (2004-2016)			Ulukhaktok A (1987-2014)			Mould Bay A (1953-1996)		
	Mean	Max	Std Dev	Mean	Max	Std. Dev.	Mean	Max	Std Dev	Mean	Max	Std Dev
Jan	3.10	21.67	3.30	5.33	24.72	4.59	1.43	22.78	2.79	2.28	24.72	3.46
Feb	3.01	24.72	3.31	5.84	25.83	4.44	1.27	16.39	2.65	2.15	23.61	3.33
Mar	2.92	22.22	2.94	4.67	16.39	2.96	1.24	20.56	2.66	2.13	26.11	3.25
Apr	2.98	16.39	2.98	5.16	21.11	3.47	1.41	20.56	2.93	1.95	19.72	2.91
May	3.33	18.61	3.02	4.95	18.61	3.07	1.60	21.67	2.95	2.48	21.11	3.00
Jun	3.33	15.00	2.90	4.94	15.83	2.42	1.67	17.50	2.84	2.80	26.39	3.29
Jul	3.53	22.50	2.95	4.51	16.94	3.13	1.52	15.56	2.59	2.86	23.33	3.23
Aug	3.63	20.56	3.16	5.22	18.06	2.87	1.50	17.50	2.69	2.78	20.56	3.27
Sep	3.57	24.17	3.23	5.59	16.67	3.41	1.72	20.00	3.00	2.97	20.00	3.56
Oct	3.39	19.17	3.16	5.87	19.17	3.85	1.95	19.17	3.38	2.35	33.89	3.35
Nov	3.12	23.61	3.17	5.53	23.06	4.31	1.65	20.56	3.03	2.23	22.22	3.14
Dec	2.99	24.72	3.08	5.00	27.22	3.83	1.38	20.00	2.78	2.30	30.28	3.38
Annual	3.25	24.72	3.11	5.22	27.22	3.61	1.53	22.78	2.87	2.44	33.89	3.28

7.2.2.4.2 Storms

Storms may enter the southern BRSEA Study Area from the Bering Strait, Northern Canada, the North Atlantic, or follow eastward migratory trajectories from the Russian Sector (Zhang et al. 2004). Atkinson (2005) studied storminess patterns in the areas surrounding the Arctic referred to as the circum-Arctic coastal regime during the Open Water Season of June, July, August, September, October. Data from weather stations in the 7 different coastal zones for a period of 1950 to 2000 were analysed. Coastal zones of interest here are zone 5 – Chukchi Sea, zone 6 – Beaufort Sea, and zone 7 – the Canadian Arctic Archipelago. Thresholds of 37 km/hour (10 m/s) for windspeed, and 6 hours for duration, were used to define a storm event, and algorithms were set up to establish counts for each region.

The BRSEA Study Area comes under the influence of systems from the Pacific via the Bering Strait, and the increasing amounts of open water align with increases in storm activity, which reaches a maximum in October. The mean storm windspeed in the BRSEA Study Area ranged from 9.9 m/s in July (the lowest value) to 10.8 m/s in October. The mean storm maximum windspeed ranged from 11.6 m/s in July to 12.8 m/s in October. The mean duration of core winds ranges from 19 to 25 hours. Atkinson (2005) concluded that the storm counts did not exhibit a steady trend but did show rapid jumps in activity and variability when different circulations prevailed.

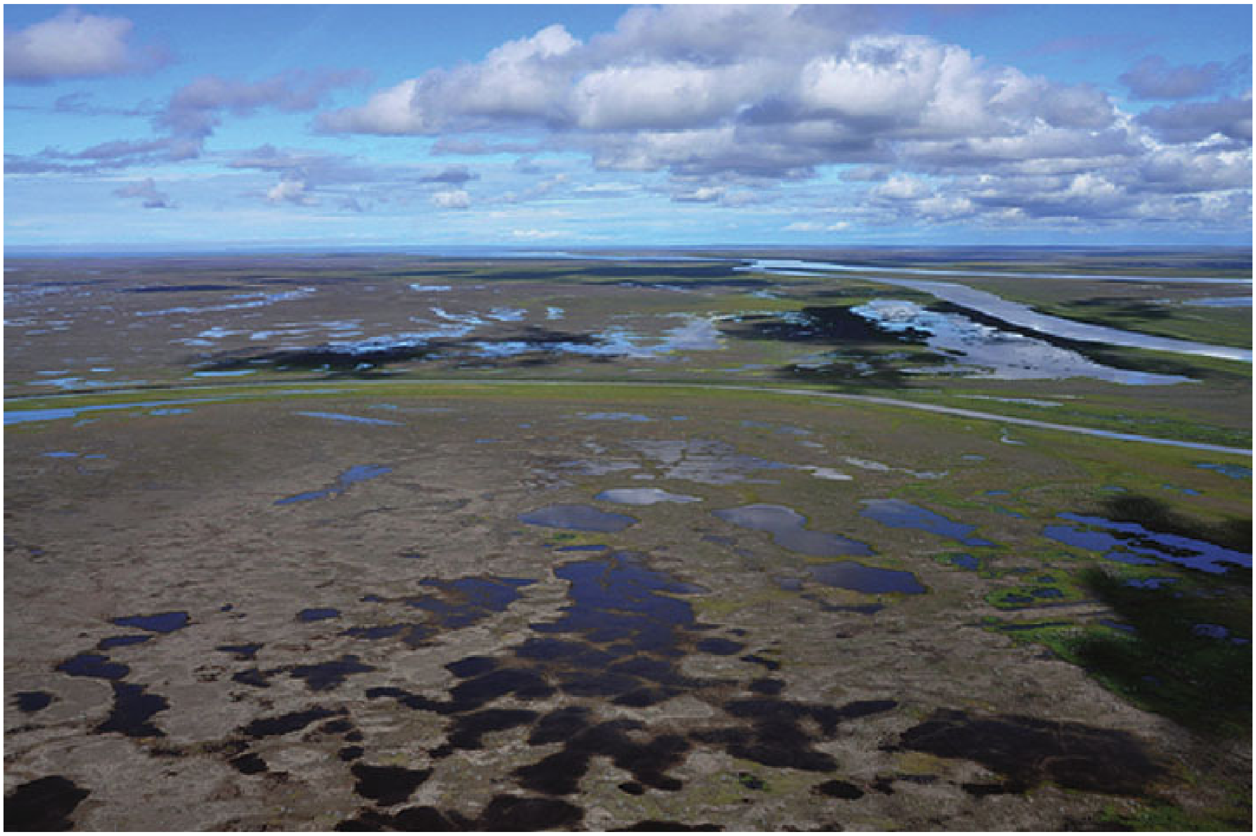
Tuktoyaktuk TLK holders have observed substantial changes in weather patterns and ice conditions over the last few decades and predicted these changes would affect how offshore hydrocarbon exploration I conducted (KAVIK-AXYS Inc. 2004b: 4-8 – 4-9). Changes include:

- more open water in the winter
- rougher ice
- delayed snowfall and freeze up
- greater numbers of icebergs
- larger and rougher pressure ridges
- weaker ice
- thinner ice in Husky (Eskimo) Lakes
- sinking permafrost
- warmer winter temperatures
- erosion is worsening
- strong summer storms

7.2.2.4.3 Storm Surges

Declines in Arctic sea ice cover and commensurate increases in fetch are elevating the potential for damaging storm surges in coastal areas of the BRSEA Study Area (Morse et al. 2009; Vermaire et al. 2013). They can manifest as flooding (positive surge), or water-level recession (negative surge), depending on the direction and intensity of the wind forcing. The largest storm surges observed along the coastline of the BRSEA Study Area have been recorded during the late autumn and early winter where some first-year sea ice is present (Manson and Solomon 2007).

Larger storm inundations can cause salinization of freshwater ponds and non-saline meadows (Pisaric et al. 2011), increase soil salinity, damage vegetation along the margins of permafrost plateaus, and melt subterranean permafrost causing underground hollows subject to collapse (thermokarst) (Kokelj et al. 2013, 2015) (Section 7.2.5.2). For example, Pisaric et al. (2011) described the impacts of a widespread storm surge inundation event in the Mackenzie River Delta (Photo 7-1) in 1999. An exceptionally high surge moved saltwater far above the normal surge lines, killed shrubs and changed the ecology of some delta lakes from freshwater to brackish lakes. Through TLK, dendrochronology, and analysis of lake diatoms, it was determined that this type of large-scale storm surge had not occurred in the Mackenzie Delta in the past 1000 years. Vermaire et al. (2013) investigated this event further and inferred an increase in storm surge activity in the region over the past 150 years. They linked this trend to increases in annual mean temperatures in the Northern hemisphere, and a decrease in summer sea ice extent. It is reasonable to expect this trend to continue with further declines in Arctic sea ice extent.



SOURCE: Photograph by T. Lantz in: Chapin III et al. 2013

Photo 7-1 Impacts of the 1999 Storm surge on vegetation of the outer Mackenzie Delta

Tuktoyaktuk is particularly vulnerable to positive storm surges, driven by strong, northwesterly winds from migratory Arctic cyclones interacting with seasonal areas of open water (fetch). Harper et al. (1987) identified a local maximum in surge elevations of 2.4 – 2.5 m above mean sea level (MSL) under northwesterly winds for Tuktoyaktuk, NWT where maximum surge elevations were limited to ~2.0 m above MSL in coastal areas to the north and west. No evidence was found for larger surges within the past 100 years; however, the observed changes to the regional climate and sea ice cover may be increasing the risk for a surge event with an elevation > 2.5 m. The frequency and magnitude of extreme high water-level events is projected to increase (high confidence) along the coastlines within the BRSEA Study Area, resulting in increased flooding and pressure on infrastructure and coastal ecosystems (Bush and Lemmen 2019).

7.2.3 Oceanography

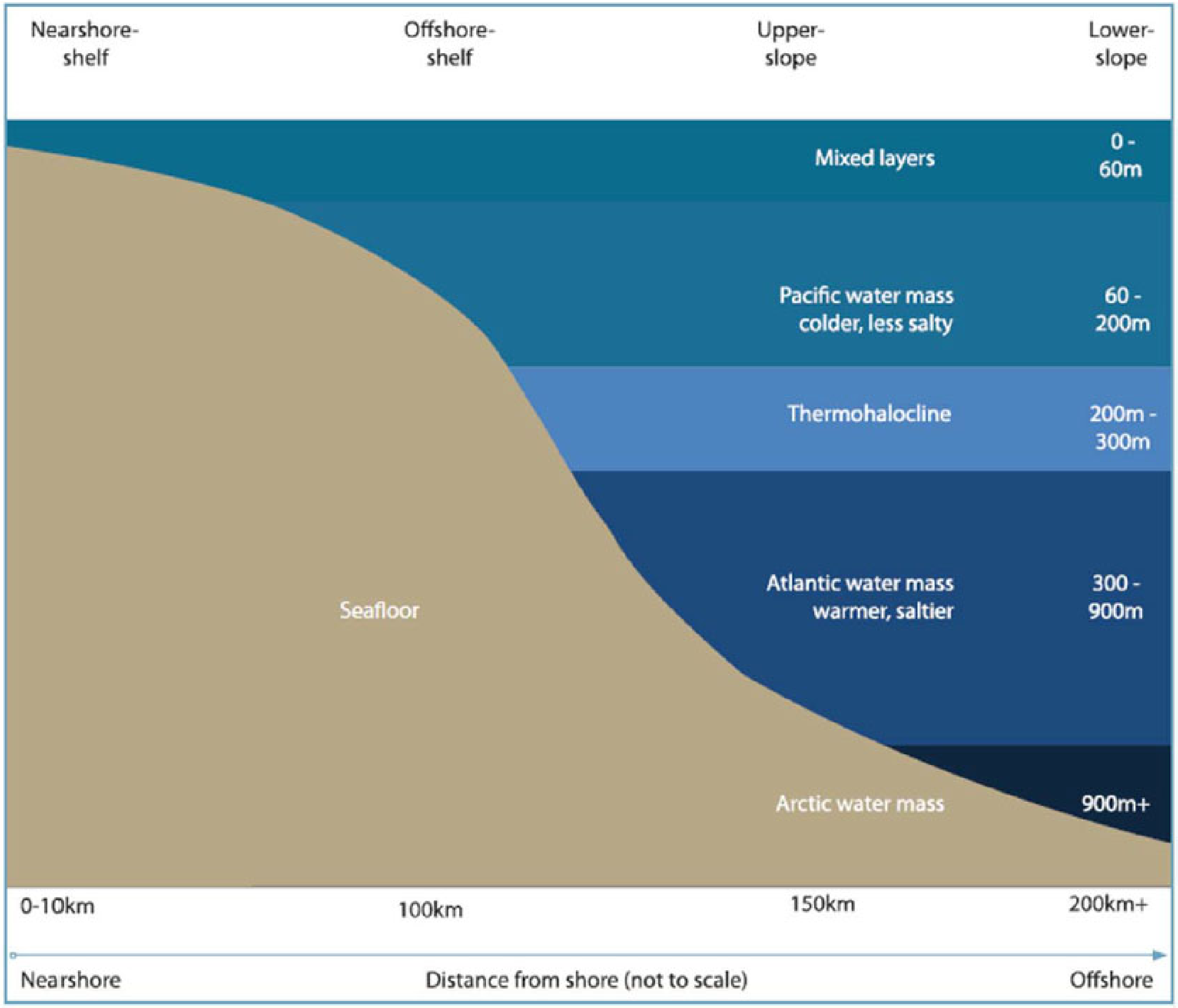
7.2.3.1 General Circulation Patterns

Ocean currents in the BRSEA Study Area are predominantly wind driven. Tidal currents are small, given the 0.5 m range in tidal heights (Hill et al. 1991). The BRSEA Study Area is dominated by a high-pressure weather system resulting in clockwise winds which drive the surface water currents and sea ice motion (Proshutinsky and Johnson 1997), known as the Beaufort Gyre. Shifts in the location of this high-pressure weather system, or the presence of low-pressure weather systems can cause the reversal of the Beaufort Gyre, and result in counter clockwise rotation of the surface currents (McLaren et al. 1987), especially in the summer months. Clockwise gyre motion tends to generate divergent forcing for sea-ice whereas counter clockwise gyre motion generates convergent forcing (Lukovich and Barber 2006; Asplin et al. 2012).

The Arctic Ocean is made up of several layers of water with differing properties depending on the source of the water (Figure 7-19). Water originating from the Pacific Ocean enters the area through the Chukchi Sea. This water is relatively warm and fresh and resides in the upper 200 m (Woodgate 2018). Atlantic water tends to be saltier and denser and resides at depths in excess of 300 m (Jackson et al. 2010). The deep Atlantic water tends to traverse eastward along the North American coast as part of its counter clockwise journey around the Arctic (Coachman and Barnes 1963). Arctic Water is found below 900 m (Majewski et al. 2017).

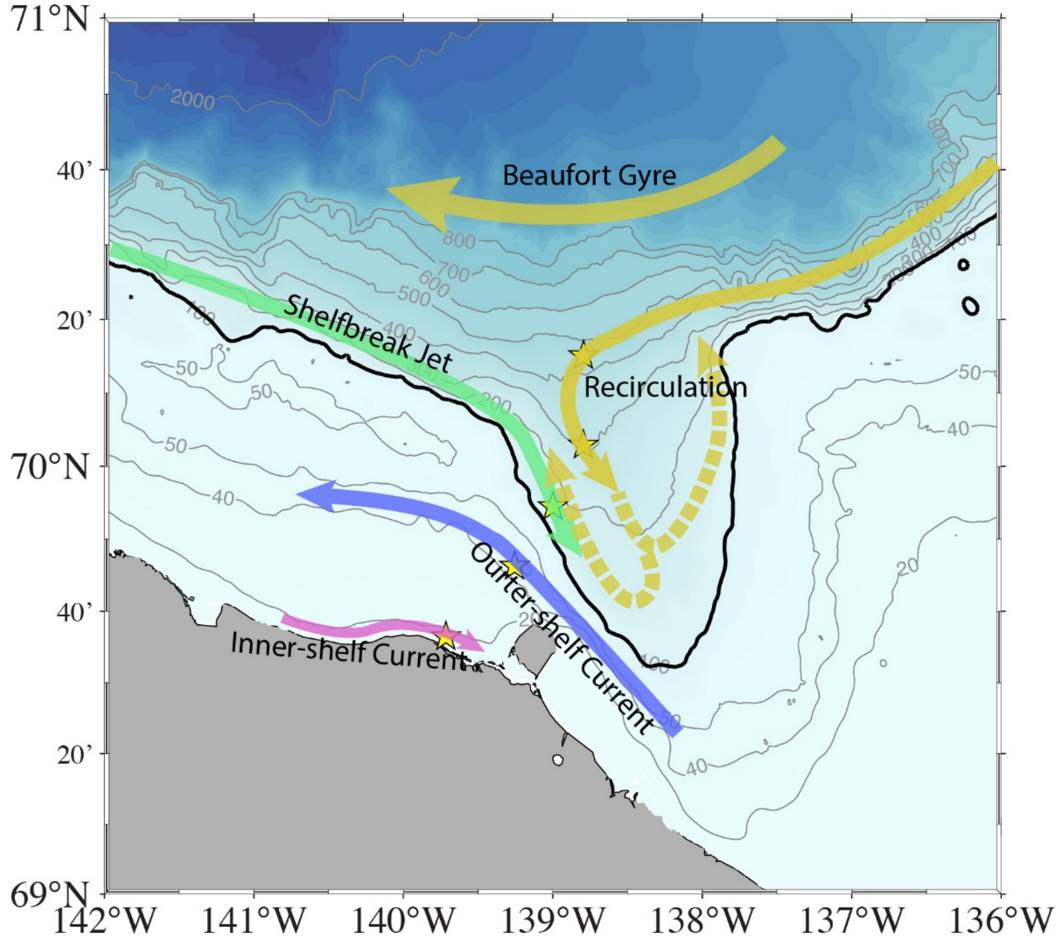
The Pacific water entering from the Chukchi Sea results in a narrow jet, about 20 km wide, which can traverse eastward at depth (i.e., 60-200m) along the shelf break off Alaska and the Yukon (Pickart 2004) (Figure 7-20). A continuation of this jet has been sporadically observed east of the Mackenzie Canyon (Figure 7-20). The jet has average speeds of 15 cm/s but can increase during storm surge events (Dmitrenko et al. 2016) to speeds of up to 120 cm/s. Storms bringing westerly winds cause storm surges that push offshore water onshore, resulting in coastal downwelling of surface waters. The downwelling results in a flow, driven by the pressure gradient, that enhances the shelf break currents. Instabilities in the shelf-break jet can spawn eddies as observed in the Canadian Beaufort (Carmack and Kulikov 1998) and along the Alaskan north slope (Manley and Hunkins 1985; Spall et al. 2007).

The plume of the Mackenzie River is another important component of the offshore circulation in the region. It is highly dependent on the wind direction and is highly seasonally dependent (Carmack and Macdonald 2002) (Figure 7-20). The freshwater plume of the Mackenzie River is smallest during November through April due to the much lower river discharges. During this period, it is confined beneath the landfast ice until the start of the river freshet and landfast ice break-up in May and June. The Mackenzie River discharges into the Beaufort Sea, especially for sediment fluxes, are further discussed in Section 7.2.3.6 along with the associated upwelling and downwelling and the implications for water quality.



NOTE: Figure as per Majewski et al. 2017.

Figure 7-19 Illustration of the Pacific, Atlantic, and Arctic water masses in the Arctic Ocean.

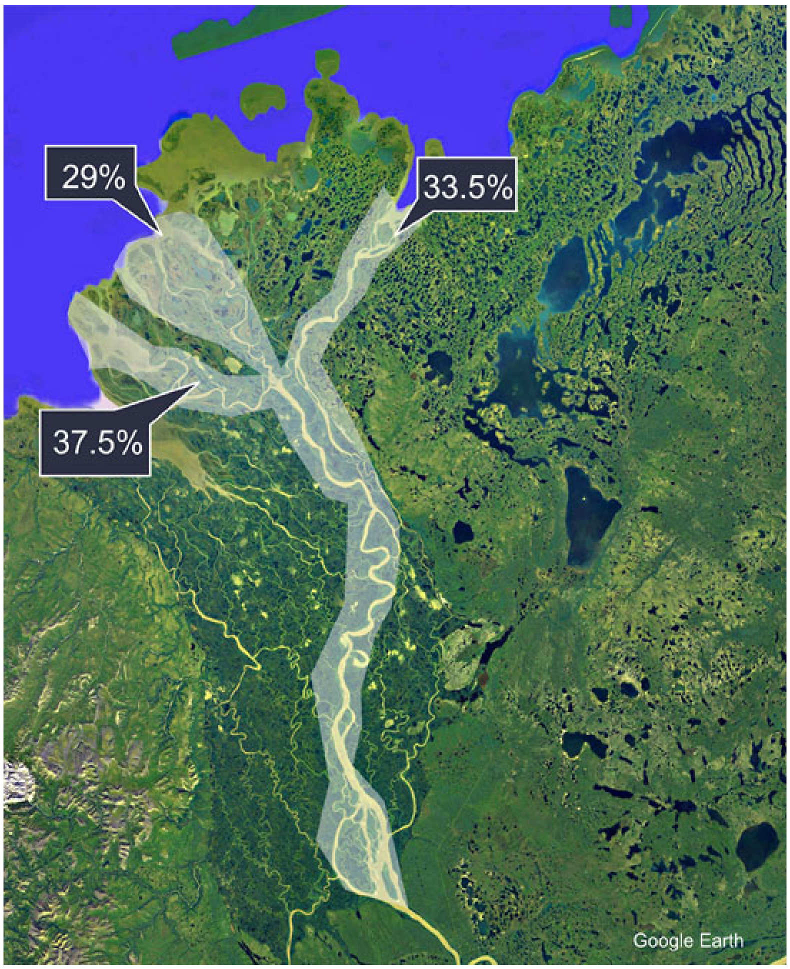


SOURCE: Lin 2019, MARES, pers. comm.

Figure 7-20 Ocean currents in the BRSEA Study Area.

7.2.3.2 Freshwater Runoff from Mackenzie River

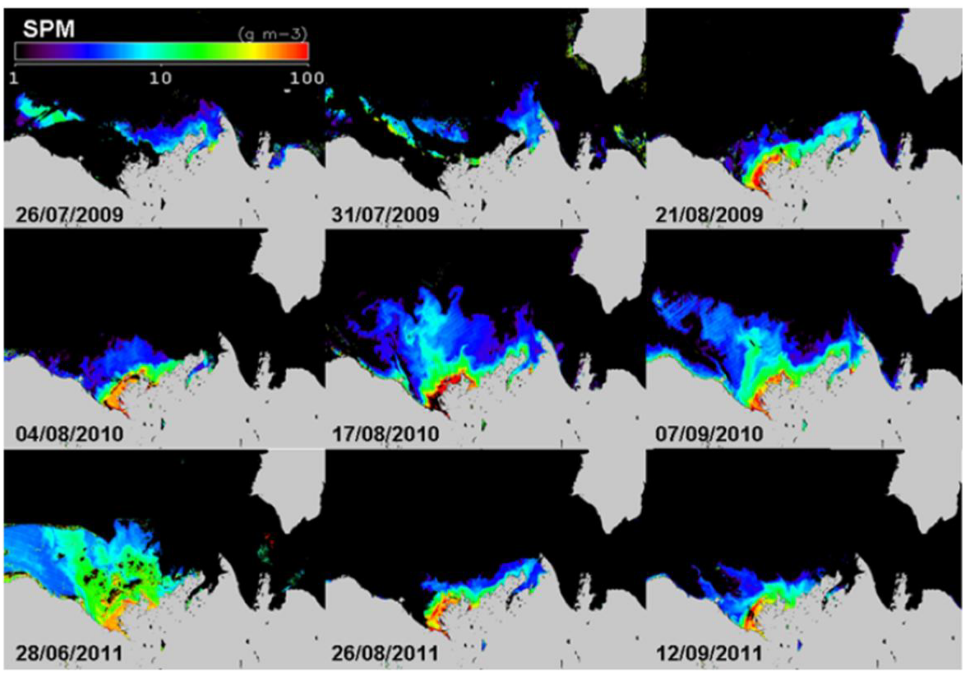
The Mackenzie River is the largest river flowing into the Arctic Ocean from North America. Approximately 90% of its discharge to the ocean is above Tsiigetchic, with most of the balance mostly from the inflowing Peel River (7%), and Arctic Red (2%) River (Emmerton et al. 2008). Discharge through the delta is distributed predominantly through three major routes (Figure 7-21).



SOURCE: Adapted from: Davies 1975

Figure 7-21 Mackenzie River discharge distributions

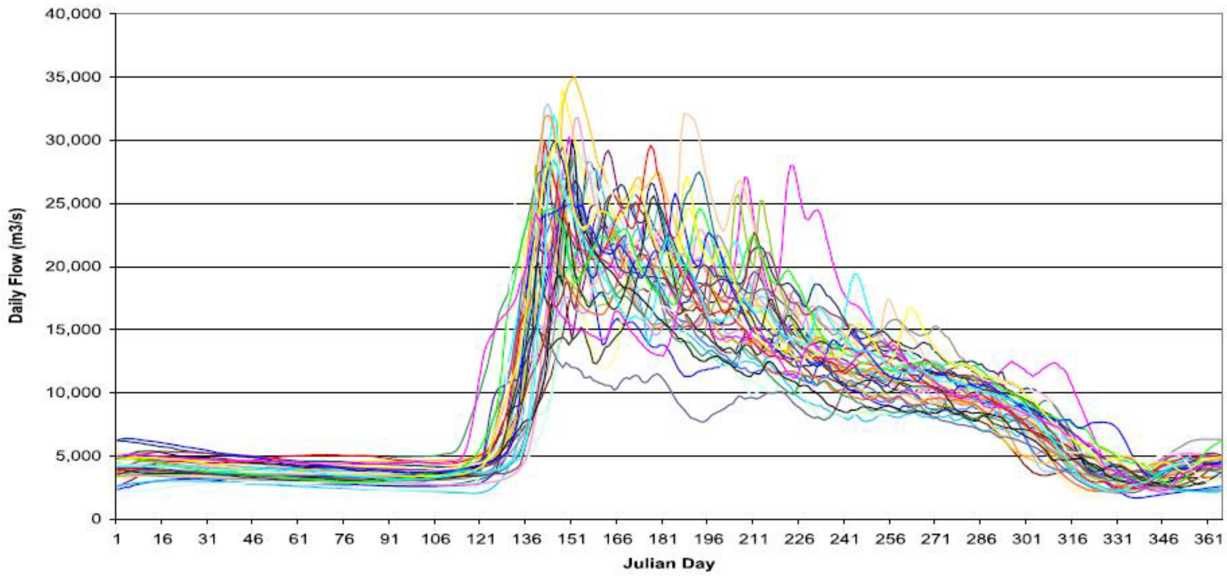
The Mackenzie River influences the BRSEA Study Area according to the season. During winter (Dec – April), river discharge is low (cold season baseflows); however, the accumulation of discharge over five months creates a freshwater reservoir under the landfast ice cover since there is no transport onto the middle and outer shelf and slope. The spring breakup (May – early July) represents a very important and dynamic period where a large volume of freshwater is released into the Beaufort Sea. The freshwater released is a combination of the very large river discharges at this time of year (e.g., spring freshet) combined with the release of inshore water that was trapped beneath the landfast ice. River discharges gradually decrease through the summer months, corresponding to the Open Water Season (July – October). Daily river discharges may be highly variable, and the freshwater river plume is strongly controlled by wind forcing. River discharge rates fall off into the autumn months (October – November), and sea ice formation reduces wind-forcing of the plume. Remote sensing permits mapping of the river plume extent during summer months; however, this becomes increasingly difficult as sea ice formation takes place (Figure 7-22).



SOURCE: Doxaran et al. 2012

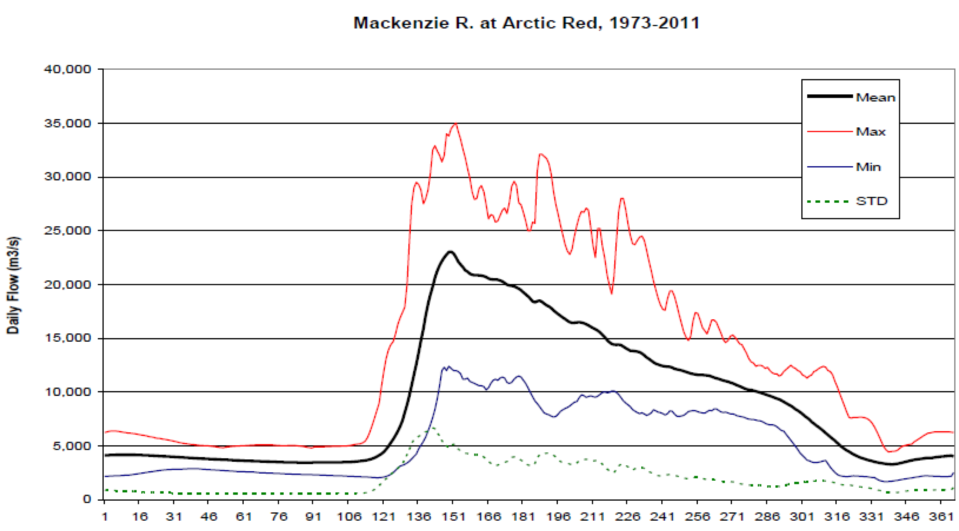
Figure 7-22 June – September ocean colour derived using MODIS imagery

The Mackenzie River flow regime is changing; over the past four decades the flow regime has been affected by an advance of snowmelt peak timing by several days, a decrease in maximum spring flows by about 3000 m^3/s, and a weaker rise in cold season base flows (Yang et al. 2015) (Figure 7-23). Daily maximum, minimum, mean flows, and standard deviations are presented for 1973 – 2011 in Figure 7-24.



SOURCE: Yang et al. 2015

Figure 7-23 Mackenzie River daily discharges for 1973 – 2011

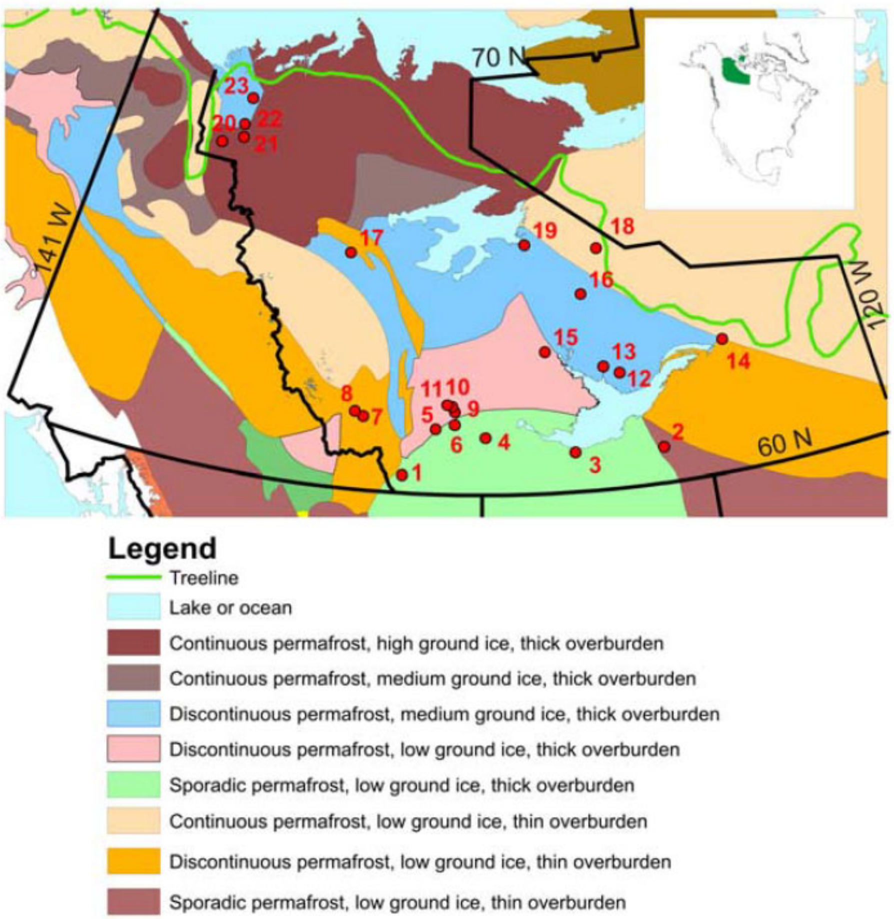


SOURCE: Yang et al. 2015

Figure 7-24 Mackenzie River daily max, min, mean flows, and standard deviation during 1973 – 2011

During 1973 – 1998 period, the start of the spring freshet in the Mackenzie Basin (British Columbia, Alberta, and Northwest Territories) has trended 2.7 days earlier per decade (Woo and Thorne 2003). This is consistent with increasing spring temperatures and the resulting earlier spring snowmelt in the basin (e.g., DeBeer et al. 2016), as well as trends in the seasonal timing of peak streamflow in Canada (Bonsal et al. 2019). Over the past several decades, spring peak streamflow following snowmelt has trended towards earlier spring flows, along with increased winter flows, particularly for the Mackenzie River basin (Bonsal et al. 2019).

Another key driver of seasonal water volume in the Mackenzie River is the availability of baseflow. Based on annual river flow at 23 river gauges in the Mackenzie River Basin (Figure 7-25; Table 7-10), winter base flow has increased significantly ($p < 0.05$) (0.5 – 271.6% /yr) in parts of the Mackenzie Basin due to enhanced water infiltration from permafrost thawing due to climate warming (St. Jacques and Sauchyn 2009).



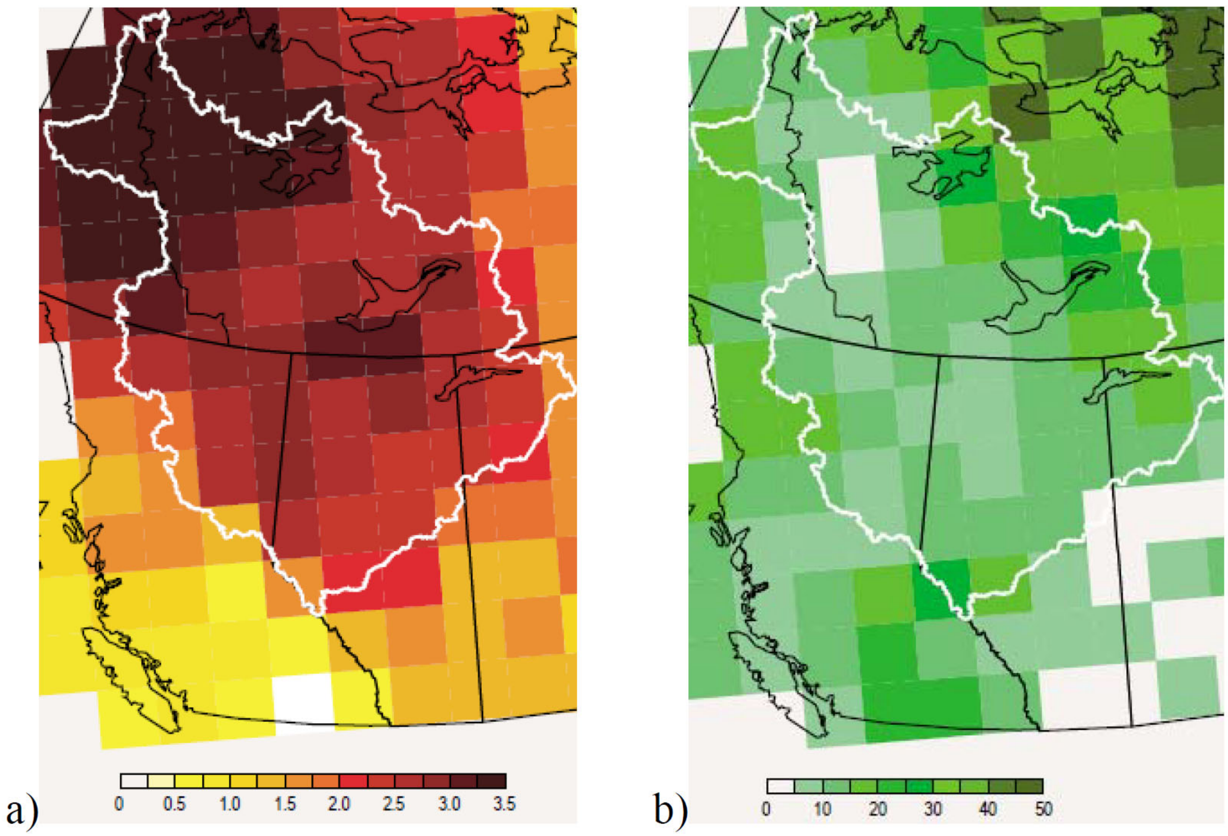
SOURCE: Adapted from St. Jacques and Sauchyn 2009

Figure 7-25 Map of the 23 river gauges and permafrost extent and type, ground ice content, and overburden thicknesses for the Northwest Territories.

Table 7-10 Changes in winter baseflow trends and relative contributions to changes in annual river flow at selected river gauges (as shown in Figure 7-26) in the Mackenzie River Basin.

Streamflow Station Name	Map ID	Period of Record	Winter Baseflow			Annual River Flow			Baseflow Contribution (%)
			Mean (m^3/s)	Total Change over Period of Record (%)	Average Change / yr (%)	Mean (m^3/s)	Total Change over Period of Record (%)	Average Change / yr (%)	
Liard River at Ford Liard	1	1966-2007	351.4	29.5	0.7	1946.5	7.5	0.2	18.1
Liard River near the mouth	9	1973-2007	477.2	31.5	0.9	2488.6	6.7	0.2	19.2
Mackenzie River at Fort Simpson	10	1965-2007	2777.4	30.4	0.7	6864.0	7.9	0.2	40.5
Mackenzie River at Norman Wells	17	1966-2007	3404.5	21.3	0.5	8512.6	0.3	0.006	40.0
Peel River above Fort McPherson	20	1975-2007	92.3	60.9	1.9	692.0	-3.4	-0.1	13.3
Mackenzie River at Red River	21	1973-2007	3740.2	26.3	0.8	9094.2	3.5	0.1	41.1
Mackenzie River at Inuvik	23	1973-2007	25.7	157.0	4.5	137.0	15.3	0.5	18.8
SOURCE: adapted from St. Jacques and Sauchyn 2009									

Yip et al. (2012) examined changes in the hydrologic cycle in the Mackenzie River Basin in northern Canada focusing on temperature, precipitation, runoff, evapotranspiration and freshwater storage[43]. During 1950 – 1998, there was a regional pattern of warming temperatures (+2.0 – 3.5°C) and increasing precipitation (+5 – 20 mm/yr) (Figure 7-26), as well as a warming trend on an annual and monthly basis, except for October.



SOURCE: Adapted from Yip et al. 2012

Figure 7-26 Trends in (a) Maximum daily air temperatures (°C) in winter and (b) increase in precipitation over the Mackenzie River Basin n (mm/yr).

43 WATFLOOD, a distributed hydrological model, was employed with two different climate input data sets: Environment Canada gridded observed data and the European Centre for Medium-range Weather Forecasting (ECMWF) reanalysis data (ERA-40).

7.2.3.3 Water Column Structure

7.2.3.3.1 Salinity

Salinity appears to be changing in different layers of the Beaufort Sea. Using measurements of salinity and temperature through the water column for 1979 to 2012, Peralta-Ferriz and Woodgate (2015) found that salinity within the mixed layer in the Beaufort Sea during November to May has been decreasing at a rate of 0.04 ± 0.01 psu/yr. In the summer months (June to September), the mixed layer has been getting saltier with rates of 0.29 ± 0.05 psu/yr in the presence of sea ice, and 0.20 ± 0.02 psu /yr when ice-free. They suggested that the salinification trend in summer may be due to changes in the fate of freshwater from the Mackenzie River. The changes in salinity may also be related to changes in the Beaufort Gyre and associated effects on upwelling (i.e., Ekman pumping) and freshwater distributions within the Arctic (Proshutinsky et al. 2009).

7.2.3.3.2 Stratification and Mixed Layer Depth

Within in the BRSEA Study Area, the depth of the mixed layer differs by season and can vary over small spatial and temporal scales (Peralta-Ferriz and Woodgate 2015). Winter mixed layer depths tend to be deeper and more variable than summer mixed layer depths due to increased mixing associated with wind forcing and brine rejection from ice formation during winter. However, based on hydrographic profiles from 1979 to 2012, the mixed layer depth in the Southern Beaufort Sea during November to May has been decreasing by 0.20 ± 0.06 m / year (Peralta-Ferriz and Woodgate 2015). In the summer months, the mixed layer depth has been increasing at a rate of 0.33 ± 0.10 m / year in the presence of ice cover, and a rate of 0.11 ± 0.03 m / year in ice-free conditions. The deepening of the mixed layer in the summers in the Southern Beaufort Sea is attributed due to the salinification of the mixed layer, leading to reduced stratification.

7.2.3.3.3 pH and Alkalinity

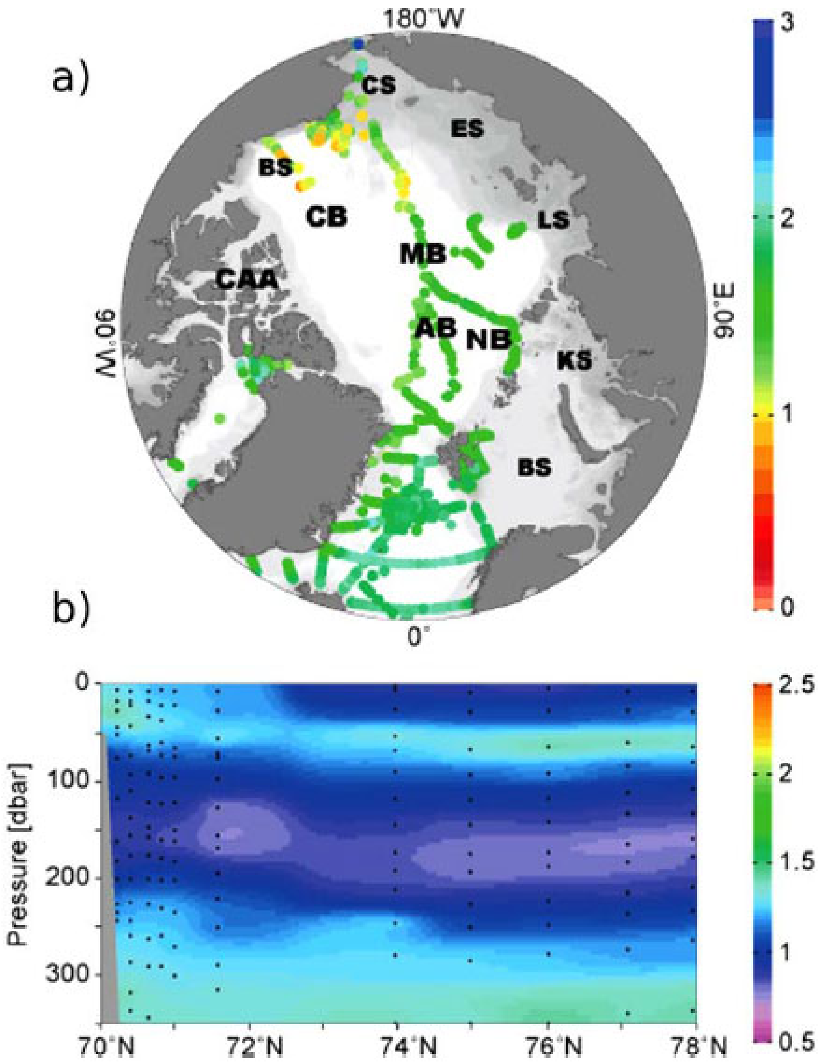
As human activity has increased globally, the carbon dioxide content in the atmosphere and carbon dioxide concentrations within the surface waters of the oceans has increased. This extra carbon dioxide can form carbonic acid which can break down into hydrogen, bicarbonate and carbonate ions. This process increases the acidity of the ocean by decreasing the pH and is referred to as ocean acidification. It reduces the concentration (saturation state) of carbonate in the water, which is important for organisms such as shellfish to build shells (calcium carbonate ($CaCO_3$)).

There are several forms of carbonate, and their calcium carbonate saturation state is quantified through a parameter known as omega[44] (Ωar) (University of Hawaii 2019). As saturation levels drop, it becomes more difficult for organisms with shells to grow and maintain their shells (NOAA 2019). Aragonite, an important crystallized form of calcium that is formed naturally in shells, has a saturation level 1.5 times that of the calcite form, making it more susceptible to undersaturation (Steiner et al. 2014) thus further

[44] Ω = [Ca2+] x [CO3-2] / [CaCO3]

stressing marine organisms which use this form of carbonate. Values of omega for calcium carbonate less than 1.0 indicate undersaturation where calcium carbonate skeletons and shells are increasingly subject to dissolution.

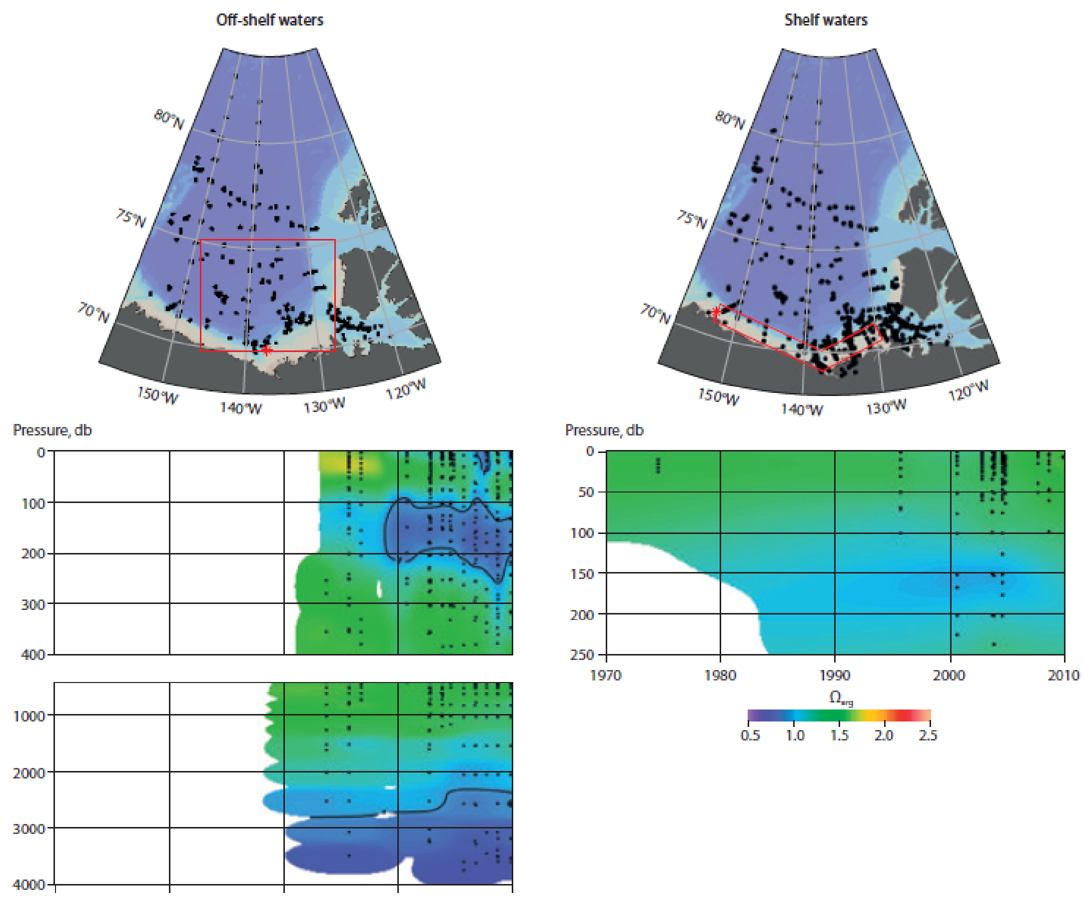
Within Canada, the Arctic has the fastest rate of acidification (Greenan et al. 2018); this is likely due to processes such as increased air-sea interactions due to reduced ice cover (Steiner et al. 2014). During 1986-2005, surface saturation levels for aragonite for most of the Arctic were 1-1.4, but with some values below 1 within the BRSEA Study Area (Figure 7-27; Steiner et al. 2014).



SOURCE: From Steiner et al. (2014).

Figure 7-27 Surface aragonite saturation levels for 1986-2005 (top). Profiles of aragonite saturation levels for August 2011 along 140 ˚W (bottom).

Spatial averages have shown how the reduction in saturation levels have become persistent at the upper halocline, from 100 – 200 m depth, starting in the late 1990's (Figure 7-28). The upper undersaturated layer has temperature/salinity properties consistent with Pacific water origin. The Pacific water has generally been prone to low alkalinities as it is old (i.e., a long duration since it was at the surface and could be ventilated) with high CO_2 levels, and has been exposed to decay of organic matter from production upstream in the Bering and Chukchi Seas, The saturation horizon had been trending upward until the mid-2000's, when it jumped sharply in the mid-2000's (Figure 7-28). Mol et al (2018) observed undersaturated waters on the shelf with a calcium carbonate saturation state (Ωar) as small as 0.83. The observations are limited to depths in excess of 20 m. Many factors can affect the alkalinity values observed on the Beaufort Shelf, or even on small spatial scales; these include upwelling of Pacific water onto the shelf, high productivity over the summer, coastal erosion, organic carbon from riverine sources, or the release of high CO_2 concentration water during ice formation are among (Bellerby et al, 2018).



NOTE: Spatial averages are from within the red boxes shown in the top panels. The black line in the lower left panel indicates unit saturation.

SOURCE: from Bellerby et al.(2018)

Figure 7-28 Spatially averaged aragonite saturation profiles versus time (x-axis) for deep water, depth > 200 m (left) and shelf water (right).

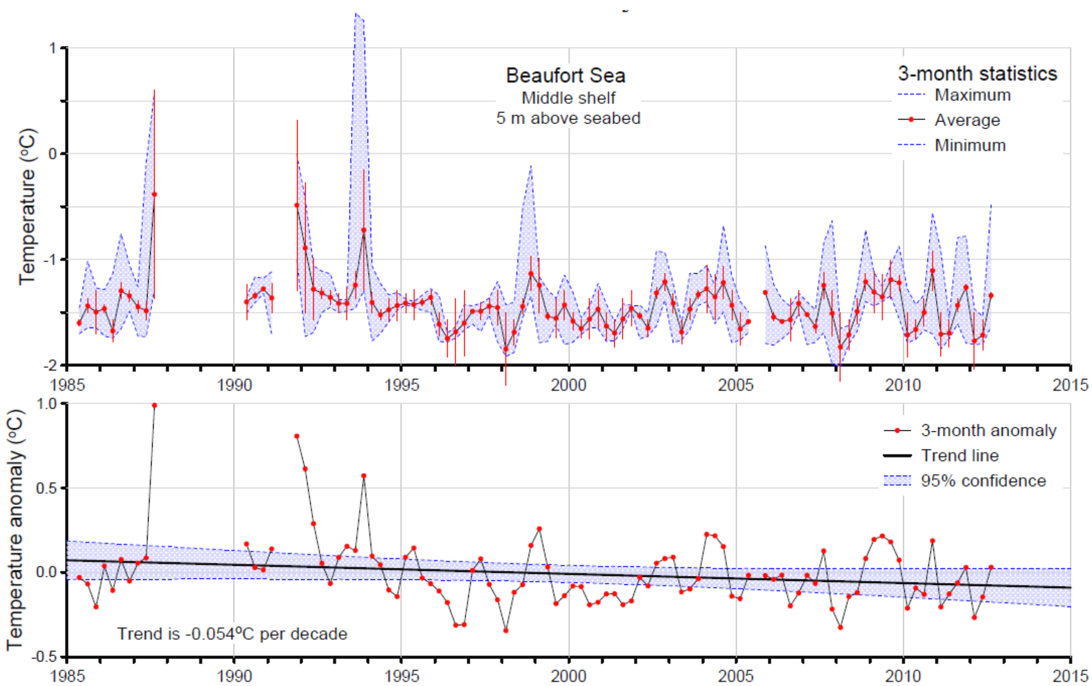
7.2.3.3.4 Dissolved Oxygen

Global trends in increasing surface stratification, reduced ocean ventilation and increasing temperatures have reduced the solubility of dissolved oxygen. Reduced oxygen solubility can lead to hypoxic or low oxygen content waters that affect marine biota such as fish and plankton. On a global scale, the world's oceans have declined in oxygen content by 2% since the 1960s (Schmidtko et al. 2017). The loss of dissolved oxygen in the Arctic has exceeded the global mean; losses in the Arctic Ocean represent 3.1% of the global losses, but the Arctic accounts for only 1.2% of the world's oceanic volume (Schmidtko et al. 2017).

7.2.3.4 Ocean Temperature and Heat Content

7.2.3.4.1 Near-Bottom Layer

The longest record of near-bottom ocean temperature within the BRSEA Study Area comes from 5 m above the seabed in the middle of the Beaufort shelf within 50 m of water and spans from 1985 to 2013 (Steiner et al. 2015) (Figure 7-29). The record shows substantial interannual variability in temperatures, but no significant long-term trend.



NOTE: The upper panel shows quarterly means and the spread between the minimum and the maximum. The bottom panel illustrates the long-term trend, but which when error bars are added, is not significant.

Figure 7-29 Mid-Beaufort shelf temperature record from 1985-2013 at 5m above bottom within 50 m of water as per Steiner et al. (2015).

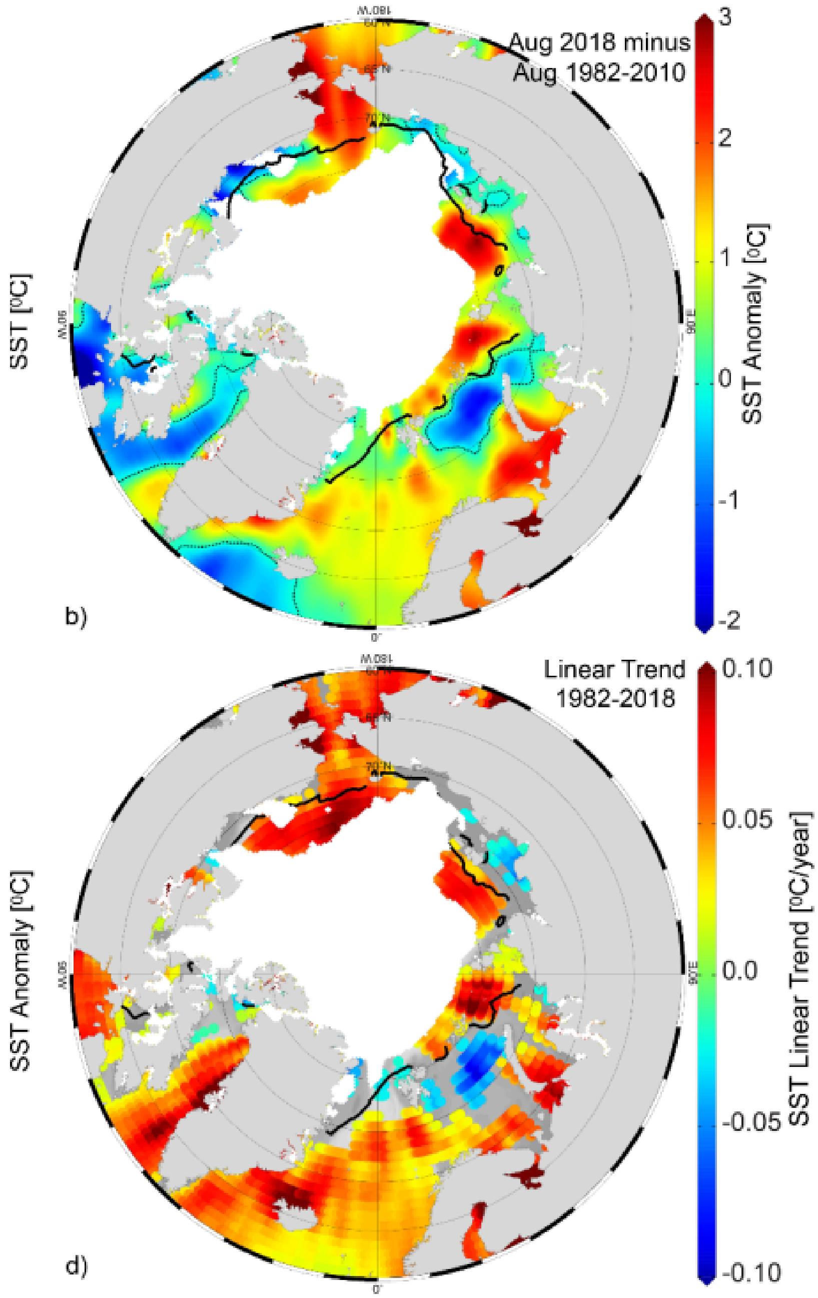
7.2.3.4.2 Mid-Water Layer Temperature Maximum

Water enters the Arctic Ocean from the Chukchi Sea. The increased density of this water due to the saltiness, relative to the Beaufort surface waters, causes it to reside between 50 and 150 m depth within the Beaufort Gyre. Reductions in ice cover in the Chukchi have allowed increased solar heating of these surface waters which are later transported to deeper water in the Beaufort. Between 1987 and 2017, the heat content that these Chukchi waters bring into the Beaufort Gyre has more than doubled, from $2x10^8 J/m^2$ to over $4x10^8 J/m^2$ (Timmermans et al. 2018) as a result of increased temperatures within the mid-water layer, as well as a thickening of this layer. Winter storms have not mixed through this layer, meaning this source of heat within the Beaufort Gyre remains in the ocean through the winter.

In 2017, observations of 11˚C temperatures in parts of the Chukchi Sea (Richter-Menge et al. 2018) have raised the question whether further warming to 13˚C within the Chukchi Sea could further decrease the density of these waters to the point of shutting down the spreading and mixing of the high vertical salinity gradient within the Beaufort Gyre (i.e., ventilation of the halocline) (Timmermans et al. 2018).

7.2.3.4.3 Sea Surface Layer Temperatures

TLK and western science are showing that Sea Surface Temperatures (SST) in the BRSEA Study Area are increasing. Observations from the Indigenous coastal community of Sachs Harbour have noted that the water temperatures seem to be getting warmer (IMG Golder and Golder Associates 2011c: 18). Based on SST information for 1982-2018 (Figure 7-30), a linear upward trend in SST in excess of 0.05˚C/year was detected offshore; a similar trend was not observed for the near-shore (at a 95% confidence interval) (Timmermans and Ladd 2018). A decreasing trend in SST of around -0.03˚C/year was observed off of South Banks Island (Figure 7-30). Analyses by the Arctic Monitoring and Assessment Program for 2017 show a similar pattern, but with the warming in the nearshore of the Southern Beaufort being more evident (AMAP 2019). The one exception was in 2018, when persistent northerly winds through August kept the sea ice from leaving the southern BRSEA Study Area; the presence of ice resulted in SSTs that were below the 1982-2010 average (Timmermans and Ladd 2018).



NOTE: White denotes the 2018 mean sea ice extent. The dotted black contour indicates zero trend. The solid black line indicates the mean ice extent for 1982-2010. Grey in the linear trends indicates regions where a 95% confidence level for the trend could not be found.

SOURCE: As per Timmermans and Ladd (2018)

Figure 7-30 August 2018 SST anomaly (top). The linear trend in SST from 1982 to 2018 (bottom).

7.2.3.5 Waves

The declining Arctic Sea ice cover and associated increase in open water is affecting the wave characteristics in the southern BRSEA Study Area.

TLK holders in Sachs Harbour, Tuktoyaktuk, and Ulukhaktok have noted that they are seeing an "August Sea in June" (Asplin et al. 2019a). People in Tuktoyaktuk also have described more open water, including during winter, and sudden severe winds that may cause large waves (KAVIK-AXYS Inc. 2004b:18-34).

A number of studies have addressed trends in wave properties in the Beaufort Sea, and the wider Arctic Ocean. Both wind speeds and wave height are increasing, particularly during the Open Water Season (Asplin et al. 2019b).

Based on wind speeds and wave characteristics during the ice-free period of June–November over the period 1985–2005, Swail et al. (2007) estimated the 99th percentile values for winds and waves for September as 13 to 17 m/s for wind with lower values towards the east, and wave heights increasing from 0 to about 3.5 m parallel to the coast and up to 4.5 m close to the shelf edge. Liu et al. (2016) estimated increases in the 99th percentile wind (at 10 m above the surface) of +0.28m/s/decade. Maximum 25-year return wind speed extremes were estimated to 18–24 m/s with lower values towards the east (Swail et al. 2007). Maximum individual wave height extremes ranged from 4 m close to the coast to 14 m close to the shelf edge.

Trends in waves over the 1970 – 2013 period, including some recent years of notable decreases in summer sea ice cover, show that significant wave heights (H_s) have increased over the BRSEA Study Area westward to the northern Chukchi Sea in September (Wang et al. 2015). Mean significant wave heights have increased at a rate of 3% to 8% per decade in July –September within the Beaufort–Chukchi–Siberian Seas region.

Due to the limited fetch conditions early in the melt season or when large volumes of ice remain present during summer months, waves do not currently fully develop during storms (Lintern et al. 2013). However, modeling has shown that by extending the fetch by as little as 100 km (i.e., ice retreat), wave heights at the coast may increase by as much as 20 cm.

There is an implicit trend and evidence for increasing wave energy along coastal areas in the BRSEA Study Area associated with open water (Thomson et al. 2016). Based on wave model hindcasts from four selected years spanning recent reduced summer sea ice conditions, larger waves and longer peak wave periods (T_P) are more common in years with a longer Open Water Season. Satellite altimeter estimates of wave energy support these trends (Thomson et al. 2016).

7.2.3.6 Water Quality

Concerns about water quality have been raised in many communities, including Sachs Harbour (IMG Golder and Golder Associates 2011c: 18) and Ulukhaktok (IMG Golder and Golder Associates 2011d: 15). A specific example was raised by a resident who used to live along one of the water channels east of Ulukhaktok who reported how the water there has become murkier over time (IMG Golder and Golder Associates 2011scod: 15).

The Mackenzie River has one of the most important impacts on the water quality of the BRSEA Study Area since it is the source of about 125-128 Mt of sediment per year (Hill et al. 1991; Carson et al. 1998). This is two orders of magnitude larger than contributions from other rivers (1.5 Mt/yr) and coastal erosion (5.6 Mt/yr) (Hill et al. 1991). Observations from the last decade indicate an increase of over 50% in sediment contributions to the Beaufort Sea by the Mackenzie River (Doxaran et al. 2015). Due to trends in increasing precipitation and air temperatures (Section 7.2.2), sediment contributions are expected to continue increasing in the next fifty years (CliC et al. 2016; Weege 2016).

The Mackenzie River delivers most of its sediment load during the spring freshet, from May into early June (Hill et al. 1991). The freshet starts prior to breakup of the landfast ice. Some of the discharge floods the surface of the ice, but much of the discharge exits from the delta region through channels below the fast ice (Hill et al. 1991). In the Open Water Season, 80% of the sediment contributions are made through the river plume (Osborne and Forest 2016). Concentrations of 100 mg/L are generally found in the Mackenzie River distributaries, but about half the sediment load is deposited within the Mackenzie River delta (Hill et al. 1991). Concentrations drop substantially between the 5 and 10 m water depths in the Beaufort Sea (Hill et al. 1991). Under easterly winds, the plume tends to be driven along the Yukon coast, but under westerly winds it is driven east along the Tuktoyaktuk Peninsula (Figure 7-20).

About 85 Mt of the 125 Mt of sediment load brought by the Mackenzie River leaves the Mackenzie Delta System (Carson et al. 1999). About 80% of the sediments entering the shelf is deposited on the shelf, and of the 20% reaching the continental slope, 10% continues onto the Canada Basin[45] (Osborne and Forest 2016).

Wind is an important factor in some of the mechanisms that drive suspended sediment concentrations and water quality. Under northwesterly winds, downwelling conditions are generated. The resultant offshore flows at depth, especially if combined with locally driven waves, can resuspend sediments (Héquette et al. 2001; O'Brien et al. 2006; Carmack and Macdonald 2002). Conversely, upwelling conditions can also generate currents at depth, but in the onshore direction (Williams et al. 2008). If the currents are fast enough, they may resuspend sediments; however, most resuspension events are associated with westerly winds.

[45] Based on modeling of sediment pathways along the Mackenzie shelf to the continental slope using values from the literature, the 2009-2011 ArcticNet-Industry Partnership and the 2011-2015 Beaufort Regional Environmental Assessment.

Sediment transport (flux) can occur during the Ice Season (e.g., November to May) in deeper water (i.e., 180 m depth), but less so at shallower depths (i.e., 80 m)[46] (Forest et al. 2015). Almost all sediment flux events were preceded by easterly winds which led to partial clearing of sea ice (e.g., polynyas). The winds then switch to westerly winds which starts downwelling flow and near-bottom currents capable of resuspending sediments. These winds also favour the shelf break jet already discussed in Section 7.2.3.1 (Figure 7-26) allowing for the creation of the mesoscale eddies. These eddies result in increased movement of suspended sediments, as well as resuspension of sediments.

Brine formation during ice growth is also believed to resuspend sediment (Forest et al. 2007). As the dense cold salty water is created, it sinks to the seabed and potentially cascades down the continental shelf, suspending and entraining sediment in its path. Flows driven by surface cooled brine reaching the seabed have been observed (Jackson et al. 2015). Experiments in a saltwater tank to model flows in a polynya have successfully resuspended sediments (Dethleft and Kempema 2007).

Over the past decade, increases in sediment export to the shelf has increased (Osborne and Forest 2016). More upwelling has extended the Mackenzie River plume further offshore to the northwest.

The Mackenzie River and delta are also natural sources of Polycyclic Aromatic Hydrocarbons (PAHs), a chemical found in coal, crude oil and gasoline. PAHs are widely distributed in the marine environment (CCME 1999, Yunker and MacDonald 1995). In the BRSEA Study Area, total PAH concentrations are highest near the Mackenzie River delta (mean = 980 ng/g) and the Mackenzie shelf (mean = 860 ng/g), then decrease slightly at the shelf edge at a depth of 200 m (mean = 500 ng/g), and decrease further offshore (mean = 400 ng/g) (Yunker et al. 1996, MacDonald et al. 2000). Most of the PAHs in the sediments of the Mackenzie shelf are supplied by the Mackenzie River (MacDonald et al. 2000). The inferred flux of PAHs from the Mackenzie River has been estimated as about 670 tonnes per year (AMAP 2010, Volume 2, Chapter 4).

The predominant source of the PAHs in the Mackenzie River and the Mackenzie shelf sediments are from natural sources within the Mackenzie drainage basin, including oil seeps (e.g., where the Mackenzie River and other watercourses cut through oil-bearing sediment layers) and runoff from peat sources (e.g., associated with decomposition of sphagnum and woody peat) (MacDonald et al. 2000, Yunker and MacDonald 1995, Nagy et al. 1986, Nagy et al. 1988). While PAHs from long range atmospheric transport of anthropogenic fossil fuel combustion products are not a major source to the sediments of the Mackenzie shelf, there is an indication that combustion PAHs may be present in sediment approximately 100 km from the mouth of the Mackenzie River (MacDonald et al. 2000).

[46] Based on sediment trap results from 2009 – 2015.

7.2.4 Sea Ice

Sea ice in the BRSEA Study Area is undergoing major changes in association with climate change and is exhibiting a great deal of natural variability, especially on seasonal and year-to-year (interannual) time scales (AMAP 2017). Virtually all the TLK holders from the six Inuvialuit communities in the ISR have observed profound changes in climate and sea ice conditions, particularly starting in the late 1980s, that have affected Inuvialuit travel and harvesting activities on sea ice. Ice floe edges and areas of open leads that were once predictable are no longer occurring in the same places from one year to the next or cannot be reached on snowmobile due to excessive rubbling of the sea ice. Hunters from Tuktoyaktuk have stated that since ~2000, multi-year sea ice has disappeared from coastal areas north of Tuktoyaktuk (Joint Secretariat 2015:189).

Some inter-community sea ice travel routes have been affected by the changing sea ice climatology. TLK holders from Sachs Harbour indicated that "…greater distances are now travelled in the winter both on land and on sea ice. The map shows how community members travel to harvest around most of the island each winter. ..there are numerous places where Sachs Harbour and Ulukhaktok travel routes intersect or overlap, specially routes travelling by skidoo. Both communities travel up the North West coast of Banks Island, along Prince of Wales Strait. Young community members in Sachs Harbour described having travelled part of the way across Amundsen Gulf and one day wanting to travel all the way to Ulukhaktok. It was noted that other community members had travelled that route before, but it had been some time since some had done it." (FJMC and IRC 2019b:127).

Key characteristics of sea ice that are important to physical and biological processes, and human activities include: areal extent, ice thickness and volume, timing of formation and break-up, ice motion, and landfast ice. These are summarized individually below.

7.2.4.1 Timing of Ice Break Up and Freeze Up

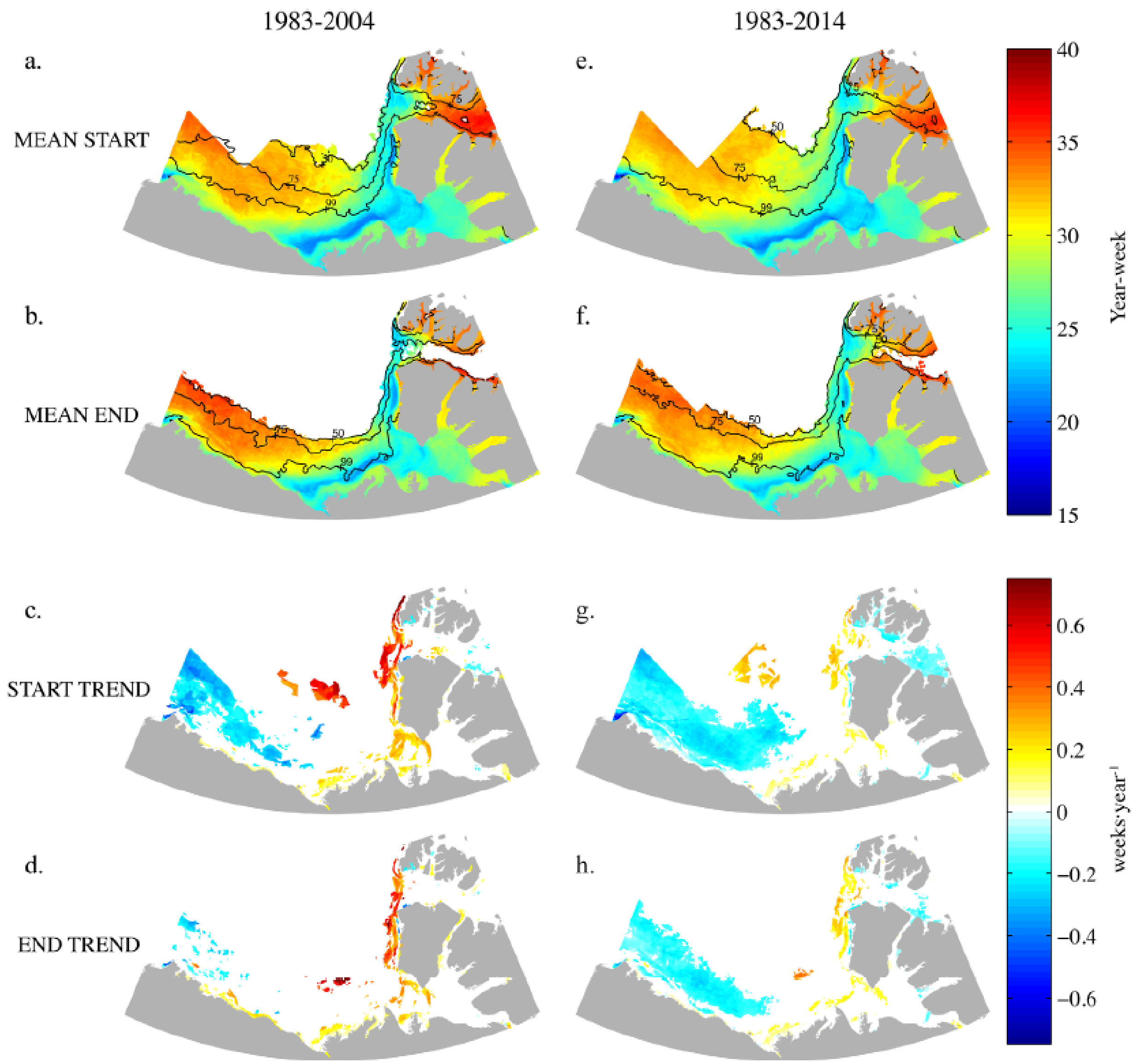
Changes in weather, water, and ice, including warmer temperatures in recent years, earlier break up of ice and later freeze up of ice were identified by TLK holders (IMG Golder and Golder Associates. 2011c: 21). Freeze up, which usually occurred in October, now occurs in November. Inuvialuit in Tuktoyaktuk have also noted that ice break-up is happening earlier, and freeze-up has been occurring later (IMG Golder and Golder Associates 2014: 7). Residents of all six Inuvialuit communities are wary of travelling on young sea ice, and delayed freeze-up is affecting the timing of their ability to safely operate snow machines (Joint Secretariat 2015:162-163). As well, earlier snowfalls insulate new ice and delay freeze up. "People have to had to change their travel patterns because of an increase in rain, which sits on top of sea ice and 'rots' it, rendering the ice potentially unsafe for travel" (IMG Golder and Golder Associates 2011f: 17-18).

Breakup in this region typically begins around 15 May within the Cape Bathurst flaw lead polynya (Figure 7-31). Breakup occurs next in the Amundsen Gulf and the entrance to M'Clure Strait (mid-June), followed by the nearshore landfast sea ice along the continental coast (Galley et al. 2012). Landfast sea ice in the southern BRSEA Study Area begins to breakup about the same time as the periphery of mobile, old pack ice. The Cape Bathurst flaw lead polynya complex is the first to reach complete breakup, typically in two weeks, indicating that breakup is controlled predominantly by sea ice dynamics (Steele and Ermold 2015).

Based on data for 1983-2014, there was a trend towards later breakup end dates across the Tuktoyaktuk Peninsula, between Cape Bathurst and Sachs Harbour, and along the west coast of Banks Island over this 32-year period (Galley et al. 2016) (Figure 7-32). These trends correspond with the reductions in mean old ice and increases in first-year ice concentrations (Figure 7-32). In contrast, the timing of the mean end of breakup occurred 2 weeks earlier over the same time frame in the offshore areas of the Mackenzie shelf region, and about 1 week earlier in the mouth of the Amundsen Gulf.

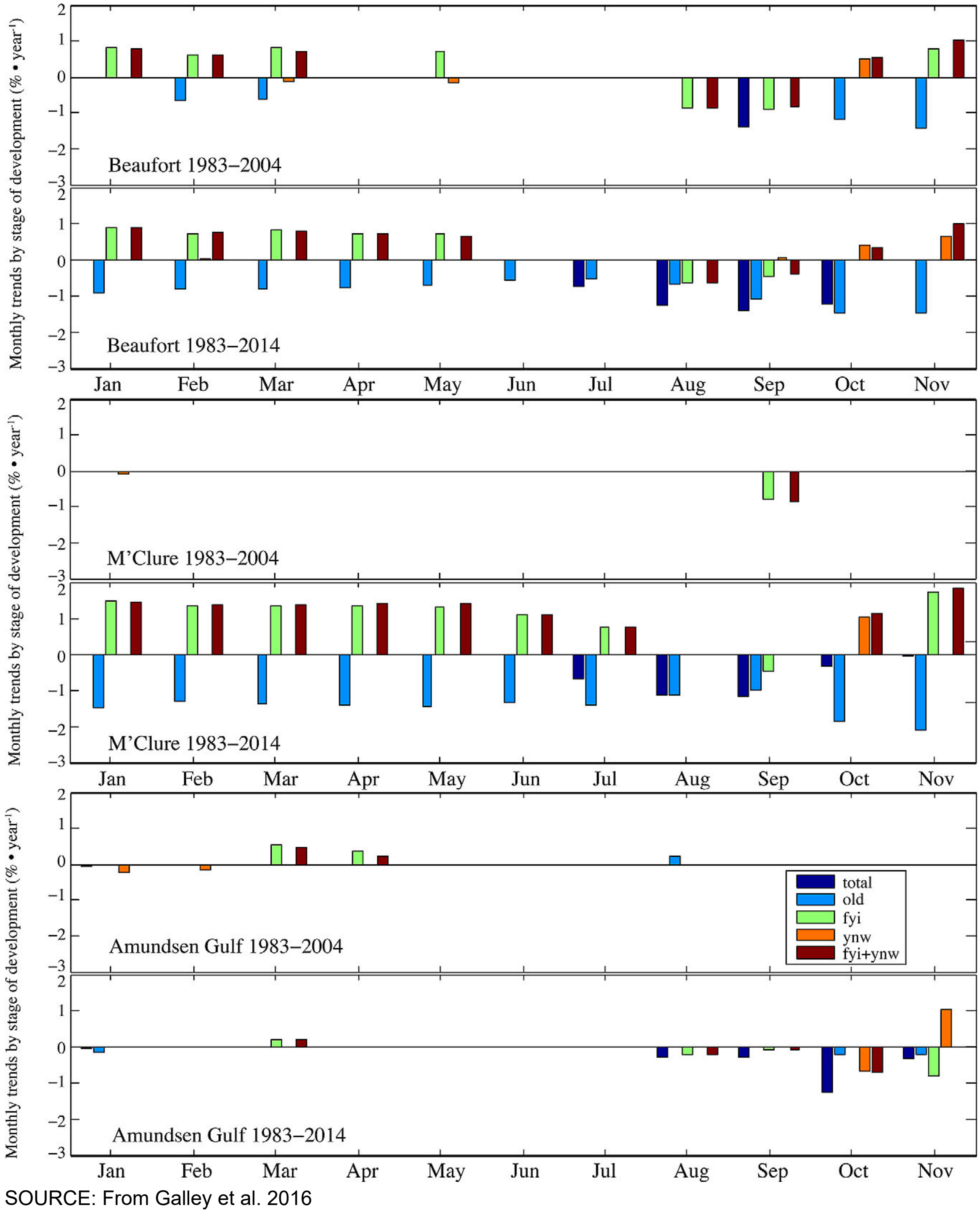
Between 1983 and 2014, the end of open water (start of freeze up) occurs earliest in the northern reaches of the study region, specifically in the M'Clure Strait and the northern BRSEA Study Area, where the mean summer ice concentrations were highest and composed almost entirely of old sea ice (Figure 7-32).

As a result of changes in freeze-up and break-up dates, linear trends in the duration of the Open Water Season have been identified (Galley et al. 2016). With the addition of 2005 – 2014 data to the analysis, the Open Water Season in the study region has been extended by up to 3 weeks / decade for the period of 1983 – 2014 (Figure 7-32). Summer ice-free areas of the study region reached freeze up one week later on average between 1983 and 2014 compared to 1983–2004, except along the west coast of Banks Island where the mean 1983–2014 start of freeze up occurred up to 5 weeks later than in 1983–2004 (Figure 7-32). The summer mean ice-free areas (Figure 7-32), have experienced significant ($p < 0.10$) trends toward later freeze up start date on the order of 1–2 weeks / decade over the period 1983–2014; these include ice-free areas in the Alaskan Beaufort, offshore of the mouth of the Mackenzie River, the mouth of Amundsen Gulf, Amundsen Gulf, off Banks Island, and the east side of Prince Alfred Island) (Galley et al. 2016).



SOURCE: From Galley et al. 2016.

Figure 7-31 Mean year-week of (a, e) freeze up start and (b, f) freeze-up end for the 1983–2004 and 1983–2014 time series. Trends in the year-week of (c, g) freeze up start and (d, h) freeze up end through the two time series. Trend data only presented at 90% significance level ($p < 0.10$).



SOURCE: From Galley et al. 2016

Figure 7-32 Trends (% yr $^{-1}$) in monthly mean sea ice concentration by stage of development in the BRSEA Study Area from 1983 to 2004 and from 1983 to 2014. Trend data are presented at the 90% significance level ($p < 0.10$).

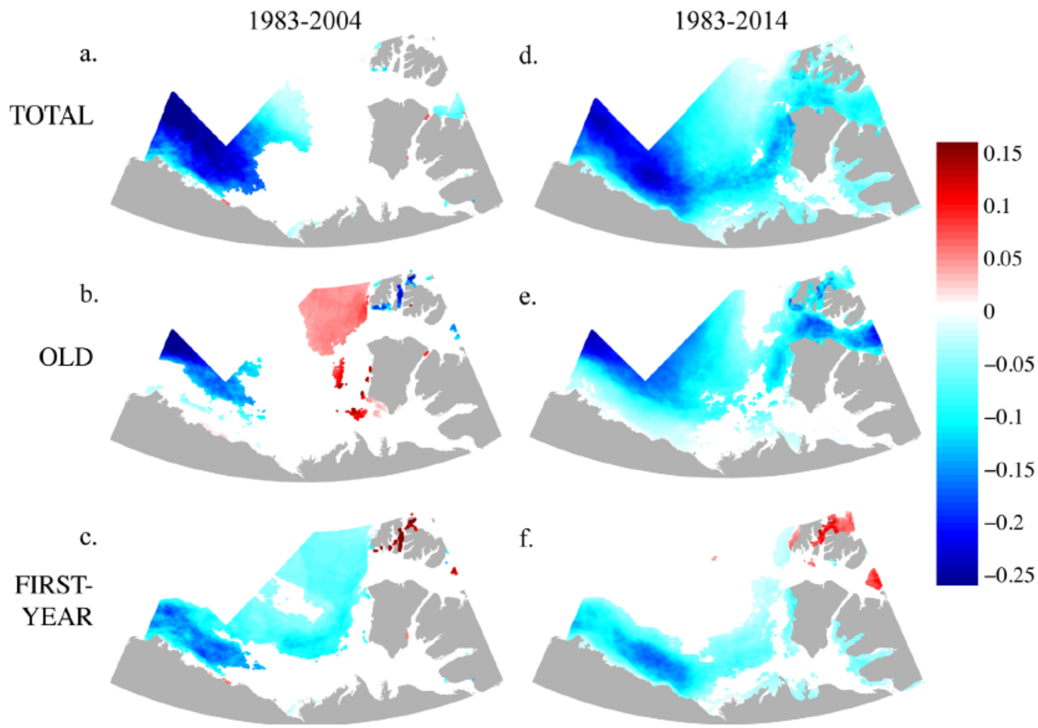
7.2.4.2 Areal Extent and Concentrations of Sea Ice

The areal extent and concentration of ice cover has changed in the BRSEA Study Area, particularly along the southern BRSEA Study Area coastline.

A number of Tuktoyaktuk residents have noted that they are seeing less ice now than in the past. The presence of large pieces of multiyear sea ice running ashore near town all summer long in the 1960s was attributed to a much colder climate (IMG Golder and Golder Associates 2014: 7). Community members from Paulatuk also noted that past sea ice conditions enabled travel patterns that typically put hunters from Paulatuk in sight of Nelson Head; however, since the 1980's, there has been more open water, and rubble ice which makes it harder to travel this far (IMG Golder and Golder Associates 2011b: 7). Floe edges and areas of open leads that were once fairly predictable and occurred in more or less the same places from one year to the next have changed or else cannot be reached on snowmobile due to excessive rubbling of the ice (Joint Secretariat 2015: 162-163). Community members in Sachs Harbour note that although everything depends on ice conditions during a given year, past ice conditions typically permitted dog races on the sea ice in early July, but now must take place earlier in the year if they are to continue (IMG Golder and Golder Associates 2011c: 17).

Between 1983 and 2014, there were statistically significant losses in total sea ice extent during July – October in the southern BRSEA Study Area (Galley et al. 2016). Declining trends in the extent of old sea ice also occurred from July – October. However, an increasing trend in first-year sea ice trend partially compensated for the loss of the old ice in July, as well as in October (Figure 7-33).

The periphery of the summer sea ice pack on the Mackenzie continental shelf and off Banks Island experienced large declines in first-year sea ice concentrations between 1983 – 2014. While there were no consistent changes in total sea ice concentrations in M'Clure Strait during January – June, or in November between 1983 – 2014; old ice concentrations declined monthly (Figure 7-33). As a result, the concentration of old sea ice is now significantly lower year-round and is being replaced by first-year sea ice outside the July – October melt season (Galley et al. 2016).



SOURCE: from Galley et al. 2016

Figure 7-33 Trends in mean summer sea ice concentrations for total, old, and first-year sea ice during (Left) 1983 – 2004 and (right) 1983 – 2014.

7.2.4.3 Sea Ice Thickness

The longest records of sea ice thickness anywhere in the Arctic come from measurements made in landfast ice (Polyakov et al. 2003; Brown and Cote 1992; Howell et al. 2016). Recent analyses suggest there has been a reduction in annual maximum ice thickness of around 25 cm (approximately 10% per year) at most locations in the Canadian Arctic Archipelago (Howell et al. 2016).

A TLK holder from Sachs Harbour noted a 40 cm decline in sea ice thickness over a four-year period during a recent community-based monitoring program, conducted with the HTC and the Aurora Research Institute on sea ice near Kellett Point (IMG Golder and Golder Associates 2011c: 19). Similar declines in sea ice thickness have been observed near Tuktoyaktuk. A hunter from Tuktoyaktuk started questioning past TLK of the local sea ice climate when he discovered the ice floe edge was only ~12 miles from the shoreline during winter 2015, and ice thicknesses were only about three and a half feet, where it should have been six to eight feet thick (Joint Secretariat 2015:10).

Sea ice thickness, and sea ice volume, have been decreasing in the deep Canada Basin waters within the BRSEA Study Area (Krishfield et al. 2014). However, the trend in the shallower continental slope waters of the BRSEA Study Area is much smaller as seen in 12 years of ice draft measurements from 1991 to 2003 which suggest only a slight thinning trend (0.07 m/decade) and high variability in the seasonal pack ice zone (Melling et al. 2005).

The thinning sea ice cover may be leading to increased development of pressure ridges and berms, particularly in coastal areas, and nearby Indigenous northern communities. The impacts of this process on hunting and travel have been noted by northern residents since there is now more rubble ice and this makes it tougher to hunt. "The winds and currents put pressure on the ice, and it piles up and makes it more difficult to travel". (Slavik 2010: 9). "Travel is not as safe" (IMG Golder and Golder Associates 2014: 7).

7.2.4.4 Sea Ice Motion

The stability of sea ice is important for the establishment of base camps for Inuvialuit community hunting expeditions onto mobile sea ice (e.g., Sachs Harbour), often for many days at a time unless they are day trips from coastal communities (Joint Secretariat 2015: 29-30).

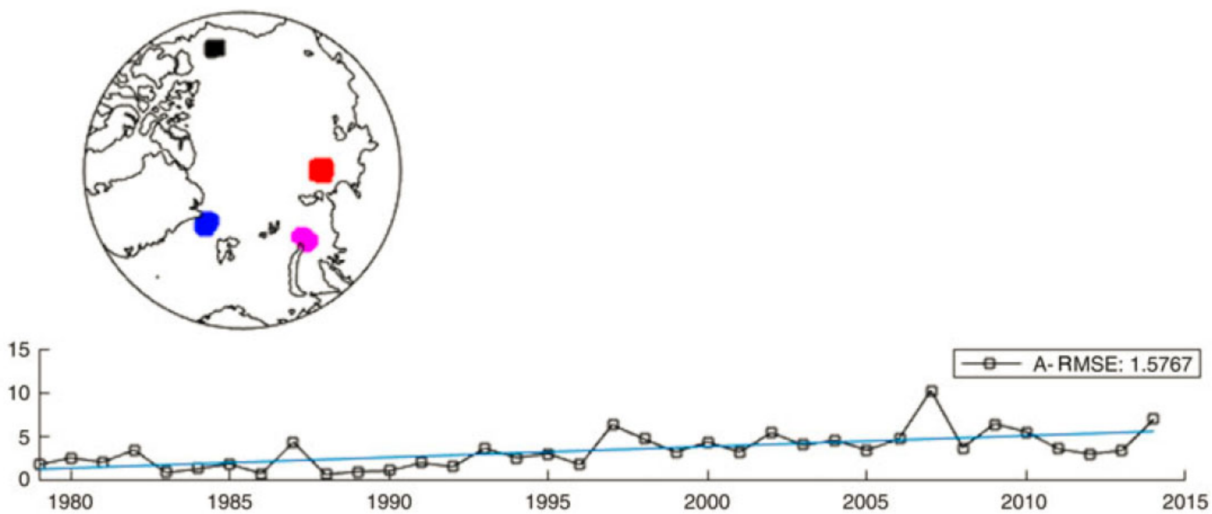
The stability of local sea ice cover is directly affected by regional-scale patterns of sea ice motion. The motion of sea ice is primarily a response to wind forcing associated with large scale atmospheric circulation patterns. However, other physical factors can play an important role. Ocean current forcing and changes in the material properties of sea ice such as contact of the sea ice keels with the seabed in shallow water areas can result in no ice motion (termed landfast ice), These processes also can change ice strength, associated with internal ice stress, which inhibits ice motion in areas where sea ice is very highly concentrated.

The presence of leads in the sea ice can also result in increased ice motion (Lewis and Hutchings 2019). Over the full Arctic Ocean, sea ice motion and deformation rates have generally been increasing over recent decades (Rampal et al. 2009). The increase in ice motion may be contributing to a commensurate increase in the spatial extent of favourable sea ice habitat (e.g., leads) for polar bears (dens in pressure ridges), and bearded seals (breathing holes along floe edges and cracks. Inuvialuit hunters from all six communities typically concentrate their efforts along these sea ice features (Joint Secretariat 2015:10).

The overall sea ice drift pattern in the BRSEA Study Area, exhibited on time scales of months and years, is characterized by the Beaufort Gyre, which is centred on the deeper waters of the Canada Basin. The gyre drives transport of ice between the coastal areas of Canada, Alaska and the Siberian Arctic across the Canada Basin and central Arctic to regions north of the Canadian Archipelago and returning to the coastal areas (Lewis and Hutchings 2019). The Beaufort Gyre ice motion is related to the Beaufort High anticyclonic atmospheric high-pressure system, which varies both seasonally (largest in spring) and over interannual time scales.

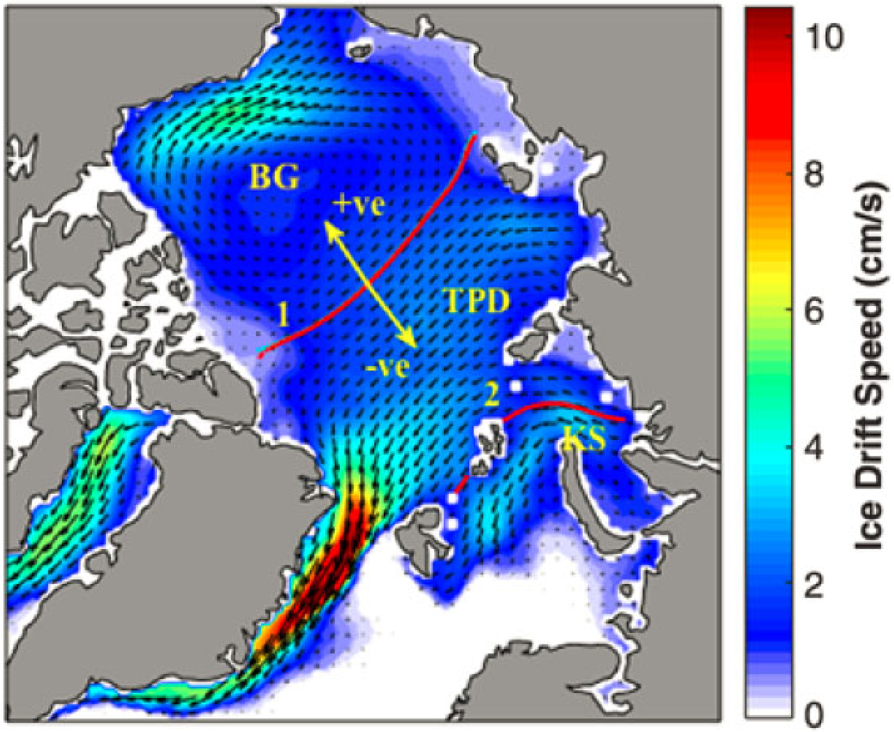
The southern Beaufort Sea has the largest sea ice velocities (Kaur et al. 2019; Lewis and Hutchings 2019; Kwok et al. 2013; Petty et al. 2016) in the western Arctic Ocean (Figure 7-34). Kwok et al. (2013) reported a trend towards strengthening of the Beaufort Gyre ice drifts over the years 1982-2009, in both winter and more prominently in summer. The multiplier that relates ice drift to wind speed exhibits an increase in the Beaufort Gyre which is attributed to reduced ice strength in this area resulting in thinning and less concentrated sea ice cover (Figure 7-35). The trend toward increasing winter sea ice drift speeds in the Beaufort Gyre within the BRSEA Study Area is clearly seen in Figure 7-34 with speeds increasing from about 2 cm/s in the early 1980s to about 5 cm/s in the middle of the present decade.

During 1980-2013, anticyclonic ice motion has been increasing with the largest increases occurring in autumn, causing an increasing export of ice out of the southern BRSEA Study Area (Petty et al. 2016). Changes in wind forcing may be contributing to this trend, but the winds increase only in the summer months and not in the fall or winter (Petty et al. 2016). The largest increase in ice motion, which occurs in autumn, appears to be related to reductions in ice strength, associated with lower ice concentrations and thinning of the sea ice, rather than due to any significant increases in wind forcing for autumn.



SOURCE: Kaur et al. 2019

Figure 7-34 Winter mean ice drift speed (cm/s) derived from passive microwave ice velocities in the BRSEA Study Area (black region in map above figure) from 1979-2015.



SOURCE: Kaur et al. 2019

Figure 7-35 Mean Arctic sea-ice drift patterns for 36 winter seasons overlain with mean winter sea ice drift speed (cm/s) from October 1979 to April 2015.

Inuvialuit community members cite the unpredictability of the increasingly thinner ice cover, and lack of stabilizing multi-year ice, grounded sea ice, and stronger wind forcing, which have increased the dangers associated with travel on the sea ice. TLK holders from Ulukhaktok have noted an increase in the frequency of strong easterly winds, thereby decreasing the predictability of the sea ice cover near their community (Joint Secretariat 2015: 44). Some community members in Aklavik have curtailed polar bear hunting beyond sight of land due to ice and safety issues; there is simply too much thin, unpredictable ice, rubbled ice or open water, especially in recent years (Joint Secretariat 2015: 45). This is a clear impact on traditional harvesting activities in the region, particularly for hunters from Aklavik who are no longer able to travel in some areas and learn the patterns of the local polar bear populations (Joint Secretariat 2015: 45).

7.2.4.5 Landfast Ice

The break between nearshore or landfast ice and the open ocean sea ice forming near the coastline is frequently described as an important hunting area for polar bears due to the large number of seals that use the break in the ice for breathing holes (WMAC-NS and AHTC 2018a: 36-37).

Inuvialuit communities are noticing substantial seasonal changes to the landfast ice climatology of the southern BRSEA Study Area and Amundsen Gulf. Community members from Paulatuk note that the Amundsen Gulf used to typically freeze over (as fast sea ice cover) from Pearce Point to Nelson Head, but now there is typically more open water and seals are beginning to move away (IMG Golder and Golder Associates 2011b: 7). Hunters from Ulukhaktok previously were able to travel and harvest polar bears towards Nelson Head; however, this has been very difficult due to break-up, rubble ice and open water since ~1999 (Joint Secretariat 2015: 165). A hunter from Tuktoyaktuk identified 1986 as the year that local sea ice was disrupted by a drastic change in the climate and suggests the changes have been escalating ever since (Joint Secretariat 2015:162-163). Warmer spring temperatures are also resulting in poor ice conditions earlier in the areas surrounding the six Inuvialuit communities, thereby disrupting hunting and observational activities that typically extended much later into the season in past years (Joint Secretariat 2015: 47).

In landlocked areas, breakup is mainly driven by warming from the sun, changes in wind and currents, and spring runoff from rivers (i.e. Melling 2002); it typically follows a consistent break-up period each year throughout the Canadian Arctic Archipelago (Galley et al. 2012). Landfast ice on open coastlines that is not heavily grounded has a higher variability in break-up dates, correlating with the cumulative amount of solar energy reaching the Earth's surface (Petrich et al. 2012). The breakup of firmly anchored landfast ice cover along areas may be initiated by the occurrence of strong winds and currents or changes in local sea level (Divine et al. 2004; Mahoney et al. 2007; Jones et al. 2016). The break-up of landfast ice near rivers can be triggered by spring discharge (Bareiss et al. 1999; Divine et al. 2003).

The declining seasonal average extent of Arctic landfast ice is, in part, caused by a later date of formation and earlier break-up, which reduces the total amount of ice growth. Over the period 1976-2007, the U.S. National Ice Center (NIC) ice charts indicate that the duration of landfast ice is decreasing by approximately 0.8 d/yr on average across the Northern Hemisphere. Canadian Ice Service charts show a declining trend for landfast ice duration of almost 3 d/yr in the Alaska Beaufort Sea and Mackenzie Delta area (Galley et al. 2012). A comparison of the landfast ice season between 1973-77 (Barry et al. 1979) and 1996-2008 shows a shortening of the landfast season of approximately 53 days (~2 d/yr) in the western BRSEA Study Area and 38 days (~1.4 d/yr) in the Chukchi Sea (Mahoney et al. 2014).

Weekly ice charts from the NIC indicate that overall landfast ice extent in the Arctic decreased by approximately 12,300 $km^2\ yr^{-1}$ (0.7% yr^{-1}) between 1976 and 2007 (Yu et al. 2013); however, the maximum extent of landfast ice in the BRSEA Study Area changed little during this time. It should be noted that the NIC results represent changes in the seasonal average extent from January to May, rather than the full maximum extent at the end of the growth season.

7.2.5 Coastal Dynamics and Sea Floor Geology

7.2.5.1 Coastal Erosion

Coastal erosion is generally increasing in the Arctic due to increasing coastal wave action, commensurate with longer durations of open water and the resulting wave fetch, as well as warming regional air and sea temperatures that thaw coastal permafrost. Coastal erosion and associated effects on infrastructure and livelihoods are common concerns expressed by community residents in the western Arctic, including the Yukon and Alaska coast.

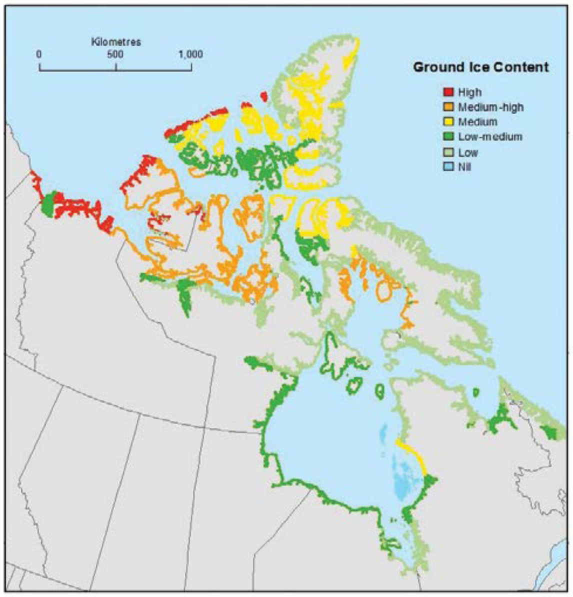
A regional analysis for the southern Beaufort Sea during 1972-2000 found no statistically significant increase in erosion rates in areas of rapid erosion (Manson and Solomon 2007). Erosion rates of 1.0 to 2.0 m/year were reasonably consistent over those three decades. However, new observations suggest "significant acceleration of coastal retreat in some parts of the Canadian Beaufort Sea region" (Atkinson et al. 2016). Indeed, some very large and quickly degrading shorelines erosion features have been noted. For example, recent field observations on shorelines on Pelly Island, NWT reported erosion rates of 40 m in 2017. Changes may be observed within a matter of days under particularly intense storms (Malenfant et al., 2019).

Tuktoyaktuk is still the regional centre of much research on this topic (e.g., McClearn 2018). Prior to establishing erosion control measures at Tuktoyaktuk, the long-term rates of coastal retreat were on the order of 2 m/year (Walker 1988) and reached up to 10 m of shoreline loss during a single storm in August 2000. However, coastal erosion rates at Tuktoyaktuk have continued to increase by 27% in the past two decades (James and Stuckey 2020); the authors state that "it is clear that current shore protection measures are not working and able to withstand the increased climate-fording events."

In a recent modelling study of coastal archaeological site variability in Kugmallit Bay (O'Rourke 2017), coastal erosion rates were calculated using aerial photographs, high-resolution satellite imagery and helicopter surveys. Subareas, such as Toker Point, exposed to heavy erosive forces were observed to erode at very high rates of as much as 4.5 m of coastal retreat in 2015 compared to 2014. This large amount of coastal retreat was associated with volatile weather patterns.

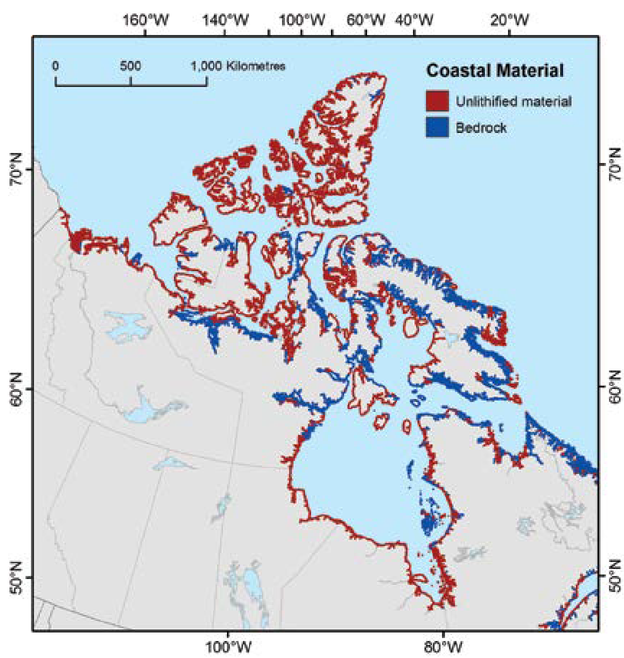
Higher permafrost temperatures can intensify coastal processes, such as thawing of the shore face (Aré et al 2008), block failure (Hoque and Pollard 2009) and retrogressive thaw slumping. Increased temperatures in permafrost also are generally associated with an increase in the thickness of the active layer, which can, in turn, destabilize coastal infrastructure (Lamoureux and Lafreniere 2015; Lamoureux et al. 2016). Because of this, several northern communities have incorporated research on changing permafrost conditions into their coastal adaptation planning (e.g., Couture et al. 2002; Forbes et al. 2014).

On the westernmost side of the BRSEA Study Area, unlithified (i.e., not compacted or converted into stone) and ice-bonded coastlines are particularly prone to coastal erosion, as reflected by their high retreat rates (Lantuit et al. 2012; Irrgang et al. 2019) (Figure 7-36 and Figure 7-37). On a pan-Arctic scale, the Beaufort Sea coastline is characterized by the strongest retreat, with coastal erosion rates exceeding 1-2 m per year (Manson and Solomon 2007; Lantuit et al. 2012) (Figure 7-38).



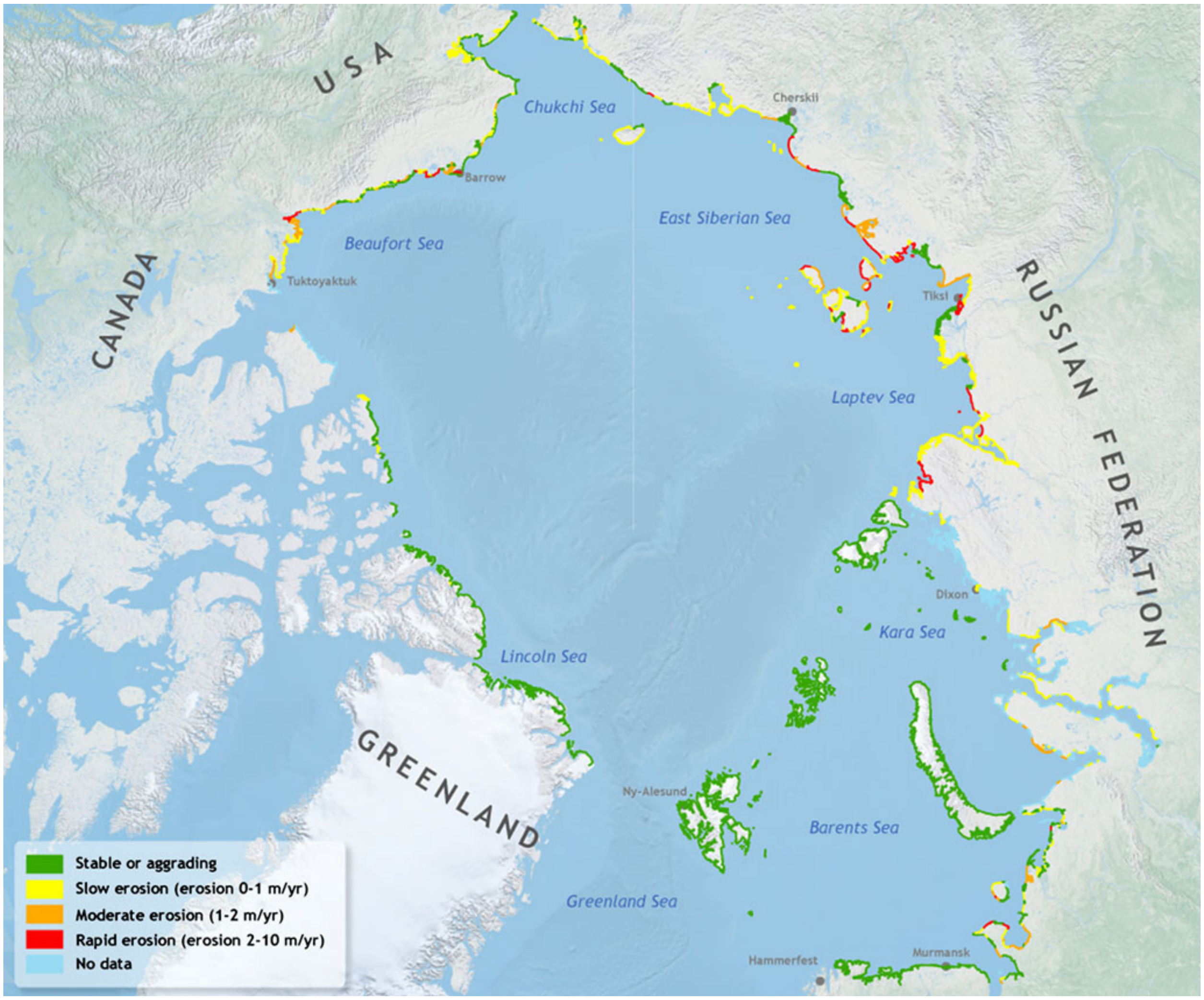
SOURCE: (Couture and Manson 2016), based on data from Natural Resources

Figure 7-36 Ground-ice volumes in the North Coast region



SOURCE: from Couture and Manson 2016

Figure 7-37 Variability of coastal material in the North Coast region



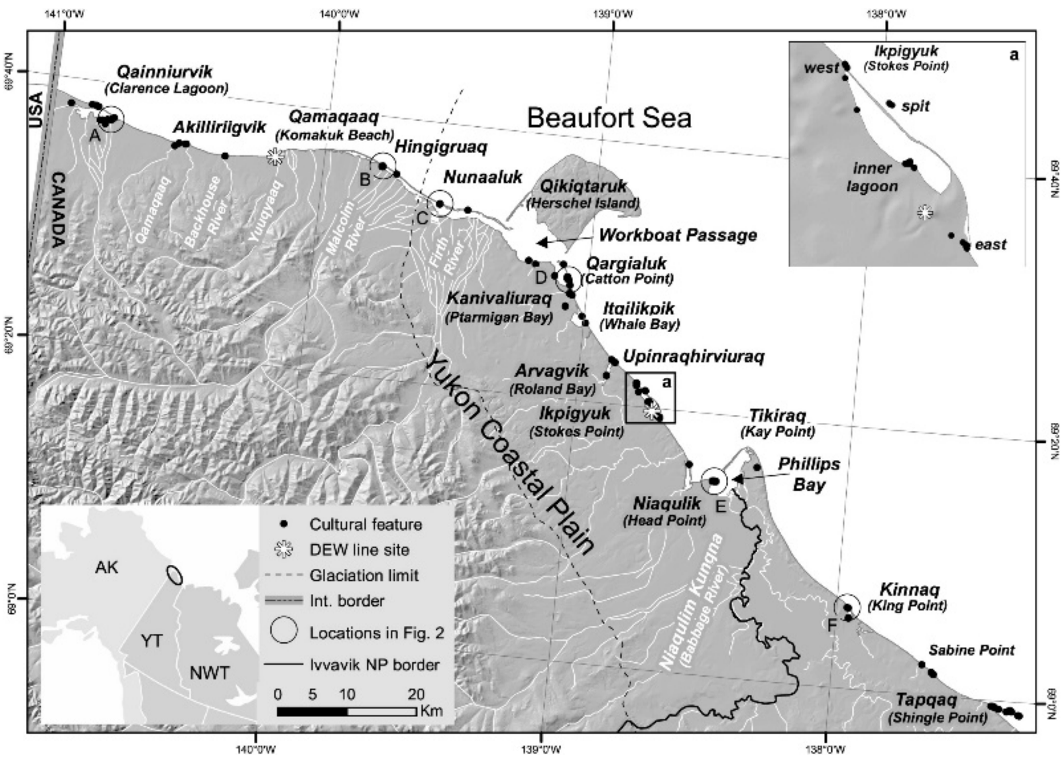
NOTE: The spatial variability in erosion rates generally observed at local scales is also a prominent regional feature.
SOURCE: Lantuit et al. 2012

Figure 7-38 Circum-Arctic map of coastal erosion rates.

Erosion rates across the Arctic are positively yet poorly ($r^2 = 0.23$) correlated with ground ice content (Lantuit et al. 2012). The poor correlation is likely explained by the presence of sea ice in some areas, which fronts the shorelines and protects the ground ice rich shores from waves. The height of the shoreface being eroded is also not a good predictor for erosion rates. The very highest shores (>50 m; McDonald and Lewis 1973) have lower erosion rates than shores with heights of less than 10 m, due to the larger quantity of debris which must be removed near very high cliffs. Except in the vicinity of very high cliffs, coastal erosion rates are not linked to elevations of the backshore (Héquette and Barnes 1990; Lantuit et al. 2012).

Another contributing factor to increased coastal erosion is the climate-change induced rises in sea levels in the Canadian North (Ford et al., 2016). The sea level rise, combined with later freeze-up (which extends the open-water season into the fall storm season when higher waves may occur), leads to increased coastal erosion.

Two site specific predictive shoreline retreat studies have been undertaken within the BRSEA Study Area. The first is the Yukon coast west of the delta (Figure 7-39; Irrgang et al. 2019), while the second is specific to Herschel Island (Radosavljevic et al. 2015).



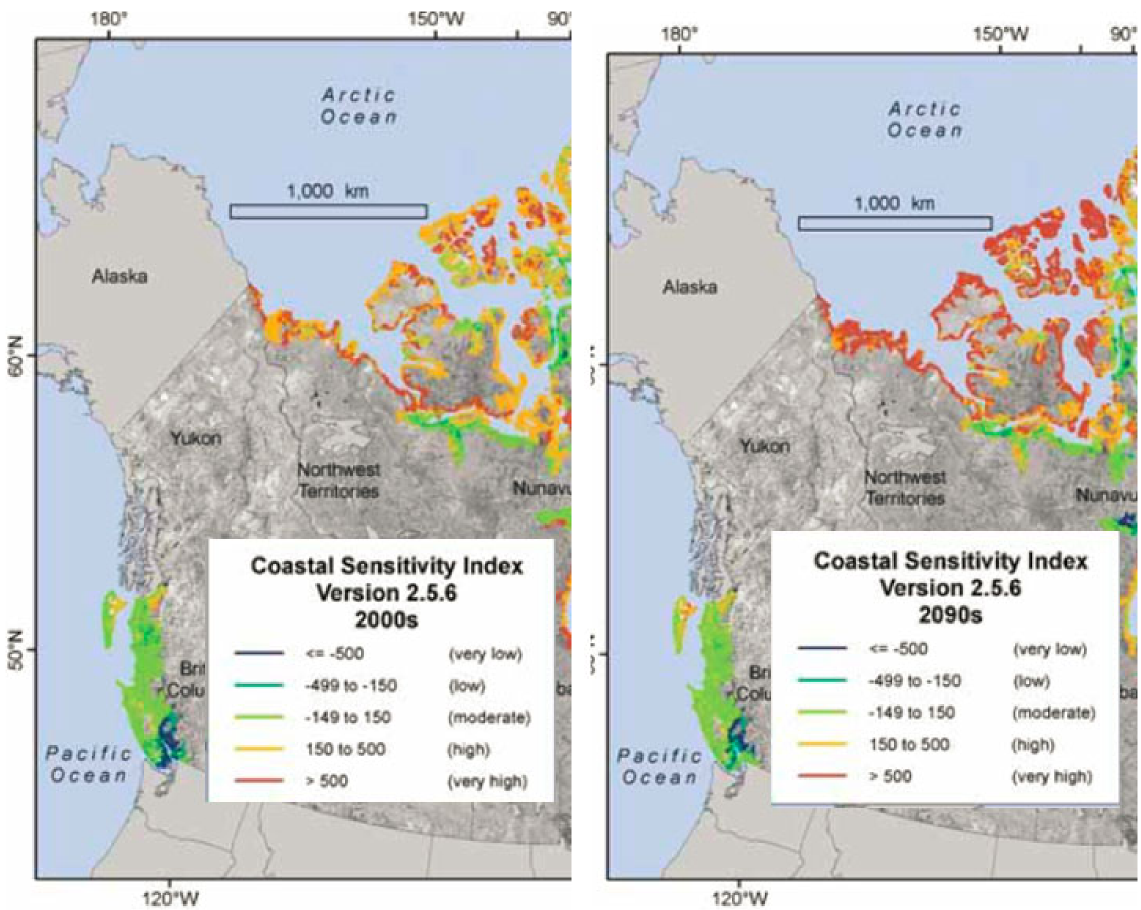
SOURCE: From Irrgang et al. 2018
Base map: 30 m Yukon digital elevation model, interpolated from the digital 1:50 000 Canadian Topographic Database (Yukon Department of Environment 2016).

Figure 7-39 Study area of the Yukon coast showing the locations of cultural features and infrastructure.

The first study was conducted to determine historical and future erosion along the 10–40 km wide Yukon Coastal Plain from the international border with Alaska, USA, in the west to Tapqaq (Shingle Point) in the east (Irrgang et al. 2018). Based on this study and other literature, the present-day coastal erosion can be as high as 9 m per year along the Yukon coast. The coastal erosion and associated flooding have the potential to detrimentally affect cultural heritage, existing infrastructure, and travel routes. Many cultural sites along the mainland coast, as well as on Qikiqtaruk (Herschel Island), have been or are about to be eroded. Investigations of the DEW line site at Qamaqaaq (Komakuk Beach) show that the landing strip has been eroding, on average, by approximately 1 m per year since the 1950s.

The second study had the objectives of assessing potential erosion and flood hazards, specifically at Herschel Island, a UNESCO World Heritage candidate site (Radosavljevic et al. 2015). Widespread erosion is occurring on Herschel Island. Rates of coastal retreat have ranged from 2.7 to 5.5 m per year (mean of 0.6 m per year). Mean coastal retreat decreased from 0.6 m per year to 0.5 m per year, for 1952–1970 and 1970–2000, respectively, and increased to 1.3 m per year in the period 2000–2011. Ice-rich coastal sections that are most exposed to wave attack exhibited the highest rates of coastal retreat.

Maps of the physical sensitivity of Canada's marine coasts in a changing climate (Chapter 6) have been developed for two time periods: early and late 21st century) (Manson et al. 2019) (Figure 7-40). These maps show that high to very high coastal sensitivities occurred in the BRSEA Study Area for the first decade of the 21st century. By the last decade of this century, the areal extent of very high coastal sensitivities within the BRSEA Study Area are predicted to increase considerably.



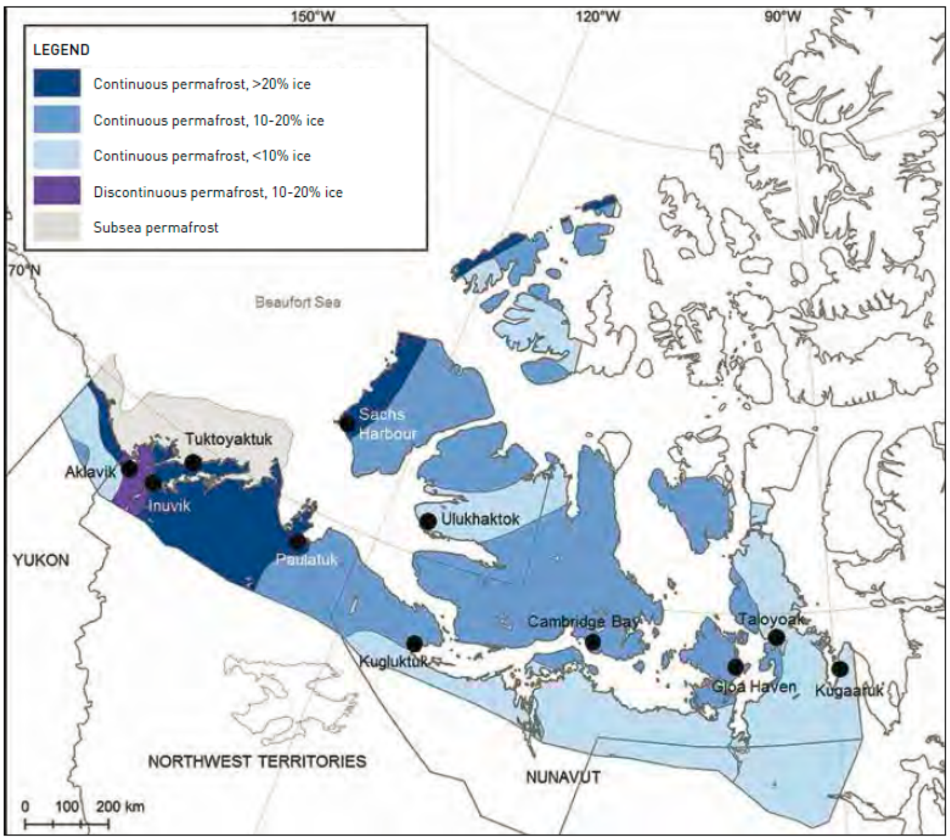
SOURCE: From Manson et al. 2019

Figure 7-40 The coastal sensitivity index for Western Canada in the early 21st century (left panel) and in the late 21st century (right panel).

7.2.5.2 Permafrost

7.2.5.2.1 Onshore Permafrost

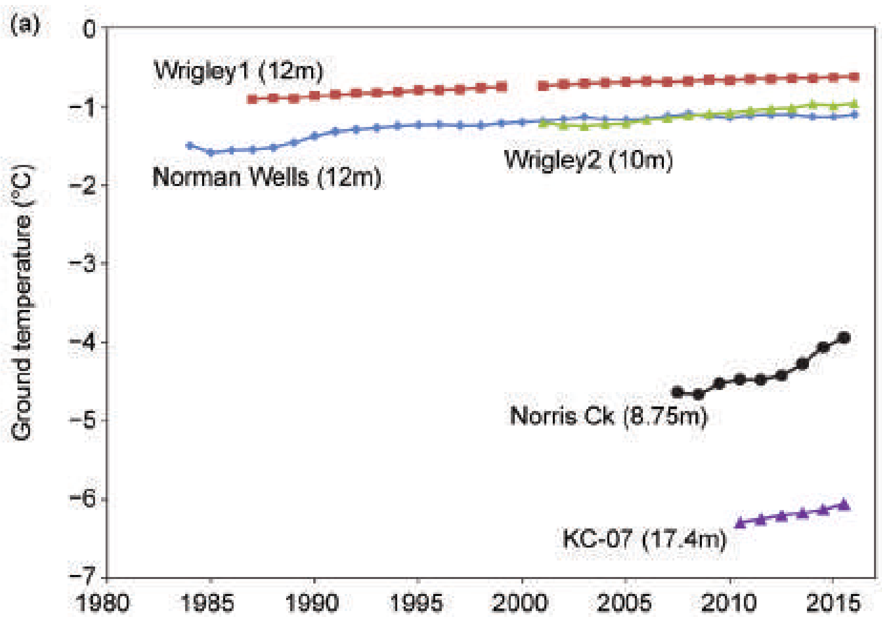
Permafrost temperatures have increased in most regions of the Northern Hemisphere since the early 1980s, with reductions in thickness and areal extent in some regions (IPCC 2014a). Increased permafrost temperature has occurred primarily in response to increased surface temperature and changing snow cover. As shown in Figure 7-41, the distribution of widespread ice-rich permafrost varies considerably in the western and central areas of the Canadian Arctic (Lamoureux et al. 2016).



NOTE: (Permafrost is continuous in all areas with the exception of the Mackenzie Delta (violet), where discontinuous permafrost with 10-20% ground ice occurs (from Lamoureux et al. 2016))

Figure 7-41 Map indicating areas with widespread ice-rich permafrost in the western and central Arctic.

In the ISR, substantially more permafrost warming has occurred since 2000 than in higher latitudes (Romanovsky et al. 2017). The distribution of variability in permafrost warming generally agrees with the pattern of average surface air temperature anomalies over this same time period. In the discontinuous permafrost of the central Mackenzie Valley (Norman Wells, Wrigley), warming has been observed since the mid-1980s, but the rate of temperature increase generally has been lower since 2000 and less than about +0.2°C per decade. In contrast, recent increases in permafrost temperature have been greater in the northern Mackenzie River region, up to +0.9°C per decade (Figure 7-42), which is likely associated with greater increases in surface air temperature over the last decade (Smith et al. 2017).



NOTES: The depths of measurement are indicated on the graph.
SOURCE: From Romanovsky et al. (2017); updated from Smith et al. (2017).

Figure 7-42 Time series of average annual permafrost temperatures in the central Mackenzie River Valley, Northwest Territories, Canada (Norman Wells and Wrigley), and in colder continuous permafrost in the northern Mackenzie Valley near Inuvik

Active Layer Thicknesses (ALT) in the Mackenzie Valley (Figure 7-43) have been measured from 25 sites with thaw tubes since 1990. There has been a general increase in ALT in this region since 2008 with a peak value occurring in 2012, about 10% greater than the 2003-2012 mean (Duchesne et al. 2015; Smith et al. 2016). This time series of ALT reveal variability over time periods of a few to several years. (Figure 7-44).

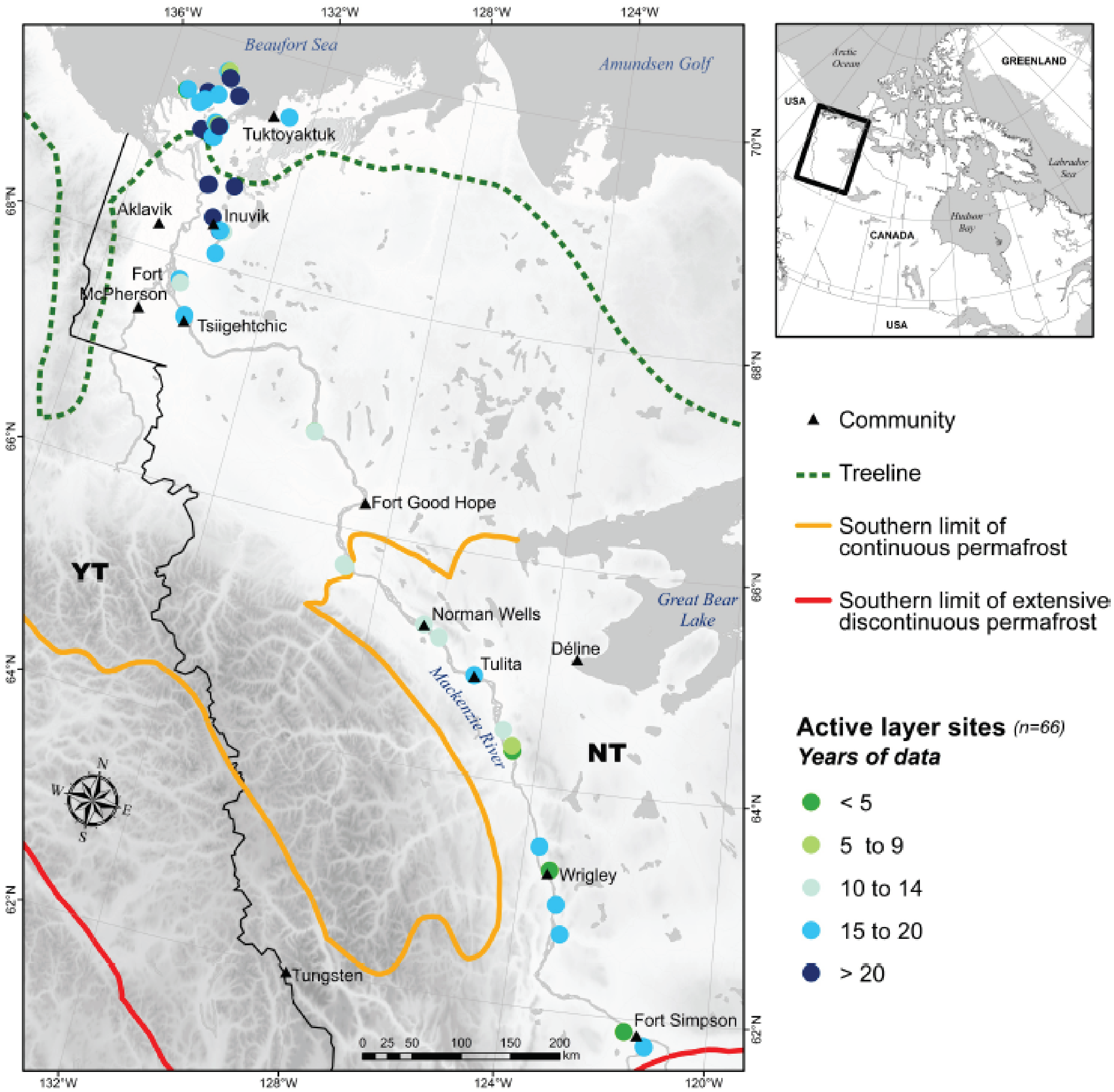
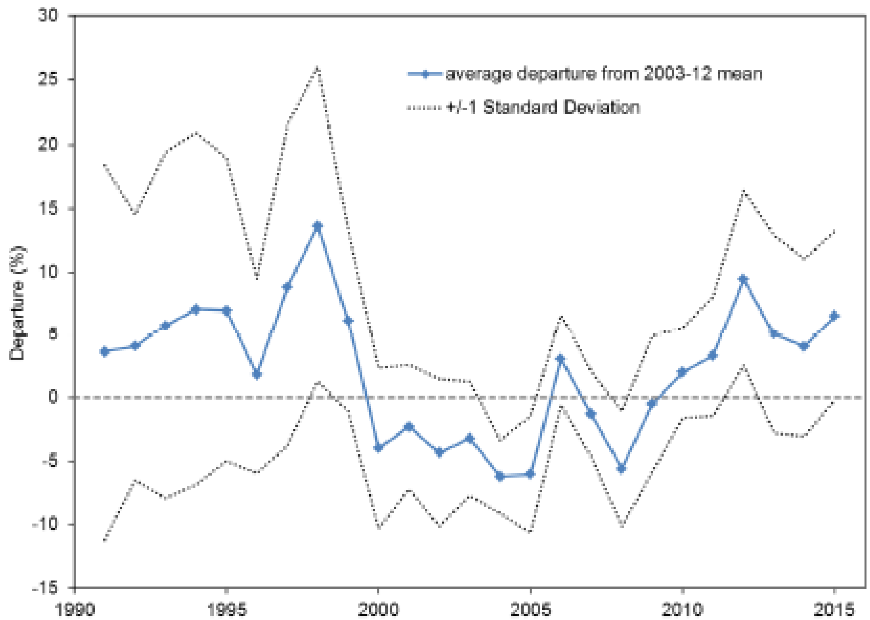


Figure 7-43 Location map of active layer monitoring sites in the Mackenzie Valley.



NOTE: 2015 ALT based only on northern sites visited in 2016
SOURCE: From Smith et al. 2017.

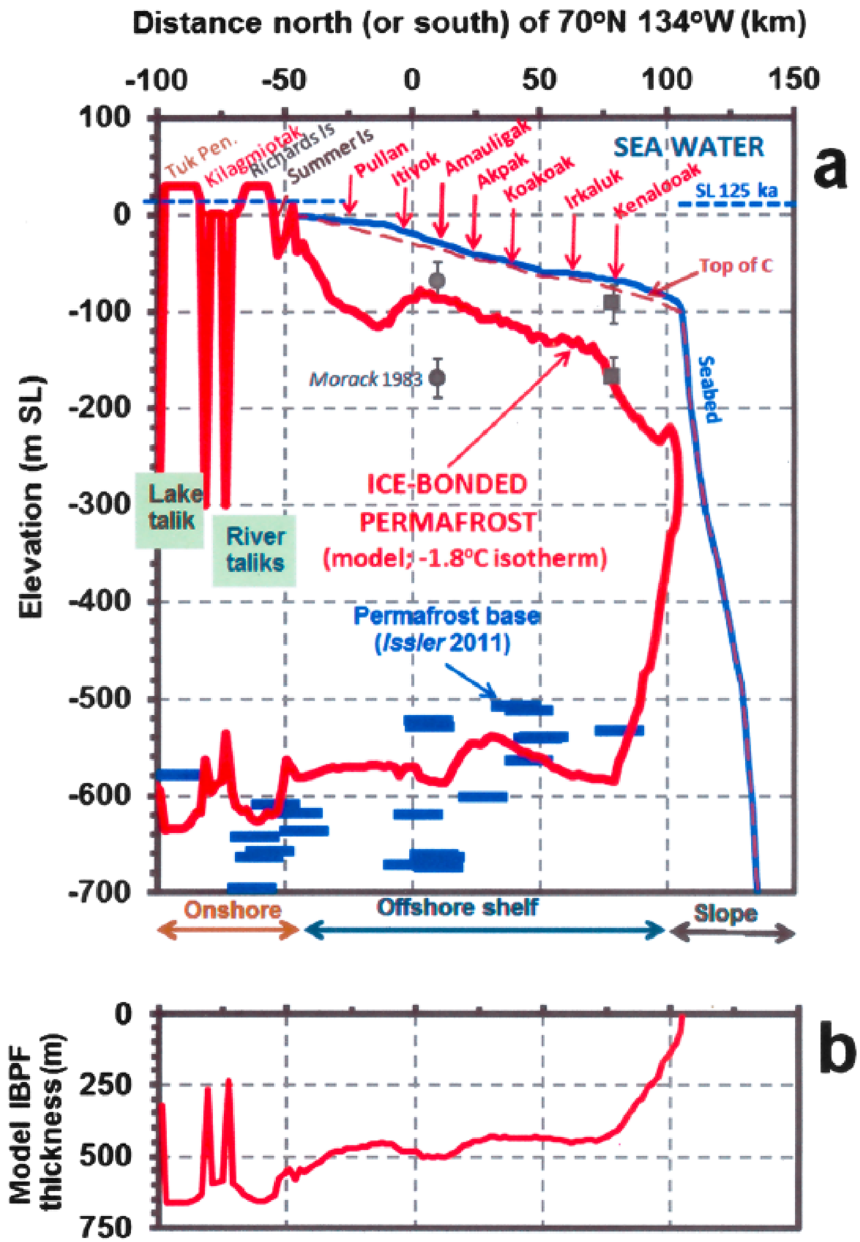
Figure 7-44 Mean ALT departures (%) from 2003-12 mean for 25 sites

A recent study within the ISR indicates that very cold permafrost might be degrading more rapidly than predicted (Farquharson et al. 2019), seemingly due to the thin vegetation/soil cover in the region that allows for a more rapid top down thaw in increasingly warming summers.

7.2.5.2.2 Offshore Permafrost

The present seaward extent of the permafrost body is the ~95 m isobath before the physical shelf/slope break; beyond that the permafrost thins out over a distance of <2 km (Figure 7-45).

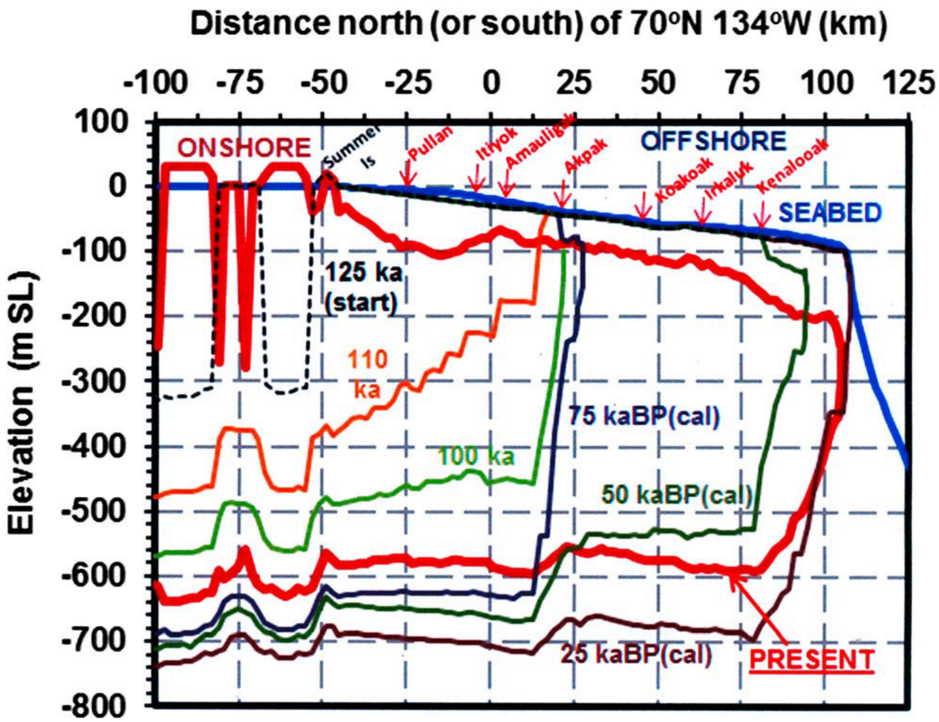
Based on modelling of subsea permafrost in the BRSEA Study Area, the permafrost body may have extended no further than the present coast during the last Interglacial period (~130,000–116,000 years BP) (Taylor et al. 2013) (Figure 7-45 and Figure 7-46). As sea level fell from the Interglacial high of ~7 m above the present sea level, permafrost advanced offshore and reached the approximate extent of the Amauligak oil field after ~15,000 years (by ~110,000 years BP). Subsea permafrost continued to advance offshore but at much reduced rates overall. This correlated with two sets of observations of sea level change in the early Wisconsinan and middle Wisconsinan (EWS and MWS); this included a notable offshore jump of 65 km within~10,000 years, in response to a ~50 m fall in sea level between the EWS (~100,000–75,000 years BP) and the MWS (~65,000–35,000 year BP) (see red profile in Figure 7-47 between 75 and 50 km). Since the Holocene marine transgression (~ last 11,500 years) the outer limit of permafrost has retreated back towards the coast approximately 2 km (Figure 7-47).



NOTE: (a) the heavy red line shows the model-predicted present extent of ice-bonded permafrost [IBPF]. (b) Vertical exaggeration for modelled permafrost thickness is ~370×

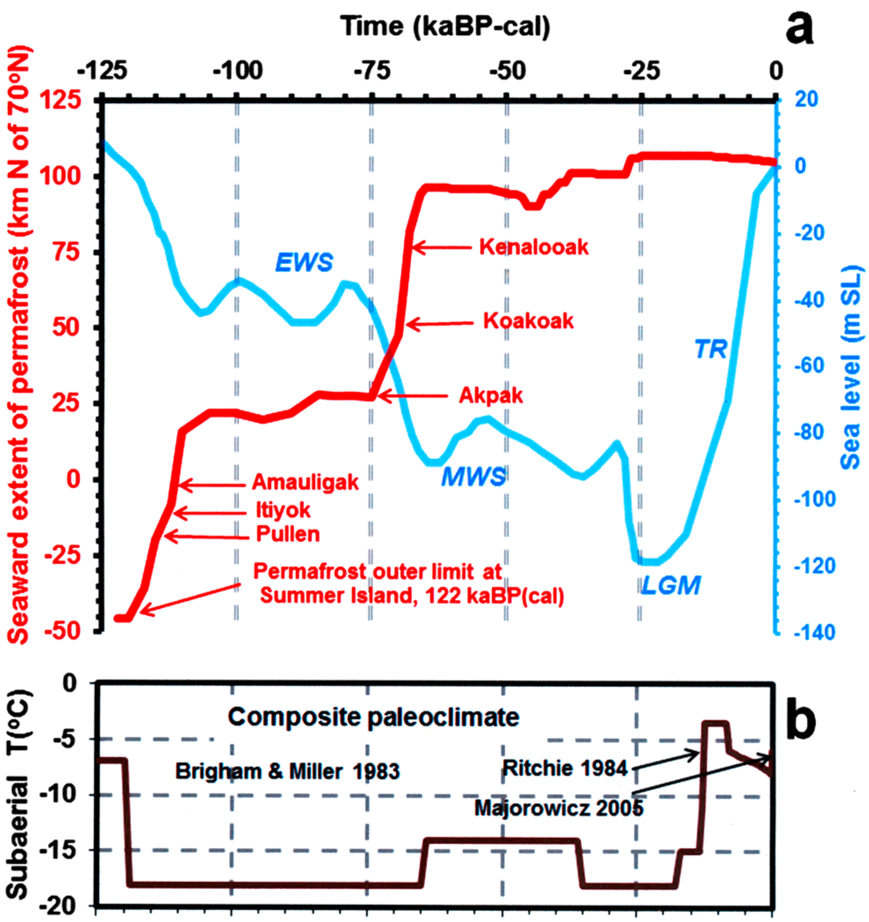
SOURCE: From Taylor et al. 2013.

Figure 7-45 Modelled permafrost versus geophysical interpretations, outer Mackenzie Delta-Beaufort shelf and slope relative to present sea level along the transect.



NOTE: 125 kaBP(cal) is the starting position for the model (i.e., the thermal equilibrium with a marine LIG).
SOURCE: From Taylor et al. 2013.

Figure 7-46 Modelled spatial and temporal evolution of the ice bonded permafrost body (IBPF) from onshore to shelf edge, at 25 ka increments since the Last Interglaciation (LIG).



NOTE: for upper panel (a):EWS and MWS, early and middle Wisconsinan stillstands in sea level; TR, marine transgression; LGM, Latest Glacial Maximum; the timing of permafrost advance to industry wells is also provided according to the names of the industry wells

SOURCE: From Taylor et al. 2013.

Figure 7-47 Advance of the seaward limit of ice-bonded permafrost relative to industry hydrocarbon wells (left axis) versus composite sea level (right axis) as shown in the upper panel; the results from a composite paleoclimate model are shown in the lower panel.

7.2.6 Coastal and Terrestrial Habitat

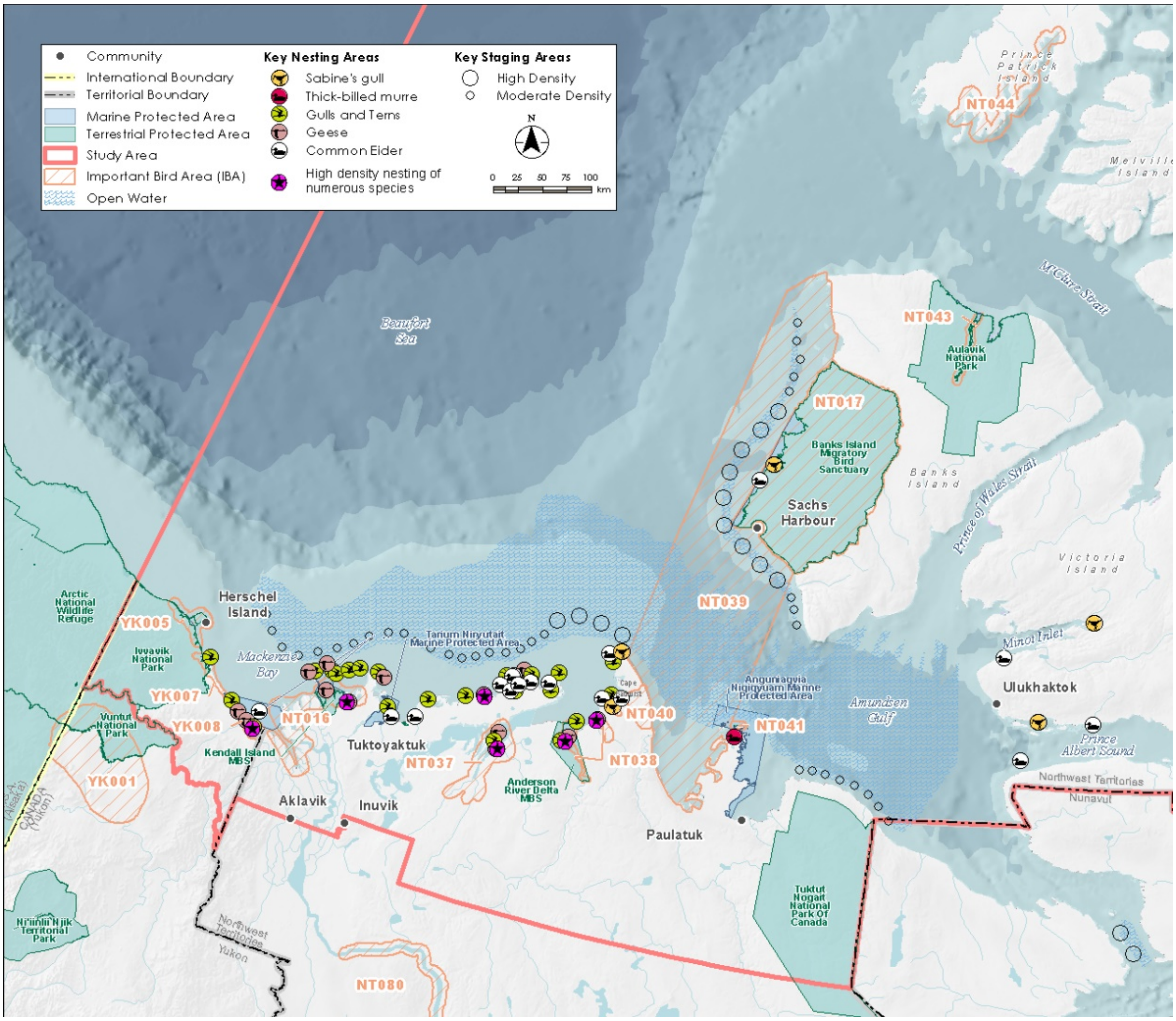
7.2.6.1 Conservation Status

Coastal and terrestrial habitats are recognized important conservation areas due to their interaction between the ocean and onshore habitats. Marine mammals, terrestrial wildlife, fish, birds, and other species depend on these diverse habitats. They provide feeding and rearing grounds during the summer for migratory birds, whales, and nearshore fish species. In the winter, anadromous fish such as char overwinter below the safety of the stable sea ice.

Coastal habitats also provide important human access to the environment. A TLK holders stated “It is used to access the ocean, facilitating harvest of whales, fish, and other local foods. I'm not against development, but I want to be able hunt 20 years down the road… we depend on fish, birds, whales every year… The coastline, where we go whaling, that’s the only place they shouldn’t be drilling in the ocean… where they [we] go camping and whaling" (ICC et al. 2006: ch 11, p. 14).

There are at least eight formally recognized marine/terrestrial protected areas in the coastal and adjacent terrestrial portions of the BRSEA Study Area, including (Figure 7-48):

- Ivvavik National Park: Porcupine caribou herd calving and Northern Yukon and Mackenzie Delta
- Tarium Niryutait Marine Protected Area: Beluga whales and other marine species
- Kendall Island Migration Bird Sanctuary: Lesser snow geese, shorebirds, songbirds, waterfowl
- Anderson River Delta Migration Bird Sanctuary: Waterfowl, songbirds
- Anguniaqvia Niqiqyuam Marine Protected Area: Beluga whales, Arctic char, ringed/bearded seals
- Tuktut Nogait National Park of Canada: Caribou, terrestrial mammals
- Banks Island Migration Bird Sanctuary: Waterfowl
- Aulavik National Park: Muskoxen, terrestrial mammals



NOTE: Includes high density nesting areas for numerous species, key staging areas and key nesting areas for Thick-billed murres, Pacific common eiders, Sabine's gulls, and gulls and terns and geese.

DATA SOURCES: Dickson and Gilchrist 2002, Latour et al. 2008; PCCP 2016:67, OCCP 2016:126-132, and TCCP 2016:17

Figure 7-48 Map of the Marine Bird Habitat in the BRSEA Study Area.

7.2.6.2 Cultural and Socio-Economic Value

Coastal and terrestrial habitats support key species for traditional harvesting. Local knowledge experts from the ISR emphasize the coastline is important for staging, whaling, fishing, bird harvest and other important activities (ICC et al. 2006: ch 11, p. 14). Western research also has emphasized how important coastal habitats are for these species (detailed below and in marine fish [Section 7.3.3], migratory birds [Section 7.3.4], marine mammals [Section 7.3.6], and polar bears [Section 7.3.7]).

Beyond traditional harvesting activities, coastal habitats support a number of important human uses (Sections 7.4.4 and 7.4.5). Most residents live in towns along the nearshore or coastal environment. Economic earnings come from coastally derived fishing, transportation, tourism, or similar industries. Water transportation remains the most economic method of transporting bulk goods, and coastal ports or barge landings zones are important for communities.

Local experts in Sachs Harbour are currently observing impacts from climate change, including beaches disappearing and seashore banks slumping (IMG Golder and Golder Associates 2011c: 19). This directly endangers coastal homes with no clear if, when, or how individuals can regain housing security. For decades, communities have experimented with a variety of methods to encourage resilient shorelines. Efforts are generally expensive, have limited funding opportunities, and produce variable success (Section 7.2.5).

7.2.6.3 Key Habitat[47]

Coastal and terrestrial habitats provide key habitats for many biological VCs. Generalized summaries are provided below; referencing the other relevant sections, which provide fuller discussions.

Coasts are experiencing erosion, thawing of shore permafrost, block failure, and thaw slumping (Coastal Dynamics [Section 7.2.5]). Coastal erosion continues and is directly changing the characteristics and quality of coastal habitats. This has made predicting future coastal distribution and ecology difficult.

Coastal oceanography (Section 7.2.3) is heavily influenced by the freshwater runoff from the Mackenzie River into the nearshore environment (Section 7.2.3.2). This changes the flow, temperature, and water quality of the nearshore environment; in particular providing habitat for fish species.

Sea ice remains an important coastal habitat influencer. At the outer reaches of the nearshore ice environment, the break between nearshore/landfast ice attracts a variety of species. This provides breathing holes for seals, attracts polar bears that hunt the seals, and residents who hunt both (Section 7.2.4.5).

Closer in, nearshore sea ice (Section 7.2.4) provides important habitat for a variety of arctic species, particularly fish. For examples, Aklavik TLK holders relate that char are present in coastal areas under the ice, and “the more ice we get, the better it is for char (IMG Golder and Golder Associates 2011a: 13)”.

[47] Specific references are provided in the sections relating to the Valued Component

Beyond char, nearshore and coastal water provide important habitat for many marine fish (Section 7.3.3). The estuaries, bays, and rivers host resident, migratory, and anadromous species, supporting a variety of rearing and breeding habitats. Many anadromous species do not move offshore; and remain in nearshore and coastal saltwater. Estuaries are important habitats for overwintering species; while also providing migratory species summer spawning areas.

A substantial portion of Canada's migratory birds (Section 7.3.4) seasonally occupy offshore and nearshore waters. Most geese, brant, swans, loons, and shorebirds utilize the nearshore and coastal environments. They rely on these waters for breeding, feeding, moulting, and raising of young (Table 7-12). Migratory birds make up an important portion of the traditional diet of the Inuvialuit.

Marine mammals (Section 7.3.6) migrate along spring nearshore polynyas, feed in shallow coastal waters, and are hunted along coastal breaks in nearshore/landfast ice. As seasonal ice melts, species often move offshore to feed on plankton blooms. Others, like belugas, prefer coastal shallow waters or estuaries throughout the summer. Seals are widely distributed, but also occupy the nearshore environment, providing important opportunities for traditional harvesting during winter.

Polar bears (Section 7.3.7) are particularly reliant on coastal habitats, since movement onto offshore ice depends on melting and refreezing of shore ice. This has become increasingly important as the population is forced to spend the summer onshore due to the lack of offshore sea ice. Denning also can occur along nearshore coasts, on top of sea ice.

Terrestrial caribou (Section 7.3.8) are also attracted to the coastal environment. They seek coastal winds for heat relief and as an escape from summer mosquitos and flies.

Humans (Section 7.4) also rely heavily on the coasts and adjacent coastal habitats for a wide range of uses. TLK holders have provided detailed information on the distribution and ecology of important coastal and terrestrial habitat. For example, Inuvik TLK holders report that a large part of the Inuvialuit traditional diet comes from coastal areas (KAVIK-AXYS Inc. 2004a p. 4-8.).

7.2.7 Gaps in our Knowledge of the Physical Environment

7.2.7.1 Knowledge Gaps Related to Atmospheric Environment

Knowledge gaps related to the atmospheric environment include:

- ambient air quality in the BRSEA Study Area is limited
- the dispersion of air contaminants in the arctic atmosphere is not well known (i.e., the dispersion in the troposphere near the surface, which is a cold, stable atmosphere for an extended period of time, has not been extensively modelled and checked against full scale data)
- little is known about the likelihood of methane releases, and quantities, from under the sea ice and from frozen tundra that is warming with the projected increases in air and sea temperature

- the influence of International Maritime Organization (IMO) requirements on the control of air pollution and GHGs in the future is not fully understood yet
- there have been few scientific studies on the potential effects for in-air noise, and fewer for lighting

7.2.7.2 Knowledge Gaps Related to Climate and Weather

Weather forecasting is an essential element in planning activities related to offshore development (e.g., wind energy, oil and gas exploration and production). The gaps in weather forecasting and understanding relate largely to the analysis and prediction of extreme events in the context of a relatively sparse network of monitoring stations. A solid understanding of the threat to projects requires an assessment, often quantitative, of the probabilities and consequences of severe weather. With the changing open water conditions, seasonal weather systems (on weekly-monthly scales) have a stronger impact, and seasonal forecasting is becoming more relevant.

TLK holders have identified that the ability to forecast the weather is getting more difficult, largely because the variability in conditions is increasing. Nevertheless, the day to day weather, is relatively well-addressed by current methods because the variance in existing weather is as great as the variance in forecast accuracy due to a changing climate base. Cumulatively, this is not necessarily the case. For example, a temperature error of a fraction of a degree on a daily basis is negligible compared to forecast inaccuracies, but the cumulative effects that contribute to the date of freezing or melting of channels can be important to the affected individuals or groups and industry.

Mathematical techniques in forecast science are evolving and can be adapted to a changing climate; however, the database of observations, particularly of extremes, is changing so that the statistical methods are starved of data. Improvements in long-term modelling are essential to improving risk forecasting (i.e., probability and consequence) necessary to support developments in this region, as the climate changes in response to anthropogenic activities in the future.

7.2.7.3 Knowledge Gaps Related to Oceanography

There is a need for more detailed understanding of the physical oceanography at the surface and within the upper layer of the ocean including timing, patterns and location of productivity (e.g., blooms). There are large knowledge gaps in relation to areas of current high primary productivity within the BRSEA Study Area, as well in areas that are within the influence of the Mackenzie River plume (over Mackenzie Bay, the Mackenzie Canyon, the Yukon shelf and slope and areas off the Mackenzie Delta and the Tuktoyaktuk Peninsula), especially during the spring break-up and freshet period and extending into summer and early fall. Other important areas are marine hotspots off Cape Bathurst extending into the mouth of Amundsen Gulf. More detailed physical oceanographic observations would allow an analysis of the underlying biophysical mechanisms, which could be used to support the development of ecosystem models which require an understanding of the underlying physical and biogeochemical processes in these subareas of the BRSEA Study Area. Improved understandings of the physical oceanographic environment at subsurface levels on the shelf and slope are required. These are important to understanding the distribution and variability of the biomass of zooplankton, marine fishes, and in benthic communities.

7.2.7.4 Knowledge Gaps Related to Sea Ice

There are large gaps in our understanding of how dynamic and thermodynamic sea ice processes might shift with the change from a multi-year sea ice regime to a seasonal sea ice regime. It has been suggested that the behaviour of sea ice dynamic processes in the seasonal Arctic Sea ice regime are notably different from past regimes where multi-year ice was present (e.g., Kwok 2018).

Regionally, changes in sea ice dynamic processes are key factors that affect Inuvialuit and other Indigenous hunting areas along the coastal areas of the BRSEA Study Area, particularly the Yukon shelf and slope, near the Mackenzie Delta, and near the coastal communities of Tuktoyaktuk, Sachs Harbour, Paulatuk, and Ulukhaktok. More information exchange is needed to inform TLK holders and help them interpret and safely use the changing sea ice. Similar information is required to plan, design, install and operate oil and gas infrastructure in offshore areas.

There is a need to better understand how the ocean and atmosphere drive variability in the timing of sea ice cover, particularly the timing of freeze-up and spring break-up and how increased sea ice mobility (e.g., Rampal et al. 2009) could influence mid-winter large-scale dynamic breakups of the sea ice in the BRSEA Study Area and Amundsen Gulf via wind forcing of the Beaufort Sea ice gyre.

There is a large gap in understanding the interannual variability of sea ice characteristics within the seasonal Arctic sea ice regime and whether year-to-year variability is expected to change, thereby affecting predictability.

Increased understanding of ocean currents (above) and ice movements are required to properly plan oil spill response and, in the unlikely event of a release, to predict oil movements and dispersion.

7.2.7.5 Knowledge Gaps Related to Coastal Dynamics and Sea Floor Geology

There is a need for more detailed studies of coastal erosion processes to be able to determine the present and future rates of coastal erosion at a higher resolution for coastal segments than is presently possible.

There is a gap in the availability of information on the long-term near bottom ocean temperatures from the coastline to the outer continental shelf. More observations and the analysis and modeling of the near-bottom oceanographic water properties are needed to better understand potential future changes to subsea permafrost and potential effects on offshore drilling activities.

Increased understanding of ocean currents (above), ice movements (above) and seafloor stability are required to design and safely deploy GBS platforms and other offshore infrastructure

7.2.7.6 Knowledge Gaps Related to Coastal and Terrestrial Habitats

Outside of a few focus areas, little information is available about coastal and terrestrial habitats in specific stretches of coastline in the BRSEA Study Area. Potential impacts of development and preparation of best management practices would be better informed by an inventory of coastal and terrestrial habitat with a multi-factorial quantitative assessment of the physical, biological, and ecological values for each microhabitat. Such information would also be crucial to the development and regular updating of oil spill response atlases for the coastline (e.g., the Beaufort Regional Coastal Sensitivity Atlas [Environment Canada 2015] needs updating given ongoing changes to the coastline of the BRSEA Study Area). Of note, as shipping and other vessel traffic in arctic waters could result in large spills of diesel fuel and other oil products; an inventory of coastal and terrestrial habitat is required regardless of whether or not oil and gas development proceeds.

7.3 Biological Environment

7.3.1 Rare and Endangered Species and Communities

7.3.1.1 Rare and Endangered Species

There are 22 listed rare and endangered species that may occur in or near the Beaufort Region. These include five species of marine mammals, one species of terrestrial mammal (three sub-species of caribou), and 14 species of waterbirds (see Table 7-11). These species have varying levels of federal protection under the Species at Risk Act (SARA); have been identified as species of conservation concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC); and/or have been identified as regionally rare by the International Union for the Conservation of Nature (IUCN).

The life history and distribution of a subset of species relevant to BRSEA are provided in Sections 7.3.2 to 7.3.8.

Table 7-11 Rare and Endangered Species and Communities in the BRSEA Study Area

Species	Scientific Name	SARA Status (Schedule 1 or 2)	COSEWIC Status	IUCN Status	Report Reference
Marine Mammals					
Beluga Whale (Eastern Beaufort Sea population)	*Delphinapterus leucas*	NA[48]	Not at Risk	Least Concern	Section 7.3.6
Bowhead Whale (Bering-Chukchi-Beaufort population)	*Balaena mysticetus*	Special Concern (Schedule 1)	Special Concern	NA	Section 7.3.6
Polar Bear	*Ursus maritimus*	Special Concern (Schedule 1)	Special Concern	Vulnerable	Section 7.3.7
Grey Whale (Eastern North Pacific population)	*Eschrichtius robustus*	Special Concern (Schedule 1)	Non-active	Least Concern	NA

48 NA indicates that the species may occur within the BRSEA Study Area, but has not been selected as an indicator and is not discussed in detail

Table 7-11 Rare and Endangered Species and Communities in the BRSEA Study Area

Species	Scientific Name	SARA Status (Schedule 1 or 2)	COSEWIC Status	IUCN Status	Report Reference
Grey Whale (Northern Pacific Migratory population)		NA	Not at risk	Least Concern	NA
Terrestrial Mammals					
Caribou (Dolphin and Union population)	*Rangifer tarandus groenlandicus × pearyi*	Special Concern (Schedule 1)	Endangered	Vulnerable	Section 7.3.8
Caribou (Barren-ground population)	*Rangifer tarandus groenlandicus*	NA	Threatened	Vulnerable	Section 7.3.8
Peary Caribou	*Rangifer tarandus pearyi*	Endangered (Schedule 1)	Threatened	Vulnerable	Section 7.3.8
Birds					
Ivory Gull	*Pagophila eburnea*	Endangered (Schedule 1)	Endangered	Near Threatened	Section 7.3.5
Red Knot, *rufa* subspecies	*Calidris canutus rufa*	Endangered (Schedule 1)	Endangered	Near Threatened	Section 7.3.4
Red Knot, *islandica* subspecies	*Calidris canutus islandica*	Special Concern (Schedule 1)	Special Concern	Near Threatened	Section 7.3.4
Buff-breasted Sandpiper	*Calidris subruficollis*	Special Concern (Schedule 1)	Special Concern	Near Threatened	Section 7.3.4
Red-necked Phalarope	*Phalaropus lobatus*	Special Concern (Schedule 1)	Special Concern	Least Concern	Section 7.3.4
Bank Swallow	*Riparia*	Threatened (Schedule 1)	Threatened	Least Concern	NA
Eskimo Curlew	*Numenius borealis*	Endangered (Schedule1)	Endangered	Critically Endangered	NA
Harris's Sparrow	*Zonotrichia querula*	NA	Special Concern	Near threatened	NA
Horned Grebe (Western population)	*Podiceps auritus*	Special Concern (Schedule 1)	Special Concern	Vulnerable	NA
Hudsonian Godwit	*Limosa haemastica*	NA	Threatened	Least Concern	Section 7.3.4
Peregrine Falcon anatum/tundrius	*Falco peregrinus anatum/tundrius*	Special Concern (Schedule 1)	Not at risk	Not Assessed	NA
Rusty Blackbird	*Euphagus carolinus*	Special Concern (Schedule 1)	Special Concern	Vulnerable	NA

Table 7-11 Rare and Endangered Species and Communities in the BRSEA Study Area

Species	Scientific Name	SARA Status (Schedule 1 or 2)	COSEWIC Status	IUCN Status	Report Reference
Short-eared Owl	*Asio flammeus*	Special Concern (Schedule 1)	Special Concern	Least Concern	NA
Common Eider	*Somateria mollisima*	NA	Not Assessed	Near threatened	Section 7.3.5

7.3.2 Marine Lower Trophic Levels[49]

Marine lower trophic levels are important to marine ecosystems because they connect primary producers to secondary, tertiary, and quaternary consumers (Hobson and Welch 1992; Cobb et al. 2008; Nelson 2013). Accordingly, the arctic food web is dependent, either directly or indirectly, on properly functioning lower trophic levels via the flow of energy and nutrients through the food web.

Marine lower trophic are discussed in the context of three broad ecological groups:

- phytoplankton (pelagic and sea-ice associated species)
- zooplankton (e.g., copepods, amphipods, and krill)
- benthic macrofauna (e.g., crab, shrimp, clams, mussels, sea urchins, sea stars, sponges, and coldwater corals)

These groups were selected for inclusion based on:

- ecological importance (e.g., nutrient cycling and energy transfer, food-web dynamics, or ecosystem services such as carbon sequestration)
- cultural importance (e.g., species or groups of species that are traditionally harvested and/or of high importance to food security for the Inuvialuit)
- linkages to other VCs (e.g., via food-web dynamics. For example, zooplankton are important food sources to other VCs such as bowhead whales, various sea birds, and some marine fish)

No commercial fishing of benthic macrofauna (e.g., mussels) occurs in the Canadian western Arctic, and no lower trophic level species are listed under SARA or COSEWIC.

The microbial loop also plays an important role in nutrient cycling in marine systems. Changing environmental conditions in the BRSEA Study Area have the potential to change the balance between autotrophs and heterotrophs (Ortega-Retuerta et a; 2012). In particular, the increase in annual river discharge and permafrost melting may provide alternative sources of organic substrates for bacteria, perhaps bringing with it a change in bacterial species composition. Overall, little is known about bacterial

[49] Although the Inuvialuit do harvest some benthic species, there is no direct information on marine lower trophic levels in the TLK Inventory. As a result, references for this section only include western scientific citations.

species composition and distribution in the BRSEA Study Area, and more information is needed to predict and understand how a changing Arctic might alter microbial carbon pathways and major biogeochemical cycles on regional and seasonal scales (Maranger et al. 2015). As a result, bacteria were not chosen as an indicator.

7.3.2.1 Phytoplankton

Marine phytoplankton (open-water and under sea-ice) are small, photosynthetic organisms that live in the upper water column. They are a vital part of marine ecosystems because they convert carbon dioxide into organic compounds (Cobb et al. 2008; Horvat et al. 2017). By doing so, they form the base of the marine food web and support higher trophic levels (Bradstreet and Cross 1982; Hobson and Welch 1992; Cobb et al. 2008; Archambault et al. 2010; Ardyna et al. 2017).

Marine phytoplankton contribute an estimated 45% to earth's annual net primary production despite making up less than 1% of earth's total biomass (Archambault et al. 2010). The Canadian Arctic has the highest diversity of marine phytoplankton (an estimated 1,002 species) compared to either the Pacific (482 species) or Atlantic oceans (626 species) (Archambault et al. 2010). In the Arctic, the two most speciose groups of phytoplankton are a group of sea-ice related (i.e., sympagic) microalgae referred to as diatoms (belonging to the Order Bacillariophyceae) (Bradstreet and Cross 1982), and a group of flagellated protists called dinoflagellates that are pelagic. Collectively, these two groups account for approximately 60% of the Arctic's phytoplankton diversity (Archambault et al. 2010).

Light and nutrient availability directly influence primary productivity in the Arctic (Ardyna et al. 2017). Primary productivity is highest near the sea surface and generally decreases exponentially with water depth (Carmack et al. 2004). In the spring (during ice cover), productivity (e.g., pelagic algae blooms and ice algae) is highest near the sea-ice edge where photosynthetically active radiation (PAR) can penetrate and nutrients are released from the ice melt (Horvat et al. 2017). Carmack et al. (2004) estimate spring productivity at about 10 mg of carbon per meter squared per day (C m^{-2} d^{-1}). In late July, productivity peaks reaching about 200 C m^{-2} d^{-1} as a result of increased PAR penetration and nutrient availability (Carmack et al. 2004). Productivity continues to be high into the fall when increased wind-driven mixing brings nutrients back into the photic zone. The interplay between light and nutrient availability can result in ephemeral hotspots of primary productivity that are relied on by higher trophic levels (Ardyna et al. 2017).

In addition, massive sub-ice blooms have recently been observed in the Chukchi sea (e.g., Mundy et al. 2009; Arrigo et al. 2012; Horvat et al. 2017), challenging the traditional paradigm of Arctic productivity predominantly occurring at the ice edge (and not below it) and indicating fundamental changes in our understanding of the system (and how it might be affected by climate change). The extent of sub-ice phytoplankton blooms has likely been underestimated by ~ 30% (Horvat et al. 2017) and warrants further study.

Phytoplankton blooms are critical events for Arctic marine food webs because they create a pulse of primary productivity that is used by higher trophic levels, especially zooplankton (Soreide et al. 2010; Merkel et al. 2012) and the benthos below (Renaud et al. 2007; Waga et al. 2019). For example, Campbell et al. (2009) report that approximately 44% of primary productivity is consumed by micro- or mesozooplankton, while the remaining 56% is either exported further offshore or transported to the sea floor (Campbell et al. 2009).

7.3.2.2 Zooplankton

Marine zooplankton are tiny animals that usually eat phytoplankton or other zooplankton. They serve as an important link in the food web by connecting primary producers (e.g., phytoplankton) to higher trophic levels (e.g., zooplankton, benthic macrofauna, fish, birds, and marine mammals) (Archambault et al. 2010; Cobb et al. 2008; Kjellerup et al. 2015; Campbell et al. 2009).

While zooplankton diversity in the Canadian Arctic (372 species identified) has not been fully characterized, the number of species in the Arctic rivals that identified in western (481 species) and eastern (381 species) Canada. Calanoid copepods (suborder copepoda) dominate the Arctic species richness chart with approximately 40 – 50% of the total number of species belonging to this suborder (Archambault et al. 2010). It is not uncommon for relatively few species (< 20) to account for the vast majority of abundance or biomass. In the Canada Basin, surveys found that copepods made up approximately 90% of zooplankton abundance and more than 80% of biomass (Rutzen and Hopcroft 2018). In the BRSEA Study Area, 44–81% of zooplankton abundance and 52–71% of biomass was dominated by *Calanus glacialis, Calanus hyperboreus, Metridia longa, Oithona similis, Triconia borealis, Microcalanus pygmae*us, and *Pseudocalanus sp*. (Smoot and Hopcroft 2017a, b). Community structure was most strongly related to temperature and salinity in the upper 200 m, suggesting that future changes in the physical environment may lead to changes in the distribution of zooplankton communities in the Beaufort Sea.

Copepods (e.g., *Calanus* spp.) are a high-quality food source for many fish, birds, and marine mammals because of their high fat content (which is in the range of 50 – 70% lipids by dry mass) (Conover 1988; Falk-Petersen et al. 2009; Kjellerup et al. 2015). Accordingly, zooplankton productivity can influence the population dynamics of numerous other Arctic species (Bradstreet and Cross 1982; Cobb et al. 2008; Falk-Petersen et al. 2009; Kjellerup et al. 2015).

In contrast, zooplankton life histories are often synchronized to that of phytoplankton. This means that zooplankton population dynamics can be influenced by factors that act on phytoplankton. For example, disruptions in sea-ice breakup and the spring melt directly affect the timing of phytoplankton blooms and, therefore, can indirectly affect zooplankton (Huntley et al. 1983; Rutzen and Hopcroft 2018; Dezutter et al. 2019). Dezutter et al. (2019) showed that a disruption to sea ice breakup in 2012 caused a mismatch in peak abundance of herbivorous zooplankton and phytoplankton productivity.

Five zooplankton “hotspots” (owing to oceanographic conditions such as temperature, salinity, depth, and upwelling events) have been identified in the eastern Beaufort Sea; these are:

- waters near to Cape Parry
- Cape Bathurst
- Tuktoyaktuk Peninsula

- Mackenzie River estuary
- near Herschel Island

These hotspots are important foraging grounds for bowhead whales during August and September (Harwood et al. 2017). Ocean currents also introduce nutrients, detritus, and plankton rich water from the boreal Atlantic and Pacific oceans. This influx supports primary productivity and higher trophic level consumers (Wassmann et al. 2015).

It has been suggested that zooplankton are not good indicators of anthropogenic impacts because of the lack of reliable and consistent data to characterize the spatial and temporal variation in zooplankton community composition (Archambault et al. 2010; Rutzen and Hopcroft 2018). This is in part a result of low sampling effort (associated with the difficulties of working in the Arctic) and high variability in zooplankton distribution and density (which are affected by geographic location, depth, and seasonality, among other factors).

7.3.2.3 Benthic Macrofauna

Benthic macrofauna include relatively small animals that live on the sea floor (e.g., crab, shrimp, clams, mussels, sea urchins, sea stars, sponges, and coldwater corals). This group includes species with a wide range of ecological and life history traits. For example, some species are mobile (e.g., crab, shrimp, and sea urchins) while others are sessile (e.g., sponges and coldwater corals). Some are filter feeders (clams, sponges, and coldwater corals), while others are omnivorous (e.g., crab) or predominantly detritivores (e.g., shrimp).

Benthic macrofauna play a key role in arctic marine ecosystems. They support nutrient cycling and energy transfer processes, are strongly linked to food-web dynamics, and often create habitat for other fish and invertebrates (Welch et al. 1992; Renaud et al. 2007; Conlan et al. 2008; Merkel et al. 2012, Nelson 2013). In addition to their ecological importance, some benthic macrofauna are culturally important (e.g., naked sea butterflies [*Clione limacine*] are used by traditional harvesters to help estimate the timing of sea ice formation; Nunavut Department of Environment 2010).

Benthic macrofaunal assemblages in the Arctic are highly variable and influenced by a suite of abiotic factors. In general, two major gradients of benthic community composition have been established: 1) in the onshore-offshore axis (driven largely by ice scour, salinity, and depth), 2) in the east-west axis (driven largely by productivity and substrate characteristics) (Cobb et al. 2008). At a finer resolution, salinity and sea bottom temperature were the most important covariates identified by Cusson et al. (2007) for determining overall community composition. However, depth was the strongest positive predictor of species richness (Cusson et al. 2007). Ice scour is also linked to invertebrate abundance and diversity and favours organisms capable of rapidly colonizing disturbed sediments (Cobb et al. 2008). Overall, taxonomic diversity is generally high in shelf and slope areas and tends to be more variable inshore (Conlan et al. 2008).

Benthic communities are estimated to use approximately 60% of new annual carbon production, which highlights the strong ecological connection between pelagic and benthic communities (hereafter referred to as pelagic-benthic coupling) (Renaud et al. 2007; Conlan et al. 2013). Ampeliscid tube-dwelling worms, which are suspension and surface deposit feeders, form dense beds that are implicated in pelagic-benthic coupling. The worms use carbon from lower trophic levels and eventually provide feeding opportunities to higher trophic levels (e.g., eastern Pacific gray whales (*Eschrichtius robustus*), benthic feeding walrus (*Odobenus rosmarus*) and spectacled eider (*Somateria fischeri*)) (Conlan et al. 2013). The strength of pelagic-benthic coupling seems to decrease as depth increases (Roy et al. 2014).

7.3.3 Marine Fish and Habitat

Marine fish and habitat are discussed in relation to major geographic areas within the BRSEA Study Area:

- nearshore (Yukon North Slope to Bailey Island)
- nearshore (Banks Island and East of Tuktoyaktuk Peninsula)
- continental shelf
- continental slope

For the purpose of the BRSEA study, five species are used as generalized indicators for marine fish and fish habitat; arctic cisco (*Coregonus autumnalis*), least cisco (*Coregonus sardinella*), Dolly Varden char (*Salvelinus malma*), arctic char (*Salvelinus alpinus*) and arctic cod (*Boreogadus saida*). These species are all traditionally harvested and utilize varied habitats in the BRSEA Study Area. In addition, demersal fish are considered indicators to represent species that are not generally harvested but play an important ecological role and have close association with seabed habitat where interaction with human activities may occur. Indicator species are discussed separately below, in the context of each geographic area where they are most prevalent.

7.3.3.1 Nearshore (Yukon North Slope to Bailey Island)

Nearshore areas of the Beaufort Sea support anadromous and marine fish species and, occasionally, freshwater species such as northern pike (*Esox lucius*) or burbot (*Lota lota)*. Anadromous species are an important food source for community members. These species include Dolly Varden char, broad whitefish (*Coregonus nasus*), humpback (lake) whitefish (*Coregonus clupeaformis*), arctic cisco, least cisco and inconnu (also known as coney) (*Stenodus leucichthys*) (Niemi et al. 2012). The most common marine species include fourhorn sculpin (*Myoxocephalus quadricornis*), arctic flounder (*Liopsetta glacialis*), saffron cod (*Eleginus gracilis*) and Pacific herring (*Clupea harengus pallasi*) (Lawrence et al. 1984).

Important fish habitat is present in the Mackenzie estuary, Shingle Point, Kugmallit Bay, McKinley Bay, coastal Tuktoyaktuk Peninsula, Yukon North Slope, and Tuktoyaktuk Harbour as reported by local TLK holders (IMG Golder and Golder Associates 2011a:14). A narrow relatively stable buoyancy boundary current of brackish water (Carmack and Macdonald 2002) flows northeast along Tuktoyaktuk Peninsula and west along the Yukon North Slope which is used by anadromous fish (Niemi et al. 2012).These corridors provided critical rearing and migratory habitat for coregonid species such as Arctic cisco (, least cisco, broad whitefish, lake whitefish, and inconnu (Percy 1975; Lawrence et al. 1984).

Coastal bays, including Tuktoyaktuk Harbour, provide important habitat for marine species of fish (Bond 1982; Lawrence et al. 1984; Hopky and Ratynski 1983). At Phillips Bay along the Yukon North Slope, 21 fish species were captured over two summers with approximately 60% being anadromous and 40% marine; Arctic cisco was the most abundant species captured (Bond and Erickson 1989).

TLK holders have identified Aklavik to Shingle Point as a good area for coney (inconnu), and areas around King Point and Running River for whitefish (IMG Golder and Golder Associates 2011a:13). TLK holders also report that coney are found throughout the Mackenzie Delta and its estuary and Tuktoyaktuk Peninsula and up the coast (ICCP 2016: 11-196). Inconnu do not all migrate to feed in the marine environment or do so every year; the degree of marine migrations by inconnu decreases with distance from the marine environment (Howland et al. 2009).

Tuktoyaktuk Harbour provides important habitat to anadromous species of fish (Bond 1982; Lawrence et al. 1984; Hopky and Ratynski 1983). TLK holders reported that fish species such as flounder, northern pike, burbot, crooked back whitefish, chum salmon *(Oncorhynchus keta)* , inconnu, lake trout *(Salvelinus namaycush)*, blue herring (pacific herring), bullhead (sculpins), and Dolly Varden char are present in Tuktoyaktuk Harbour and along the coast (IMG Golder and Golder Associates 2011e: 10). Tuktoyaktuk Harbour may also provide spawning habitat for slender eelblenny (*Lumpenus fabricii*), blackline (or pighead) prickleback (*Acantholumpenus mackayi*), and rainbow smelt (*Osmerus mordax*) (Ratynski 1983).

Pacific herring are captured from July to September in Tuktoyaktuk Harbour and those caught in July and August are full of roe (ICCP 2016: 11-197). TLK holders identified two runs of Pacific herring into Tuktoyaktuk Harbour; a first run in July and a second run in September (IMG Golder and Golder Associates. 2014.: 5). Pacific herring are known to spawn in Tuktoyaktuk Harbour around break-up (Gillman and Kristoffereson 1984).

Whitefish is typically harvested in the harbour from breakup until September, but are harvested in the larger Tuktoyaktuk area year-round. TLK holders noted that during periods when winds are from the west, the catch increases, while the more easterly winds tend to decrease numbers of whitefish caught (IMG Golder and Golder Associates. 2014: 3).

All five species of Pacific salmon are captured periodically in communities bordering the Beaufort Sea; however, only chum salmon are known to have spawning populations in the Mackenzie River system (Stephenson 2006). With the possible exception of Pacific salmon, anadromous species found in the Beaufort Sea do not move offshore but remain in nearshore areas. At Philips Bay along the Yukon North Slope, only arctic cisco venture out to the 5 m isobath (Bond and Erickson 1989) and all anadromous species spawn in freshwater systems.

Between the depths of 10 m to 100 m along the Beaufort Shelf, the two most common fish species captured include Arctic cod, also known as polar cod (*Boreogadus saida*) and Pacific herring (Majewski et al. 2006; North/South Consultants and KAVIK-AXYS Inc. 2004a, b, c). Arctic cod are a keystone species transferring energy from lower (e.g., zooplankton) to upper trophic levels (e.g., marine mammals, seabirds and other fish) (Bradstreet et al. 1986; Welch et al. 1993; Darnis et al. 2012; Kortsch et al. 2015). Arctic cod, pricklebacks (Stichaeidae) and sculpins (Cottidae) were the three most abundant larval and post-larval fish captured in the nearshore and shelf waters between 1984 and 1987 (Chiperzak et al. 1990, 2003). Sampling reported by Walkusz et al. (2011) recorded the highest abundance of larval and juvenile arctic cod at station depths of 20-30 m, corresponding with the location of the frontal zone where the Mackenzie River plume water and open seawater meet. Since arctic cod are found throughout the Beaufort Sea and marine waters of the ISR, they will also be discussed in relation to the continental shelf and slope in those respective sections.

Fish that overwinter in coastal estuarine waters include arctic cisco, least cisco, rainbow smelt, Pacific herring and saffron cod, as well as the nearshore demersal fish community (e.g., blennies, sculpins, eelpouts); however, the extent of available overwintering habitat varies with freshwater inflow and ice cover (Sekerak et al. 1992). Sampling in the Canadian Arctic revealed distinct communities in coastal waters, segregated by depth (<50 m and >50m) and salinity. Majewski et al. (2013) found that depths <50m were characterized by *Gymnocanthus tricuspis* (Arctic staghorn sculpin), while depths >50m were characterized by *Ulcina olrikii* (Arctic alligatorfish). Larger physical processes likely play a substantial role in fish distributions (e.g., upwellings, plumes).

7.3.3.1.1 Arctic cisco

Arctic cisco are relatively abundant in the region and have no conservation status federally or in the Northwest Territories. They are traditionally harvested and of cultural importance to the communities where they are most prevalent (ICCP 2016:116, ACCP 2016:120; TCCP 2016:135 and PCCP 2016:115).

Arctic cisco occur along the coastal waters of the mainland of the ISR and are often the most abundant fish species along the coast (Cobb et al. 2008, Niemi et al. 2012). Young-of-the-year fish disperse from the Mackenzie River west and east along the coast, depending on the channel of the river they migrated from (Cobb et al. 2008). Some westward migrating young-of-the-year follow the coastline to the Colville River, Alaska, where they spend the next 5–7 years maturing before migrating back to the Mackenzie River, to spawn (Cobb et al. 2008). Current year spawners will return to the Mackenzie River and its major tributaries in July through September. They primarily feed on invertebrates such as copepods, mysids and amphipods (*Themisto sp.)* but will also prey on small fish (Lawrence et al. 1984).

7.3.3.1.2 Least cisco

Least cisco are relatively abundant and have no conservation status federally or in the Northwest Territories. They are traditionally harvested and of cultural importance to the communities where they are most prevalent (ICCP 2016:129, ACCP 2016; 130; TCCP 2016:148).

Least cisco occur westward to the Yukon/Alaska border (Cobb et al. 2008) and east of Tuktoyaktuk Peninsula in Liverpool Bay (Bond and Erickson 1993). The highest concentrations of least cisco in the summer are near the Mackenzie Delta (Cobb et al. 2008). Some will migrate up coastal streams to lakes (Bond and Erickson 1989). Spawning occurs in the Mackenzie River and its major tributaries in the fall. Coastal diet consists of invertebrates such as copepods, mysids, amphipods, polychaetes and small fish (Lawrence et al 1984).

7.3.3.1.3 Dolly Varden char

Dolly Varden char is listed on Schedule 1 of the federal Species at Risk Act and designated by COSEWIC as Special Concern. The Northwest Territories General Status Rank is sensitive. This species is of high cultural value for both the Inuvialuit and Gwich'in and is harvested by both Indigenous groups.

Dolly Varden char spawn in the headwaters of small arctic rivers such as the Big Fish, Rat, Vittrekwa, Babbage and Firth Rivers. The char parr remain in the rivers for approximately three years before entering the Mackenzie estuary to feed in summer (DFO 2003). In the fall, they migrate back to their respective river systems to overwinter and return each summer to the coast to feed. Maturity is generally reached at 5-6 years. The Big Fish char population appears to spawn every year (Sandstrom and Harwood 2002) but in other north slope rivers, spawning generally occurs every second year (DFO 2003).

Dolly Varden char mainly use the western freshwater corridor along the Yukon North Slope, either moving west from the Mackenzie River (GRRB et al. 2010) or east from the Firth and Babbage Rivers (IMG Golder and Golder Associates 2011a:13).

7.3.3.2 Nearshore (Banks Island and East of Tuktoyaktuk Peninsula)

TLK holders identified Liverpool Bay, Kugaluk River and Miner River estuaries and Husky Lakes as important spawning areas for Pacific herring and lake trout (ICCP 2016: 31) in nearshore areas in the area east of the Tuktoyaktuk Peninsula, including Banks Island. Wood Bay and the coastal area around Baillie Islands are important nursery and overwintering areas for both anadromous and marine fish (ICCP 2016: 37). In a fish survey conducted on the west side of Liverpool Bay and Wood Bay, catches were dominated by arctic cisco, saffron cod and arctic flounder with smaller catches of broad whitefish, lake whitefish and least cisco (Bond and Erickson 1993).

Arctic cod are present throughout Franklin Bay and Darnley Bay (PCCP 2016: 48). Large aggregations of arctic cod were observed in the winter of 2003-2004 in Franklin Bay occurring mainly between 140 m to the bottom (225 m). The abundance of Arctic cod in embayments may play an important role in the Beaufort Sea ecosystem (Benoit et al. 2008).

Arctic cisco is abundant in the coastal waters of Franklin Bay and Darnley Bay. These waters also provide feeding habitat for anadromous arctic char (PCCP 2016: 48). TLK holders reported that some char caught around Tipitituyak (in the Paulatuk area) may have been Pacific salmon (KAVIK-AXYS Inc. 2012:3-5). Saffron cod are found in large numbers in coastal waters near Cape Parry (PCCP 2016: 48).

The Cape Bathurst polynya and Prince of Wales Strait are both productive marine environments (SCCP 2016: 49) suggesting they are important areas for fish as well. Arctic char use coastal habitats adjacent to rivers flowing into coastal areas (SCCP 2016: 38). TLK holders in Sachs Harbour indicated that fish in Sachs Harbour include arctic char, salmon, trout, whitefish, cod and herring, but flounder is not common. (IMG Golder and Golder Associates 2011c: 11). Greenland cod have been observed in spawning condition at the mouth of the Sachs River (Chiperzak, 2019, pers. comm.). TLK holders from Ulukhaktok identified important habitat for arctic char in coastal waters along Victoria Island (OCCP 2016: 28,50).

Kelp beds are important habitat for a variety of macroinvertebrates and fish in other arctic regions and farther south (Filbee-Dexter 2019), and kelp presence is used by DFO for identifying Ecologically and Biologically Significant Areas in the north Pacific for marine use planning (e.g., Rubidge et al. 2018). Kelp beds are extremely rare in the BRSEA Study Area (Paulic et al. 2012). TLK holders have been identified kelp beds in several areas (e.g., Argo Bay Wise Bay and Darnley Bay (KAVIK-AXYS Inc. 2012; Paulic et al. 2012). Kelp beds have been observed near the entry to Summers Harbour (Chiperzak 2019, pers. comm.). Their distribution is severely limited by the availability of rocky substrates (Jerosch 2013) in addition to general limiting factors such as ice cover, scour and colder than optimal growing temperatures (Filbee-Dexter 2019). Species-specific use this kelp bed has not been documented.

7.3.3.2.1 Arctic Char

Arctic char populations appear stable and have no conservation status federally or in the Northwest Territories. They are culturally important and an important food source for the communities of Sachs Harbour, Paulatuk and Ulukhaktok (SCCP 2016:88; PCCP 2016:112; OCCP 2016:105). They are also a high research priority in these communities.

Anadromous arctic char occur east of Tuktoyaktuk Peninsula and in the Arctic Archipelago. They feed on invertebrates and fish in coastal areas (PCCP 2016: 112). In Darnley Bay, arctic char have been reported feeding on amphipods, sandlance (*Ammodytes* sp.), and capelin (*Mallotus villosus*) (Harwood and Babaluk 2014). Spawning mainly occurs in rivers between late September and early October (PCCP 2016:112). Coastal migrations from freshwater starts at between 3-5 years depending on the system, entering coastal waters at break-up and returning back to freshwater in the fall (PCCP 2016: 112).

Key marine habitat includes coastal Banks Island (SCCP 2016: 38:105), Horton River estuary, coastal areas of Darnley Bay (PCCP 2016: 26) and coastal areas of Victoria Island (OCCP 2016: 51).

7.3.3.3 Continental Shelf

Arctic cod is the most abundant fish in the Arctic Sea, making up approximately 95% of the pelagic fish community (Benoit et al. 2008; Fortier et al. 2015). As noted earlier, Arctic cod are an important trophic link between sea-ice algae and pelagic primary producers and higher trophic levels (e.g., ringed seals, beluga), which are harvested by Inuit peoples (Steiner et al. 2019). Arctic cod in continental slope waters are discussed further in Section 7.3.3.4.

Based on benthic fish trawls, two groups of demersal fish assemblages were identified on the continental shelf by depth; one species group at <50 m and the other > 50m. Based on relative abundance and distribution, Arctic Staghorn Sculpin dominated the <50m group, followed closely by Arctic Cod and Canadian Eelpout (*Lycodes polaris*). . Arctic alligator fish were the most prevalent in the >50 m group, again followed by Arctic cod (Majewski et al. 2013).

7.3.3.4 Continental Slope

On the continental slope of the US Beaufort Sea, arctic cod accounted for 92% of the total number of fish captured and 80% of the total weight (Rand and Logerwell 2011). The second most abundant taxon were eelpouts (Lycodes spp.) that made up 3.5% of the total number of fishes captured and 13% of the total weight. Other species included six species of sculpins, Bering flounder (Hippoglossoides robustus) and Greenland halibut (Reinhardtius hippoglossoides).

The Canadian Beaufort Sea was assessed using bottom trawling in the shelf and slope habitats between 20 and 1000 m depths (Majewski et al. 2017). Highest catch biomasses occurred at 350 m and 500 m depth slope stations, coinciding with 0° C temperatures in the Pacific–Atlantic thermohalocline and Atlantic water mass. The species captured were similar to those reported by Rand and Logerwell (2011).

7.3.3.4.1 Arctic cod

Arctic cod are abundant and widely distributed and have no conservation status federally or in the Northwest Territories. Arctic cod are not harvested but are a food source for culturally important harvested species of marine mammals such as beluga whales and ringed seals and various seabird species.

Arctic cod are found throughout the marine waters of the ISR. They are a small short-lived cod rarely reaching 300 mm in length and 7 years in age (Bradstreet et al. 1986). In Amundsen Gulf, spawning arctic cod start aggregating at depth precisely when the ice cover consolidates in early December and move to deeper areas once the photoperiod (daylight) increases (Fortier et al. 2014). The hatching season of arctic cod extends from January to July in Arctic seas that are influenced by large rivers (Fortier et al. 2014) (as is the case in the BRSEA Study Area with the Mackenzie River) and on the sea-ice algal bloom under the ice in spring (Fortier 2015).

Young arctic cod (1-2 years) feed on the ice-associated zooplankton on the underside of sea ice (Kohlbach et al. 2017). In water along the continental slope, the largest congregations of arctic cod were detected within the Atlantic water mass along the Beaufort continental slope (250–350 m) and near the bottom of Barrow and Mackenzie canyons, where temperatures were above 0°C (Crawford et al. 2012a). Likewise, recent studies on the eastern Beaufort Sea shelf have found an abundance of juvenile arctic cod in the top 15 m between July to October, with peak abundance observed in August (Wiese et al. 2019). Geoffroy et al. (2015) also found that age-0 arctic cod stayed <100 m in depth and descended to deeper waters in September. For adult cod, biomass abundance was mostly below 200 m between October and March, with peak abundance observed in December (Wiese et al. 2019), likely to avoid diving predators (Geoffroy et al. 2015). Similarly, Majewski et al. (2015) found most adult cod biomass was between 200 – 500 m. Smaller arctic cod on shelf habitat (<200 m deep) feed on algae eating copepods while larger arctic cod on sloping habitat (>200 m deep) feed on copepod eating amphipods.

Multifrequency split-beam acoustic data collected in October–November 2003 revealed that Arctic cod split into two distinct layers. Age-0 Arctic cod are distributed between 0 and ~60 m depth without any clear large-scale biomass trend. Adult Arctic cod distribute into offshore mesopelagic (middle) water layer between ~200 and 400 m and congregate on sloping bottoms (between 150 and 600-m isobaths) along the Mackenzie shelf and into the Amundsen Gulf basin (Benoit et al. 2014, Geoffroy et al. 2015).

Deep water bays such as Franklin Bay may be important spawning areas for arctic cod as reported by Benoit et al. (2008). Under ice habitat where ice algae grow provides important habitat for young arctic cod, while adults utilize deeper warmer waters between 150-600 m depth (Benoit et al. 2014, Crawford et al. 2012a).

7.3.4 Migratory Birds

Within the ISR, the Beaufort Sea supports nationally significant numbers of marine birds with over 40 species occurring regularly in offshore and nearshore waters (Alexander et al. 1988; Johnson and Herter 1989). Major species groups occurring in the Beaufort Sea include ducks; geese and swans; loons; gulls, terns and jaegers; murres and guillemots; and shorebirds. The region provides important breeding grounds and staging areas for millions of waterfowl, seabirds, and shorebirds. Due to their abundance in the region, these migratory birds also provide an important annual traditional harvest for some local Inuvialuit communities (Byers and Dickson 2001; Inuvialuit Community Based Monitoring Program 2019; Joint Secretariat 2003).

Inuvialuit communities in the ISR have expressed concerns regarding the effects of future tanker and ice breaker traffic and oil/gas development on migratory birds, including negative impacts on nesting waterfowl and associated uses by communities with subsequent impacts on the Inuvialuit traditional way of life (PCCP 2016: 61). In addition, there are concerns that aircraft (especially helicopter) activity in the region could disrupt migratory bird hunting areas and distribution. It has also been observed that climate change is affecting the length of the hunting season; for example, geese are arriving and laying eggs earlier, and spending less time in the region (PCCP 2016: 83, Overall, it is recognized that climate change is affecting migratory geese in the Arctic, including the timing of reproduction, although the effect may vary by location (e.g., low versus high Arctic) (Lameris et al. 2019).

As the focus of the BRSEA is on marine areas within the ISR, the focus here is on birds who utilize coastal and offshore marine areas within the BRSEA Study Area. As a result, passerine species are not a focal species group (despite migration pathways occurring over marine waters); nor are terrestrial non-migratory birds as per the *Migratory Birds Convention Act* (e.g., falcons, owls). For the purpose of the BRSEA, birds are divided into two VCs: migratory birds and seabirds. The migratory bird VC focuses specifically on geese, brant, swans, loons, and shorebirds. The seabird VC focuses on sea ducks, gulls and murres.

The key concerns for migratory birds in the region are habitat loss and alteration and sensory disturbance effects during breeding activities. Because offshore activities in the Status Quo and the three oil and gas development scenarios have limited potential to affect land-based breeding habitat (where there are species-specific differences in habitat use and timing), the focus of the data synthesis and assessment for the migratory bird VC is on coastal and offshore habitats that are used by the majority of migratory bird VC species groups. Given that the species groups (e.g., geese, loons, shorebirds) for the Migratory Bird VC have similar patterns of habitat use (i.e., coastal vs. offshore) and seasonal distributions (i.e., open water, life stage), species-specific indicators were not used. Instead the discussion centers on use of habitats and seasons patterns for all migratory birds. Where there are important differences, for example loons using offshore leads or foraging post-breeding, these exceptions are noted.

While the majority of species covered by the migratory bird VC will utilize nearshore (i.e., marine coasts) and/or coastlines (i.e., coastal flats), some loons will also use offshore leads during spring migration. During this period, the distribution of loons will overlap with species such as common eider (*Somateria mollisima*) and long-tailed duck (*Clangula hyemalis*).

7.3.4.1 Conservation Status

Most migratory birds in the BRSEA Study Area have secure populations; however, four species that can be found in offshore and coastal habitats, red knot (*Calidris canutus)*, buff-breasted sandpiper (*Calidris subruficollis),* Hudsonian godwit (*Limosa haemastica)*, red-necked phalarope *(Phalaropus lobatus*), have been designated as at risk by COSEWIC and/or are listed on Schedule 1 of SARA (see Section 7.3.1).

7.3.4.2 Cultural Value

Many migratory bird species are used traditionally by local Inuvialuit communities, as identified through oral and written evidence provided by TLK holders. Each of the six Inuvialuit communities in the ISR have provided detailed TLK with respect to migratory birds in their community conservation plans (CCPs). With respect to migratory birds, the CCPs provide information regarding important areas where community members undertake traditional land use practices including harvesting of migratory birds, as well as details on the importance of the habitat for migratory birds and recommended guidelines for management and conservation of bird populations and their habitat (e.g., ACCP 2016: 33, 55; ICCP 2016: 40, 42; OCCP 2016: 34, 48; PCCP 2016: 61, 82; SCCP 2016: 30, 32, 39; TCCP 2016: 28, 36, 44, 56).

Geese, swans, brant, ducks, and some shorebirds are used for subsistence (meat, eggs, and feathers) during the spring, summer and fall. The importance of traditional harvesting, including harvesting of migratory birds, is well demonstrated by the Inuvialuit harvest studies and community monitoring programs (Joint Secretariat 2003, Fabijan et.al 1993; Inuvialuit Community Based Monitoring Program 2017, 2018, 2019; FJMC and IRC 2019a; 2019b, 2019c.).

7.3.4.3 Distribution and Ecology

The number, diversity and distribution of migratory birds using the Beaufort Sea vary with season. Spring migration in the BRSEA Study Area generally begins in late April with the peak in May and early June (i.e., spring transition). During spring migration, most, if not all, of the western Canadian breeding population of some migrant species (i.e., king and common eiders) use offshore leads. Large numbers of birds also congregate in key coastal areas during moulting and fall staging. Nesting and brood-rearing take place from May to early August (i.e., Open Water Season) depending on the species. Fall staging and migration starts for most species during August to late September (i.e., Open Water Season; see Alexander et al. 1988).

Important habitat for birds has been identified in both offshore and coastal areas, including the recurring offshore leads and polynyas off Cape Bathurst, Banks Island and the Mackenzie Delta (Alexander et al. 1997) and coastal bays such as Shallow and Mallik Bays in the outer Mackenzie Delta, and McKinley Bay on the Tuktoyaktuk Peninsula (Alexander et al. 1988; Latour et al. 2008). The seasonal distribution, abundance and occurrence of birds in the Beaufort Sea are summarized in Table 7-12.

Table 7-12 Annual Distribution of Migratory Birds in the Beaufort Sea

Lifecycle Phase	Marine Habitat Use	Species	Comments
Spring Migration	*Offshore* Polynyas and open water leads off Cape Bathurst, Banks Island and the Mackenzie Delta are important areas (Alexander et al. 1997; Mallory and Fontaine 2004). 100,000's of birds concentrate in these leads for a brief period of time during their eastward migration to rest, feed and court (Alexander et al. 1997; Dickson and Gilchrist 2002).	Loons (e.g., Pacific loon, red-throated loon), eiders, long-tailed duck	The Beaufort Sea is used by eastward migrating birds in the spring (May and June). The spring distribution of birds in offshore and nearshore areas is closely tied to the occurrence of open water.
	Nearshore Coastlines where landfast ice has retreated.	Geese, brant	
Nesting and Brood-Rearing	Offshore Majority of nesting and brood-rearing birds make little use of offshore areas. Seabirds (guillemots and murres) and some loons are the exception; these species may forage considerable distances from nest sites (Alexander et al. 1997).	Guillemots, murres, loons	Red-throated loons (*Gavia stellate*) will forage in coastal waters to provide food for their young (Dickson and Gilchrist 2002). Numerous small colonies of snow geese, black brant, glaucous gulls, and common eiders nest along the Beaufort Sea coastline (Alexander et al. 1988). Two colonies of snow geese also occur along the eastern Beaufort Sea coastline: one occurs on small islands in the Outer Mackenzie Delta and the other in the Anderson River Delta (Alexander et al. 1988). Two small seabird colonies occur along the Beaufort Sea coastline; a colony of about 800 thick billed murres (*Uria lomvia arra*) nests on cliffs at Cape Parry, and a colony of approximately 60 black guillemots (*Cepphus grille*) nest within rock piles and old buildings on Herschel Island (Dickson and Gilchrist 2002). Guillemots are currently declining in Herschel Island (Eckert et al. 2006). Black guillemots feed on inshore fish within 15 - 30 km of nest sites, while murres may feed further from shore (Dickson and Gilchrist 2002; Mallory and Fontaine 2004).
	Nearshore Large numbers of nesting and brood-rearing birds use nearshore and coastal areas along the Beaufort Sea during late June and July (Alexander et al. 1988); numerous species nest along the coast on islands or suitable mainland areas and forage in nearshore marine waters, coastal wetlands, and sheltered bays (Alexander et al. 1988).	Eiders, Pacific black brant, snow geese, greater white-fronted geese, tundra swans, glaucous gulls and Arctic terns	

Table 7-12 Annual Distribution of Migratory Birds in the Beaufort Sea

Lifecycle Phase	Marine Habitat Use	Species	Comments
Nesting and Brood-Rearing (cont'd)			Birds nesting inland, such as the greater white-fronted goose (*Anser albifrons*), may also lead their young to the coast during brood-rearing (AMEC 2004). Large numbers of brood-rearing waterfowl, including geese and swans, have been observed on the outer Mackenzie Delta coastline (Alexander et al. 1988; LGL 2004)
Moulting and Moult Migration	*Offshore* Birds such as king eiders and some common eiders, migrate through the Beaufort Sea to moult in the Chukchi and Bering seas. This migration is described as the 'moult migration' and is summarized separately from fall migration which refers to the post-moult (rather than pre-moult) migration of birds.	Eiders, long-tailed ducks and scoters	Westward movement of birds across offshore areas of the Beaufort Sea begins with the moult migration of king eiders *(Somateria spectabilis*) in late June (Dickson et al. 2001, 2006; Oppel et al. 2008). King eiders in the Beaufort Sea area moult in distinct locations away from the nesting and wintering grounds in the Chukchi and Bering seas (Dickson et al. 2001, 2006; Oppel et al. 2008). Movement in the eastern Beaufort Sea is staggered from late June to mid-September. Satellite tracking showed that male king eiders departed the nesting grounds between late June and mid-July, and staged for 2 - 5 weeks off Banks Island and Cape Bathurst in water <50 m in depth (Alexander et al. 1997; Dickson et al. 2001, 2006). Tagged female king eiders departed the breeding grounds from late July to mid August (Dickson et al. 2001, 2006). During moult migration, both male and female king eiders moved in a broad front up to 200 km offshore from the Mackenzie Delta (Dickson et al. 2001, 2006). Similar to king eiders, some tagged male common eiders also undertook moult migration across the Beaufort Sea in July, while others moulted near their breeding grounds (Environment Canada 2005 cited in KAVIK-AXYS Inc. 2009). Female common eiders moulted within 50 km of the nesting colony and, unlike some males, did not undertake an extensive moult migration across the Beaufort Sea (Environment Canada 2005 cited in KAVIK-AXYS Inc. 2009). Moult migration of male common eiders across the Beaufort Sea is likely rapid, based on the quick transit of birds during fall (post-moult) migration (Environment Canada 2005 cited in KAVIK-AXYS Inc. 2009).

Table 7-12 Annual Distribution of Migratory Birds in the Beaufort Sea

Lifecycle Phase	Marine Habitat Use	Species	Comments
Moulting and Moult Migration (cont'd)	*Nearshore* Large numbers of ducks (primarily males and failed breeding females from inland areas) migrate to coastal areas of the Beaufort Sea to moult their flight feathers Birds concentrate in sheltered waters in coastal bays and behind barrier islands and spits (Alexander et al. 1988). These areas likely provide abundant invertebrate food (Dickson and Gilchrist 2002).	Long-tailed duck, white-winged scoter, surf scoter, scaup and red-breasted merganser	Movements of birds to moulting sites begin in late June, and peak numbers in coastal areas typically occur from late July to mid-August (Barry et al. 1981, cited in Cobb et al. 2008; Johnson and Richardson 1982). Over 100,000 ducks moult along the Beaufort Sea coast, with the most common species being long-tailed duck, white-winged scoter *(Melanitta deglandi*), surf scoter *(Melanitta perspicillata*), scaup and red-breasted merganser *(Mergus serrator*) (Alexander et al. 1988, Cornish and Dickson 1994; Cobb et al. 2008). Key moulting areas include McKinley Bay, Phillips Island, Kukjuktuk Bay and Hutchinson Bay areas on the Tuktoyaktuk Peninsula, Phillips Bay and adjacent areas along the Yukon coast, and Workboat Passage at Herschel Island (Alexander et al. 1988, Cornish and Dickson 1994; LGL 2004; Latour et al. 2006).
Fall Migration	*Offshore* Similar to moult migration, a number of birds likely move through offshore areas of the Beaufort Sea during the fall (post-moult) migration. During oceanographic surveys, birds were clumped with marine mammals at bathymetric features such as canyons, submarine ridges and shelf breaks (Harwood et al. 2005), which may reflect areas of higher productivity and food availability.	Eiders, long-tailed ducks, loons, seabirds (possibly murres), gulls and kittiwakes	Based on satellite telemetry data, female common eiders and some male common eiders undertake fall migration across offshore areas of the Beaufort Sea during October (Environment Canada 2005 in KAVIK-AXYS Inc. 2009). Long-tailed ducks that moulted on Victoria Island and the Queen Maud Gulf were also tracked moving through the Beaufort Sea in October (Dickson et al. 2006). Migration of long-tailed ducks across the Beaufort Sea was rapid and occurred within 4 – 7 days (Dickson et al. 2006). Whether long-tailed ducks are abundant in deeper offshore areas of the Beaufort Sea during fall migration is unknown. Harwood et al. (2005) reported few long-tailed ducks in offshore areas of the Beaufort Sea during August to September.
SOURCE: This table is based on information provided in the BP Exploration Pokak 3D Seismic Program: Project Description (KAVIK-AXYS Inc. 2009).			

7.3.4.4 Key Habitat

Key terrestrial and marine bird habitats (see Mallory and Fontaine 2004; Latour et al. 2008), including Important Bird Areas (IBAs) provide important habitat for migratory birds and are found throughout the ISR (see Figure 7-48). They span a variety of coastal and offshore habitats, including sheltered inlets and bays, estuaries, exposed waters (i.e., leads), sounds, islands, and islets. For the BRSEA, migratory bird habitat associated with the marine environment can be summarized into three primary habitat types (or zones) (after Mallory and Fontaine 2004): (1) coastline, (2) open sea (including inshore, nearshore, and offshore components out to the 200-nautical-mile limit of the exclusive economic zone), and (3) polynyas/offshore leads.

7.3.4.4.1 Coastline

Most of the key coastal habitat sites in the Northwest Territories have been identified (Alexander et al. 1991; Latour et al. 2008), and several are protected as migratory bird sanctuaries (Figure 7-48); these areas typically include both terrestrial and marine components. Key coastal habitat sites includes important shoreline features such as wetlands, salt marshes, mudflats, and estuaries.

Many species of birds, particularly gulls, waterfowl, waterbirds, and shorebirds, rely on these areas to feed during breeding or migration or to rear young. For instance, during the breeding period, most shorebird species forage on freshwater invertebrates, although marine crustaceans, amphipods, and molluscs may make up a portion of their diet. Loons, geese and swans breed primarily on marshy tundra, marshy/inland lakes and bays. Most nests are located near water and often on islands. Turnstones, sandpipers, plovers and phalaropes use the onshore habitats (e.g., tundra, rivers, and lakes) in the ISR primarily for breeding but may use coastal or offshore habitats for staging during migration (Cornell Lab of Ornithology 2019).

7.3.4.4.2 Open Sea

Open sea habitats have been recognized as one of the most understood zones with respect to migratory birds. Migratory birds rely on both the benthic (substrate of aquatic basins) and pelagic (water column) realms of the open sea.

Most benthic feeders forage in the euphotic zone (0–50 m), where enough light penetrates to allow photosynthesis. Other pursuit divers (e.g., murres) use the surface (epipelagic) layer (0–200 m deep) including the surface layers where photosynthesis occur (i.e., euphotic zone) and barely lit layer (dysphotic zone) where light is sufficient to permit pursuit divers to forage, but insufficient for photosynthesis in the dysphotic zone (Montevecchi and Gaston 1991).

Offshore sites are important as feeding areas, particularly for colonial-nesting seabirds, spring migration staging areas (McLaren 1982), for moulting (Huettmann and Diamond 2000) and overwintering areas for some species (Durinck and Falk 1996).

Loons spend most of their time on open water and come to land mainly to nest; loons are expected to stage in marine environments during migration to southern wintering locations. Loons may be found group feeding for fish on lakes in the late summer and during fall migration.

Unlike other shorebirds, phalaropes will use offshore marine environments during migration.

7.3.4.4.3 Polynyas and Shore Leads

Polynyas are areas of open water surrounded by ice that may be caused by a variety of factors, including currents, tidal fluctuations, wind, or upwellings (Stirling 1981; Lewis et al. 1996; Barber et al. 2001; Melling et al. 2001). In addition to recurrent polynyas, there are extensive systems of shore leads throughout the Arctic that are maintained largely by offshore winds and local currents (Smith and Rigby 1981).

Polynyas and shore leads provide the open water that is required as feeding sites for migrating birds and form important migration corridors and staging areas (Alexander et al. 1997).

7.3.5 Seabirds

Seabirds are valued components of marine and coastal ecosystems because of their ecological value, cultural importance and traditional use by Inuvialuit, their vulnerability to environment changes, and regulatory considerations as migratory birds.

The southern Beaufort Sea is an important region for marine birds as thousands of seabirds, sea ducks, shorebirds, and geese use its marine habitats for breeding and molting and as corridors during migration every year (see Table 7-12).The Bathurst polynya and lead system develop annually around the 30-m-depth contour in the western Amundsen Gulf (Marko 1975, Hannah et al. 2009). This is important marine habitat for all seabird indicators because of its predictability and high productivity. Marine currents and variable bathymetry produce upwellings along Banks Island and the Tuktoyaktuk Peninsula (Hannah et al. 2009).

For the purpose of the BRSEA study, seabirds are defined as marine birds that spend most of their life cycle at sea except for breeding. Three seabird species are used as generalized indicators for this VC: Thick-billed Murre (*Uria lomvia*; hereafter murres), Pacific Common Eider and Sabine's Gull (*Xena Sabine)*. Each represents a different life history and foraging ecology, and together through changes in their behavior, population numbers, or productivity, constitute a robust group to help describe spatial and vertical use of different parts of the marine environment of the BRSEA Study Area: oceanic (beyond the continental shelf - murres), neritic (continental shelf-eiders and gulls) and littoral zones (intertidal-eiders and gulls).

Habitats within the BRSEA Study Area are critical for the survival and population health of seabirds that breed in the Canadian arctic. Although long-lived, the sexual maturity of seabirds is slow and annual productivity is low and variable; for example murre (Gaston and Jones 1998), eider (Goudie et al. 2000), and Sabine's gull (Day et al. 2001).

Human activity has the potential to influence the survival of marine birds in the BRSEA Study Area. These include 1) direct mortality from hunting, collisions with offshore structures (i.e., attraction to light), oil spills, or entanglement in fishing nets; 2) habitat degradation through release of contaminants or overexploitation of food resources such as fish, krill and molluscs; 3) sensory disturbance and change in behaviour; and 4) direct loss of habitat to industrial, urban, or recreational development (Dickson and Gilchrist 2002).

Seabirds, represented by these three species, and particularly eiders, are important for Inuvialuit traditional use within the BRSEA Study Area (ICC et. al. 2006:11-187; SCR 2011:12; KAVIK-AXYS Inc. 2012: 3-14; OCCP 2016:132).

7.3.5.1 Thick-billed Murre

7.3.5.1.1 Conservation Status

The thick-billed murre has not been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and it is ranked sensitive by the Working Group on General Status of NWT Species (2016).

Thick-billed murres breed in a single location in the western Canadian Arctic within the ISR, at least 1300 km away from the closest murre colony in Alaska or Nunavut (Johnson and Ward 1985). The number of murres nesting in the Cape Parry Migratory Bird Sanctuary, NWT, varies between 500 to 900 individuals each year (Alexander et al. 1997; Latour et al. 2008). The Cape Parry Thick billed murre belongs to the subspecies *Uria lomvia arra*, which is larger and less abundant than the Atlantic subspecies *Uria l. lomvia* (Storer 1952; Tigano et al. 2015).

Thick-billed murres are vulnerable to anthropogenic threats such as fisheries bycatch, hunting for food and mortality due to collisions with oil platforms and oil spills (Gaston and Hipfner 2000; Wiese et al. 2001; 2004a). They are also very susceptible to disturbance when nesting; they easily flushed off cliffs when startled leaving eggs/chicks vulnerable to predation (Mallory et al. 2009; Brisson-Curadeau et al. 2017). Despite their capability of accessing prey at different levels of the water column, thick-billed murres are sensitive to reductions in food supply particularly when breeding (Gaston and Hipfner 2000). The single location of murres in the BRSEA Study Area (i.e., Cape Perry) makes them more vulnerable to catastrophes (Latour et al. 2008). Thick-billed murres are particularly vulnerable during the swimming migration, which is performed by flightless adults (due to moult) and chicks still not able to fly.

Global warming may cause changes in the timing and duration of the Open Water Season in the Beaufort Sea (Section 6.3.2.3). These changes may benefit thick-billed murres by extending feeding periods before and after the breeding season. Nonetheless, changes in ice-driven food webs and preferred prey species may also occur and would adversely affect adult and young body condition with ultimate effects on population numbers. Changes in dominant food species – decreases in arctic cod and increases in capelin – have already been observed over a 33-year period in the diet of murres in eastern Arctic colonies (Gaston and Elliott 2014). Finally, predicted changes in wind speed and storms may also affect feeding and cause nest abandonment at the colony (Mallory et al. 2009).

7.3.5.1.2 Cultural Value

Cape Parry MBS, identified as site No 422D in the Paulatuk Community Conservation Plan (PCCP 2016: 67), is an important site for the Community of Paulatuk because it holds the only nesting thick-billed murre colony in western Canadian Arctic (PCCP 2016: 67). Cape Parry MBS is located within the Anguniaqvia niqiqyuam Marine Protected Area (ANMPA) designated in November 2016.

Thick-billed murres are not hunted for food in ISR, which occurs in other colonies in the Atlantic (Gaston and Hipfner 2000). However, egg collections are occasionally carried out at the top end of Cape Parry for eiders, geese and murres as a side activity while whaling (KAVIK-AXYS Inc. 2012: 3-14).

7.3.5.1.3 Distribution and Ecology

Thick-billed murres have an arctic and subarctic circumpolar distribution, and breed during the Open Water Season in the Atlantic, Arctic and Alaska (Gaston and Hipfner 2000). Inuvialuit TLK holders identified the murre breeding season as between May and August (PCCP 2016: 67).

Thick-billed murre lay a single egg on the bare rock of cliff edges. Both parents incubate the egg (30 days) and take turns brooding and feeding the chick, mainly fish, several times per day (Gaston and Jones 1998). After 15-20 days, the chick departs to sea with the male, which cares for the chick for 2 months until independence (Burke et al. 2015).

Murres are principally pelagic, capable of diving to depths > 150 m (Gaston and Hipfner 2000). They can forage up to 200 km from their colony but their foraging during the breeding season varies substantially among colonies (Gaston and Nettleship 1981; Harding et al. 2013; Gaston et al. 2013). There is a gap of knowledge about both the foraging ranges and diets of Cape Parry murres. However, it is expected that foraging ranges are between 70-140 km from the colony based on recent estimates derived from telemetry data from eastern Canadian colonies (Mallory et al. 2018).

Thick-billed Murres are dietary generalists feeding on a variety of pelagic and benthic fish and invertebrates (e.g., amphipods, euphausiids, shrimp, squid) (Gaston and Hipfner 2000; Elliott et al. 2008). Forage fish species such arctic cod, capelin and sand lance (*Ammodytidae sp*.), and cephalopods such as squid (*Gonatopsis sp.*) are frequent prey items found in diets of murres in the Canadian eastern Arctic (Gaston and Jones 1998; Gaston and Hipfner 2000). These prey species are commonly found throughout waters bordering the coast of Paulatuk (PCCP 2016: 71), Sachs Harbour in the Amundsen Gulf region (capelin, Shields 1988), and the area just off Cape Parry (squid; Paulic et al. 2011; shrimp (*Padalus spp*): SCCP 2016:115; KAVIK-AXYS Inc. 2012: 3-5). Other commonly captured marine fish families in the southeastern Beaufort Sea and possible prey for Cape Parry murres are the sculpins, snailfish (*Liparidae*) and pricklebacks (Cobb et al. 2008)

7.3.5.1.4 Key Habitat

Open water and the Cape Bathurst polynya and leads are important foraging habitats for Thick-billed murres during annual breeding and spring and fall migration (Figure 7-48). Murres can also use the coastline during the at-sea chick stage when the male and chick travel along the coastline for ~1000 km after leaving the colony (Frederiksen et al. 2016). Murres are expected to be found mostly on the continental shelf and slope off Cape Parry during the breeding season and traveling along the coastline of either side of Cape Parry late in the open season.

The offshore habitat adjacent to Cape Parry is particularly important for this species during the breeding season. Marine currents and a variable bathymetry in this area result in upwelling currents that produce a rich marine environment (Marko 1975; Sévigny et al. 2015). Mallory et al. (2018) proposed environmental protection buffers around thick-billed murre colonies in the Arctic, with the size of the buffer varying between 70 and 140km depending on colony size.

The Cape Bathurst polynya near Cape Parry is thought to be important foraging habitat for murres during the open water and transition seasons. Marine currents and variable bathymetry produce upwellings along Banks Island and the Tuktoyaktuk Peninsula (Hannah et al. 2009). It has distinctive and more abundant mesozooplankton assemblages than in the neritic shelf, and deep slope (Darnis et al. 2008) and is a possible “hotspot” for cephalopods (Gardiner and Dick 2010).

Habitat use and routes during migration are unknown for Cape Parry murres. Nonetheless, they are expected to use the recurrent leads and polynyas that serve as a migration corridor for many other marine birds (Alexander et al. 1997; Mallory and Fontaine 2004).

Based on geolocation studies, adult male and chick murres from Cape Parry are expected to be present within the BRSEA Study Area in September-October (Burke et al. 2015; Gaston et al. 2013). The male and chick can travel together up to 1000 km along the coast, and adults alone can travel another 2000 km more to open waters (Frederiksen et al. 2016). Migration routes might be westward along the Beaufort Sea and Mackenzie Bay area based on at-sea survey observations of individuals during the transition season (Harwood et al. 2005; Wong et al. 2014).

7.3.5.2 Pacific Common Eider

7.3.5.2.1 Conservation Status

The Pacific Common Eider breeds in the BRSEA Study Area and is the largest sea duck in North America. It is considered near Threatened by the IUCN (BirdLife International 2018) and ranked sensitive by the Working Group on General Status of NWT Species (2016).

Population estimates and trends for Canada are currently based on a count obtained about every 10 years during spring migration at Point Barrow, Alaska (Suydam et al. 2000). After declines in the late 20th century, recent counts suggest the population has increased since the mid-1990s to over 100,000 eiders (CWS Waterfowl Committee 2017).

Pacific common eiders are particularly vulnerable to shipping disturbance and oil spills because they congregate in large, dense flocks during winter, moulting and migration. Over 20,000 common eiders (or over 25% of the total Beaufort Sea population) congregate in open water leads in the ice off Cape Bathurst during spring migration (Alexander et al. 1997). Eiders are also one of the most frequent marine birds that collide with offshore wind farms and oil/gas infrastructure (Day et al. 2005; Robinson Willmott et al. 2013). They are harvested for traditional purposes (adults, eggs, and down feathers) by Inuvialuit (KAVIK-AXYS Inc. 2012: 3-14; ICC et. al. 2006: 11-150). Eiders are sensitive to nesting habitat degradation, as well as disruption of foraging habitat that could result in the reduction and quality of their preferred prey (e.g., mollusks, echinoderms, mussels). Contaminants are a special concern because eiders eat benthic organisms such as mussels that are filter feeders, known to concentrate pollutants from the water column (Rainbow 1996; Mallory et al. 2004).

Climate change may benefit Pacific common eiders if warming results in fewer late springs, possibly increasing their annual average productivity. However, the presence of a greater expanse of open water could cause storm tides to occur earlier in the year, thereby affecting birds nesting in low-lying areas along the coast (Mallory et al. 2009).

7.3.5.2.2 Cultural Value

Pacific Common Eider or Qaigavik are traditionally used by Inuvialuit. The Inuvialuit collect eggs for food and eiderdown for making pillows and parkas (KAVIK-AXYS Inc. 2012: 3-14; ICC et. al. 2006: 11-150; WMAC-NS and AHTC 2018b: 23,78)

A study of traditional harvesting of King and Common Eiders in the ISR estimated the traditional harvest of Pacific Common Eiders in Canada and Alaska at 2,500 birds per year (Fabijan et al. 1997). Within the ISR, approximately 152 Common Eiders were harvested per year during the spring between 1987-1998 (Fabijan et al. 1997). The Inuvialuit Harvest Study 2018 identified that hunters from in Ulukhaktok harvested 276 common eiders (Inuvialuit Community Based Monitoring Program 2019: 15). Inuvialuit TLK holders from Paulatuk stated, “they generally do not eat any type of bird that lives in the ocean, like king eider ducks, because they have a "fishy" taste” (IMG Golder and Golder Associates 2011b: 12).

There is a common concern in all Inuvialuit communities of declining populations of eiders in the region (e.g., PCCP 2016: 137; OCCP 2016: 127). Observations by Inuvialuit TLK holders noted fewer juvenile ducks and a general decrease in geese, ducks, and swan numbers in 2010 (IMG Golder and Golder Associates 2011a: 17). They also stated that there have been changes in goose migration routes, and duck numbers appear to be lower than previously (IMG Golder and Golder Associates 2011f: 15). Some Inuvialuit TLK holders have mentioned that eiders have been seen in January and February and wonder if they now spend the winter in the area (KAVIK-AXYS Inc. 2012: 3-14).

Important areas for egg collection by Inuvialuit are at Egg Island, near Argo Bay in Darnley Bay and on the islands in the Clapperton area near Paulatuk (KAVIK-AXYS Inc. 2012: 3-14). Residents in Ulukhaktok harvest eider eggs in small numbers on the islands in Safety Channel (Kay et al. 2006).

7.3.5.2.3 Distribution and Ecology

The Pacific common eider breeds along the mainland coast of the Beaufort Sea of the Yukon east into Coronation and Queen Maud gulfs, as well as Banks and Victoria islands, NWT (Barry 1986; CWS Waterfowl Committee 2017) (Figure 7-48). They are present in the BRSEA Study Area from May to August. (Alexander et al. 1997; OCCP 2016: 125). Pacific common eiders winter off the southeast Chukotsk Peninsula, Russia and St. Lawrence Island, Alaska and are highly philopatric to those locations (Dickson 2012). Females return to their natal breeding site and are highly philopatric to that area (Dickson 2012; Petersen and Flint 2002).

During the Spring Transition Season, hundreds of thousands of eiders stop temporarily in leads of open water in the southeastern Beaufort Sea to rest, feed, and court (Alexander et al. 1997). They use the open water leads, particularly the continuous band of open water extending from Herschel Island to Cape Bathurst to the north end of Banks Island (Alexander et al. 1997). Most Pacific Common eiders remain along the mainland coast, migrating eastward from Cape Bathurst to a second staging area in the Dolphin and Union Strait (Barry 1986; Alexander et al. 1997). Pacific common eiders nest on small, offshore islands secure from arctic foxes (*Alopex lagopus*; Barry 1986).

Females alone incubate ~ 5 eggs for 26 days (Goudie et al. 2000). Moulting eiders concentrate in sheltered bays and behind barrier beaches along the Tuktoyaktuk Peninsula and on Banks Island (Latour et al. 2008). Few Pacific common eiders are seen moving through the Beaufort Sea in the fall because their migration is staggered (June-November, Barry 1986; Suydam et al. 1997), and they tend to migrate farther than 5 km offshore (Dickson 2012).

Pacific Common Eiders feed on bottom-dwelling invertebrates, especially intertidal and subtidal mussels, but also on crustaceans and echinoderms (sea urchins), mollusks, small fish and fish eggs (Cornish and Dickson 1997; Alexander et al. 1988). Mussels are harvested by Inuvialuit in Sachs Harbor (IMG Golder and Golder Associates 2011c: 11). The precocial duckling eider, especially in young-down stages (<2 week old), eat different foods from hens, being dependent at first on small, soft prey items, notably insects, amphipods, and small gastropods such as periwinkles and chink shells (*Lacuna* spp.), sandworms (*Nereis* spp.) and herring eggs (Palmer 1976 cited in Goudie et al. 2000).

Pacific Common Eiders prefer to feed in water less than 15 m deep (Alexander et al. 1997). They tend to concentrate in the shallowest open water areas: off the Tuktoyaktuk Peninsula and Cape Bathurst, where the ice edge is usually located near the 20 m bathymetric contour, and in the narrows in Dolphin and Union Strait, where the water is less than 20 m deep (Mallory et al. 2009).

Maximum foraging distances for eiders during breeding is 50–80 km but most foraging occurs within 3 km in areas not influenced by sea ice (Dickson 2012; Mallory et al. 2018). They may feed within 15 km where landfast or pack ice may still be present during breeding (Janssen and Gilchrist 2015 cited in Mallory et al. 2018).

7.3.5.2.4 Key Habitat

Within the BRSEA Study Area, eiders are expected to use the coastline from Herschel Island in the west to Victoria Island in the east (Figure 7-48).

The southern coast of the Amundsen Gulf and the open water just west of Cape Bathurst are important areas during the spring migration because large aggregations of Pacific eiders occur regardless of ice conditions (Alexander et al. 1994; Dickson and Gilchrist 2002). The highest number and density tend to occur between Cape Lyon and Clinton (Alexander et al. 1994).

The most important nesting areas for Pacific Common Eider within the BRSEA Study Area is Prince Albert Sound off western Victoria Island and along the south coast of Victoria Island and Banks Island (Cornish and Dickson 1997; Latour et al. 2008). Eiders also breed in a more scattered nesting groups on small islands at McKinley Bay, along the Tuktoyaktuk Peninsula (Latour et al. 2008) and on Herschel Island (Burns 2012) (Figure 7-48). A 15 km buffer was recommended to define key marine sites around common eider breeding colonies (Goudie et al. 2000; Iverson et al. 2014). This boundary would likely capture much of the area used by females and broods early after hatching and generally identify those sites with a high probability of large bird densities on the water.

The availability of food and safe environment for both the female and precocial ducklings (able to dive at age of 2 days old; Goudie et al. 2000) is key for their survival and ultimately eider population health.

7.3.5.3 Sabine 's Gull

7.3.5.3.1 Conservation Status

Sabine's gull (*Xema sabini*) is an unusual and distinctive arctic gull that breeds at high latitudes but winters in coastal upwelling zones of the tropics and subtropics (Day et al. 2001). Breeding distribution is more tied to the Arctic than for any other gull species nesting in the BRSEA Study Area.

Sabine’s gull is considered to be low concern by the IUCN (BirdLife International 2018) and ranked secure by the Working Group on General Status of NWT Species (2016).

There is no current information of Sabine’s gull population size within the BRSEA Study Area. In 1992-94, population estimates of Sabines’ gulls in their main breeding colonies within the ISR were < 1700 individuals at Banks Island, and < 180 individuals at Victoria Island (Cornish and Dickson 1996). The population size at Banks Island has apparently declined dramatically since the 1950s when it was estimated at 25,000 individuals (Manning et al. 1956).

Sabine’s gulls are sensitive to disturbance during the nesting season, when human activity could seriously jeopardize their breeding success. Predation is one of the main causes of egg/chick loss during the breeding season (Stenhouse et al. 2001; Mallory et al. 2012). Sabine’s gull population vulnerability to collision risk mortality at offshore wind turbines has been ranked as moderate (Bradbury et al. 2014). Increases in adult mortality appear to correlate with extreme climate events in regions far beyond their Arctic breeding grounds (Fife et al. 2018).

Global warming may extend the open season and availability of prey for Sabine's Gulls during the spring and fall migration resulting in improved productivity and reduced mortality over winter. As for eiders, the presence of a greater expanse of open water could cause storm tides to occur earlier in the year affecting birds nesting in low-lying areas along the coast (Mallory et al. 2009)

7.3.5.3.2 Cultural Value

Sabine's gulls or Iqilgariaq are traditionally harvested, both for their eggs and meat (ICC et. al. 2006: 1-187; OCCP 2016: 132). Sachs Harbour residents noted that gulls nest on Banks Island and some people eat their eggs (SCR 2011: 12). Gull eggs and sea ducks are harvested in the spring and summer in Tuktoyaktuk (IMG Golder and Golder Associates 2014: 12). In Paulatuk, young gulls are preferred for harvesting (IGC 2020, pers. comm.).

While Inuvik TLK holders were hesitant to isolate a specific species as more or less important than another, they indicated that some of the most commonly harvested species are those that supply traditional foods or clothing, such as beluga whales, fish, muskrat, geese, caribou and, for some, goose and seagull (all species) eggs (KAVIK-AXYS Inc. 2004a: 1-4).

7.3.5.3.3 Distribution and Ecology

Sabine's Gulls enter the Canadian Beaufort Sea during the spring transition in early May (Day et al. 2001) and breed during the open season. Within the ISR, they breed in the northwest Mackenzie District (from Richards Island east to Cape Bathurst and Franklin Bay, primarily along coast), on Banks Island (primarily on western half of island) and Victoria Island (especially the eastern side which is outside the BRSEA Study Area) (Manning et al. 1956; Parmelee et al. 1967).

Within the BRSEA Study Area, Sabine's gulls' nest in small colonies on islands and spits (Alexander et al. 1988). Nesting primarily occurs along the coast but up can be to 20 km inland (Parmelee et al. 1967, Johnson and Herter 1989). Prior to laying and during incubation, Sabine's gulls feed primarily on insect invertebrates found in fresh or brackish water (Day et al. 2001). They lay clutches of three eggs. After their eggs hatch, chicks and adults move to coastal areas, where chicks are provisioned and continue their development (Stenhouse et al. 2001). Chicks fledge at 20 days. Most nests on the Yukon-Kuskokwim Delta occur within approximately 50 km from coast, and they are often widely spaced in open areas (few in inaccessible sites; Brown et al. 1967).

Fall migration begins as soon as the young can fly well or shortly after family groups move to saltwater (Day et al. 2001). When migrating, Sabine's gulls fly low over water, settling frequently; in Alaska, they migrate 5–15 m above water and 25–90 km offshore (Day et al. 2001).

During migration, Sabine's gulls feed primarily on beaches and in marine waters usually over the continental shelf and shelf-break, occasionally near shore or farther offshore (Campbell 1970). The diet during this marine period is poorly known but is possibly primarily zooplankton, crustaceans, fishes, and fishing offal (Day et al. 2001).

7.3.5.3.4 Key Habitat

Sabine's gull requires two main habitat types during their time in the BRSEA Study Area. During the Open Water Season, they require undisturbed nesting habitat in coastal areas and islands for breeding. During the raising chicks and migration, they require open water coastal and offshore areas with available marine prey.

Key nesting areas for Sabine's gull within the BRSEA Study Area are shown in Figure 7-48. Small groups of nesting birds are found along the Tuktoyaktuk Peninsula, but the main colonies are in the Baffin Island and Victoria Island regions (Latour et al. 2008). Victoria Island holds possibly 3% of the Canadian population of Sabine's Gull (approx. 800 individuals; Cornish and Dickson 1996). Albert Islands and other coastal areas have been identified as important habitats for Sabine's gulls in Ulukhaktok (OCCP 2016: 97).

7.3.6 Marine Mammals

The discussion of marine mammals is focused on species that are most common within the BRSEA Study Area; bowhead whale (*Balaena mysticetus*), beluga whale (*Delphinapterus leucas*), ringed seal (*Phoca hispida)* and bearded seal (*Erignathus barbatus*). Although other species including killer whales (*Orcinus orca)*, narwhal *(Monodon Monoceros*), gray whales, harp seals *(Pagophilus groenlandicus*) and walrus have been observed in the Canadian Beaufort Sea, they are considered infrequent visitors (Cobb et al. 2008). Local residents have reported that killer whales have been observed in McKinley Bay (IMG Golder and Golder Associates 2014: 5) and that "walrus are very rare in the area around Sachs Harbour, but occasionally one will be seen in the area. Walrus are not often harvested, with only two or three harvested in the last few years." (IMG Golder and Golder Associates 2011c: 11). When asked about the harvesting or presence of other types of whales, TLK holders reported that years ago, killer whales were seen near Kendall Island and Herschel Island, but are not common in the region. (IMG Golder and Golder Associates 2011b: 8).

7.3.6.1 Bowhead Whale

7.3.6.1.1 Conservation Status

The Bering-Chukchi-Beaufort population of bowhead whale is listed on Schedule 1 of the SARA as Special concern due to severe depletion from historical commercial whaling, life history characteristics (e.g., long generation time) and uncertainty about how bowhead would respond to habitat change due to climate change (COSEWIC 2009).

7.3.6.1.2 Cultural Value

Bowhead whales, known by the Inuvialuit as Arviq, are hunted by Indigenous people in Alaska and Russia for food, materials, and cultural significance (International Whaling Commission n.d.). Local Inuvialuit note that bowhead whales are observed offshore in the Canadian Beaufort Sea, but are not regularly harvested (IMG Golder and Golder Associates 2011c: 9). Aklavik hunters harvested one bowhead whale in 1991 and 1996 (ACCP 2016: 126). The Inupiat (Alaska) hunt bowhead whales every spring during the migration from the Bering Sea to the Canadian Arctic (International Whaling Commission n.d.). Indigenous groups have traditionally found many uses for different parts of the whale: the blubber of the whale was used as fuel, bones were used to construct houses, and the baleen was used to make fishing lines and bird traps (Kuhnlein and Humphries 2019).

7.3.6.1.3 Distribution and Ecology

Bowhead whales migrate north from the Bering Sea (where they winter) in April to the Chukchi Sea, and then east to the Canadian Beaufort Sea and Amundsen Gulf (Quakenbush et al. 2012) where they remain for up to four months during the Open Water Season (summer) (Fraker et al. 1979a). From August to October, the whales migrate west to Point Barrow, then to the Chukotka coast (Alaska and Russia) where they slowly travel south as the winter season begins. By December, most of the whales return to the Bering Sea.

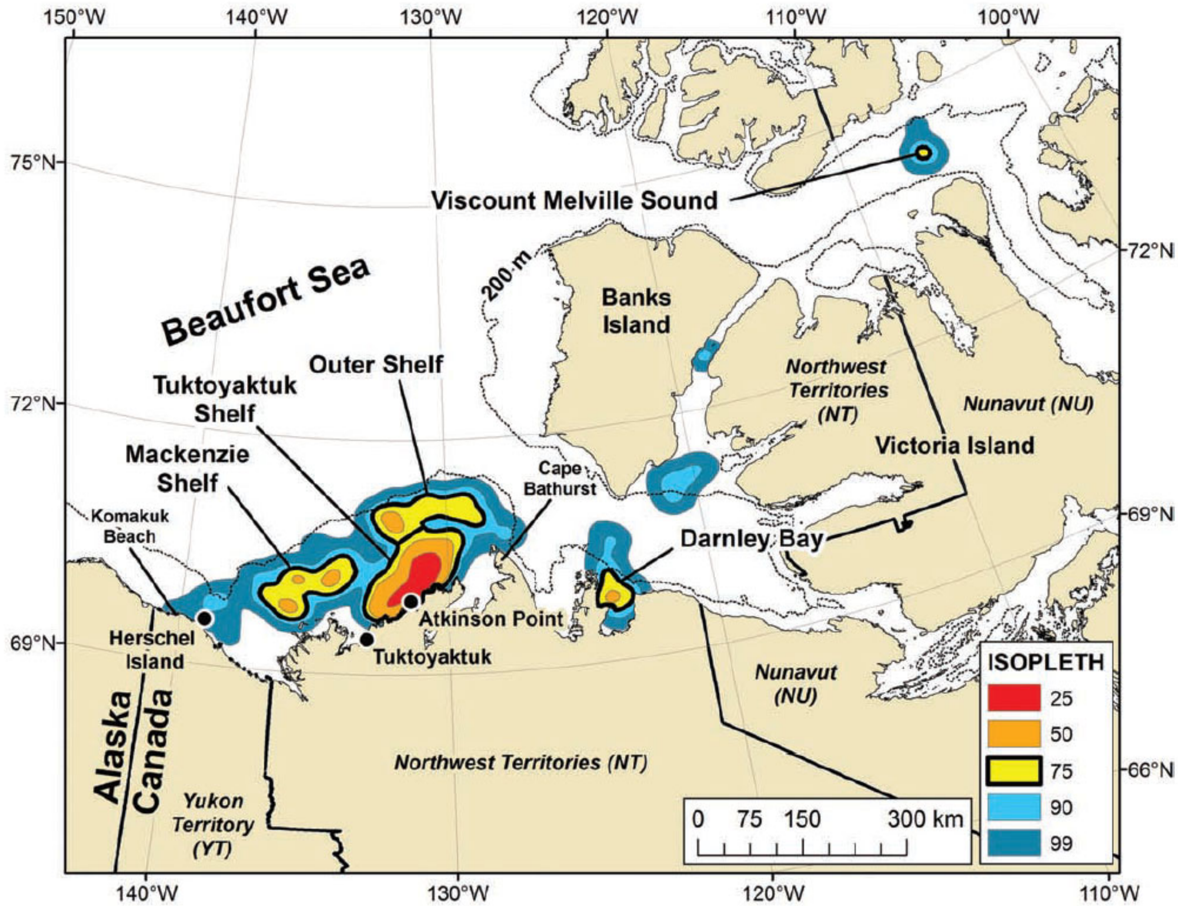
Bowhead whales tend to be spatially and temporally segregated based on size classes, sex, and reproductive conditions (Koski and George 2008). Small subadult whales (<10m) are generally found in shallow (<20m) coastal habitats, and larger whales are more common with increasing water depth (LGL Limited 1988). The smaller whales also tend to arrive in the Alaskan Beaufort Sea for overwintering in late August, with mothers and calves arriving in early September, and adults arriving in late September. Temporal and spatial segregation may be attributed to predatory pressure and diving ability (Finley 2001).

Stomach samples collected from western, central and eastern areas of the Beaufort Sea show that bowhead whales prefer euphausiids and copepods during the spring and copepods, gammarid amphipods, hyperiid amphipods and decapods, euphausiids and cumaceans during the fall (Lowry et al. 2005; Sheffield et al. 2014).

7.3.6.1.4 Key Habitat

The spring bloom of phytoplankton in the Beaufort Sea promotes zooplankton production in the summer months, when bowhead whales will prey on copepods and euphausiids in masses at all depths (Laidre et al. 2007). As noted in Section 7.3.2.2, zooplankton “hotspots” provide important foraging habitat for bowhead whales during the Open Water Season. These areas have been identified in the waters near to Cape Parry, Cape Bathurst, along the Tuktoyaktuk Peninsula, the Mackenzie River estuary, and near Herschel Island (Harwood et al. 2017) (Figure 7-50). Bowhead whales then migrate to the Bering Sea, where they are likely to mate during the late winter to early spring. Gestation can last 12 to 16 months, and mothering whales calve in the spring in the Bering Sea (Quakenbush 2008).

Sea ice is crucial in determining habitat range for the bowhead whales as it affects the length of Open Water Season. With increasing open water days (Section 6.3.2.3), bowhead whales are found closer to shore in the Beaufort Sea, which may be a direct effect of more feeding opportunities due to greater upwelling when ice cover is farther from the shore (Druckenmiller et al. 2018).



SOURCE: Harwood et al. (2017)

Figure 7-49 **Bowhead whale aggregation areas in the Southeast Beaufort Sea based on inferred foraging behaviour during August to September for 2006 to 2012.**

7.3.6.2 Beluga Whale

7.3.6.2.1 Conservation Status

There is no schedule or status for beluga under SARA. The Eastern Beaufort Sea population of beluga whale is currently designated Not at Risk by COSEWIC (2004), but its status is up for review in 2021. A population aerial survey in the region took place in 2019 that will inform the review and population assessment (L. Loseto 2020, pers. comm).

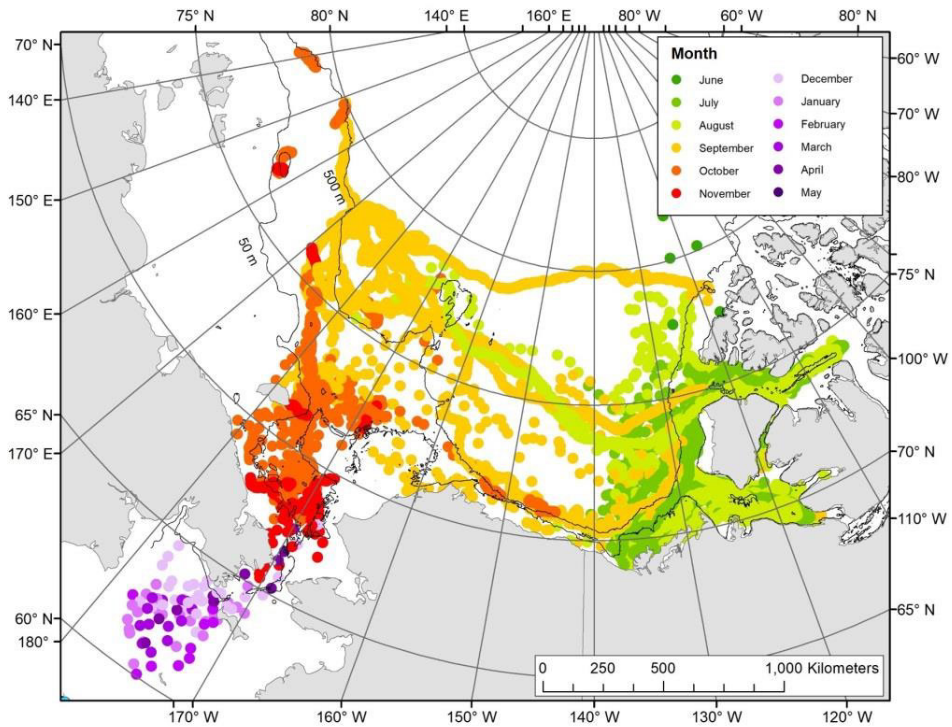
7.3.6.2.2 Cultural Value

Beluga whale, known by the Inuvialuit as Qilalugaq, are important to the Inuvialuit and Inupiat (Alaska). Beluga whales from the Beaufort population are hunted at sustainable levels by Indigenous people in the Northwest Territories and Alaska (Harwood et al. 2002a). Inuvialuit TLK holders reported that muktuk (outer skin and blubber) harvested from the beluga whales was very important to the people of Tuktoyaktuk for traditional use and as a currency for barter for Arctic char and caribou with other communities. (IMG Golder and Golder Associates 2011b: 7). TLK holders from Tuktoyaktuk indicate that harvesting of beluga occurs in July and August and can take place in the channel at the north entrance to Tuktoyaktuk Harbour. Whaling activities usually follow the coast towards Hendrickson Island. It is uncommon to travel north or northeast for whaling (IMG Golder and Golder Associates 2014: 5). TLK holders in Aklavik noted that socio-political and environmental changes over the past century have led to the younger generation in the community shifting away from the traditional lifestyle, resulting in a decline in beluga harvesting (Worden 2018).

The Tarium Niryutait Marine Protected Area (MPA) was officially announced on August 26th 2010 and includes a number of areas that have been used for traditional harvesting of beluga by the Inuvialuit (DFO and Fisheries Joint Management Committee 2013). The MPA was Canada's first arctic MPA and consists of three individual areas called Niaqunnaq, Okeevik, and Kitigaryuit. The MPA and these three specific areas are important to the Inuvialuit from cultural, traditional use and economic perspectives; specifically, the MPA protects harvesting traditions for residents of Aklavik, Inuvik and Tuktoyaktuk.

7.3.6.2.3 Distribution and Ecology

Beluga whales are seasonal migrants to Canada's Western Arctic, occupying summer range in the southeastern Beaufort Sea and Amundsen Gulf during the Open Water Season (Allen and Angliss 2013; Harwood and Smith 2002). Data from tagged beluga whales compiled between 1993 – 2018 show seasonal habitat usage throughout the BRSEA study area (Figure 7-50). Annual spring migrations involve crucial timing and movement through heavy ice conditions (Barber et al. 2001; Norton and Harwood 1986). Beluga whales arrive in the southeast Beaufort Sea in late May and June (Fraker 1979b). Spring sea ice conditions are important determinants of the timing and movement of beluga into the Beaufort Sea and subsequent aggregations in the Mackenzie Estuary (Fraker 1979a,1979b; Huntington et al. 1999).



SOURCE: Storrie 2020, pers. comm.

Figure 7-50 Seasonal movement of Eastern Beaufort Sea beluga whales tagged from 1993 to 2018 (n = 50) with each colour representing a different month of location data

During late July and early August, beluga whales travel back and forth from the Mackenzie Estuary to deeper waters off the coast, moving along the continental shelf from Herschel Island to around Cape Bathurst (Harwood et al. 1996; Harwood and Kingsley 2013; Richard et al. 2001). During this time, their distribution becomes broad and is characterized by small groups dispersed across the shelf and offshore waters of the Beaufort Sea (Harwood and Kingsley 2013). Preliminary data from a recent tagging survey in 2018 and 2019 has shown that beluga dive to the seafloor along the continental slope to forage (L. Loseto 2020, pers. comm). Core areas where beluga tend to congregate in July and August have been identified extending from the Mackenzie River Delta and along the Tuktoyaktuk Peninsula to the entrance of Liverpool Bay, in Viscount Melville Sound and Amundsen Gulf in early summer, near the Mendeleev Ridge in late summer, and along the Beaufort Slope throughout the summer. (L. Loseto 2020, pers. comm, Hauser et al. 2014). Residents of Sachs Harbour have noted that, after the beluga whales have finished breeding and feeding, they travel north of Banks Island and Victoria Island. One TLK holder noted that whales usually follow the same route. Another TLK holder noted that the whales sometime go around Banks Island. Residents also note that the highway for beluga whales is the open water polynyas, which stay open all year round. The polynyas were observed to be moving closer to Banks Island, whereas they used to be further out to sea (IMG Golder and Golder Associates 2011c: 10). The density of beluga in the estuary generally peaks during the first half of July and declines gradually thereafter until August, when most of the whales have moved offshore (Fraker et al. 1979a).

Belugas are mostly observed in shallow water during the summer season (i.e., in depths less than 50 meters) (Barber et al. 2001; Hornby et al. 2016; Loseto et al. 2006). More recently, it has been shown that beluga prefer warm sea surface temperatures (>2°C) and a mid-to-high chlorophyll concentration, which are indicative of enhanced local productivity and/or upwelling (Hornby et al. 2017). Previous studies (Harwood et al. 1996) have found that belugas are aggregated in several offshore areas such as: 10-30 km to the northwest of west Mackenzie Bay, within 5-10 km of shore off the Tuktoyaktuk Peninsula, the Baillie Islands, the mouth of the Horton River, 50-80 km off Cape Bathurst in the approximate area where the Bathurst polynya often recurs in winter, and in central Amundsen Gulf, approximately 50 km north of Pearce Point.

During the Open Water Season, feeding is a key activity for beluga whales (Hornby et al. 2017; Loseto et al. 2006; Norton and Harwood 1986; Richard et al. 2001). Size related dietary studies suggest that larger sized beluga preferred offshore arctic cod whereas smaller sized beluga feed on prey in near shore habitats that included near shore arctic cod (Loseto et al. 2009). Another study performed in 2014 (Loseto et al. 2018a), found that the predominant fish species was arctic cod and other fishes included sculpins, saffron Cod (*Eleginus gracilis*), walleye pollock (*Theragra chalcogramma*) and pacific sandlance (*Ammodytes hexapterus*). Arctic cod from nearshore and offshore regions is the most important summer diet item to the Beaufort Sea beluga population (Loseto et al. 2009).

Hunters in Tuktoyaktuk have reported that the beluga whale harvest has recently been influenced by changes in the timing of migration, poorer body condition, and changing ice conditions generally understood to result from climate change (Waugh et al. 2018). Further evidence of an ecological shift was observed when an unusually high number of beluga were present and harvested near Ulukhaktok in 2014 (Loseto et al 2018a), Stomach analysis indicated that the dominant prey item was sandlance, rather than Arctic cod; the latter is generally considered the preferred prey item for beluga whale (Loseto et al 2018).

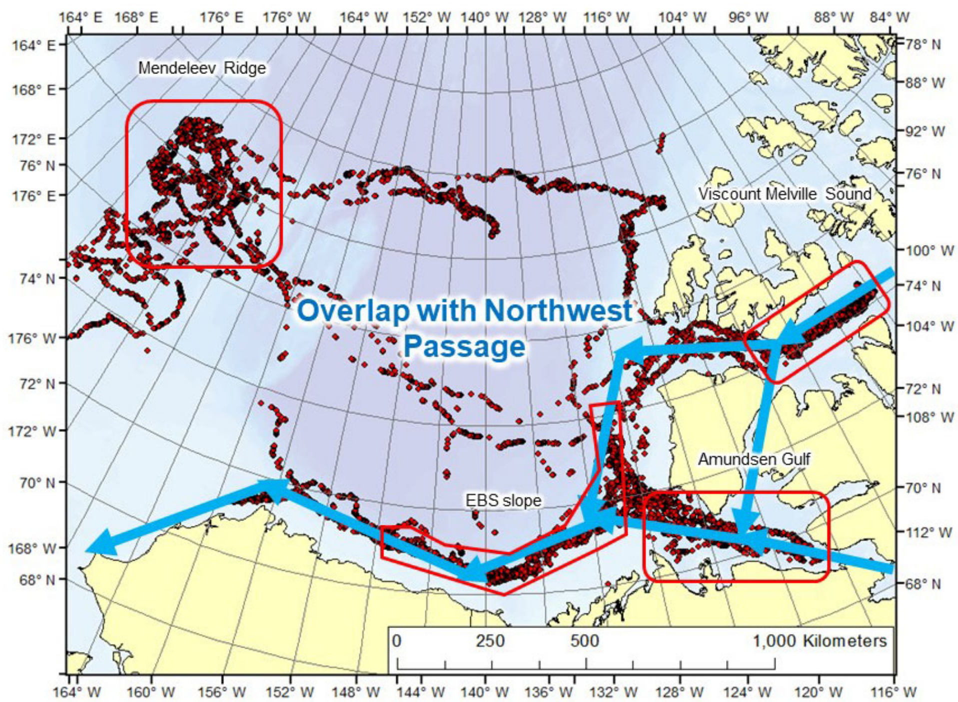
7.3.6.2.4 Key Habitat

Beluga whale habitat selection in the Beaufort Sea is influenced by features such as depth, slope, proximity to bathymetric features and ice type (Hauser et al. 2017; Loseto et al. 2006). These features together promote and guide beluga distributions in the Beaufort Sea, regional productivity, foraging opportunities and protection from predators such as killer whales (e.g., Higdon et al. 2006; Laidre et al. 2006). Recent satellite tagging surveys completed in 2018 show substantial overlap between areas of high use by belugas during the ice free season and the proposed shipping route through the Northwest Passage (Figure 7-51).

During the summer, belugas aggregate in nearshore habitats and estuaries forming one of the largest beluga summering aggregations in the world (Fraker et al. 1979a; Norton and Harwood 1986; Smith and Sjare 1990). The reason why belugas come into estuaries is not completely understood (Loseto et al. 2018a). Some hypotheses include moulting, refuge, calving and feeding (Fraker et al. 1979a, b; Harwood et al. 1996; Hornby et al. 2017; Loseto et al. 2018a; St. Aubin et al. 1990a, b). Recent work completed by Whalen et al (2019) has shown that belugas seem to prefer sandy shoal habitat in the estuary and may use it to rub on and scrape off moulting skin, thus supporting the hypothesis that beluga may come to the estuary during the annual moult. Similarly, Scharffenberg et al (2019) has shown that movement of belugas within the estuary is influenced by temperature, salinity, and wind speed and that individuals move farther into the estuary during periods of cold oceanic influxes.

Sea ice is an essential habitat for beluga in the spring (Hornby et al. 2016). Ice edges are regions of high productivity during early spring ice melt and may provide protection from weather and/or predators (e.g., killer whales) (Asselin et al. 2012; Heide-Jørgensen et al. 2010).

Climate change induced ecosystem changes may be a reason why belugas are more common in the offshore Beaufort Sea in recent years (Harwood and Kingsley 2013). According to Harwood and Kingsley (2013), enhanced upwelling of nutrients along the Beaufort slope and the increased pelagic marine productivity, could have allowed belugas to access resources in the offshore Beaufort Sea more easily or for longer periods of time, when compared to previous 1980s survey data.



SOURCE: Storrie 2020, pers. comm.

Figure 7-51 Areas of high use by Eastern Beaufort Sea beluga whales tagged in 2018, showing overlap with the proposed route of the northwest passage.

7.3.6.3 Ringed Seal

7.3.6.3.1 Conservation Status

The ringed seal does not have a schedule or status under SARA. It was designated as "Special Concern" by COSEWIC in 2019 (COSEWIC 2019) due to ongoing "reductions in the area and duration of sea ice due to climate warming in the Canadian Arctic, with consequent reductions in suitable pupping habitat due to loss of stable ice and a lower spring snow depth".

7.3.6.3.2 Cultural Value

Ringed seals, known by the Inuvialuit as Natchiq, were traditionally harvested in the region for their pelts, oil and meat. TLK holders in Sachs Harbour indicate that young seals are preferred for eating and people sometimes make dry meat from seal meat. Seal oil is sometimes used to attract polar bears *(Ursus maritimus)* during hunting or as a dipping sauce for other food. Seal pelts are used to make traditional clothing such as mittens, hats and other crafts including purses (IMG Golder and Golder Associates 2011c: 10). TLK holders in Paulatuk note that seals are not hunted much anymore in that community, but seal meat may be eaten when it is very cold since it is a heavier meat than caribou and is still fed to dogs. Because of the anti-fur lobby in Europe, seal pelts are not as valuable as they once were[50]. As a result, seals are not hunted very often, except occasionally for something different to eat or when elders request seal meat (IMG Golder and Golder Associates 2011d: 8).

7.3.6.3.3 Distribution and Ecology

Ringed seals are present in the Beaufort Sea year-round, making localized and sometimes larger scale movements within the region to feed or breed (Cobb et al. 2008). Breeding occurs on the ice in the winter, and adults generally maintain limited ranges of up to 30 km^2 during this time (Harwood and Stirling 1992; Kelly et al. 2010a). Breathing holes and lairs for thermal protection are maintained during the winter months. Non-breeding subadults do not establish territories and may remain at the periphery of breeding habitat or disperse more widely before freeze-up to access greater food availability and reduce competition with the core density of seals at breeding habitat (Harwood et al. 2012a). Pupping in mid-April occurs in birth lairs that are excavated beneath the snow on sea ice and pups remain with their mother for up to two months (Smith 1987). Prior to sea ice break up, ringed seals generally haul out on the sea ice along the coast to moult (Stirling et al. 1982).

During the Open Water Season, seals have been shown to disperse up to 1,800 km from their winter ranges (Kelly et al. 2010a). Aggregations of ringed seals congregate around what are suspected to be areas of high prey density (Harwood and Stirling 1992; Smith 1987). Although the location of these aggregations varies from year to year, they are commonly reported north of the Tuktoyaktuk Peninsula

50 Note that European Union trade ban on seal products does not include products from "hunts conducted by Inuit or other indigenous communities" provided that specific conditions on the fur origin and documentation are met (https://ec.europa.eu/environment/biodiversity/animal_welfare/seals/seal_hunting.htm).

and Amundsen Gulf (Harwood and Stirling 1992; Smith 1987). During the Fall Transition Season, adults move to the landfast ice to establish breeding territories within the same home ranges they used in the previous season (Kelly et al. 2010a). Non-breeding animals may migrate further west as far as the East Siberian Sea (Cobb et al. 2008; Harwood et al. 2002b).

Water depth, location relative to ice edge, snow depths, and ice deformation have been shown to influence seal density in the Beaufort Sea. Densities tend to be greatest at depths between 5m and 35m, on flatter, less deformed ice nearest to the fast ice edge (Frost et al. 2004). Changing sea ice and water temperatures affect the distribution and availability of ringed seal prey, which subsequently affect diet, body condition, productivity, and pup survival of ringed seals (Crawford et al. 2015). Reducing sea ice cover alters key habitat for feeding, breeding and resting, ultimately reducing survivorship (Moore and Huntington 2008).

Ringed seals feed on pelagic and semi-demersal fish and invertebrates in the water column, but they are widely adaptable in their feeding habits. Unlike the bearded seal (*Erignathus barbatus*), the ringed seal does not consume sedentary or burrowing animals (McLaren 1958).

The composition of the ringed seal diet changes with season and region. During the spring to summer period, saffron cod is the primary consumed prey in the northeastern Bering and the southeastern Chukchi Sea. In this same time period, shrimps were found in the stomachs of seals in northcentral Bering Sea, and amphipods in central Beaufort Sea. From late summer to early fall, amphipods are dominant in the diet of ringed seals in the central Beaufort and southeastern Chukchi sea. Saffron cod become prevalent again during the fall, and dominant prey transitions to arctic cod in all regions (Lowry et al. 1980).

7.3.6.3.4 Key Habitat

In winter, seals are observed in the Cape Parry area as evidenced by polar bear hunting of seals in this area. (KAVIK-AXYS Inc. 2012: 3 - 9). As subadult ringed seals do not need to maintain territories, they tend to move south towards the Bering Sea ice edge for better feeding opportunities (i.e., reduced competition) and less exposure to predation (Crawford et al. 2012b). Key habitat for seals is closely associated with sea ice and prey availability and includes breeding areas along the northern coast of the Tuktoyaktuk Peninsula from Kugmallit Bay eastward to the Baillie Islands, Franklin and Darnley bays, the sounds and inlets of Amundsen Gulf, and along the west coast of Banks Island (Cobb et al. 2008).

7.3.6.4 Bearded Seal

7.3.6.4.1 Conservation Status

Bearded seals are currently classified as a species of “Least Concern” and have no status or schedule under SARA. The population has a broad distribution and appears to be stable (Kovacs 2016).

7.3.6.4.2 Cultural Value

Bearded seals, known by the Inuvialuit as Ugruk, are an important traditionally harvested species for the Inuvialuit. They are mainly hunted for food and pelts (Kovacs 2016). The meat is used as food for the community but also to feed dogs. The pelts of bearded seals are tough but flexible and are used to make rope, boat covers and traditional clothing such as boot soles and mittens (IMG Golder and Golder Associates 2011c: 10; Stewart and Lockhart 2005). Oil is also harvested from the seals and is used during polar bear hunts, and for food (IMG Golder and Golder Associates 2011c: 10).

Harvesting of bearded seals is currently not closely monitored in Canada (Kovacs 2016); however, there is no indication that the population is in decline (Quakenbush et al. 2011).

7.3.6.4.3 Distribution and Ecology

Bearded seals are found throughout the Arctic (south of 85° N) and sub-Arctic (Kovacs 2016). They are primarily found in the southern part of the BRSEA Study Area, with their distribution concentrated along the north of the mainland coast from the Alaska/Yukon border, east to the Baillie Islands, the western and southern coasts of Banks Island, and around the Cape Bathurst polynya (Cobb et al. 2008; Stirling et al. 1982).

They are a non-migratory species, but seasonal movements have been observed, mainly in the western Arctic (Kovacs 2016). There is little information available on the movement of bearded seals specifically in the Beaufort Sea. In the neighboring Chukchi and Bering seas, their movements are thought to be linked to the expansion and retraction of ice specific foraging hotspots (Cobb et al. 2008; Gryba et al. 2019). Bearded seals go through a moulting period from April to August and remain on the ice during this period (Kovacs 2016).

Bearded seals are a vocal species and use vocalizations for breeding and to defend territories (MacIntyre et al. 2013).

Pupping occurs from late March to mid-May. Pups are born on the pack ice or fractures of small floes of annual sea ice (Kovacs 2016), and are nursed on ice for approximately 24 days, although this is thought to vary depending on location and could be as little as 12-18 days (Burns et al. 1981; Kovacs 2016). During the nursing period, the mother spends 80% of her time in the water, likely foraging; however, it is also speculated that this is an adaptive response to polar bear predation (Kovacs 2016). Polar bears and walruses are the primary predators of bearded seals in the BRSEA Study Area (Cobb et al. 2008).

Bearded seals are mostly benthic feeders with a diet that consists of mainly fish (including arctic cod), and benthic invertebrates such as shrimp, molluscs and crabs (Cobb et al. 2008; Kovacs 2016). Their dietary habits appear to fluctuate with expanding and retreating ice (Antonelis et al. 1994; Kovacs 2016); however, little is known about the dietary habits of individuals found in offshore, deeper waters (Cobb et al. 2008).

7.3.6.4.4 Key Habitat

Bearded seals are generally solitary animals (Cobb et al. 2008; Kovacs 2016). They are primarily found on sea ice in areas of shallow water (less than 200m), due to the high productivity of benthic organisms in these waters (Cobb et al. 2008; Smith 1981). Their habitat preference is for moving pack ice and, although non-migratory, they are known to undertake seasonal movements based on the advancement and retraction of sea ice (Kovacs 2016). Bearded seals are largely pelagic during the Open Water Season (Cobb et al. 2008). Juveniles are known to follow fish up some of the rivers in the fall (Cameron et al. 2018). TLK holders noted that seals follow fish up the West Channel of the Makenzie River and into the delta and spend long periods of time welling in freshwater, such as in Coney Lake, and may overwinter in freshwater parts of the delta. For example, the water at Shingle Point has been observed as 'fresh' in springtime (IMG Golder and Golder Associates 2011a: 12).

7.3.7 Polar Bear

7.3.7.1 Conservation Status

Polar bears are currently listed as ‘’vulnerable’’ to extinction by the International Union for the Conservation of Nature (IUCN) (Wiig et al. 2015). In Canada, polar bears are listed as a species of Special Concern under SARA (ECCC 2011). They were reassessed in 2018 as Special Concern (COSEWIC 2018). They are also listed as Special Concern in the Northwest Territories under the territorial Species at Risk (NWT) Act (GNWT 2014).

There are an estimated 20,000-25,000 polar bears globally (COSEWIC 2008; Crockford 2018; Regehr et al. 2016). The Canadian subpopulations comprise approximately 15,500 individuals (COSEWIC 2008). There are 19 subpopulations of polar bears globally, four of which overlap with the BRSEA Study Area: the Northern Beaufort Sea, Southern Beaufort Sea, Viscount Melville Sound and the Arctic Basin subpopulations (Regehr et al. 2016) (see Figure 7-52). The defined subpopulations are not mutually exclusive and, given that bears can travel large distances, they do not account for geographic overlap of individuals. Subpopulations were defined using movement analysis of tagged female bears and genetics (Amstrup et al. 2004; Bethke et al. 1996, Full publication date: Feb. 1996; Taylor et al. 2001). There is variability (0.4-8.9%) in the annual rates of exchange between subpopulations (Taylor et al. 2001) and there has been considerable exchange of bears between the Northern and Southern Beaufort Sea populations (Amstrup et al. 2004).

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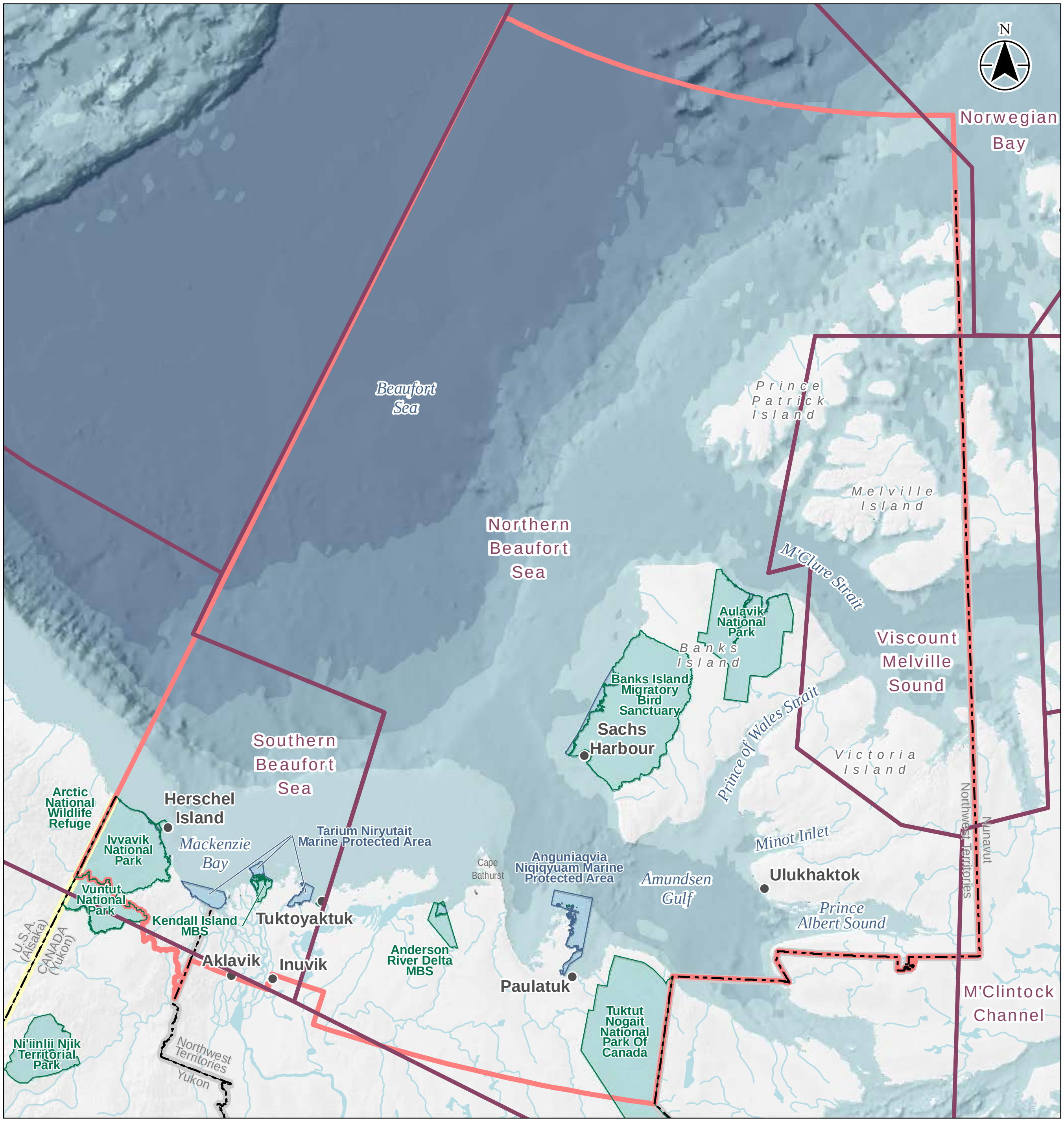

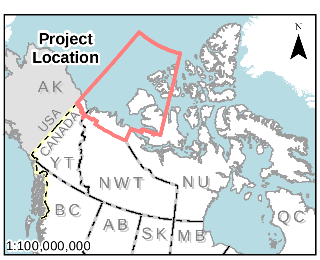

- Community
- International Boundary
- Territorial Boundary
- Watercourse
- Waterbody
- Marine Protected Area
- Terrestrial Protected Area

Bathymetry Depth (m)
- < 200
- 200 - 1000
- 1000 - 2000
- 2000 - 3000
- > 3000

- Study Area
- Polar Bear Subpopulation

0 50 100 150 200 250 300 km
1:8,000,000 (at original document size of 11x17)

KAVIK-STANTEC INUVIALUIT REGIONAL CORPORATION

Project Location
Beaufort Sea,
Northwest Territories,
Canada

Project Number 123513135
Prepared by LTRUDELL on 20191105
Discipline Review by JBECKETT on 20191105

Client/Project
Inuvialuit Regional Corporation
Beaufort Region SEA

Figure No.
7-52

Title
Polar Bear Subpopulations
that overlap with the BRSEA Study Area

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Natural Resources Canada

The Northern Beaufort Sea subpopulation is estimated to be between 825-1135 polar bears (Stirling et al. 2011) and is considered to be stable and likely increasing (Stirling et al. 2007). The Southern Beaufort Sea subpopulation is considered to currently be in decline (COSEWIC 2008; Crockford 2018; Regehr et al. 2016); however, local knowledge from the area suggests that the subpopulation is stable (Joint Secretariat 2017). Based on capture-recapture data collected from 2001-2006, the Southern Beaufort Sea subpopulation is estimated to be 1526 bears (95% CI 1211-1841) (COSEWIC 2008). The most recent available abundance estimate of the Viscount Melville Sound subpopulation is based on a 1992 survey and estimated 161+/- 40 bears (Taylor et al. 2001). The Viscount Melville Sound and Arctic Basin subpopulations are currently presumed to be stable or likely increasing (COSEWIC 2008). The Arctic Basin region is generally understood to be a catchment area for several adjacent subpopulations with bears moving throughout the region as a summer refuge while the ice recedes from more southern regions. Although there is evidence that some polar bears may remain in this region year-round, abundance estimates have not been completed and, the size of the Arctic Basin subpopulation is currently unknown (Joint Secretariat 2017).

Threats to polar bears are largely based around the sea-ice dynamics of the region, which influences prey availability (Amstrup et al. 2008). Currently, based on western science, the Southern Beaufort Sea subpopulation is the only subpopulation of polar bear in decline in the Study Area; however, TLK suggests the population is stable. The initial cause of this possible decline was a result of thick ice events during the summer during 2004-2006 that caused prey (ringed seals) to leave the area (Harwood et al. 2012b; Stirling et al. 2008). Seals prefer thinner ice, the ice edge or land fast ice that allows them to maintain breathing holes and access feeding habitat The Viscount Melville Sound subpopulation was distributed across large areas of multi-year ice and, in turn, has a low number of ringed seals. It is thought that this subpopulation might temporarily benefit from sea-ice decline as it could potentially increase the accessibility of prey (COSEWIC 2008).

The ISR has established management plans to promote sustainability of the polar bear population while maintaining traditional Inuvialuit use (Joint Secretariat 2017). Management is currently coordinated through the Yukon and Northwest Territories (NWT) governments in conjunction with the Inuvialuit and Environment Canada, as established under the Inuvialuit Final Agreement (IFA) (COSEWIC 2008). The Inuvialuit currently have the exclusive right to harvest polar bears in the ISR, meaning that they are allocated the Total Allowable Harvest and may permit non- Inuvialuit to harvest a portion of that allowable harvest (Joint Secretariat 2017). Commercial tags are currently split between communities across the BRSEA Study Area. Quotas are based on the premise that the number of females harvested does not surpass one third of the subpopulation quota (Joint Secretariat 2017).

7.3.7.2 Cultural Value

Polar bear, known by the Inuvialuit as Nanuq, were historically hunted by the Inuvialuit people for food and clothing. Polar bear play an important economic role to the community through commercial hunting and guiding. The polar bear is often used in communities to teach about ice safety and knowledge (Joint Secretariat 2017). The Inuvialuit use polar bear symbology in much of their storytelling and traditions. The polar bear is often a symbol of strength and intelligence to Inuvialuit (Joint Secretariat 2017).

7.3.7.3 Distribution and Ecology

Polar bears are found in the circumpolar Arctic (Peacock et al. 2015). They are distributed across large areas, dictated by ice flow and the availability of prey (COSEWIC 2008). Their distribution is largely dictated by the abundance of ringed seals in an area (Amstrup et al. 2007). Polar bears have the capability of travelling large distances across the areas they are found in; however, they are known to show long term fidelity to home ranges and denning habitat (Amstrup et al. 2000; Amstrup et al. 2007; Taylor et al. 2001).

Polar bears are found most frequently around high productivity areas, which are normally where ice is constantly moving (Amstrup et al. 2007). Throughout their range, polar bears have shown preference to habitat that is on ice over shallow waters (less than 300m in depth) (Amstrup et al. 2007; SWG 2016) and recent data have shown that they have some home range fidelity across years (Boucher et al. 2019). Movements of polar bears throughout their ecoregions are dependent on the melting and refreezing of ice along the shore (Amstrup et al. 2000). However, the Southern Beaufort Sea subpopulation historically spends the entire year offshore (aside from denning females) (Atwood et al. 2016). While the majority still remain on sea ice during the Open Water Season, the use of land has become more common for this population (Atwood et al. 2016). Both males and females have been found on offshore ice during the Open Water Season since there are greater abundances of prey available to them (COSEWIC 2008). Females are generally found closer to shore than the males due to the proximity to denning habitat.

Denning habitat is generally found along coastal areas within the BRSEA Study Area (COSEWIC 2008). Dens are most commonly found on land for most of the subpopulations of polar bear (including the Northern Beaufort Sea and Viscount Melville Sound subpopulations), although the Southern Beaufort Sea subpopulation has been observed to have dens on sea ice (Amstrup and Gardner 1994; Ferguson et al. 2000). The proportion of these dens on ice has declined (62%-37%) in recent years due to reduction in sea ice (COSEWIC 2008).

Polar bears within the BRSEA Study Area feed on ringed seals (primarily the young) but are opportunistic and have been known to feed on bearded seals, narwhal and belugas (Amstrup et al. 2007; Stirling 1997).

Polar bears are top predators and can live for up to 30 years (COSEWIC 2008). As with other mammalian species, females generally live longer than males due to sex-selective harvest methods and higher probability of males becoming a problem in communities (COSEWIC 2008). Maturity in polar bears varies between the sexes. Females have been reported to reach maturity at 4 years, with high rates of litters being recorded by the age of 6. The reproductive interval between pregnancies varies among the subpopulations. Male polar bears mature at 5-6 years; however, if older male bears are present, the maturation of younger male bears may be delayed (COSEWIC 2008; Rosing-Asvid et al. 2002).

7.3.7.4 Key Habitat

Polar bear habitat is dictated by sea-ice characteristics and the distribution of ringed seals (Barber and Iacozza 2004; Stirling and Lunn 1997). TLK holders emphasize that variability in sea ice dynamics within and across years has a direct impact on polar bear distribution and use of key habitat (Joint Secretariat 2015). Key habitat within the BRSEA Study Area includes annual pack ice, pressure ridges between first-year and multi-year ice floes, and at the floe edge between marginal and landfast sea ice (COSEWIC 2008; Stirling and Derocher 1993; Stirling et al. 1982). Habitat used by polar bears as summer refugia when the sea ice retreats has been identified west of Banks Island at the edge of the pack ice and at terrestrial locations near the remains of traditionally-harvested bowhead whale in Alaska (Pongracz and Derocher 2016).

Key habitat for dens is mainly around areas that can accommodate drifting snow, such as pressure ridges and land banks (Durner et al. 2010). Land-fast ice and drifting multi-year ice are important habitats for the Southern Beaufort Sea population (Amstrup et al. 2007; SWG 2016), although there has been a notable decline in the use of ice for dens. TLK holders have identified maternal dens along the western and southern shores of Banks Island and portions of Victoria and Melville Islands, along the coastline near Paulatuk between Cape Parry and Clinton Point, and along the Yukon North Slope to Herschel Island (Joint Secretariat 2015). Females generally enter maternity dens in late October and remain there until spring (COSEWIC 2008).

7.3.8 Caribou

7.3.8.1 Conservation Status

Barren-ground caribou (*Rangifer tarandus groenlandicus)* herds that overlap the ISR lands include: Tuktoyaktuk Peninsula, Cape Bathurst, Bluenose-West and Porcupine herds (Figure 7-53). Part of the annual Bluenose-East caribou range overlaps the southeast corner of the ISR lands (GNWT 2014); this includes congregations of animals in Tuktut Nogait National Park during July. Barren-ground caribou are currently listed as threatened under the *Species at Risk (NWT) Act* (GNWT 2018b) and assessed as threatened by COSEWIC (2016). Barren-ground caribou are not currently listed under Schedule 1 of SARA (Government of Canada 2019a).

In 2013, the Porcupine herd (*Rangifer tarandus granti*) was estimated at approximately 197,000 animals (including calves) and increasing (GNWT 2018c). Based on 2017 survey results, the Porcupine herd has increased from 197,000 to 218,000 (Alaska Department of Fish and Game 2017; Caikoski 2017 cited in Porcupine Caribou Technical Committee 2018).

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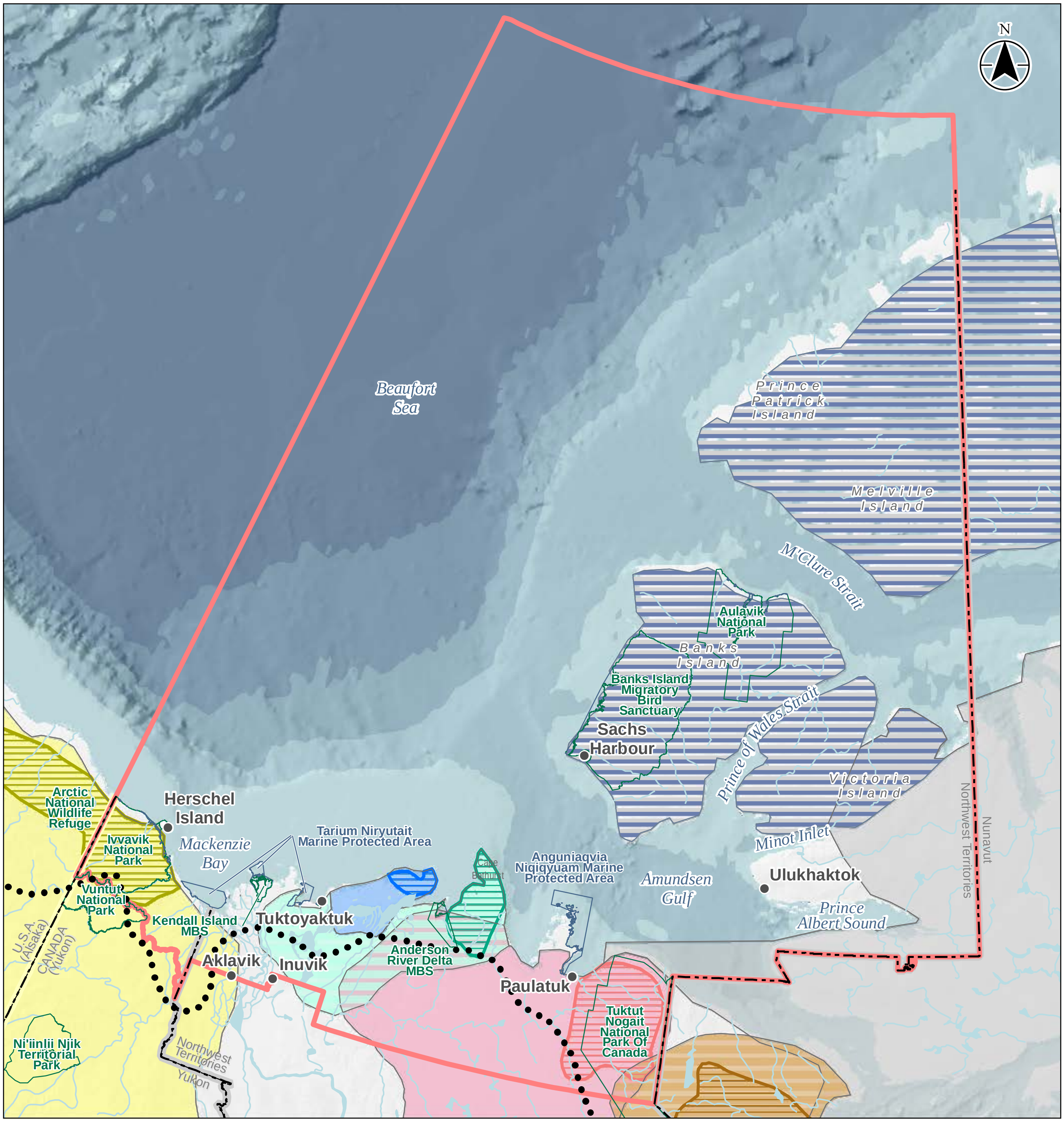
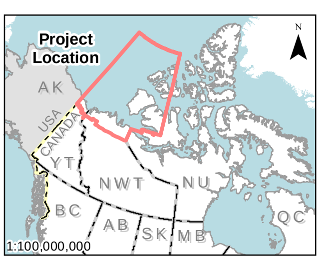




Community
Treeline
International Boundary
Territorial Boundary
Watercourse
Waterbody
Marine Protected Area
Terrestrial Protected Area

Bathymetry Depth (m)
< 200
200 - 1000
1000 - 2000
2000 - 3000
> 3000

Study Area

Caribou Calving Grounds and Ranges
(Species at Risk Committee, 2017. Species Status Report)
Bluenose East, Calving Grounds
Bluenose East, Range
Bluenose West, Calving Grounds
Bluenose West, Range
Cape Buthurst, Calving Grounds
Cape Buthurst, Range
Dolphin and Union, Range
Peary Caribou, Range
Porcupine, Calving Grounds
Porcupine, Range
Tuk Peninsula, Calving Grounds
Tuk Peninsula, Range

0 50 100 150 200 250 300 km
1:8,000,000 (at original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Natural Resources Canada, Species at Risk Committee (2017)

KAVIK-STANTEC
INUVIALUIT REGIONAL CORPORATION

Project Location
Beaufort Sea,
Northwest Territories,
Canada

Project Number 123513135
Prepared by LTRUDELL on 20191108
Discipline Review by DEBNER on 20191108

Client/Project
Inuvialuit Regional Corporation
Beaufort Region SEA

Figure No.
7-53

Title
Caribou Ranges in the Inuvialuit Settlement Region

In 2015, population estimates indicated 1,701 individuals for the Tuktoyaktuk Peninsula herd, 2,259 for Cape Bathurst, 15,274 for Bluenose-West, and 38,592 for Bluenose-East (SARC 2017). Based on 2018 survey results, the Cape Bathurst herd has increased from the 2015 estimate to 4,500 individuals. The Tuktoyaktuk Peninsula herd has declined to 1,500 (-11.7% change since 2015) and the Bluenose-East herd has declined to 19,000 since the 2015 population estimate (-50.7% change since 2015). The Bluenose-West population is believed to be stable at about 21,000 (GNWT 2018d).

In addition, to barren-ground caribou, Peary caribou (*Rangier tarandus pearyi*) also occur on all islands within the ISR lands, including on Banks Island and Victoria Island. Peary caribou are currently listed as threatened under the *Species at Risk (NWT) Act* (GNWT 2014) and listed as endangered on Schedule 1 of SARA (Government of Canada 2019a). In 2015, COSEWIC re-assessed Peary caribou as threatened (COSEWIC 2015).

The most recent surveys from Banks Island and northwestern Victoria Island indicate a total of about 2,252 mature individuals for this subpopulation, the majority of which were observed on Banks Island (COSEWIC 2015). The latest surveys have indicated a modest increasing trend in numbers on Banks Island compared to the 2010 survey (up from 1104 individuals), whereas numbers on Victoria Island have declined from 263 to only four individuals (COSEWIC 2015).

Dolphin and Union caribou (*Rangifer tarandus groenlandicus* × *pearyi*) also occur within the ISR on Victoria Island and are considered to be discrete from Peary caribou and barren-ground caribou based on their morphology, genetics and behaviour (e.g., seasonal migrations across the sea ice of the Dolphin and Union Strait) (McFarlane et al. 2016, ECCC 2018c). Dolphin and Union caribou are listed as special concern under the federal *Species at Risk Act* (SARA) and the Government of the Northwest Territories *Species at Risk (NWT) Act (*ECCC 2018c*)*. However, in 2017, COSEWIC re-assessed the status of Dolphin and Union caribou as endangered due to declining numbers (COSEWIC 2017). In 2015, the population was estimated at 18,413 ± 6,795 (95% CI, 11,664- 25,182). There has been an overall exponential decline of over 50% since 1997. Inuit Qaujimajatuqagit (IQ), Aboriginal Traditional Knowledge and local knowledge have also noted a declining trend of about 80%, which accelerated after 2010 (COSEWIC 2017).

Climate change may have both positive and negative effects on caribou. Warmer temperatures may result in increasing forage availability due to an extended growing season and increased forage biomass. A longer growing season that increases summer forage availability may increase summer fat accumulation, which may result in increased reproductive rates and winter survival (Johnson et al. 2016). However many of the effects of climate change are predicted to have negative consequences including: (i) changes in summer range conditions (e.g., phenological mismatches), which can negatively affect reproduction; (ii) increased wildfire activity on winter ranges, which would result in changes to availability of preferred winter food such as terrestrial lichens; (iii) more frequent snow-on-ice events, which would also reduce accessibility to winter forage; and (iv) increased summer insect harassment, which can result in decreased body condition (see Mallory and Boyce 2018).

Overall, changes in quality and quantity of both summer and winter ranges can result in changes in distributions and migratory behavior of caribou (Mallory and Boyce 2018) as well as fine-scale movement patterns due to increased vegetation productivity (Rickbeil et al. 2018). In addition, Peary caribou and Dolphin and Union caribou populations migrate across sea ice between seasonal ranges (Poole et al. 2010, Mallory and Boyce 2019). Warming temperatures and changes in annual timing of ice formation and breakup (i.e., phenology) would directly affect migratory behaviour (Jenkins et al. 2016, Mallory and Boyce 2018). For Peary caribou, sea ice coverage that reduces dispersal and inter-island movement ability, could have serious consequences for long-term metapopulation persistence (Mallory and Boyce 2019).

7.3.8.2 Cultural Value

Caribou play an essential role in the lives of the Inuvialuit. While barren-ground caribou are harvested year-round by the Inuvialuit, they are hunted most frequently during summer and fall migration when caribou pass near communities or along the coastline such as at Shingle Point or Barge Lake (WMAC-NS and AHTC 2009: 19,20,22,62). Peary caribou are also harvested but it is limited and harvest quotas on harvest are in place due to their low numbers. The communities of Sachs Harbour and Ulukhaktok traditionally harvest Peary caribou within the ISR (SARC 2012). Dolphin and Union caribou are harvested by the communities of Kugluktuk, Umingmaktok, Bathurst Inlet and Paulatuk during the winter/spring, Ulukhaktok in the summer/fall, and Cambridge Bay in both seasons (ECCC 2018c).

The total number of barren-ground caribou harvested by both traditional hunters and resident hunters has decreased across the NWT compared to harvests 30 or 40 years ago (SARC 2017). The Tuktoyaktuk Peninsula caribou have seasonal protection through application of a closed harvesting season in regulations (SARC 2017). All harvesting is currently closed on the calving grounds of the Cape Bathurst herd near Cape Bathurst, Husky Lakes, and Liverpool Bay (SARC 2017).

7.3.8.3 Distribution and Ecology

The annual distribution of the Tuktoyaktuk Peninsula, Cape Bathurst and Bluenose-West herds is almost entirely within the NWT, whereas the Porcupine herd range includes Alaska, Yukon, and the NWT. The barren-ground caribou calve in tundra barrens near the arctic coast and winter below the treeline (International Porcupine Caribou Board 1993; SARC 2017).

Nutrient content according to stage of plant growth, as opposed to plant species, is a key driver for forage selection by barren-ground caribou (SARC 2017). On summer ranges, barren-ground caribou habitat selection balances reducing exposure to insect harassment while obtaining high quality forage. During the winter months, lichens are the preferred winter forage in the taiga and on the tundra.

TLK holders from Sachs Harbour have identified M’Clure Strait between Banks Island and Melville Island, as well as Prince of Wales Strait between Banks and Victoria Islands, as important for spring and fall caribou migration (SCCP 2016). Community knowledge has suggested the frequency of inter-island movement is less when populations are low (Johnson et al. 2016). Given the recent declines in Peary caribou, the smaller populations may partly explain decreasing inter-island movement. Recent aerial surveys indicate Peary caribou herds are fragmented and distinct where there is little migration between Banks and northwest Victoria Island and Queen Elizabeth Islands to the north (see SARC 2012; Johnson et al. 2016).

TLK holders from the communities of Sachs Harbour and Ulukhaktok indicates that Peary caribou rely on various lichens, especially in the autumn and winter (SARC 2012), which is consistent with western science. In June, caribou show a preference for moss campion which grows in sandy locations. After the snow is gone in mid-July, feeding is more focused on areas rich in sedges, grass, willows, and mountain sorrel. The main factor influencing their patterns of space use is forage availability. Space use patterns are influenced by icing and snow cover and shift seasonally and over longer time frames in response to changing plant phenology and forage availability and accessibility (Johnson et al. 2016).

7.3.8.4 Key Habitat

Caribou use seasonal migrations and local movements to meet their requirements for forage and to minimize the risk of predation and insect harassment (COSEWIC 2016; SARC 2017).

Barren-ground caribou use a variety of habitats ranging from low elevation coastal plains to inland tundra with rocky or hilly areas (COSEWIC 2016) that provide access to winter forage or relief from insects (i.e., windblown areas). The coastline is an important habitat for caribou because offshore winds provide relief from heat and mosquitoes (WMAC-NS and AHTC 2009: 29, 30,31).

The Tuktoyaktuk Peninsula herd uses the north end of the peninsula for calving and insect relief (TCCP 2016:131). Important winter habitat for Tuktoyaktuk Peninsula, Cape Bathurst, and Bluenose-West herds includes the western portion of the Tuktoyaktuk Peninsula and the Anderson River south to the ISR boundary (TCCP 2016:67).

The Cape Bathurst herd uses the Cape Bathurst peninsula for calving and insect relief areas. After calving, they rut and winter inland on the tundra northwest of Inuvik (ICCP 2016). They rut east of Husky Lakes, and winter in the Parsons Lake – Husky Lakes area and to the south (ACCWM 2014). Tuktoyaktuk and Inuvik community members have reported the Bluenose-West herd calve near the Hornaday, Brock and Horton Rivers (TCCP 2016:131; ICCP 2016:99).

The Porcupine caribou herd primarily calves in the coastal plains in eastern Alaska and western Yukon, but they are also known to calve in the mountains (International Porcupine Caribou Board 1993; WMAC-NS and AHTC. 2009: 23, 44, 50, 51, 53, 54). Overall, variability in calving location relates to weather and the timing of migration.

Peary caribou on Banks and Victoria Islands use a variety of barren (polar desert) and tundra habitat types, including mesic-xeric upland habitats with sparse-moderate vegetation cover dominated by dwarf shrubs (white mountain avens (*Dryas integrifolia*) and arctic willow (*Salix arctica*)), sedges and grasses (Johnson et al. 2016). During winter, upland habitats and high elevation areas with low snow cover and snow hardness are selected. Lichen is also considered an important dietary component in fall and winter.

TLK holders indicate that Peary caribou on Banks Island winter in valleys, ravines, and side-hills, and summer on hills and slopes along the coast (SARC 2017). Although Peary caribou on Banks Island have been reported to use the north part of the island for calving, Sachs Harbour Community Conservation Plans indicate additional calving areas around Jesse and De Salis Bays (SARC 2017).

Dolphin and Union caribou travel across the sea ice to Victoria Island to calve but calving is dispersed and they typically disperse across the island in summer, including within the ISR.

7.3.9 Invasive Species

The introduction of invasive species to a region can pose a large threat to ocean ecosystem health on a regional scale (IMO 2019). For the purposes of the BRSEA, an invasive species is defined as *species that are not native to a given ecosystem (that is, when a species is present due to an intentional or unintentional escape, release, dissemination, or placement into that ecosystem as a result of human activity) and which may cause economic or environmental harm, including harm to subsistence species and activities, or harm to human health* (CAFF 2013). There are two primary pathways by which invasive species are likely to be introduced in the marine environment: via aquaculture operations, or by the exchange of ballast water (IMO 2017a; Molnar et al. 2008). Additional pathways include recreational boating and marine debris; translocated piers, docks, and pilings; and the release or escape of live animals (CAFF and PAME 2017).

Introduced species are wide ranging and can include microbes and bacteria (Starliper et al. 2015), phytoplankton and seaweeds (Mathieson et al. 2010), zooplankton (Ware et al. 2015) and, in particular, crustaceans (Niimi 2004).

Invasive species have altered marine habitats around the world by displacing endemic species and reducing local diversity or abundance (Grosholz et al. 2000), changing community structure and food web dynamics (Trussell et al. 2004), and altering fundamental processes such as nutrient cycling (Molnar et al. 2008). Some alien species have also caused billions of dollars of damage from fouling of coastal infrastructure or effects on commercial fisheries (Lovell et al. 2006; Pimentel et al. 2005).

While the issue of invasive species is not currently a severe problem in arctic waters (Boertmann and Mosbech 2011; Molnar et al. 2008), continued development in the Arctic (e.g., increased shipping traffic) coupled with the predicted effects of climate change (see Section 6.4) will likely increase the overall risk posed to this marine ecosystem (Goldsmit et al. 2017; Ware et al. 2015).

While most ecosystems are vulnerable to species introductions (Catford et al. 2012), the unique and inhospitable nature of the Arctic may provide it with limited protection against the establishment of alien species (Ware et al. 2015). However, as the Arctic warms, lower latitude species may establish more easily in arctic waters (Kourantidou et al. 2015). Consequently, pre-emptive yet practical mitigation strategies are needed. This should include efforts to establish long term monitoring programs that determine baseline ecological conditions and apply techniques for early detection of the presence of non-native species (Heywood et al. 2017).

The amendments to the ballast water regulations (which came into effect Oct 2019) will help to reduce the risk of introducing alien species by large shipping traffic (IMO 2019), but should not be relied upon alone to mitigate all risks. Instead, an additional adaptive framework that prioritizes risks should be devised and adhered to by any participating industry in the Arctic. The framework should implement new technologies or best management practices as they become available and feasible (Goldsmit et al. 2017; Kourantidou et al. 2015).

7.3.10 Gaps in our Knowledge of the Biological Environment

7.3.10.1 Knowledge Gaps Related to Marine Lower Trophic Levels

The is a lack of understanding in how climate change will affect primary producers. Change in precipitation may lead to changes in snow cover and affect light penetration through ice and influence under ice production. Decreases in sea ice will decrease that production and associated edge effects but may increase open water plankton blooms. The net results of these dynamics on production, location, timing and magnitude of primary production and thus subsequent consequences for the marine system are yet to be identified overall, and specifically for the BRSEA Study Area.

There is much uncertainty around the impact of climate change on zooplankton production, location, timing and magnitude. There could be possible increases or intrusion of Atlantic species through increased upwelling of Atlantic waters onto the shelf. There are anticipated changes in the advective intrusion from the Pacific via the coastal current and shelf break jet. How these two external factors might modify the local zooplankton community with subsequent on upper trophic levels is unclear.

The is a lack of a regional long-term data for zooplankton that could be used as a robust baseline. Similarly, there is a regional lack of data on local and regional scales for both epifauna and infauna species distribution and abundance. In addition, there is a lack of information on the microbial community in BRSEA Study Area, a key component in nutrient cycling for this system that is being subjected to changes due to warming ocean temperatures and changes in river discharges.

7.3.10.2 Knowledge Gaps Related to Marine Fish and Habitat

There is a general gap in our baseline understanding of non-harvested fish species and their essential habitat within the BRSEA Study Area. In addition, there is uncertainty in our understanding of the effects of climate change on fish distribution and abundance within the BRSEA Study Area.

It is unknown what the winter distribution is for arctic cod within the BRSEA Study Area and whether the apparent genetic split between east and west populations created around the Mackenzie river inflow is important for future population sustainability. There is a lack of a regional abundance estimate and population structure understanding for arctic cod within the BRSEA Study Area.

7.3.10.3 Knowledge Gaps Related to Migratory Birds and Seabirds

Updated information is needed on the location, status and population number of migratory birds and seabirds nesting in the BRSEA Study Area. Most of the 'current' information is from surveys conducted in the 1990's. The lack for up to date baseline data makes prediction of potential effects difficult.

Foraging ranges, diets and migration routes of thick-billed murres and Sabine's gulls in the BRSEA Study Area are unknown, and their determination would allow for better assessment of spatial and temporal overlap with human activities in the area.

There is a lack of baseline data on contaminant levels in migratory birds, seabirds, fish and marine invertebrates in the BRSEA Study Area. These unknowns makes prediction of potential effects difficult.

7.3.10.4 Knowledge Gaps Related to Marine Mammals

Marine mammal populations within the BRSEA Study Area have been extensively studied and monitored in recent decades, providing a good understanding of ecology and important habitat. However, given the rapidly shifting conditions in the Arctic, habitat use is expected to shift, especially for ice dependent species like seals. The ultimate implications for population dynamics are unclear

Given the pace of environmental change, a better understanding is needed in regard to ongoing changes in body condition, prey availability, key habitat availability, and abundance and distribution. Such information will be critical to understanding how populations are adapting to their changing environment and managing and maintaining long term sustainability.

Specific knowledge for beluga whale have been identified following recent tagging studies and include relationships between and behavior of belugas which are found in pods in estuarine regions; philopatry to specific areas of the Beaufort Sea region; the ecological purpose of estuarine regions such as Kugmallit Bay; and female and juvenile behavior once leaving the estuary. This and new data on beluga whale should be considered in relation to future projects and human activities,

7.3.10.5 Knowledge Gaps Related to Polar Bear

Polar bear populations are well studied within the BRSEA Study Area, but ongoing measurement of population abundance estimates of the Southern Beaufort population are needed to confirm current and future population trends and resolve discrepancies between quantitative estimates and TLK. Accurate assessment of population abundance will be critical in managing the long-term sustainability of polar bear in the region.

Given their close association with sea ice habitat, ongoing monitoring of shifting habitat use, prey availability, and body condition will contribute to the understanding of how polar bears are responding to shifting habitat conditions and climate change.

7.3.10.6 Knowledge Gaps Related to Caribou

Continued research and monitoring, including the incorporation of TLK, on population status, distribution (including seasonal distribution, migration patterns), and habitat use is highly recommended. Such baseline information is critical in the understanding how human activity and climate change are influencing populations in the region.

7.3.10.7 Knowledge Gaps Related to Invasive Species

There is a lack of information on the occurrence and prevalence of invasive species in the BRSEA Study Area. Given potential ecological, cultural and economic implications, a long-term monitoring program should be considered to determine baseline ecological conditions and apply techniques for early detection of the presence of non-native species.

7.4 Human Environment

The VCs for the Human Environment are: Economy, Demographics, Infrastructure, Traditional Activities, Cultural Vitality and Public Health. Information for these VCs was drawn from a number of Inuvialuit and federal and territorial government sources. Key sources included the Inuvialuit Indicators Project (IRC 2020a), multiple sources of TLK (Appendix B), Statistics Canada (multiple references), Canadian Northern Economic Development Agency (2019) and the NWT Bureau of Statistics (multiple references).

7.4.1 Economy

7.4.1.1 General Economy of NWT/ISR

In 2018, the NWT had a GDP of C$5.1 billion (in 2012 dollars), or about C$115,000 per capita (Table 7-13). Approximately 25% of this GDP was attributable to the public sector (e.g., education, healthcare, public administration), with the balance to the private sector. In 2018, diamond mining was, by far, the largest industrial sector in NWT, accounting for over $1.7 billion in GDP (approximately 34% of the territory's total GDP). By contrast, oil and gas extraction in 2018 accounted for only $38.5 million in GDP, down from $290.7 million in 2013, and a peak of $852 million in 2001 (all values in chained C$2012 dollars) (NWT Bureau of Statistics 2019b).

GDP growth in NWT exceeded that of Canada from 2011 to 2017; however, growth is projected to slow or decline with the eventual closure of the diamond mines (CANOR 2019). The Canadian Northern Economic Development Agency, in partnership with territorial and Indigenous governments, stakeholders, and other federal agencies, operate a number of services and business lines to advance economic development in NWT, including the Strategic Investments in Northern Economic Development Program, the Northern Aboriginal Economic Opportunities Program, the Northern Adult Basic Education Program, and the Northern Projects Management Office (CANOR 2019).

The economy of the ISR is based substantially on government services and transfers, which account for a large proportion of financial inflows to the region. Approximately 45% of the workforce in the ISR is directly employed in the public sector (education, health, and public administration) (7-53). A proportion of the non-public sector employment is also related to the purchase of goods and services by various government organizations, and by household spending of public sector employees, underscoring the importance of the public sector to the economy of the ISR.

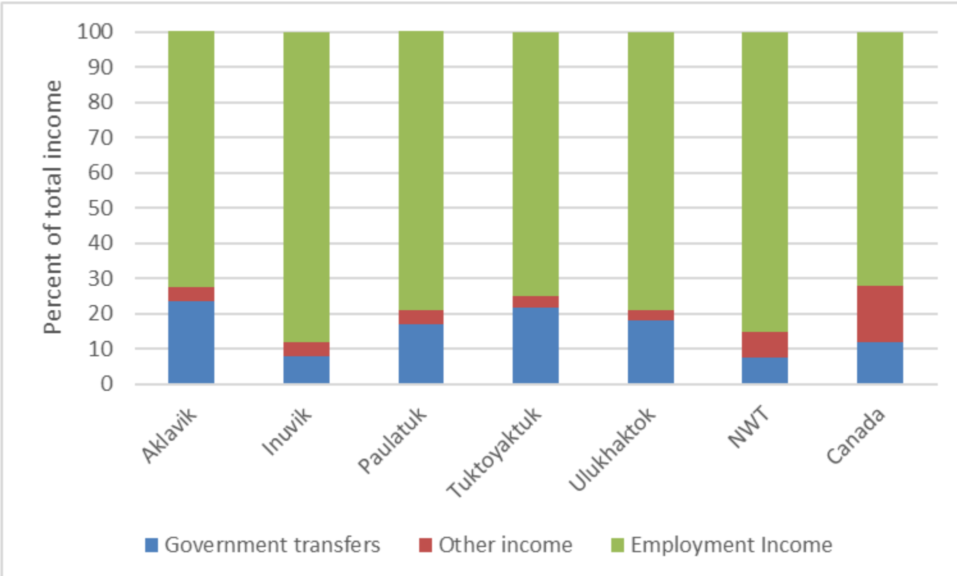
Table 7-13 Northwest Territories Gross Domestic Product 2003 – 2018

Sector	GDP contribution (Millions chained C$2012)			
	2003	**2008**	**2013**	**2018**
Agriculture, forestry, fishing, hunting	9	12	15	11
Mining, quarrying, oil and gas	2410	2084	1226	1798
Utilities	62	82	69	73
Construction	356	420	416	419
Manufacturing, trade, transportation	386	518	558	613
Information & cultural industries	86	84	95	87
Finance, administration, insurance, real estate, professional services	601	666	683	724
Arts, entertainment, recreation, hospitality	105	108	121	103
Education, healthcare, other services	450	530	532	582
Public administration	602	605	664	714
Total	**5066**	**5108**	**4378**	**5124**
SOURCE: NWT Bureau of Statistics 2019b				

Employment was the largest source of income for ISR residents in 2016 (Figure 7-54). However, government transfers are important sources of income for residents age 15 and over in many ISR communities, accounting for 16.9% of income in Paulatuk, 18.1% in Ulukhaktok, 21.6% in Tuktoyaktuk, and 23.4% in Aklavik. By contrast, the proportion of income from government transfers in Inuvik is only 7.7%, reflecting its much lower unemployment rate compared to other ISR communities (Figure 7-55).

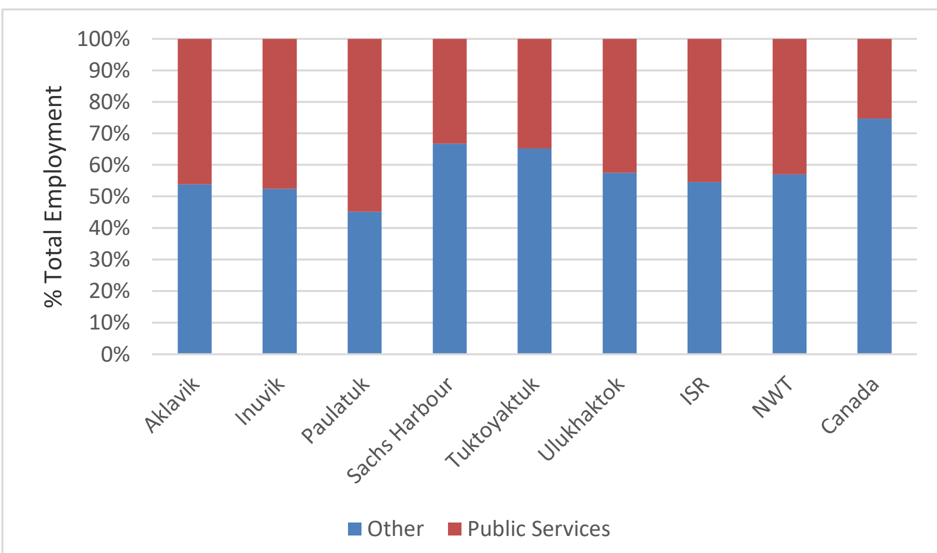
Tourism and guiding are important sources of revenue for some communities. Tourism and business travel is a major industry in NWT, worth nearly $150 million annually (GNWT 2017). The opening of the Inuvik to Tuktoyaktuk Highway has resulted in a substantial increase in tourist visits to both Inuvik and Tuktoyaktuk (McKay 2018, Shober 2019). Arctic cruises are an important source of tourism visits to ISR communities. In the 2017 cruise season, five ships visited the area, with four ships stopping at Ulukhaktok, and one at Paulatuk and Tuktoyaktuk (GNWT 2017).

Guided hunting for polar bears is recognized by Inuvialuit TLK holders as having high economic value, particularly in Tuktoyaktuk (Slavik, D. 2010: 24-25, KAVIK-AXYS Inc. 2004b: 18-495). The sale of furs, carvings, clothing, and other products has also contributed to household income in the ISR (Inuit Qaujisarvingat Knowledge Centre 2019). Paulatuk TLK holders indicated that commercial fishing used to occur in the Paulatuk area, but this industry was shut down in 1988 due to a decline in the quality and quantity of arctic char (IMG Golder and Golder Associates 2011b: 10).



NOTE: "Government transfers" consists of cash transfers from federal, territorial, and municipal governments. "Employment income" includes wage income, income from commissions, and net income from self-employment. "Other income" includes investment income and private pension income. Data for Sachs Harbour are not available.
SOURCES: Statistics Canada 2017b,c,d,f,h,i

Figure 7-54 Breakdown of Income of Residents aged 15 and over in ISR communities, NWT and Canada 2016



NOTE: "Public Services" is the proportion of total employment in the following industries: education services, health care and social assistance, and public administration. "Other" is employment at all other industries.
SOURCES: Statistics Canada 2017b,c,d,e,f,g,h,i

Figure 7-55 Percent of Public Service and Other Employment in the ISR, NWT and Canada 2016

7.4.1.2 Education Attainment

While the population in Inuvik has a similar overall level of education attainment as the NWT, a much lower proportion of the population has attained a high school or higher education in other ISR communities (Table 7-14). From 2006 to 2016, all ISR communities experienced a growth in the proportion of the population attaining a high school or higher education. However, in 2016 only 39% of Inuvialuit or Inuit persons had attained this education level, less than half that for Canada overall (Table 7-14). While social and historical factors contribute to the lower level of education attainment in ISR communities, the authors of a 2016 study argue that student achievement and well-being in the ISR could be improved by adopting more culturally responsive teaching and curriculum (Berger et. al. 2016).

Table 7-14 Education Attainment

Location	2016 Population 15 and over	Percentage of population 15 and over with high school or higher education		
		2006	2011	2016
Canada	30.2 million	76	80	82
NWT	32,330	67	69	73
ISR	4,025	55	58	60
Aklavik	450	39	48	56
Inuvik	2350	69	69	71
Paulatuk	210	30	30	40
Sachs Harbour	85	44	53	50
Tuktoyaktuk	640	34	37	39
Ulukhaktok	290	29	37	43
Inuvialuit/Inuit Persons		37	37	39
SOURCE: IRC (2020a)				

7.4.1.3 Labour Force

In 2016, the ISR had a lower labour force participation rate and higher unemployment rate than the NWT overall (Table 7-15). There was substantial variation in 2016 labour force participation between different ISR communities, with Inuvik, Paulatuk, and Sachs Harbour having participation rates close to 70%, while Aklavik, Tuktoyaktuk, and Ulukhaktok had rates closer to 60%. From 2006 to 2016 there was a 4% decline in labour force participation in ISR, similar to that experienced in the NWT, which dropped by 4%. Labour force participation dropped most markedly in Inuvik (14% decline) and Aklavik (16%), while Paulatuk experienced a 19% increase in labour force participation over the 2006 to 2016 period (NWT Bureau of Statistics 2019c).

The unemployment rate within the ISR has historically been substantially higher than for NWT overall (Table 7-15). While the 2016 unemployment rate of Inuvik compared favourably with that of the NWT, the other five ISR communities had far higher rates, ranging from 16.7% in Sachs Harbour to 28.6% in Aklavik.

Table 7-15 Community Labour Force Activity

Location	2016				Participation rate			Unemployment rate		
	Population 15 and over	Labour force	Employed	Unemployed	2006	2011	2016	2006	2011	2016
NWT	32,330	23,945	21,415	2,535	76.5	75.4	74.1	10.4	11.4	10.6
ISR	4,025	2,780	2,390	415	71.6	67.5	69.1	22.9	23.3	14.9
Aklavik	450	280	205	80	54.5	46.2	45.6	28.4	32.7	28.6
Inuvik	2350	1760	1610	155	79.8	76.4	68.5	11.2	13.6	8.8
Paulatuk	210	145	110	35	58.1	53.7	69	28.0	31	24.1
Sachs Harbour	85	60	50	10	70.6	64.7	70.6	25.0	-	16.7
Tuktoyaktuk	640	360	275	95	57.6	50.8	56.2	33.3	27.4	26.4
Ulukhaktok	290	175	140	40	65.5	54.8	60.3	22.2	14.7	22.9
SOURCE: NWT Bureau of Statistics 2019c										

7.4.1.4 Household Income

Outside of Inuvik, median household incomes in ISR communities are far below the NWT average (Table 7-16), reflecting both the relative lower level of economic activity and higher level of unemployment in these communities. In 2015, median household incomes in Aklavik, Tuktoyaktuk, and Ulukhaktok were less than half that of the NWT overall, while those in Paulatuk and Sachs Harbour were also substantially below the NWT average. Inuvik's much higher median household income level reflects its lower unemployment rate and its role as the regional administration centre in the ISR (NWT Bureau of Statistics 2019d).

Table 7-16 Household Income, 2006 – 2015

Location	Median family income (2016$)			2011 to 2016 percent change	2006 to 2016 percent change
	2006	2011	2016		
NWT	93,699	105,887	117,688	11.1	25.6
Aklavik	40,884	44,225	52,608	19.0	28.7
Inuvik	90,455	97,945	108,117	10.4	19.5
Paulatuk	52,566	75,969	75,264	-1.0	43.2
Sachs Harbour	x	x	68,352	NA	NA
Tuktoyaktuk	46,875	58,090	55,424	-4.6	18.2
Ulukhaktok	38,938	52,429	54,592	4.1	40.2
NOTE: "x" means data not available					
SOURCE: NWT Bureau of Statistics 2019d					

7.4.1.5 Consumer Prices

Table 7-17 compares food price indices between ISR communities and Yellowknife from 2001 to 2019 based on NWT Community Price Surveys. The costs of transporting goods to remote ISR communities is reflected in the much higher food prices, relative to Yellowknife. The year-round roadway accessibility of Inuvik is reflected in the lower food prices compared to other ISR communities; Tuktoyaktuk had been accessible by ice-road in the winter; in 2017, the Inuvik-Tuktoyaktuk Highway (NWT Highway 10) opened providing all-season road access to the community.

Table 7-17 Food Prices Comparison, 2001 – 2015

Location	2001	2004	2010	2012	2015
Yellowknife	100	100	100	100	100
Aklavik	183	183	174	174	170
Inuvik	147	140	150	149	157
Paulatuk	193	222	196	198	185
Sachs Harbour	188	197	177	189	175
Tuktoyaktuk	165	206	162	168	162
Ulukhaktok	182	188	204	195	186
SOURCE: NWT Bureau of Statistics 2019e					

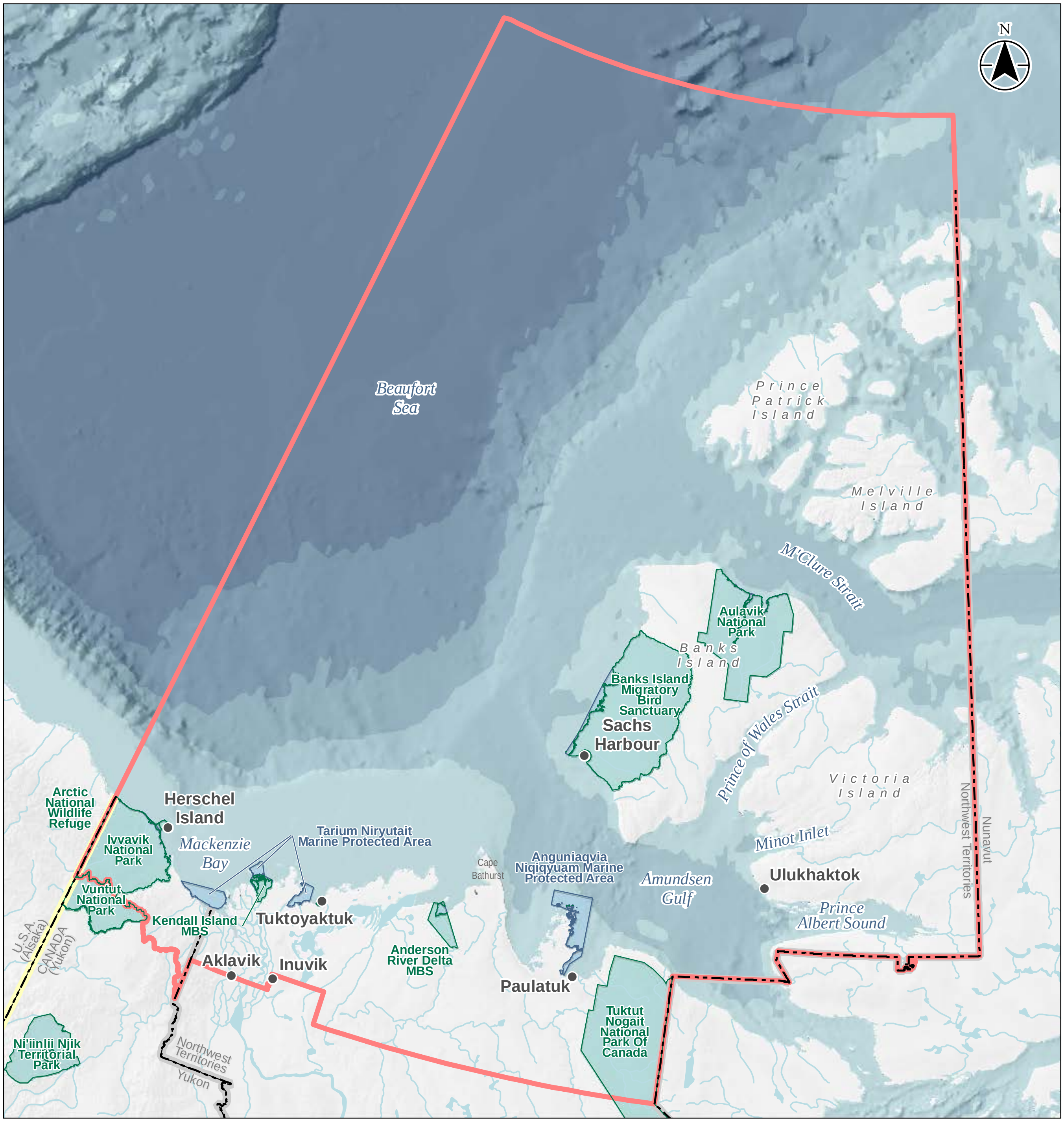
7.4.2 Demographics

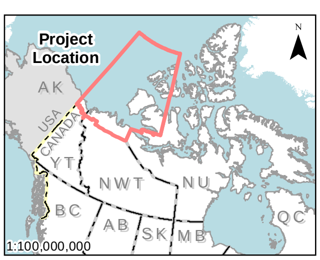
7.4.2.1 Population Demographics

The assessment of Demographics considers the following communities within the ISR: Aklavik, Paulatuk, Inuvik, Sachs Harbour, Tuktoyaktuk, and Ulukhaktok (Figure 7-56). Inuvik is the government, business, and transportation centre of the ISR, and is the largest community, accounting for nearly 60% of the ISR's total population in 2018 (Table 7-18).

Between 2013 and 2018, the population of the NWT increased by 1.7% and that of the ISR by 1.3%. Half of the six communities in the ISR saw an increase, ranging from 0.5% (Inuvik) to 8.9% (Tuktoyaktuk). The populations of the other three communities decreased over this period, with Sachs Harbour experiencing the greatest decline (9.0%). Each of the remaining ISR communities have fewer than one thousand residents (Table 7-18).

In the NWT and ISR, the percentage of the Indigenous population identifying as Inuit is 19.5% and 68.6%, respectively (Table 7-19). Within the ISR, the majority of residents who identify as Indigenous in each community are Inuvialuit. This percentage is highest in Sachs Harbour (90.9%) and lowest in Aklavik (53.9%) (Statistics Canada 2017a).





Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Natural Resources Canada

Community
International Boundary
Territorial Boundary
Watercourse
Waterbody
Marine Protected Area
Terrestrial Protected Area
Bathymetry Depth (m)
< 200
200 - 1000
1000 - 2000
2000 - 3000
> 3000

Study Area

0 50 100 150 200 250 300 km
1:8,000,000 (at original document size of 11x17)

KAVIK-STANTEC INUVIALUIT REGIONAL CORPORATION

Project Location
Beaufort Sea,
Northwest Territories,
Canada

Project Number 123513135
Prepared by LTRUDELL on 20191115
Discipline Review by SJONES on 20191115

Client/Project
Inuvialuit Regional Corporation
Beaufort Region SEA

Figure No.
7-56

Title
Communities within Inuvialuit Settlement Region

Table 7-18 Population Statistics – 2012 – 2018

Location	Total Population			Population, Indigenous Identity	Percentage Indigenous Identify
	Population		Percent Change		
	2013	2018	2013 – 2018		
NWT	43,805	44,541	1.7%	22,369	50.2%
ISR	5,920	5,998	1.3%	4,541	75.7%
Aklavik	656	623	-5.0%	584	93.7%
Inuvik	3,518	3,536	0.5%	2,293	64.8%
Paulatuk	304	302	-0.7%	265	87.7%
Sachs Harbour	122	111	-9.0%	99	89.2
Tuktoyaktuk	902	982	8.9%	898	91.4%
Ulukhaktok	418	444	6.2%	402	90.5%
NOTES: Numbers may not add due to rounding					
SOURCE: NWT Bureau of Statistics 2019a					

Table 7-19 Inuvialuit Population, 2016

Location	Indigenous Identity	Inuvialuit/Inuit Identify	Percentage Inuvialuit/Inuit Identity
Canada	1,673,785	65,030	3.9%
NWT	20,860	4,075	19.5%
ISR	4,541	3,115	68.6%
Aklavik	584	315	53.9%
Inuvik	2,293	1,315	57.3%
Paulatuk	265	235	88.7%
Sachs Harbour	99	90	90.9%
Tuktoyaktuk	898	790	88.0%
Ulukhaktok	402	370	92.0%
NOTES Numbers may not add due to rounding			
SOURCE: Statistics Canada 2017a			

Between 2008 and 2017, while the natural population change (i.e., as a result of births and deaths) in the NWT and ISR have been positive, both have experienced substantial net out-migration (Table 7-20). In the NWT, the annual natural increase averaged 520 people between 2005 and 2015. However, over the same period, there was net out-migration from the NWT every year, with an annual average loss of 423 people. All communities in the ISR experienced net out-migration between 2008 and 2017. Population projections suggest this trend will continue, indicating that the population of the ISR will decrease by 7.5%, from nearly 6,000 to 5,549, between 2018 and 2035 (GNWT 2018e).

Out-migration is fueled by young people accessing post-secondary education and finding jobs elsewhere, mainly in Canada's western provinces (Brockman 2017). Most in-migrants to the NWT come from other Canadian jurisdictions. In the past, most were drawn by job opportunities and competitive pay, but they are also discouraged by the high cost of living and distance from their families and home communities (Northwest Territories Department of Finance 2015).

Table 7-20 Population Changes by ISR Community, 2008 – 2017

Location		2008 – 2012	2013 – 2017	2008 – 2017
NWT	Total population change	276	1288	1564
	Natural population change	2547	2170	4717
	Net migration	-2271	-882	-3153
ISR	Total population change	-24	4	-20
	Natural population change	414	348	762
	Net migration	-438	-344	-782
Aklavik	Total population change	45	-13	32
	Natural population change	28	33	61
	Net migration	17	-46	-29
Inuvik	Total population change	-49	-92	-141
	Natural population change	266	163	429
	Net migration	-315	-255	-570
Paulatuk	Total population change	5	-10	-5
	Natural population change	21	34	55
	Net migration	-16	-44	-60
Sachs Harbour	Total population change	-6	-2	-8
	Natural population change	6	8	14
	Net migration	-12	-10	-22
Tuktoyaktuk	Total population change	-3	95	92
	Natural population change	68	80	148
	Net migration	-71	15	-56
Ulukhaktok	Total population change	-16	26	10
	Natural population change	25	30	55
	Net migration	-41	-4	-45
SOURCE: NWT Bureau of Statistics 2019a				

7.4.2.2 Age and Gender

The population of the ISR is composed of slightly more males (50.3%) than females (49.7%). Within each of the communities, males and females each represent approximately 50% of the population (Table 7-21). The dependency ratio, which compares the number of people of non-working age with the number of working age, is generally higher in ISR communities compared to the NWT when considering those under 15 years of age (Table 7-21). A high dependency ratio means those of working age, and the overall economy, face a greater burden in supporting the non-working population.

Table 7-21 Population by Age and Gender, 2018

Location	Gender		Age-Category			Dependency Ratio	
	Male	Female	0-14	15-59	60+	Percent < 15 years	Percent > 60 years
NWT	22,912	21,629	9,105	29,455	5,981	.31	.20
ISR	3,014	2,984	1,390	3,833	761	.36	.20
Aklavik	311	312	164	365	94	.45	.26
Inuvik	1,754	1,782	780	2,303	453	.34	.20
Paulatuk	160	142	80	190	32	.42	.17
Sachs Harbour	57	54	11	69	17	.36	.25
Tuktoyaktuk	516	466	249	623	110	.40	.18
Ulukhaktok	216	228	106	283	55	.37	.19
SOURCE: NWT Bureau of Statistics 2019a							

7.4.3 Infrastructure

The six communities within the ISR have similar community infrastructure, with airports, inns, town halls, general stores, post offices, RCMP detachments, and churches (Table 7-22). All communities, apart from Inuvik, have trucked potable water delivery and sewage pickup. Inuvik has an above-ground, gravity-flow piped system within a utilidor system (i.e., an above-ground enclosed utility to carry water and sewage).

Within the ISR, there are 1,920 private households of which 32% are owned and 68% are rented. The average value of a home in the ISR in 2016 was $248,443 and average monthly rent was $921 (Statistics Canada 2018). The Northwest Territories Housing Corporation is responsible for public housing in the ISR and offers programs to support home ownership.

There are 16 hotels, inns, and bed-and-breakfasts in the ISR. The largest hotel in the region is the Mackenzie Hotel in Inuvik with 32 rooms. There are also 3 campgrounds in Inuvik (Northwest Territories Tourism 2019).

The Inuvik Regional Hospital is the only hospital in the ISR. It has 51 beds and offers emergency services, acute care, diagnostic imaging, laboratory, long-term care, rehabilitation, health promotion, and obstetrical care. It has an operating room and it also administers an on-site pharmacy. There are health clinics in the other communities, providing such services as emergency treatment, immunization, and pre- and post-natal health (Northwest Territories Health and Social Services Authority 2019).

Table 7-22 Infrastructure and Services in ISR Communities

Infrastructure/Services	Aklavik	Inuvik	Paulatuk	Sachs Harbour	Tuktoyaktuk	Ulukhaktok
Transportation Infrastructure						
All weather access road	No	Yes	No	No	Yes	No
Winter access road	Yes	No	No	No	No	No
Air strip/Terminal	Yes	Yes	Yes	Yes	Yes	Yes
Marine Supply Facility	No	Yes	Yes	Yes	Yes	Yes
Health Infrastructure						
Hospital/Clinic	No	Yes	No	No	No	No
Health Centre	Yes	Yes	Yes	Yes	Yes	Yes
Women's Shelter/Transition House	No	Yes	No	No	Yes	No
Education						
Highest grade taught at local school	12	12	12	9	12	12
Post-secondary facilities	No	Yes	No	No	No	No
Municipal/Judicial Infrastructure						
Fire hall	Yes	Yes	Yes	Yes	Yes	Yes
Police	Yes	Yes	Yes	Yes	Yes	Yes
Waste Disposal	Solid, Sewage	Solid, Sewage	Solid, Sewage	Solid, Sewage	Solid	Solid, Sewage
& Utility Infrastructure Communication						
Television/Radio	Yes/Yes	Yes/Yes	Yes	Yes	Yes	Yes
4G Cellular	Yes	Yes	No	No	Yes	No
Electricity generation	Diesel	Natural Gas/Diesel	Diesel	Diesel	Diesel	Diesel
Business Infrastructure						
Financial services	No	Yes	No	No	No	No
Grocers	Yes	Yes	Yes	Yes	Yes	Yes
SOURCE: NWT Bureau of Statistics 2019f						

There are no paved highways in the ISR. The Dempster Highway runs from near Dawson City to Inuvik and is an important transportation route for the Mackenzie Delta and Beaufort Sea (DFO-SCEWG 2009). In 2017, the 138 km Inuvik Tuktoyaktuk Highway opened allowing year-round access to Tuktoyaktuk. There is no road access (winter or gravel) to Ulukhaktok, Paulatuk, or Sachs Harbour (GNWT 2019a).

There is an airfield in each community within the ISR, with the Inuvik Airport serving as the regional hub and supporting commercial and military flight operations across the Western Arctic. It has a single runway, five taxiways, commercial buildings, and a military base (Transport Canada 2016). Several air charter companies are based there. Aklak Air is the primary provider of air transportation in the ISR offering scheduled passenger, cargo and charter air services, as well as specialized community services such as medevac. Canadian North and Air North provide daily passenger service to Whitehorse and to several locations in southern Canada.

Sealift (marine shipping) is an important means of moving cargo during the ice-free season, and it is the only way to transport large and heavy items. Tuktoyaktuk Harbour is the only harbour on the Canadian Beaufort Sea coast and for 75 years or more has served as the main transshipment location for barged goods coming down the Mackenzie River and then along the Arctic coast. The harbour is open to vessel traffic from mid-June to mid-October and has water depths greater than 20 m. The Canadian Coast Guard (CCG) conducts operations in the area, maintaining aids to navigation and serving as fixed or drifting marine research platforms (DFO-SCEWG 2009).

Education in the ISR is overseen by the Beaufort-Delta Education Council. It is the most northerly school board in the NWT and it serves approximately 1,400 students (Beaufort Delta Education Council 2019). There are seven schools for children from kindergarten to grade 12 in the ISR communities. Post-secondary education is available at Aurora College’s Inuvik Campus, which offers developmental studies as well as certificate, diploma, and degree programs. Approximately 150 full-time students attend the College.

Infrastructure in the ISR is primarily built on continuous permafrost and, as such, is at risk due to changing environmental conditions (Lamoureux et al. 2016, see also Section 7.2.5.2). Building foundations, particularly those built before the 1990s, roads, air strips, and other critical infrastructure depend on stability of substrate in a permafrost environment to maintain their design function. These structures can be susceptible to foundation subsidence due to inadequate planning to preserve underlying permafrost. This results in increased maintenance and remediation costs and repairs necessary to upgrade deficient building foundations and are often expensive (Stern and Gaden 2015).

7.4.4 Traditional Activities

Hunting, trapping, and fishing as traditional activities are of key importance to Inuvialuit communities in the ISR (Joint Secretariat 2003). Many Inuvialuit depend on country foods for subsistence (ICC et al. 2006:14-6). As identified by Aklavik, Inuvik and Tuktoyaktuk Working Groups, the Husky Lakes area is important for past and present use by Inuvialuit for year-round traditional fishing, hunting, trapping and berry picking (ACCP 2016: 31). Community members from Aklavik and Inuvik indicated that they travel across the entire Mackenzie Delta, going everywhere there is water (FJMC and IRC 2019a: 18-23). Inuvialuit from Inuvik catch many types of fish, and important fishing areas include East Whitefish Station, Kendall Island, and Kittigazuit. Fishing also occurs in the Firth and Babbage Rivers, Philips Bay, BAR-C area, and the middle channel of the Mackenzie River (IMG Golder and Golder Associates 2011f: 10-11.) Argo Bay has both cultural and ecological importance for Inuvialuit from Paulatuk, as it is used for fishing, whaling, hunting, and trapping (KAVIK-AXYS Inc. 2012: 3-19).

The importance of traditional harvesting is shown by the information provided by the Inuvialuit harvest study (Joint Secretariat 2003, Fabijan et.al 1993). The Inuvialuit collected detailed harvest information during a 10-year study during which all Inuvialuit beneficiaries over 16 years of age in each of the six ISR communities were interviewed monthly and asked what, when, where and how much they harvested, for over 60 species (Joint Secretariat 2003). The harvest study atlas, although only showing a few years of species harvest locations, gives clear documentation of the importance of the land for traditional harvesting (Fabijan et al 1993).

Reliance on country foods in providing dietary staples is high, with hunted and fished foods generally preferred over store bought foods both for reasons of health and cultural vitality (Joint Secretariat 2003). For members of the Paulatuk community, country foods and harvesting are essential components of Inuvialuit culture (FJMC and IRC 2019a: 10). For Tuktoyaktuk community members, there is a general consensus that traditional food is healthier than store-bought foods and that people are encouraged by Health Canada to eat as much country food as possible. (IMG Golder and Golder Associates 2014: 12).

Statistics available from NWT Bureau of Statistics (2019c) included data for households who participated in hunting, trapping, or fishing. In the period of 1999-2014, five of six communities in the ISR experienced growth in percentage of people over 14 who participated in hunting, while households in Sachs Harbour experienced a decline (Table 7-23). Four of the six communities experienced growth in trapping participation, while the remaining two experienced a decline. Fishing participation experienced positive growth for five of six communities, while declining slightly in Sachs Harbour. Additional data on participation in traditional practices by ISR communities is available at www.indicators.inuvialuit.com (IRC 2020a).

Table 7-23 Persons 15 Years and Older that Hunted, Trapped or Fished, 1999 – 2014

Location	Activity	1999 Percent	2004 Percent	2009 Percent	2014 Percent	2009 – 2014%	2004 – 2014%
NWT	Hunting or Fishing	42.0	36.7	39.4	44.7	13%	22%
	Trapping	6.1	5.9	6.2	6.1	-2%	3%
Aklavik	Hunting or Fishing	35.8	49.3	53.7	59.8	11%	21%
	Trapping	14.6	21.1	18.3	14.9	-19%	-29%
Inuvik	Hunting or Fishing	46.2	32.6	40.8	44.9	10%	38%
	Trapping	8.2	7.2	7.9	7.0	-11%	-3%
Paulatuk	Hunting or Fishing	64.4	49.5	68.7	71.7	4%	45%
	Trapping	-	13.8	9.9	5.3	-46%	-62%
Sachs Harbour	Hunting or Fishing	69.3	77.3	72.6	68.3	-6%	-12%
	Trapping	5.9	6.8	10.5	9.6	-9%	41%
Tuktoyaktuk	Hunting or Fishing	60.0	56.9	54.4	66.0	21%	16%
	Trapping	10.4	8.4	5.8	8.5	47%	1%
Ulukhaktok	Hunting or Fishing	72.6	76.1	66.9	80.4	20%	6%
	Trapping	12.6	5.5	7.8	5.8	-26%	5%

NOTE:
"-" means data is zero or is too small to be expressed

SOURCE: NWT Bureau of Statistics 2019g

7.4.4.1 Harvested Species

Inuvialuit communities in the ISR harvest a wide range of marine and terrestrial species (Table 7-24). Harvested species include polar bears, beluga whales, seals, various species of fish, migratory and marine birds, and caribou. Inuvialuit look forward to communal loche fishing in creeks during fall, and in trading fish such as Arctic char with other communities (ICC et al. 2006: 11-229). Based on local knowledge experts in each community, harvesting includes the following (by community):

- Aklavik hunters and trappers harvest caribou, grizzly bear, and fish from the area lying between the eastern border of Ivvavik National Park (with the exception of the fish hole at the top of the Babbage River, inside the Park) and the west side of the Mackenzie Delta, the southern boundary of the ISR and the Beaufort Sea (WMAC-NS and AHTC 2008; ACCP 2016: 97). Aklavik residents hunt polar bears in the springtime at Herschel Island and Kay Point, and the hunters travel out on the ice off the coastal areas (IMG Golder and Golder Associates 2011a: 3-10).
- Polar bears are hunted by Sachs Harbour community members (IMG Golder and Golder Associates 2011c: 9).

- Ulukhaktok local experts indicated that between the summer and fall months, seals are hunted in channels south of Ulukhaktok (IMG Golder and Golder Associates 2011d: 9). Ulukhaktok community members use two large areas for hunting caribou, and fishing for char and trout year-round: on Wollaston Peninsula, south of Prince Albert Sound, which includes the Kugaluk River, and an inland area on the Prince Albert Peninsula north of Minto Inlet and south of the Engaloak River (OCCP 2016: 56; 132).
- Aklavik community members hunt for caribou along the Eastern North Slope, East of Babbage River, and fish for char and grayling in the Babbage River in April (TCCP 2016: 113).

Table 7-24 Species Commonly Harvested by Inuvialuit Communities

Community	Species Harvested
Aklavik	Marine mammals: bearded and ringed seal, beluga, polar bear Fish: burbot, Dolly Varden, cisco, herring, inconnu, pike, whitefish Birds: Geese – brant, Canada, greater white-fronted, snow Ducks – mallard, oldsquaw, pintail Other – ptarmigan, scoter, swan, wigeon
Inuvik	Marine mammals: bearded and ringed seal, beluga, polar bear Fish: burbot, inconnu, pike, Lake whitefish, Broad whitefish Birds: Geese – brant, Canada, greater white-fronted, snow Ducks – mallard, oldsquaw, pintail Other – ptarmigan, scoter, swan, wigeon
Paulatuk	Marine mammals: bearded and ringed seal, beluga, polar bear Fish: burbot, char, cod, flounder, grayling, herring, trout, whitefish Birds: Geese – brant, Canada, greater white-fronted, snow Ducks – pintail, oldsquaw Other - ptarmigan, scoter, swan, wigeon
Sachs Harbour	Marine mammals: bearded seal, ringed seal Fish: char, cisco, Cod, herring, Trout, whitefish Birds: Geese – brant, Canada, greater white-fronted, snow Ducks – pintail, oldsquaw Other – ptarmigan, swan
Tuktoyaktuk	Marine mammals: bearded and ringed seal, beluga, polar bear Fish: burbot, char, Cod, Flounder, Grayling, inconnu, pike, Trout Birds: Geese – brant, Canada, greater white-fronted, snow Ducks – mallard, pintail, Eider, oldsquaw Other - ptarmigan, scoter, swan, wigeon

Table 7-24 Species Commonly Harvested by Inuvialuit Communities

Community	Species Harvested
Ulukhaktok	Marine mammals: bearded and ringed seal, beluga, Polar Bear Fish: cisco, Cod, pike, Trout, whitefish Birds: Geese – brant, Canada, greater white-fronted, snow Ducks – Eider, oldsquaw Other – ptarmigan, swan
SOURCE: Joint Secretariat 2003	

7.4.4.2 Locations and Timing of Harvesting Activities

Inuvialuit in the ISR hunt and fish year-round, throughout the Ice, Open Water, and Transition seasons, and many of the valued species are best harvested at specific times of year. Important traditional use areas for Inuvialuit in Inuvik include Kendall Island (Ukiivik), Ikalupik Harbour on Kendall Island, Garry Island, Baby Island, East Whitefish Station, Kittigazuit, Kidluit Bay, Indian Camp, West Whitefish Station (Niakunuk), and Shingle Point (Tapqaq) (Devon Canada Corporation 2004b: 18-23). These areas are important for cultural and harvesting activities, especially fishing and beluga harvesting in the summer months (June to August) and polar bear hunting in the early spring months (March to May). These areas

Hunters and fishers draw on a range of locations and resources around the ISR, including many islands, harbours, points, rivers, lakes, and coastal areas. Aklavik local experts indicated they use areas from Shallow Bay and Ellice Island in the east to Shingle Point in the west for beluga hunting. They indicated that Kendall Island, an important whaling area for many Inuvialuit, especially those from Tuktoyaktuk and Inuvik, is an easier and less dangerous location to hunt belugas (KAVIK-AXYS Inc. 2004a: 4-2). Paulatuk community members use Argo Bay year-round for fishing, whaling, hunting, and trapping. Beluga whales may be harvested there in summer months, and ringed seals in September (KAVIK-AXYS Inc. 2012: 3-9; 3-19;3-20). Beluga whales are commonly harvested in July and August by the people of Tuktoyaktuk in Kugmallit Bay and along the coast to Pullen Island. A TLK holder noted that local inhabitants usually hunted beluga whale closer to Pullen Island later in the year and another TLK holder added that most of the whales are harvested near Hendrickson Island (IMG Golder and Golder Associates 2011e:7).

Inuvik harvesters use a wide range of areas, including the coast of Tuktoyaktuk Peninsula, the coast of the North Slope west to Herschel Island, Ivvavik National Park, and Husky Lakes (FJMC and IRC 2019a: 18-23). Ulukhaktok hunters harvest caribou around the Minto Inlet area where Peary caribou predominate; however, harvest shifts to Dolphin and Union caribou from the Prince Albert Sound area, when northern animals are scarce (OCCP 2016: 96).

Specialized camps may be set up to organize and centralize harvesting activities, and harvesters often combine traditional activities, such as fishing while whaling, to maximize success. Tuktoyaktuk harvesters often have a camp, multiple seasonal camps, or access to a camp in the Tuktoyaktuk area. They indicated that the camps are usually seasonal, depending on what they are harvesting, and can include camps for summer fishing and making dry fish, camps for fall fishing, and separate camps for caribou harvesting or trapping (IMG Golder and Golder Associates 2014: 10). When harvesting polar bears, Aklavik hunting expeditions may establish base camps on stable ice, often for many days at a time (Joint Secretariat 2015: 29-30). Tuktoyaktuk hunters described multi-year rubble piles as very important locations for polar bear harvesting, as they serve as a camp location, particularly 24 to 32 km north of Pullen Island (IMG Golder and Golder Associates 2014:8). The community of Paulatuk has summer char, whitefish and beluga harvesting camps located on the coast within the Anguniaqvia niqiqyuam Area of Interest (ANAOI) in areas close to important habitat for char, beluga, and ringed and bearded seals (PCCP 2016: 84). During winter, Aklavik harvesters set up ice fishing holes on the channels of the Mackenzie Delta near Aklavik or in the vicinity of their trapping camps (WMAC-NS and AHTC 2018b: 79-81).

7.4.4.3 Access Modes

Inuvialuit in the ISR access traditional resources in a number of ways, including on foot and by watercraft, snowmobiles and all-terrain vehicles. The use of dog sleds, long needed for hunting on the land and ice, is now less common, but has advantages. Experienced Inuvialuit harvesters have indicated that dog teams have advantages over modern snow machines, including being able to sense dangerous ice conditions (Joint Secretariat 2015: 37).: 37). A TLK holder from Sachs Harbour indicated that dogs are able to sniff out seal breathing holes (IMG Golder and Golder Associates 2011c: 11). Despite this, snowmobiles are widely used, enabling hunters to spot and access wildlife on land and ice quickly, travel long distances daily, and carry heavy loads. Inuvik harvesters reported that they do not camp as frequently as in the past, since snowmobiles make it possible to travel long distances in a short period of time (IMG Golder and Golder Associates 2011f: 3).

Due to changing ice conditions, Inuvialuit hunters and fishers must contend with longer periods of open water. Experienced harvesters from Sachs Harbour, Ulukhaktok, and Paulatuk indicated that thinner, unpredictable ice mean less polar bear hunting (Joint Secretariat 2015: 45). Pursuing seals and polar bears often requires access to the mouths of harbours and areas around islands. Paulatuk harvesters indicated that polar bears are often hunted along leads in the ice (KAVIK-AXYS Inc. 2012: 3-13). Whaling is undertaken from boats and may require both water and ice passage.

Inuvialuit hunters and fishers are concerned that continued economic activity will affect their ability to access traditional resources. For example, in Tuktoyaktuk, harvesters cross the harbour to access harvesting areas and, in late fall, when the ice is freezing up in the harbour, ship traffic can create channels that snow machines cannot cross (KAVIK-AXYS Inc. 2009: 10-5). Many Inuvialuit are dependent on ice-based passage for access to resources such as polar bears, seals, and fish, so an increase in shipping (and attendant rise in the use of icebreakers) in nearshore areas could affect access.

7.4.5 Cultural Vitality

Cultural vitality can be understood as "creating, disseminating, validating, and supporting arts and culture as a dimension of everyday life in a community" (The Urban Institute 2006:4). For Inuvialuit communities in the ISR, cultural vitality is a framework for both the containment and transference of traditional practices and beliefs, as well as a means of reinforcing cultural values and history (AMAP 2017: 125-139).

Hunters, trappers, and Elders from all six of the Inuvialuit communities in the ISR indicated that "our culture and traditions are important! And when you take that away from the people, we take a lot of pride from them" (Slavik, D. 2010: 7). Important indicators of cultural vitality include Inuvialuit language use, the practice of camping on and within traditional territories and areas, and engaging in traditional activities, including hunting, trapping, fishing, gathering, preparation and consumption of country foods, and landscape appreciation. Tuktoyaktuk community members indicated that spending time on the land with children and young people was important for the maintenance of TLK and culture (IMG Golder and Golder Associates 2014: 10). One person mentioned that young people can speak their language easier when they are out on the land but have trouble with it when they are in town, where English is now the dominant language (IMG Golder and Golder Associates 2014: 10).

Inuvialuit TLK holders have also indicated that in addition to nutritional and economic value, fish and fishing are integral to Inuvialuit ways of life and enjoyment of life (e.g., to communal loche fishing and trading fish such as arctic char; ICC et al. 2006: 11-229). These practices are valuable to Inuvialuit for nutritional, cultural, and economic reasons. In particular, they can serve as vectors for the reinforcement and transmission of traditional practices and values across generations.

Oil and gas activity has implications for wildlife that are of key importance to Inuvialuit, including polar bears, seals, whales, and fish. Paulatuk TLK holders are concerned about the effects of a potential well blow-out or oil spill. TLK holders rely on marine animals for food and believe that, if there were a spill, it would have a large impact on their community due to ocean currents and the effects on the animals they harvest (IMG Golder and Golder Associates 2011b: 14). Sachs Harbour TLK holders voiced concerns about how an oil spill would affect the whole region, and one TLK holder said that a spill would affect their food supplies (e.g., food security) (IMG Golder and Golder Associates 2011c: 20). TLK holders from Ulukhaktok stated that the marine wildlife may be affected by smells from the industrial equipment and the potential for oil spills in the water, and that, if there were an oil spill, the wildlife would move away to a cleaner area (IMG Golder and Golder Associates 2011d: 16).

The Ulukhaktok Community Working Group were concerned that marine traffic will have a negative impact on the area's resources and resource users. These impacts may be caused by the disruption of ice, noise disturbances to marine life, or interference with traditional land use activities. In addition, if tanker traffic occurs, there were concerns about the impact that an oil spill could have on the renewable resource base in the region (OCCP 2016:42). A harvester from Sachs Harbour indicated concerns regarding industrial contamination, and its effects to wildlife: "Well, bear are on the top of the food chain. And whatever the seal gets from contamination, the bigger animals get from feeding on it… [but] it's not just the polar bear we're concerned about, it's the fish and caribou, everything on the land" (Slavik, D. 2010: 57).

Hunting for large marine mammals such as polar bear, has long been an important demarcator of Inuvialuit status, and the ability to transfer cultural knowledge about polar bear hunting could be degraded by offshore industrial activities. Harvesters from Paulatuk and Tuktoyaktuk indicated that polar bear hunting represents a rite of passage, and that the successful hunting of one's first polar bear marked a crucial step in Inuvialuit development as a harvester (Slavik, D. 2010: 7).

Country foods and harvesting are essential components of Inuvialuit culture (IRC 2020b). Inuvialuit TLK holders have indicated that the knowledge and skills needed to harvest in the Arctic are extensive, and crucial in knowing how to survive in an extreme climate. Harvesting success also requires knowledge of animal behavior, butchering, and proper storage (FJMC and IRC 2019a: 10). Impacts to those sources translate to effects on culture, sense of well-being, and communities. Concerns were also noted regarding the potential for pollution resulting from oil and gas activity, which could have effects on both cultural and human vitality. Inuvik TLK holders expressed concerns regarding seismic impacts to fish, whales, bearded seals, crabs, and clams, concerns regarding the effects of project-related noise on polar bears (Ibid.: 4-4), and effects to waterways and fish resulting from a lack of cleanup after seismic activity (Ibid.: 4-15). Specific impacts of climate change and the five scenarios are further expanded on in Chapter 8.

7.4.5.1 Indigenous Languages

Language is a key indicator of cultural vitality (Petrov 2018: 171; 181-182). Sallirmiutun, Uummarmiutun, and Kangiryuarmiutun are the three languages that are spoken in the ISR; these are collectively known as the Inuvialuktun language (https://www.irc.inuvialuit.com/language-0). The cultural vitality of Inuvialuit communities could be affected through diminishing Indigenous language retention and transference.

All six communities in the ISR are home to Inuvialuit who identify an Indigenous language as their mother tongue (NWT Bureau of Statistics 2019a). The percentage of Indigenous language speakers in NWT has declined in the period between 1989 and 2014 (NWT Bureau of Statistics 2019b). One of the communities in the ISR (Sachs Harbour) has experienced a growth in spoken Indigenous language, while the remaining five communities have all experienced declines in spoken Indigenous language. Additional Indigenous language statistics are provided in Table 7-25.

Language trends were analyzed using data made available by the NWT Bureau of Statistics. Trend analysis indicates that from the period of 2006-2016, all six communities in the ISR experienced change in Indigenous language as mother tongue or Indigenous language as home language. Inuvik experienced an increase of Indigenous language use in both categories, while the remaining five communities all experienced reduction in Indigenous language use (Table 7-26).

Table 7-25 Percent Indigenous Persons 15 Years and Older that Speak Indigenous Languages, 1989-2014

Location	1989	1994	1999	2004	2009	2014	2009 - 2014 % change	2004 - 2014 % change	1994 - 2014 % change
NWT	55.6	50.1	45.1	44.0	38.0	38.5	1%	-13%	-23%
Aklavik	21.8	28.1	18.7	19.3	19.2	11.5	-40%	-40%	-59%
Inuvik	26.5	25.3	24.8	17.6	16.2	20.5	27%	16%	-19%
Paulatuk	32.1	25.4	27.0	X	23.4	21.3	-9%	0%	-16%
Sachs Harbour	38.0	26.1	27.6	26.9	40.0	39.1	-2%	45%	50%
Tuktoyaktuk	37.7	30.1	25.3	28.3	22.3	24.4	9%	-14%	-19%
Ulukhaktok	96.4	71.3	58.2	76.3	60.1	52.7	-12%	-31%	-26%
NOTE: “x” means data suppressed									
SOURCE: NWT Bureau of Statistics 2019h									

Table 7-26 Indigenous Language Use

Location	Percent of Population with Indigenous Language as Mother Tongue		Percentage of Population with Indigenous Language as Home Language				
	2011	2016	2006	2011	2016	2011 – 2016 % change	2006 – 2016 % change
NWT	13.4	11.2	5.9	5.9	4.9	-17%	-17%
ISR	11.0	9.7	-	2.1	1.3	-38%	-
Aklavik	12.8	10.2	2.5	0.0	1.7	-	-32%
Inuvik	6.2	4.9	0.6	0.3	0.8	167%	33%
Paulatuk	7.9	18.9	3.4	0.0	0.0	-	-100%
Sachs Harbour	22.7	14.3	8.0	0.0	0.0	-	-100%
Tuktoyaktuk	11.7	12.2	5.7	2.9	1.1	-62%	-81%
Ulukhaktok	30.0	32.9	11.4	16.3	3.8	-77%	-67%
NOTE: “-“ means data are unavailable							
SOURCE: Statistics Canada 2015, 2017a; NWT Bureau of Statistics 2019i							

7.4.5.2 Arts and Crafts

Traditional activities for Inuvialuit communities in the ISR also include engaging in creative and artistic pursuits. Aklavik, Inuvik, and Paulatuk community members reported using rabbit fur in the duffles for mukluks, in blankets, and in arts and crafts (ACCP 2016: 116; ICCP 2016: 116; PCCP 2016: 114). Sachs Harbour community members make mitts, purses, or crafts from polar bear hides (IMG Golder and Golder Associates 2011c: 9), and use seal pelts to make traditional clothing such as mittens, hats and other crafts, including purses (IMG Golder and Golder Associates 2011c: 10). Sachs Harbour members also use caribou hides for clothing and crafts (SCCP 2016: 79). Ulukhaktok community members make clothing and crafts from wolf hides (PCCP 2016: 105).

Data collected by the NWT Bureau of Statistics (2019d) for arts and crafts production included the categories of carvings, drawings or paintings, sewing or needlecraft, weaving or basketmaking, jewelry, performing arts, books, plays, music, and other. The total production of arts and crafts in the ISR for 2013 was 1,244 pieces with each of the six Inuvialuit communities in the ISR producing arts and crafts. The percentage of communities in the ISR that had residents aged 15 years and older who produced arts and crafts was higher at 27.0 percent than for the rest of the Northwest Territories at 23.3 percent (Table 7-27). Arts and crafts output ranged from a high of 635 pieces (Inuvik) to a low of 42 (Sachs Harbour). Total output was shown to be relative: 42 of the 104 Sachs Harbour residents were engaged in producing arts and crafts, for a participation rate of 40.4 percent. By comparison, Inuvik reported 2,588 people, with a participation rate of 24.5 percent.

Table 7-27 Production of arts and crafts, persons 15 years and older, 2013

Location	Persons 15 & Over	Produced Arts and Crafts (# pieces)	Percentage
NWT	34,087	7,947	23.3
ISR	4,569	1,244	27
Aklavik	550	134	24.4
Inuvik	2,588	635	24.5
Paulatuk	244	85	34.8
Sachs Harbour	104	42	40.4
Tuktoyaktuk	721	202	28.0
Ulukhaktok	362	146	40.3
SOURCE: NWT Bureau of Statistics 2019j			

7.4.6 Public Health

7.4.6.1 General Health

The Canadian Community Health Survey shows that there was an increase in the prevalence of many chronic health conditions from 2001 to 2014, in both NWT and Canada (Table 7-28). However, the rates have grown more rapidly in the NWT compared to Canada as a whole. For example, in 2001, the proportion of the population that is 12 years of age and over with asthma in NWT was similar to that of Canada, while the rates of arthritis/rheumatism, high blood pressure, and diabetes in NWT were approximately two-thirds the Canadian averages. By 2014, the prevalence of asthma, arthritis/rheumatism, diabetes, and mood disorder in NWT was similar to or higher than the Canadian average. The change in diet and lifestyle behaviors is likely contributing to the rapid increase in chronic health conditions in NWT. Additional information on chronic health conditions and health related incidences such as injury rates and the number of premature deaths within communities in the ISR is available at Inuvialuit Indicators (IRC 2020a).

Table 7-28 Chronic Health Conditions, NWT and Canada, 2001 – 2014)

Condition	Location	Condition prevalence (percent of population 12 and over)					
		2001	2005	2009	2014	2009 to 2014 % change	2001 to 2014 % change
Asthma	Canada	8.4	8.3	8.2	8.1	-1%	-4%
	NWT	8.5	8.4	6.9	8.7	26%	2%
Arthritis/Rheumatism	Canada	15.3	16.4	14.9	16.0	7%	4%
	NWT	10.5	12.2	13.4	15.6	16%	49%
High blood pressure	Canada	12.7	15.0	16.8	17.7	6%	39%
	NWT	8.1	9.1	13.2	13.1	-1%	62%
Diabetes	Canada	4.2	4.9	6.0	6.7	13%	62%
	NWT	2.7	3.6	5.2	7.4	42%	170%
Mood disorder	Canada	..	5.6	6.5	7.9	22%	0%
	NWT	..	5.7	7.0	8.1	16%	0%
SOURCE: NWT Bureau of Statistics 2019k							

7.4.6.2 Diet and Nutrition

The consumption of foods obtained from harvesting, hunting and fishing is an important component of the population health and cultural identity of the Inuvialuit and, as discussed in Section 7.4.4, a wide range of such foods are harvested and consumed. In 2013, 75.5% of ISR households reported some consumption of meat obtained from hunting and fishing, with the proportion increasing to over 92% for communities other than Inuvik. In 2014, 24.4% of ISR households consumed meat primarily obtained from hunting or fishing, with the proportion of such households ranging from 9.5% (Inuvik) to 57.5% (Paulatuk). Data from the 1999 NWT Labour Force Survey and 2004, 2009, and 2014 Community Health surveys show that households in ISR communities have been reducing the proportion of meat in their diets obtained from hunting or fishing between 7 and 51%, with Sachs Harbour being the exception where it increased by 52% (Table 7-29).

Table 7-29 Consumption of meat obtained from hunting or fishing

Location	Eat some meat obtained from hunting and fishing (percent of households), 2013	75% or more of meat obtained from hunting or fishing (percent of households)					
		1999	2004	2009	2014	2009 - 2014 % change	1999 - 2014 % change
NWT	65.0	21.5	17.5	15.4	13.8	-10%	-36%
ISR	75.5	36.5	32.6	23.0	24.4	6%	-33%
Aklavik	94.9	31.2	28.2	20.2	19.7	-2%	-37%
Inuvik	64.6	20.8	17.7	12.8	9.5	-26%	-55%
Paulatuk	92.7	62.0	51.4	39.6	57.5	45%	-7%
Sachs Harbour	94.7	29.4	41.4	32.8	44.6	36%	52%
Tuktoyaktuk	93.7	46.7	49.3	30.3	33.3	10%	-29%
Ulukhaktok	92.3	61.0	45.9	46.3	30.2	-35%	-51%
SOURCE: NWT Bureau of Statistics 2014a							

Store bought processed foods contain higher levels of sugar, salt, and trans fats and, while energy rich, may lack the micronutrients, such as vitamins and minerals contained in traditional foods (Robinson 2018). The high cost of transporting foods to northern communities means that the longer lasting but less nutritious processed foods may be more available and affordable than nutritious but perishable foodstuffs such as fresh vegetables and fruit (Kenny et al. 2018). The shift in consumption towards store bought over traditional foods has been associated with an increased prevalence of some adverse health conditions in Inuit, including higher rates of obesity, Type 2 diabetes, and heart disease (Sharma 2010, Robinson and Filice 2008).

7.4.6.3 Housing

Housing is an important social health determinant. Physical housing conditions can affect the health of household members directly due to factors such as potential exposure to hazardous materials, mold or pest infestation, and energy inefficiencies. Individuals living in a home in poor state of repair or with structural deficiencies are also more susceptible to accidents and injury (Hernandez and Suglia 2016). Housing affordability can also impact physical and mental health due to factors such as stress related to housing costs, fear of eviction, overcrowding, and homelessness (Hernandex and Sualia 2016). With the exception of Inuvik, households in ISR communities are less likely to have affordability problems, possibly due to the much higher proportion of households living in public housing in most ISR communities (Table 7-30). With the exception of Inuvik, households in ISR communities have a much higher likelihood of need for major repairs than for NWT overall (Table 7-30).

Table 7-30 Housing Indicators, NWT and ISR, 2009 - 2016

Location	Percentage of households with affordability problem			2016 Percentage of households own housing	2016 Percentage of households in public housing	Percentage of households with homes in need of major repairs		
	2009	2014	2016			2009	2014	2016
NWT	14	16	12	54	15	16	-	18
ISR	16	10	10	32	33	18	12	22
Aklavik	4	7	7	35	57	35	21	30
Inuvik	21	13	12	33	17	10	6	14
Paulatuk	13	5	-	28	61	43	20	33
Sachs Harbour	13	5	-	25	50	30	29	38
Tuktoyaktuk	8	7	7	33	62	33	26	44
Ulukhaktok	8	3	8	20	60	14	11	32

7.4.6.4 Health Behavior Indicators

Health lifestyle indicators compiled in the Canadian Community Health Survey show that, in 2014, alcohol consumption and physical inactivity of NWT residents aged 15 and over was similar to that for Canada's overall population (Table 7-31). However, NWT residents were 83% more likely to smoke and 87% more likely to consume alcohol heavily (five or more drinks at one time) than the Canadian population. Long-term trends in the proportion of the NWT and Canadian populations engaged in potentially adverse health behaviors are similar.

Table 7-31 Health Behavior Indicators, NWT and Canada, 2001 – 2014

Condition	Location	Behavior prevalence (percent of population 15 and over)					
		2001	2005	2009	2014	2009 to 2014 % change	2001 to 2014 % change
Current Smoker	Canada	26.9	22.6	20.8	18.4	-11%	-31%
	NWT	48.9	37.9	38.5	33.7	-13%	-31%
Current Drinker	Canada	79.2	79.9	79.5	76.9	-3%	-3%
	NWT	76.0	75.3	73.2	75.7	3%	0%
Heavy Drinker	Canada	16.1	17.9	18.1	18.1	0%	12%
	NWT	31.0	27.4	30.6	33.8	11%	9%
Physically Inactive	Canada	50.4	47.9	47.2	45.9	-3%	-9%
	NWT	50.2	50.7	50.7	43.7	-14%	-13%
SOURCE: NWT Bureau of Statistics 2014b							

Data collected during the 2014 NWT Community Survey show that alcohol consumption was less common in most ISR communities than in NWT overall (Table 7-32). However, among those who do drink, heavy drinking appears to be more common in most ISR communities than in the NWT.

Table 7-32 Alcohol consumption prevalence, NWT and ISR communities, 2014

Location	Persons 15 & Older	Current drinker (Consumed alcohol in last 12 months, percent)	Proportion of current drinkers that consumed five or more alcohol servings at one time		
			Once a month	2 to 3 times a month	Once or more a week
Northwest Territories	34,087	64.8	19.8	17.0	7.6
ISR	4,569	60.9	23.5	19.1	-
Aklavik	550	52.8	16.5	32.8	15.6
Inuvik	2,588	65.6	24.0	18.4	11.5
Paulatuk	244	53.2	5.1	20.9	X
Sachs Harbour	104	59.6	11.6	12.8	X
Tuktoyaktuk	721	57.6	25.8	23.4	6.5
Ulukhaktok	362	39.9	56.4	2.4	67.2

NOTE
“X” indicates zero or too small to be expressed

SOURCE: NWT Bureau of Statistics 2014c

Inuvialuit TLK holders have voiced concerns relating to the social impacts, including the transition from a traditional to a wage economy, unequal resource distribution during economic shifts, effects of increased drug and alcohol use, and changes to diet. A Tuktoyaktuk TLK holder believed that large projects bring social changes and expressed concern that potential job opportunities and perceived ease and access to money may lead to increased alcohol and drug problems (IMG Golder and Golder Associates 2011e: 14). T:K holders from Ulukhaktok expressed concerns about the potential for increased drug and alcohol use in the community (IMG Golder and Golder Associates 2011d: 16). A harvester from Sachs Harbour indicated that being able to continue to harvest was vitally important: “A lot of people work for wages, but I hunt for wages – it’s what I live off” (Slavik, D. 2010: 12).

7.4.6.5 Community Cohesion

Community cohesion generally refers to aspects of togetherness and bonding exhibited by members of a community. It is a determinant of health because relationships between individuals are important for physical and psychosocial well-being (USDHHS-ODPHP 2019). The 2014 NWT Community Survey collected data on two community cohesion indicators, sense of belonging and volunteerism (Table 7-33). In general, ISR residents indicated a strong sense of belonging, with 83.0% of the population age 15 or over rating their sense of belonging as “very strong” or “somewhat strong,” compared to 78.5% for NWT overall. Volunteerism rates also tended to be higher in ISR communities than in the NWT.

Table 7-33 Community Cohesion Indicators

Location	Persons 15 & Older	Sense of belonging (2014)			Volunteered in 2013 (percent)
		Very strong (percent)	Somewhat strong (percent)	Somewhat/ very weak (percent)	
NWT	34,087	34.7	43.8	13.0	47.5
ISR	4,569	38.9	44.1	11.0	48.8
Aklavik	550	44.7	42.4	10.0	43.3
Inuvik	2,588	31.6	47.3	14.8	51.1
Paulatuk	244	60.4	21.2	5.5	45.7
Sachs Harbour	104	52.8	31.3	5.9	50.0
Tuktoyaktuk	721	50.9	37.5	4.9	50.0
Ulukhaktok	362	39.9	56.4	2.4	67.2
SOURCE: NWT Bureau of Statistics 2014d					

7.4.6.6 Crime Rates

While crime rates in most ISR communities trended downward over the 2006 to 2016 period, rates of property crime and violent crime tend to be higher in the ISR region than in NWT overall, and far higher than for the Canadian population (Table 7-34).There is a strong correlation between socio-economic disadvantage and involvement in the criminal justice system; factors such as poverty, unemployment, inadequate educational opportunities, poor living conditions, and alcohol abuse contribute to the higher proportion of Indigenous persons coming into conflict with the law (Correction Services Canada 2013). Other contributing factors to the high crime rates in ISR are the rapid social and economic changes associated with the shift from the traditional economy. In a traditional economy, men had well defined roles, whereas in the current market economy, many households are substantially dependent on government support, and the social role of men is less defined (Charron et. al. 2010).

Table 7-34 Crime Rates, Canada, NWT, ISR communities, 2006 - 2016

Location	Property Crime Rate (Crimes per 1,000 persons)			Violent Crime Rate (Crimes per 1,000 persons)		
	2006	2011	2016	2006	2011	2016
Canada	49	35	32	14	12	11
NWT	193	233	206	82	86	78
ISR	333	380	249	146	114	103
Aklavik	201	284	204	141	133	72
Inuvik	357	467	258	133	103	91
Paulatuk	284	286	112	271	177	173
Sachs Harbour	-	130	217	-	87	52
Tuktoyaktuk	428	245	302	209	124	144
Ulukhaktok	181	194	234	82	123	106
SOURCE: IRC (2020a)						

7.4.7 Environmental Contamination and Human Health

Health surveys undertake in the mid-2000s showed that Inuit across the four Inuit regions had much higher blood serum levels of some environmental contaminants, including lead, mercury, selenium and some persistent organic pollutants (POPs[51]) compared to the general Canadian population (Health Canada 2017). Elevated levels of such environmental contaminants can adversely affect pre-natal and childhood development and contribute to chronic health conditions in adults (Health Canada 2017).

Inuvialuit can be exposed to environmental contaminants through a number of pathways. Some traditionally harvested fish and marine mammals may contain elevated levels of environmental contaminants due to bioaccumulation. For example, beluga meat and ringed seal have much higher mercury levels compared to other traditionally consumed foods within the ISR (Health Canada 2017). Traditional users can also be exposed to environmental contaminants through several non-food related mechanisms including lead from paint and ammunition or transmitted via dust (Health Canada 2017). Cigarette smoking has been associated with higher levels of cadmium.

Long term biomonitoring programs have shown that the blood serum levels of some environmental contaminants in Inuit have been declining due to factors such as reduced consumption of traditionally harvested foods and reduced usage of lead-based ammunition (Health Canada 2017). However, climate change could increase the environmental loading of some contaminants through mechanisms such as increased volatilization of organic compounds at lower latitudes due to higher temperatures, and subsequent transportation north via precipitation and river systems (Parkinson and Evengard 2009). Inuvialuit in Aklavik have expressed concern over effects of contamination on water and whales (KAVIK-AXYS Inc. 2004a: 4-5)/

Traditional food storage techniques include air-drying of fish and meat, below ground cold storage within permafrost layers, and fermentation. Increased ambient temperatures could result in food spoilage, and potential for outbreaks of food-born botulism and other gastrointestinal diseases (Parkinson and Evengard 2009). Climate change may also result in the northward shift of a variety of animal and insect-borne vectors for human diseases (Showalter 2017, CPHA 2019, CCA 2019). For example, the northward expansion of the beaver (*Castor canadensis*) has expanded the range of *Giardia lamblia*, a water borne parasitic infection that can be contracted through the consumption of untreated surface water (Parkinson and Evengard 2009).

Inuvialuit TLK holders have expressed concerns about the potential for environmental contamination associated with oil and gas development. Tuktoyaktuk TLK holders observed wildlife getting sickly wherever oil and gas companies have sites and fear that traditional foods are being contaminated (KAVIK-AXYS Inc. 2004b:4-10). Tuktoyaktuk TLK holders stressed the importance of avoiding spills and water and soil contamination, due to effects on marine mammals and other wildlife important as traditional

[51] Persistent organic pollutants (POPs) comprise several classes of synthetic organic molecules that were used for a number of industrial, agricultural and vector control applications. These molecules tend to be chemically stable (i.e., do not break down easily), bioaccumulate in shellfish, fish and other animals, and can have adverse human health outcomes. Examples are dichlorodiphenyltrichlorethane (DDT), polychorinated biphenyl (PCB) congeners and polybrominated diphenyl ethers (PBDE).

foods (KAVIK-AXYS Inc. 2004b: 4-4, 4-5). Similar concerns have been expressed by TLK holders from Aklavik (KAVIK-AXYS Inc. 2004c: 4-5) and Inuvik (KAVIK-AXYS Inc. 2004a: 4-5).

7.4.8 Gaps in our Knowledge for the Human Environment

7.4.8.1 Knowledge Gaps Related to Demographics

Although recent statistical data is available on demographics within ISR communities, including population and demographic breakdown, Indigenous and Inuvialuit population, population changes and net migration, a more detailed understanding of why people migrate to or from ISR would help with predictions of how the ISR population and communities may respond to different economic scenarios.

7.4.8.2 Knowledge Gaps Related to Economic Environment

Recent ISR community specific information is available on the workforces within ISR communities, household income, and food prices. However, statistical information on the breakdown of the economy within the ISR or individual communities is limited. Such information would help inform predictions of how ISR communities may respond to different economic development scenarios.

7.4.8.3 Knowledge Gaps Related to Infrastructure and Services

More detailed information on infrastructure and service capacities within the ISR would inform an assessment of how community infrastructure and services may be affected by activities within the different scenarios.

7.4.8.4 Knowledge Gaps Related to Cultural Vitality

No apparent gaps

7.4.8.5 Knowledge Gaps Related to Traditional Activities

No apparent gaps.

7.4.8.6 Knowledge Gaps Related to Community Health

The most current population health data within ISR communities dates from the 2014 Canadian Community Health Survey and the 2014 NWT community surveys. More up to date information that reflects the latest trends and developments regarding population health in ISR communities would be helpful.

Although there is good information on exposure of ISR communities to environmental contaminants through long-term biomonitoring programs, a better understanding of specific mechanisms for transportation and exposure of some environmental contaminants, such as POPs, and linkages to health outcomes would be beneficial. Additional information on such pathways may inform a human health risk analysis of such contaminants in the context of various potential economic development scenarios.

8 ENVIRONMENTAL EFFECTS: SUMMARY OF FINDINGS

8.1 Introduction

The goal of the Data Synthesis and Assessment Report is to provide an understanding of the type and potential environmental effects that could arise from existing and future human use (in particular different intensities of oil and gas developments) in the BRSEA Study Area (Section 1.2). For the purpose of this assessment, environmental effects include potential adverse effects and favourable effects (i.e., benefits). Throughout this assessment, Inuvialuit TLK and western science have been used together to provide valid, reliable observations about natural phenomena and environmental conditions that could meaningfully contribute to the characterization of baseline conditions, the assessment of environmental effects and how climate change could influence residual effects.

This Chapter summarizes for each of the physical, biological and human VCs, the range of potential residual adverse effects and benefits that could be associated with activities within the five different hypothetical scenarios defined in Section 3.1: Status Quo (Scenario 1); three differing intensities of offshore oil and gas development (Scenarios 2 through 4) and an accidental large release of oil (Scenario 5).

The review of potential effects indicates that adverse effects are typically associated with impacts to the physical and biological environment and some aspects of the human environment (e.g., strains on infrastructure, public health concerns, changes in traditional use and cultural vitality). Benefits largely occur through positive changes in the local and regional economy, increased employment and wage income, and associated benefits related to the possible development of new infrastructure. Changes in the predicted ranges of environmental effects on each VC as a result of climate change are also described in the context of potential influence on the baseline conditions of VCs, and altered effects pathways that may change the characterization of residual effects.

The summary of environmental effects presented here is based on the detailed assessment of potential environmental effects for each VC as provided in Appendix D. For additional information on the context and scope of this Data Synthesis and Assessment Report, readers of this section also are referred to previous sections on the assessment methodology (Chapter 4), use of TLK (Chapter 5); Climate Change (Chapter 6) and the State of Knowledge (Chapter 7).

8.2 Use of Traditional and Local Knowledge

TLK and western science were used together throughout the assessment of potential effects to aid in the understanding of baseline conditions, effect pathways, the characterization of effects, approaches to mitigate and manage potential adverse effects, and methods to monitor changes through follow-up programs such as Environmental Effects Monitoring (EEM) programs.

When used together, TLK and western science provided strong insight on past and potential future environmental effects on the Inuvialuit and biophysical and human environment within the BRSEA Study Area. Accordingly, these two knowledge systems were cited together throughout the detailed assessment in Appendix D to support and justify the summary of assessment of environmental effects presented here.

For the physical environment, TLK was especially useful in describing effects associated with different human activities, industrial uses and oil and gas development, for example:

- How vessel movements and ice breaking can affect landfast ice, ice conditions during the Fall Transition and the Spring Transition seasons, including the formation of leads and open areas, ice stability, and refreezing of the ice following disturbances
- Identifying areas susceptible to coastal modification and erosion
- Predicting effects of emissions or discharges from industrial activities on air and water quality
- Describing impacts of sea states, wind, ice, precipitation and fog on the conduct of certain development activities (e.g., vessel movements, aircraft operations, overwintering of equipment)

For the biological environment, TLK was used to identify and characterize effects of oil and gas activities and other human activities on marine biota, including:

- Behavioural responses of marine and anadromous fish, seals, whales, polar bear, caribou and other wildlife to human disturbances, including vessel traffic, aircraft overflights, presence and operation of offshore platforms
- Use of habitat by different species or wildlife groups, including changes in seasonal use of habitat, local and regional movements, and seasonal migrations
- Shifts in the local or regional abundance of marine species
- Reductions or losses of some species or the introduction of new species
- Changes in animal health and mortality as a result of exposure to discharges or oil spills

For the human environment, TLK provided information on how human and industrial activities can affect traditional uses, cultural vitality, and socio-economic conditions, for example:

- Disturbance of Inuvialuit traditional harvesting, seasonal or permanent camps, cultural sites, travel and other activities by industrial activities and associated transportation
- Changes in the timing and use of travel routes between Inuvialuit communities and traditional use sites (and between traditional use sites) as a direct result of human activities (e.g., ice breaking and effects on travel and fish harvesting)
- Changes in the location of traditional harvesting areas, timing of the harvest or the harvesting methods as a result of anticipated or actual industrial uses or human activities and associated effects on harvested species
- Effects of employment and the wage economy on the ability of Inuvialuit to participate in traditional harvesting and cultural activities, as well as longer-term effects on inter-generational transmission of language, culture and other traditional practices to young people

- Effects of these changes on food security and the economic health of Inuvialuit communities
- Identification of conservation areas (including protected areas) and management or exclusion of certain industrial and human activities within these areas, including guidelines on appropriate activities and practices (e.g., the creation of the Beluga Whale Management Zones to reduce interference of vessels and aircraft with use of the Mackenzie River estuary by beluga whales and associated harvesting activities of the Inuvialuit)

Inuvialuit TLK also provided an understanding of how climate change has combined and may combine with effects of human and industrial activities to modify traditional uses and cultural vitality. TLK was used to identify and corroborate mitigation measures to reduce potential adverse effects and promote beneficial effects to the biophysical or human environment, as well as approaches to monitor the extent of effects and the effectiveness of mitigation measures through follow-up programs.

Additional information on the use of TLK in the preparation of the Data Analysis and Assessment Report is provided in Chapter 5. Additional information on the sources of TLK are provided in Appendix B.

8.3 Scope of the Assessment

8.3.1 Scope

Following the structure used in Chapter 7: State of Knowledge, the assessment of effects summarized here (and detailed in Appendix D) focuses on three major components and associated VCs:

- Physical Environment
- Biological Environment
- Human Environment

For each VC, the detailed assessment provides information on:

- scoping, including identification of indicators, spatial and temporal boundaries, and characterization terms for potential residual effects
- pathways through which adverse effects or positive benefits may occur
- potential adverse effects and benefits associated with each of the five scenarios
- approaches to manage and mitigate effects for each VC and scenario; including reduction of adverse effects and improvements in positive benefits
- characterization of residual environmental effects for each VC and scenario
- cumulative effects
- potential effects of climate change on the VC, as well as the effect pathways, residual effects and cumulative effects for each VC and scenario
- information and data gaps that should be addressed to better understand potential adverse effects and benefits on the VC
- recommendations for monitoring and follow-up

8.3.2 Use of Scenarios

As discussed earlier (Section 3.1), the five hypothetical scenarios were deliberately developed to each include different types of infrastructure, human and industrial activities and geographic locations (within the BRSEA Study Area). The scenarios are not predictions of actual future projects or proposed projects; rather, they are intended to provide a framework to explore and evaluate plausible development futures for the Beaufort Region with the intention of supporting the IRC and CIRNAC in developing future policy, legislation, regulations, management processes and information needs for the BRSEA Study Area (Section 3.1).

To facilitate the consideration of these plausible futures, the hypothetical scenarios were intended to be qualitative in detail, space and time. While some quantification of volumes and intensities of activities is provided, these are general in nature. The scenarios are not spatially or temporally explicit (i.e., the scenarios are not based on a specific footprint in a specific location or on specific dates). Activities and infrastructure in each scenario could occur in several locations within the BRSEA Study Area. To provide wide geographic coverage in the assessment, the three oil and gas development scenarios covered a range of locations relative to the coastline of the ISR, with different water depths and locations relative to the continental shelf and slope.

The scenarios were assumed to occur over a thirty-year period from 2020-2050. While the scenarios have a degree of temporal specificity (e.g., timing and sequence of specific activities, installation of infrastructure), the timing of events is not exact. Temporal aspects are explored according to generalized ice- and ice-free seasons rather than calendar months (i.e., Spring Transition, Open Water, Fall Transition and Ice seasons). Only the offshore aspects of these scenarios are considered in the assessment; the land-based components of the development are outside of the BRSEA Study Area.

The five scenarios considered in the BRSEA are as follows:

- Scenario 1 (Status Quo) includes a number of activities that are already occurring in the BRSEA Study Area (e.g., use of snowmobiles and small motorized vessels, local aircraft movements and larger aircraft overflights, community resupply by large vessels, cruise tourism vessels, and transits by large vessels) or that might occur in the future in nearshore areas (e.g., wind turbines) and in moderate to very deep water over the continental shelf and slope and Arctic basin (e.g., increased international shipping and cruise tourism vessels).
- Scenario 2 (Export of Natural Gas and Condensate) considers development and operation of a GBS platform 15-20 km offshore for export of natural gas (from land-based fields and processing facilities), a subsea pipeline from shore to the GBS platform, and year-round movement of LNG carriers to and from the west (e.g., past the Alaskan Beaufort Sea).
- Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf) considers development of a subsea oil field and oil production from an offshore platform in a location on the continental shelf ~80 km offshore with year-round movements of oil tankers to and from the west.

- Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope) considers seismic exploration followed by development of a deep-water oil field, subsea pipeline infrastructure and an offshore platform for oil production and storage that is located on the continental slope ~100 km or greater offshore. Oil tankers would move year-round to and from the west, as well as to and from the east during the Open Water Season.
- Scenario 5 (Large Oil Release Event) considered potential consequences of a large surface oil release within the plume of the Mackenzie River (i.e., nearshore), as well as a surface and a subsea release outside the plume (i.e., moderate to very deep water over the continental shelf and slope).

Given the lack of spatial and temporal details and the general descriptions of the intensities and volume of specific activities and processes, this strategic environmental assessment of potential ranges of environmental effects on VCs focuses on identification and descriptions of effect pathways and general characterization of potential and residual effects. As mentioned, the assessment is not intended to be quantitative or assign significance, nor would such an assessment be appropriate given the scope of the Data Synthesis and Assessment Report or the intent of the BRSEA.

8.3.3 Outline of the Chapter

The intent of this chapter is to summarize the positive and negative outcomes or effect conditions[52] for each of the VCs under each of the five hypothetical scenarios. As seasonal changes in ice conditions and open water are major influences on VCs and the potential impacts of human and industrial use, the assessment summaries highlight the different seasons according to ice conditions during which effects could occur (i.e., Spring Transition, Open Water, Fall Transition and Ice seasons). Readers interested in the detailed scenarios, effect characterizations and VC specific findings are referred to the full assessment in Appendix D.

The potential environmental effect conditions across all VCs that are associated with development intensity are considered first (Section 8.4.1) (Scenarios 1 to 4 provide a range of increasing development intensity for the BRSEA Study Area), followed by the potential environmental effect conditions that typically arise from different types of routine human and industrial activities (regardless of scenario) (Section 8.4.2). Summaries of the environmental effect conditions and a visual summary table are provided for development intensity, and types of activities.

Section 8.5 summarizes the potential residual effects conditions for each VC that could result from a large oil release. A visual summary of effect conditions is also provided.

Section 8.6 summarizes the key findings for potential cumulative effects across the different VCs and scenarios. Lastly, Section 8.7 summarizes the primary effects of climate change (as described in Chapter 6) on VCs within the 30-year time horizon of this assessment, as well as how effect pathways

[52] The methodology for rating the effect condition for a different combinations of VC, scenario or activity, and season based on the maximum effect characteristics and direction (adverse or positive) is described later in this chapter (Sections 8.4.1.1 and 8.4.2.1).

and the characteristics of potential environmental and residual effects on a VC might change with climate change.

Considerations for monitoring, research and management related to the environmental effects that might arise from the different activities within the five scenarios are summarized in Chapter 9.

8.4 Assessment of Residual Environmental Effects at a Glance

This chapter provides readers with a succinct summary of the potential residual environmental effects, in relation to:

- how an increasing intensity of industrial development and human activities might alter potential residual effects to different VCs. This was addressed by looking at how environmental effects change as development intensity increases from Status Quo to Scenario 2 (low intensity), then Scenario 3 (moderate intensity) and finally Scenario 4 (high intensity). Effects of a large oil release event (Scenario 5) are discussed in Section 8.5.
- how different types of routine industrial and human activities (regardless of development scenario) can result in different residual effects to different VCs. For example, what are the effects that typically occur as a result of vessel use and icebreaking, and how does the suite of effects for an activity such as shipping differs from the suite of effects from infrastructure, aerial support or waste emissions and discharges.

Residual effects specific to the activities within the Status Quo and the three oil and gas development scenarios are discussed in this section. Residual effects of a large oil release are discussed in Section 8.5. Cumulative effects are discussed in Section 8.6.

Potential adverse residual effects and positive benefits for each VC under each scenario were characterized according to the methodology and terminology described in Chapter 4. The detailed assessment in Appendix D provides effect characterizations and justification for those characterizations for each combination of VC, effect, and season.

To summarize and visualize each potential adverse effect or benefit on a VC, the residual effects characteristics for geographic scope, duration, magnitude and direction (from the detailed assessment in Appendix D) were used to derive a single metric referred to as an “effect condition”. Effect condition is based on a simple index scale of negligible, low, moderate and high. A shading scheme, similar to that used for the detailed assessment (Appendix D) was used here to provide a visual summary of effect conditions for adverse and positive effect conditions. Different approaches were used to derive the effect condition and visual summaries for VCs relative to (1) development intensity and (2) types of routine industrial and human activities (regardless of the scenario). These approaches are described in Sections 8.4.1.1 and 8.4.2.1, respectively.

8.4.1 Environmental Effects and Development Intensity

8.4.1.1 Approach and Methodology

Using the effects characterization terms from the detailed assessment in Appendix D, the direction, geographic scope, duration and magnitude determinations (Table 8-1) for each environmental effect were used to derive an effect condition for each VC under each level of development intensity (low, moderate and high) (Table 8-1). Where an effect characteristic in the detailed assessment in Appendix D was expressed as a range, the highest determination was used. For example, if the magnitude was characterized as low to moderate, moderate magnitude would be used. An effect condition that is adverse is shaded in blue tones, while a positive effect condition is shown in green. White cells indicate a negligible effect.

Table 8-2 shows the highest potential effect condition for each combination of VC and scenario throughout a year (i.e., all four ice seasons). However, as the effect condition may not be same throughout the year, the seasons during which the effects may occur are indicated. As an example, an effect might range from negligible through to high, depending on the seasonal use by the VC or the season(s) when an industrial activity might occur (e.g., Ice Season verses the Open Water Season). In this particular example, a high effect condition would be used in the discussion of residual effects and the visual summary tables.

Residual effect conditions in Table 8-2 assume that mitigation measures applicable to routine operations for each of these activities have been implemented. Details on predicted VC-specific residual effects and mitigation measures are provided in Appendix D; mitigation measures are summarized in Section 9.2 and listed in Appendix F. Recommendations for monitoring needs related to potential effects that result from Scenarios 1-4 are discussed in Section 9.3. Planning, preparedness and response considerations for a large oil spill, as investigated under Scenario 5, are summarized in Section 9.4.

A summary of the underlying effect characteristics that support the effect conditions for each VC under each development intensity is provided in Appendix E. Readers seeking information on how a single effect characterization was derived should refer to Appendix D. It should be noted that these are based on the effect pathways described for each scenario, and do not include potential impacts of climate change (Chapter 6). Climate change considerations are summarized separately in Section 8.7.

Table 8-1 Residual Effects Characterization Definitions (see Appendix D) and Decision Matrix for Adverse or Positive Residual Effect Conditions.

Residual Effects Characterization

	Categories	Definitions
Magnitude	Negligible	No measurable change
	Low	A measurable change but within range of natural variability or adaptive capacity
	Moderate	Measurable change with potential of long term effect
	High	Measurable change with relative certainty of long term effect
Direction	Positive	A net benefit
	Adverse	A net reduction or loss
	Neutral	No net change
Geographic Extent	Footprint	restricted to the footprint of the activity
	Local	effects extend into the local (immediate) area around the activity
	Regional	residual effects extend into the regional area (i.e., within the BRSEA Study Area)
	Extra-regional	residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area)
Duration	Short term	restricted to one phase or season
	Medium term	extends through multiple seasons, phases or years
	Long term	extends beyond the life of the project/activity
	Permanent	measurable parameter unlikely to recover to existing conditions

Potential Residual Effect Condition

Geographic Scope	Duration	Magnitude			
		Negligible	Low	Moderate	High
Footprint	Short term				
	Medium term				
	Long term				
	Permanent				
Local	Short term				
	Medium term				
	Long term				
	Permanent				
Regional	Short term				
	Medium term				
	Long term				
	Permanent				
Extra-Regional	Short term				
	Medium term				
	Long term				
	Permanent				

Geographic Scope	Duration	Magnitude			
		Negligible	Low	Moderate	High
Footprint	Short term				
	Medium term				
	Long term				
	Permanent				
Local	Short term				
	Medium term				
	Long term				
	Permanent				
Regional	Short term				
	Medium term				
	Long term				
	Permanent				
Extra-Regional	Short term				
	Medium term				
	Long term				
	Permanent				

Potential Residual Effect Condition	
	high adverse effect condition
	moderate adverse effect condition
	low adverse effect condition
	negligible effect condition
	low positive effect condition
	moderate positive effect condition
	high positive effect condition

NOTE: see Section 8.4.1.1 for the methodology used to derive the residual effect condition ranking and shading

Table 8-2 Potential Residual Effect Conditions of VCs for Each Scenario

Possible Scenarios → (Development Intensity →)	Scenario 1 Status Quo	Scenario 2 Export of Natural Gas and Condensate	Scenario 3 Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf	Scenario 4 Large Scale Oil Development within Exploration Licenses on the Continental Slope
Physical VCs				
Atmospheric Environment (Air Quality, GHG, Noise, Light)				
Climate and Weather	NA	NA	NA	NA
Oceanography (water quality)				
Sea Ice			Ice, Spring, Fall	Ice, Spring, Fall
Coastal Dynamics and Sea Floor Geology				
Coastal Habitat				
Biological VCs				
Marine Lower Trophic Levels				Year-round
Marine Fish and Habitat			Open Water	Open Water
Migratory Birds			Spring, Open Water	Spring, Open Water
Seabirds			Spring, Open Water, Fall	Spring, Open Water, Fall
Marine Mammals			Year-round	Year-round
Polar Bear				
Caribou				
Human VCs				
Economy	Year-round	Year-round	Year-round	Year-round
Demographics		Year-round	Year-round	Year-round
Infrastructure		Year-round / Year-round	Year-round / Year-round	Year-round / Year-round
Traditional Activities		Year-round / Year-round	Year-round / Year-round	Year-round / Year-round
Cultural Vitality		Year-round	Year-round	Year-round
Public Health	Year-round			

Potential Residual Effect Condition

- high adverse effect condition
- moderate adverse effect condition
- low adverse effect condition
- negligible effect condition
- low positive effect condition
- moderate positive effect condition
- high positive effect condition

NOTE: Seasons (as defined in Section 1.7) when effects would be present are indicated. Split cells indicate that certain scenarios may result in both adverse and positive effects.

8.4.1.2 Scenario 1 – Status Quo

Activities associated with Scenario 1 are expected to result in negligible effect conditions on the physical and biological VCs. For the Human VCs, Public Health is expected to show a low adverse effect condition under the Status Quo scenario due to a combination of factors, including a continuation of the relatively high rates of smoking and drinking and growing incidence rates of chronic health conditions, such as asthma and heart disease. However, the Economy is expected to show a moderate benefit, as tourism and offshore wind energy projects would create some jobs. The wind energy projects also could result in lower energy costs within the communities and improved energy security. This could result in a moderate reduction in the average cost of living within those communities.

8.4.1.3 Scenario 2 –Export of Natural Gas and Condensates

Activities associated with Scenario 2 are expected to result in negligible effect conditions on the physical and biological VCs.

The largest expected adverse effect of Scenario 2 for the Human Environment is on Traditional Activities. Moderate adverse effect conditions would likely result due to the overlap of construction and operational activities in nearshore areas (i.e., within 20 km from shore) with areas that are commonly used by Inuvialuit for traditional uses or changes in the distribution of species that are important for traditional use. Low adverse effect conditions are anticipated on Infrastructure and Cultural Vitality. The latter is linked to the effects on traditional uses but also because of potential effects on some Cultural Vitality indicators, such as language, that could occur when Inuvialuit interact with non-Inuvialuit.

Economy and Demography are predicted to benefit from Scenario 2 activities. The Economy is expected to react highly positively to Scenario 2, which would likely create increased employment opportunities for all ISR community members and result in substantial capital inflow. Such benefits may last throughout the operations period if there is regional retention of royalties and tax revenues, which could in turn have positive effects on Traditional Activities and Infrastructure if those resources were used to support them. Demographics would also benefit at a local level with job-related increases in the local populations during the life of the project.

As noted earlier, this scenario assumes that all gas production and processing is on land (i.e., outside of the BRSEA Study Area) and, therefore, outside of the scope of this assessment. As a result, positive benefits and adverse effects to the Human Environment VCs in land areas within the ISR, NWT and Yukon are not considered in this assessment. These would include similar types of effects to the Human Environment VCs discussed above, as well as additional benefits such as improved regional energy security and independence, reduced carbon emissions (from use of natural gas instead of diesel fuel), potential decreased energy costs and new land-based infrastructure. Potential adverse effects of land-based development on the biophysical environment are also outside the scope of the BRSEA (e.g., air emissions, loss or change in fish and wildlife habitat, sensory disturbance).

8.4.1.4 Scenario 3 -Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

Activities associated with Scenario 3 are expected to affect various components of the physical, biological and human environment. Sea ice would experience a low adverse effect condition due to activities in the local vicinity of a GBS and short-term effects from icebreaking during vessel transits. Effects on ice could be greater if icebreaking were to occur in landfast ice during the mid-late Spring and late Fall Transition seasons, and in the immediate vicinity of the GBS.

From a biological perspective, the Marine Fish and Habitat, Migratory Birds, Seabirds and Marine Mammal VCs are all expected to show low adverse effect conditions in response to Scenario 3 activities. Residual effects of underwater noise associated with seismic exploration are anticipated to affect different life stages of fish and marine mammals in proximity to the noise source. Potential changes in behaviour of seabirds and migratory birds as a result of habitat alterations from aircraft and vessel traffic (including icebreakers), disturbance of nesting colonies, and collisions with infrastructure or vessels due to artificial lighting during spring migrations could occur in vicinity of human activities. Marine mammals could experience low level effects due to habitat alteration in the vicinity of the GBS and from underwater noise.

Effects levels on Human VCs are similar to those described under Scenario 2 with two important differences. Given that most of the activities under Scenario 3 are expected to occur farther offshore, the adverse effect condition for Traditional Activities is expected to be low instead of moderate (but occur through the same effect pathways) as most development activities and facilities would not overlap in space or time with Traditional Activities. The positive effect condition on Demographics due to increased job opportunities is expected to be moderate under Scenario 3 as this large-scale oil development would result in even more job opportunities and result in higher capital inflow compared to Scenario 2.

8.4.1.5 Scenario 4 - Large Scale Oil Development within Exploration Licenses on the Continental Slope

Effects from activities associated with Scenario 4 are expected to be similar to those described in Scenario 3 and affect various components of the physical, biological and human environment. The only additional expected residual effect would be on marine lower trophic levels due to potential effects on benthic macrofauna in the area of the offshore development due to seabed disturbance. Similarly, benthic fish and fish habitat are expected to be affected by these benthic disturbances as well as from the 3D seismic program in proximity to the noise source.

8.4.2 Environmental Effects from Different Types of Routine Activities

8.4.2.1 Approach and Methodology

To summarize how different routine industrial and human activities might affect VCs, activities from the Status Quo and the three oil and gas development scenarios were sorted into six categories based on the types of anthropogenic disturbance:

- vessels (commercial, recreational, ice-breaking)
- seismic surveys

- offshore structures and related activities (e.g., drilling, pipelines, dredging)
- aircraft activities (fixed wing and helicopters)
- routine discharges and waste management
- logistical and administrative facilities

Since these routine activities could occur throughout the BRSEA Study Area at varying intensities depending on the scenario, effect conditions were ranked and shaded as adverse (blue), negligible (white), positive (green) or mixed (gray) effects. More detailed considerations of the geographic scope, duration, and magnitude effect characteristics, as were done in Section 8.4.1, were not possible given the large range of effects from these activities across scenarios and seasons.

Residual effect conditions in Table 8-3 assume that mitigation measures applicable to routine operations for each of these activities have been implemented. Details on predicted residual effects and mitigation measures are provided in Appendix D; mitigation measures are summarized in Section 9.2 and listed in Appendix F. Recommendations for monitoring needs related to potential effects that result from these routine activities are discussed in Section 9.3.

8.4.2.2 Vessels

Vessel activities are predicted to continue increasing over the next 30 years and will include commercial, recreational, national security and other vessel uses. Vessels can adversely affect physical, biological and human VCs by emitting noise, light, GHGs and other air pollutants; disturb habitat and displace animals from preferred locations needed for reproduction or foraging; lead to wildlife mortality through collisions; or lead to increased pressures of existing infrastructure. At the same time, increased destination vessel traffic could result in increased infrastructure development, capacity building, and job opportunities leading to potential benefits for the Economy, Demographics, and Traditional Activities. Conversely, vessels of all kinds carry fuel either as cargo or propellant, and their increased presence and movement in the BRSEA Study area increases the risk of oil spills. Mitigation measures for potential environmental impacts from vessels are well established (see Section 9.2) and are most effective if spatial and temporal overlap with sensitive species and traditional activities can be reduced or avoided locally and regionally.

8.4.2.3 Seismic Surveys

Vessel-based seismic surveys are an important part of offshore oil and gas development. Aside from the potential impact from the vessels themselves noted above, the underwater noise emitted during seismic operations has the potential to adversely affect the less motile life stages (eggs and larvae) and species (benthic) of fish, as well as diving seabirds and marine mammals. Given the potential effect on the health and distribution of marine wildlife, seismic surveys could also indirectly affect Traditional Activities and Cultural Vitality. Because wildlife monitoring is required during seismic surveys, such activities could result in temporary job opportunities and thus benefit the economy. Mitigation measures for potential environmental effects from underwater noise generated during seismic surveys are also well established (see Section 9.2), and can be reduced through use of exclusion zones, ramp-up procedures when starting airguns during seismic survey, and avoiding ecologically sensitive locations and times of year.

Table 8-3 Potential Residual Effect Conditions of VCs by Types of Activities

Activities	Vessels (commercial, recreational, ice-breaking)	Seismic Surveys	Offshore Structures and related activities (e.g. drilling, pipelines, dredging)	Aircraft activities (helicopters and planes)	Routine Discharges and Waste Management	Logistical and Administrative Facilities
Physical VCs						
Atmospheric Environment (Air Quality, GHG, Noise, Light)	Noise, light, air quality	Noise, light, air quality	Noise, light, air quality	Noise, light, air quality		Light
Climate and Weather	GHG emissions count towards Canada GHG targets	GHG emissions count towards Canada GHG targets	GHG emissions count towards Canada GHG targets	GHG emissions count towards Canada GHG targets		
Oceanography (water quality)			Water quality through increased suspended sediments		Water quality through grey water discharges	
Sea Ice	Black carbon on ice		Black carbon on ice	Black carbon on ice		
Coastal Dynamics and Sea Floor Geology			Dredging, pipelines and drilling impacts on coastal erosion and sub-sea permafrost			
Coastal Habitat			Dredging and pipeline impacts on coastal habitat			Coastal habitat disturbance
Biological VCs						
Marine Lower Trophic Levels			Minor impacts on plankton; dredging, pipelines and drilling impacts on benthos		Habitat quality impacts	
Marine Fish and Habitat	Coastal habitat disturbance	Seismic noise effects on behaviour, physiology, mortality of eggs, larvae and benthic species	Dredging, pipelines and drilling impacts on fish benthic habitat			
Migratory Birds	Sensory disturbance from in-air noise and light		Sensory disturbance from light	Sensory disturbance from in-air noise		
Seabirds	Sensory disturbance from in-air noise and light; habitat disturbance from ice breaking	Seismic noise effects on behaviour of diving seabirds	Sensory disturbance from light	Sensory disturbance from in-air noise		
Marine Mammals	Habitat disturbance through ice-breaking, collision and entrapment risk	Seismic noise effects on behaviour, physiology, mortality of marine mammals		Sensory disturbance from in-air noise		
Polar Bear	Habitat disturbance through ice-breaking		Habitat alteration			
Caribou	Habitat disturbance through nearshore ice-breaking			Sensory disturbance from in-air noise		
Human VCs						
Economy	Increased employment from tourism	Increased employment	Increased employment	Increased employment from tourism and increased commercial traffic		Real estate development
Demographics	Reduce out-migration or increase immigration with increased job opportunities		Reduce out-migration or increase immigration with increased job opportunities	Reduce out-migration or increase immigration with increased job opportunities		Reduce out-migration or increase immigration with increased job opportunities
Infrastructure	Use of on-shore infrastructure development or increased maintenance, increased use		Use of on-shore infrastructure development or increased maintenance, increased use	On-shore infrastructure development or increased maintenance, increased use		Real estate development Improvements in airports, roads, municipal and other infrastructure
	Industry improvements in marine infrastructure		Industry improvements in marine, airports, roads, municipal and other	Improvements in airports and roads		
Traditional Activities	Reduced participation and food security; subsistence activities could be affected through changes in harvested species	Reduced participation and food security; subsistence activities could be affected through changes in harvested species	Reduced participation and food security; subsistence activities could be affected through changes in harvested species	Reduced participation and food security; subsistence activities could be affected through changes in harvested species		
	Wage economy could allow improvements in equipment and supplies for harvesting		Wage economy could allow improvements in equipment and supplies for harvesting	Wage economy could allow improvements in equipment and supplies for harvesting		Wage economy could allow improvements in equipment and supplies for harvesting
Cultural Vitality	Adverse effects through changes in harvested species and presence of non-Inuvialuit; benefits from language programs and wage economy	Adverse effects through changes in harvested species	Adverse effects through changes in harvested species and presence of non-Inuvialuit; benefits from language programs and wage economy	Adverse effects through changes in harvested species		Adverse effects through presence of non-Inuvialuit; benefits from language programs and wage economy
Public Health	Impacts of these activities on public health could be positive and negative. The ability to generate more household income can lead to better education and training levels, which improves mental health and public health overall. Increased household incomes could also improve the ability of households to purchase market foods, but these may not be healthier than subsistence foods. Participation in wage-based employment could result in less time spent on traditional harvesting; however, greater disposable household income could also be used for the purchase of equipment and supplies needed to undertake harvesting activities. Human health risk may result from exposure to contaminants, including direct exposure, such as to airborne or waterborne contaminants, and exposure via the consumption of contaminated foods. The fear (or perception) that foods may be subject to contamination can also have health-related consequences, such as avoidance behaviours or mental stress. Impacts on cultural vitality may lead to a decline in public health.					

Potential Residual Effect Condition	
(blue)	Activity could cause adverse effect condition on VC
(white)	Activity could have negligible effect condition on VC
(green)	Activity could lead to positive effect condition for the VC
(grey)	Activity could result in positive or adverse effect conditions on VC

NOTE: Text in the cells provides a summary explanation of the effect pathways leading to the indicated effect condition.

8.4.2.4 Offshore Structures

The presence of offshore oil and gas structures and their related activities have the potential to affect most VCs. Effects on employment from these offshore activities is expected to be positive, which would also benefit Demographics and possibly Infrastructure (e.g., onshore development and maintenance). However, from a physical and biological perspective, effects are expected to be adverse through increases in noise, light, and air emissions, effects on water quality, and habitat disturbance at the ocean surface and the ocean floor. Likewise, effects on Traditional Activities and Cultural Vitality are expected to be primarily adverse because of the indirect effect on physical and biological resources, and the direct effect of an increased presence of non-Inuvialuit workers. The extra wages, could, however, have a potential positive effect on Traditional Activities as it could allow improvements of equipment and affordability of supplies to support them. The effects on Public Health from these offshore activities is mixed, depending on the balance between economic benefits and effects on Traditional Activities, diet and mental health. Finally, the presence of offshore oil and gas structures in the BRSEA Study area increases the risk of oil spills. Offshore activities are tightly regulated, and many different mitigation measures exist depending on the specific activities (see Section 9.2). Most of these activities have extensive permitting and monitoring requirements and industry best practices that guide them (see Section 9.2 and Section 9.3 for further discussion). For future projects, regulatory agencies and project proponents will need to determine how new baseline surveys, ongoing monitoring of baseline conditions, and follow-up or monitoring programs for environmental effects and mitigation might best be accomplished.

8.4.2.5 Aircraft Activities

Aircraft activities are predicted to increase in the BRSEA Study Area due to oil and gas development, other industrial uses, or tourism. Like vessels, helicopters and planes emit noise, light and air pollutants that adversely affect the Atmospheric Environment, are inconsistent with Canada's GHG emissions targets, and can lead to black carbon deposition on sea ice. Generated in-air noise can further affect Migratory Birds, Seabirds, Marine Mammals and caribou, although standard and easily implementable mitigation measures like overflight exclusion zones and minimum height requirements generally reduce such effects. Where these measures are not successful, Traditional Activities, Cultural Vitality and Public Health could be indirectly and adversely affected. On the other hand, increased aircraft activities may lead to infrastructure improvements and more employment opportunities, and hence benefit regional demographics and provide financial support for Traditional Activities.

8.4.2.6 Routine Discharges and Waste Management

Few effects are expected from routine discharges and waste management from vessels and offshore structures in the BRSEA Study Area. These activities are heavily regulated on an international and national basis and monitored (Section 2.5 and Section 9.2), such that potential effects are expected to be negligible on all VCs except possibly on water quality and marine lower trophic level habitat near offshore structures. Such effects would mainly occur through the permitted discharge of grey water, bioaccumulation of permitted discharge levels of heavy metals and PAHs, or changes in habitat from the permitted discharge of clean cooling water, drilling muds and cuttings.

8.4.2.7 Logistical and Administrative Facilities

The potential development and use of logistical and administrative facilities (e.g., logistical support bases, ports, airfields, roads, ports and buildings) would be a positive effect from activities associated with Scenarios 1 to 4. Such new development would generate onshore employment opportunities, thus benefiting the Economy, Demographics and possible Traditional Activities. Depending on the scale of these developments and hiring practices, Cultural Vitality could be adversely affected through an increased presence of resident non-Inuvialuit workers. Additionally, increased infrastructure would likely mean increases in light pollution and possible disturbance or destruction of coastal habitat.

8.5 Residual Effects of a Large Oil Release Event

All VCs except climate and weather would be adversely affected by a large oil release event. Effect conditions may differ based on the location and timing of the oil release, the VC (i.e., some VCs are more susceptible to effects of oil than others), and the temporal and spatial overlap of the VC in relation to the oil release site and the trajectory of the oil (Table 8-4).

8.5.1 Residual Effects on the Physical Environment

Adverse effect conditions of an oil spill on the physical environment are expected to be highest on Oceanography and Coastal Habitat, both of which would affect other VCs such as Lower Trophic Levels, Fish and Fish Habitat, Migratory Birds, Seabirds and Marine Mammals, as well as Traditional Activities, Cultural Vitality, and Public Health. Water quality (Oceanography) would be most severely affected during a sub-sea release outside of the Mackenzie River plume during the Open Water Season, although adverse effects are expected during all seasons and at all locations. Coastal Habitat would be most severely affected by a surface spill in the Open Water Season within the Mackenzie River plume. Oil can be washed ashore and directly affect coastal habitats, or PAHs can reach the benthos via flocculation. Oil spill clean-up activities along the coastline can degrade coastal habitats and lead to coastal erosion and, in turn, lead to effects on the broader biological environment.

Clean-up activities for large oil releases can result in direct adverse effects to the biophysical and human environment, as well as require substantial increases in coastal vessel and aircraft traffic to support clean-up activities. Coastal stability may see a moderate adverse effect condition, particularly during the Open Water Season; this effect could vary considerably depending on the amount and type of oil to be cleaned up and the location of the oil release relative to the coastline and sensitive sites.

Table 8-4 Potential Resdiual Effect Conditions of VCs for Scenario 5

Possible Scenario →	Scenario 5 Large Scale Oil Release	
Physical VCs		
Atmospheric Environment (Air Quality, GHG, Noise, Light)	Open Water	
Climate and Weather	NA	
Oceanography (water quality)	Year-round	
Sea Ice	Ice, Spring, Fall	
Coastal Dynamics and Sea Floor Geology	Spring, Open Water, Fall	
Coastal Habitat	Open Water	
Biological VCs		
Marine Lower Trophic Levels	Year-round	
Marine Fish and Habitat	Year-round	
Migratory Birds	Spring, Open Water	
Seabirds	Spring, Open Water, Fall	
Marine Mammals	Year-round	
Polar Bear	Year-round	
Caribou	Open Water	
Human VCs		
Economy	Year-round	
Demographics	Year-round	
Infrastructure	Year-round	Year-round
Traditional Activities	Year-round	
Cultural Vitality	Year-round	
Public Health	Year-round	

Potential Residual Effect Condition	
(dark blue)	high adverse effect condition
(medium blue)	moderate adverse effect condition
(light blue)	low adverse effect condition
(white)	negligible effect condition
(light green)	low positive effect condition
(medium green)	moderate positive effect condition
(dark green)	high positive effect condition

NOTE: Seasons (as defined in Section 1.7) when effects would be present are indicated. Split cells indicate that the scenario may result in both adverse and positive effects.

Air quality and sea ice would likely experience low adverse effect conditions. Air quality in the vicinity of the release would be temporarily affected (i.e., days after release of fresh oil) through the evaporation of volatile organic compounds (VOCs) in surface oil. This would be of particular concern for spills during the Open Water Season on the ocean surface within the area of the Mackenzie River plume. For spills outside the area of the Mackenzie River plume and for spills during other seasons, the VOC concentrations are expected to be lower, and not exceed onshore ambient air quality standards for coastal receptors. Adverse effects of an oil spill on sea ice would occur through the introduction of contaminants through brine channels and into cracks, cavities, and melt ponds. In addition to the oil itself, dark residue from burning oil-in-ice would decrease the albedo of the sea ice, particularly as the melt season advances.

8.5.2 Residual Effects on the Biological Environment

All biological VCs except for caribou are likely to experience high adverse effect conditions either directly or indirectly through effects on water quality and coastal habitat as described above. For Marine Lower Trophic Levels, some Marine Fish and Habitat, seals and polar bears, effects of oil releases could occur year-round. Seabirds and migratory birds, some fish species (e.g., anadromous) and several whale species are not present during the Ice Season, but could be affected by residual oil during the following Spring Transition and Open Water seasons (depending on the success of oil removal and cleanup).

Adverse effects of spilled oil on lower trophic levels include mortality and change in health and behaviour through direct contact or ingestion of oil-fouled prey and habitat degradation in oil-fouled areas, including decreased light penetration and associated potential effects on growth of primary producers and subsequent effects to zooplankton and benthos. The greatest effects of an oil spill on plankton would be during periods of ice-associated or open water phytoplankton blooms in spring and summer/fall, or as a result of a subsea release under longer-term, multi-year ice where the oil would get trapped under thick ice and be difficult to remove.

Fish and fish habitat could be adversely affected through direct contact (gill fouling) and ingestion of oiled prey, which can affect fish health, growth rates, productivity, and movement. Oil in sediments or along shorelines could alter and degrade fish habitat and, subsequently, affect local harvesting as residents may be asked to not harvest (i.e., an area closure) or may choose to not harvest fish they believe are tainted.

The Migratory Birds and Seabirds VCs could be adversely affected through changes in health, behaviour, mortality risk and habitat quality. Contact of birds with oil would result in reduction of the waterproofing, insulating, and buoyancy properties of feathers leading to hypothermia and mortality. Spilled oil could also result in loss or degradation of habitat, reduction in prey species or quality (due to oil exposure), or sublethal effects due to ingestion, inhalation, or adsorption of oil through preening or consumption of contaminated prey. The Migratory Birds and Seabirds VCs could be directly affected by oil spills occurring during the Open Water and Spring Transition seasons and, indirectly, by oil releases during the Fall Transition and Ice seasons as such effects could linger to the following breeding season. Different species could be highly sensitive to spills in different locations depending on their habitat use and distribution at different times of the year relative to the distribution and weathering of oil.

For the Marine Mammals VC, effects of a large oil release event on beluga and bowhead would be most severe if the event were to occur during the Open Water Season, regardless of location within or outside the plume of the Mackenzie River. Effects on whales could occur through inhalation of evaporated or volatilized components of oil, or through ingestion of affected prey. Seals could be affected year-round through effects on their haul out habitat, breathing holes and birthing lairs, as well as through the fouling of fur (newborn seals), inhalation of evaporated or volatilized components of oil, or through ingestion of affected prey.

Polar bears would be most severely affected if there were a surface release onto sea ice that occurred during the Spring or Fall Transition seasons while polar bears are actively hunting, and female bears and cubs are entering or emerging from denning habitat. Adverse effects on the health and behaviour of polar bears could also occur if the availability or quality of prey species is affected or if oil is ingested through grooming or eating of fouled prey. There might also be a higher potential for mortality from human bear conflicts if response and clean-up activities lead to increased contact with humans.

Caribou would likely be the least affected biological VC. Most effects would be indirect such as changes in the availability of coastal habitat due to oiling or spill response activities. As such, the greatest effect on caribou would be from a large release of oil within the Mackenzie Plume during the Open Water Season.

8.5.3 Residual Effects on the Human Environment

Effect condition of human environment VCs resulting from of a large oil spill would be adverse, could occur year-round, and range between moderate and high except for the Infrastructure VC where the effect is expected to be mixed. A surface release within the Mackenzie River plume during the Open Water Season would likely have the most severe economic effects because of the greater risk of shoreline oiling and consequent higher clean-up costs and higher magnitude effects on economically valuable environmental resources (including tourism values). Environmental degradation from a large surface oil release would likely affect tourism interest and activity in the region and could result in widespread mortality and/or contamination of traditionally harvested species, including fish, birds, seals, and beluga whales. The degree of such effects would depend on the nature of the spill and seasonality but would cause subsequent effects on Cultural Vitality and Public Health. In addition, a reduction in the availability and quality of country foods would result in households needing to increase expenditures on market foods, which would adversely affect household economics. The loss of Traditional Activities, and employment related to tourism could result in some out-migration due to measurable or perceived degradation in lifestyle, food security, or economic opportunities.

The effect of a large oil release on Infrastructure, although overall predicted to be adverse, is mixed. A large spill would most certainly require that additional response personnel and support teams be brought from outside the ISR. It is expected that many off these workers would mobilize and be lodged in self-contained accommodations within service and supply bases (e.g., Tuktoyaktuk and Summers Harbour). However, depending on the number of additional personnel brought into the region, some may need to be housed in commercial accommodations and require the use of civic infrastructure and services while in the region. The use of emergency services and equipment, harbour and air transport infrastructure, and storage facilities, would place additional demands on local infrastructure in the short-term. However, the capacity of such infrastructure may have been upgraded to support hydrocarbon development as part of oil spill planning and preparedness, or new infrastructure needed during an extended spill response could result in a lasting improved infrastructure.

8.6 Cumulative Effects

Cumulative effects that might occur as a result of different human and industrial activities in Scenarios 1 through 4 are discussed in detail for each VC and Scenario in Appendix D. As outlined in Section 4.1.7, cumulative effects assessments were conducted as follows: For Scenario 1 (Status Quo), only activities within that scenario were considered. For the three oil and gas development scenarios (Scenarios 2 through 4), the assessment of cumulative effects included effects of activities within the specific development scenario, in combination with the activities in Scenario 1, as it was assumed that ongoing human and other non-oil and gas activities would be occurring at the same time as the specific hydrocarbon development in the scenario. The assessment did not include cumulative effects of multiple simultaneous development scenarios (e.g., cumulative effects of Scenarios 2 and 4). Cumulative effects were not assessed for hypothetical incidents such as a large oil release (Scenario 5) given the number of unknowns (e.g., degree of temporal and spatial overlaps of a hypothetical spill with other activities).

8.6.1 Cumulative Effects on the Physical Environment

Few cumulative effects on VCs within the physical environment are expected. Given the low residual effects on the Atmospheric Environment associated with activities in scenarios 1 to 4, it is unlikely that cumulative effects from concurrent activities in the region would result in meaningful changes in air quality, acoustics, or light. The cumulative GHG emissions are expected to be negligible compared to national or global emissions (emissions are anticipated to be less than 0.1% of national emissions), but the release of even small quantities may affect Canada's ability to meet Paris Agreement emission reduction targets.

From a water quality perspective, the primary cumulative effect of potential concern would be suspended sediment concentrations from seabed preparation and installation of structures, anchoring of wareships and the FPSO, and spudding of wells. Cumulative effects on water quality are expected to be minor or negligible; however, monitoring of sensitive areas during concurrent operations (if they occur) should be undertaken to assess potential effects on water quality and implement appropriate operational and management actions. Concerns about cumulative effects of suspended sediment concentrations can be further allayed by staggering activities and operations in space and time.

No notable cumulative effects on Sea Ice are expected as a result of scenario activities. Icebreaking activities may locally add to climate driven decreases in ice cover and affect the timing, seasonal predictability, structure, and stability of ice in the vicinity of such activities. However, the regionally predicted impacts of ongoing climate change of ice are expected to far outweigh this local effect.

Cumulative effects on coastal stability and subsea permafrost are expected to be local and of low magnitude. The largest effects on subsea permafrost conditions would be associated with climate and natural processes, resulting in low to high adverse effects, varying by geographic location. By comparison, the cumulative effects due to human activities in Scenarios 1 to 4 are expected to be smaller, although these human effects could exacerbate the total adverse effect.

Likewise, cumulative effects on coastal habitat are predicted to be small. Impacts from climate change are predicted to amplify or cause more substantial effects. However, these changes would occur regardless of the effect of human activities described in the scenarios.

8.6.2 Cumulative Effects on the Biological Environment

Cumulative effects could affect some of the biological VCs, especially where habitat disturbance from some activities may overlap with direct behavioural, physiological or health effects from others. For the Migratory Birds VC, effects resulting from multiple human activities could act cumulatively with changes in habitat quality and availability due to climate change and result in higher magnitude effects. This could be the case if Spring Transition and Open Water season activities associated with the development of infrastructure and subsea pipelines in the nearshore overlap with commercial and tourist related vessel traffic, resulting in cumulative effects to Migratory Birds. Cumulative effects could also be experienced by Seabirds, including changes in behaviour, health and mortality rates. Murres and gulls, which are highly vulnerable to habitat displacement and airborne noise disturbance at their breeding colonies, are expected to have increased residual effects on the health and potential for mortality (e.g., chicks). The presence of any permanent offshore structures and increased vessel traffic throughout their foraging range could additionally increase the potential for disturbance, changes in habitat use, or mortality due to collisions. Eiders may be most vulnerable due to their massive movements during spring migration. Increases in the occurrence of storm surges associated with climate change could affect seabird nesting and foraging in nearshore areas with potential effects on health and fitness. Such cumulative effects are at highest risk of occurring for Scenario 4 activities, which includes vessel movements through Amundsen – Queen Maude Gulf and the Northwest Passage during the Open Water season, which would bring higher numbers of vessels in proximity to a number of important areas for the Seabirds VC. Careful spatial and temporal planning within the BRSEA Study Area could substantially reduce residual cumulative effects for Seabirds.

Increased intensity, longer duration and geographic overlap of human activities associated with activities in Scenarios 1 to 4 could increase the probability of exposure of Marine Mammals to underwater noise events and increase the footprint of the ensonified area around activities that occur simultaneously in space or time.

Cumulative effects associated with project specific and regional shipping and icebreaking could have a measurable effect on marine mammal habitats in the region. The combined effect of multiple activities (e.g., transits of vessels in the mid- to late Spring Transition season) on sea ice habitat could result in changes in mortality risk due to the increased abandonment of birthing lairs by ringed seals and/or a lack of alternative birthing lairs that are not subject to disturbance. Cumulative effects of vessel noise could potentially extend across the region and outside the region, as beluga and bowhead whales spend part of the year outside of the Beaufort Sea. In addition, the rapid shift in marine mammal habitat quality and availability that is predicted to result from climate change could amplify effects and exert substantially more pressure on marine mammal populations to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change, resulting in higher magnitude effects on marine mammal populations than at present.

For polar bears, development pressure on nearshore regions, the development of offshore structures, increased vessel traffic, changes in remaining areas of sea ice and associated disturbances to polar bear prey could aggregate in time or by geographic location and result in cumulative effects to polar bear. As noted, vessel transits through channels in the Northwest Passage and Amundsen-Queen Maude Gulf are expected to increase as the duration of the Open Water Season increases; this would likely bring vessels closer to polar bears than offshore transits across the southern or central Beaufort Sea. As for other marine mammals, the rapid shift in polar bear habitat quality and availability that is predicted to result from climate change is expected to amplify effects and exert substantially more pressure on the population to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change to result in high magnitude effects on polar bear. Early identification of risks and regional co-management of whale, seal, and polar bear populations are key to reducing the potential for cumulative effects to result in reduced viability of polar bear populations in the region.

In contrast to the above, no cumulative effects from industrial and human activities in the four scenarios are expected on Marine Lower Trophic Levels, Marine Fish and Habitat, and caribou. Given the low magnitude and limited spatial extent of residual effects on Marine Lower Trophic Levels associated with routine activities in Scenarios 1 to 4, it is unlikely that concurrent activities in the region would result in adverse regional cumulative effects. However, the severity of effects of climate change on lower trophic levels over the 30-year assessment period is not well understood and, hence, assessing cumulative effects in that context is uncertain. Disturbance to, and loss of, seabed habitat could affect benthic fish species and seismic surveys could affect eggs, larvae and more sessile benthic species. Climate change induced effects on Marine Fish and Habitat could reduce overall resiliency of populations and communities and result in lower ability to withstand effects from multiple activities. However, these effects would be restricted to the immediate area around the footprint for infrastructure and are unlikely to overlap in time. As a result, cumulative effects from habitat disturbance or habitat loss are not expected for Marine Fish and Habitat. Also, given the limited overlap of activities in Scenarios 1 to 4 with caribou and negligible effects throughout, no cumulative effects are expected for caribou.

8.6.3 Cumulative Effects on the Human Environment

Cumulative effects on human environment VCs could be beneficial or adverse.

Offshore development activities described in Scenarios 2 to 4, combined with activities of Scenario 1, would result in a beneficial cumulative effect to the economies of the ISR, NWT and Yukon through an increase in and diversification of employment opportunities. This also could include expanded opportunities for training and education of Inuvialuit, and increased use of and growth of Inuvialuit service and supply businesses. In the ISR, the degree of these benefits would depend on the terms of the benefit agreements with industry and the capacity of the Inuvialuit and Inuvialuit businesses. There also may be potential for ownership participation by Inuvialuit organizations in oil and gas projects or specific components of projects.

The cumulative effect on Demographics is predicted to be neutral to positive depending on how much the current decline in population within ISR would be offset by employment opportunities (and associated in-migration of Inuvialuit and other workers) for the Status Quo (e.g., increased tourism related job opportunities) and the three oil and gas development scenarios. Effects of climate change on demographics are likely to be adverse (e.g., out-migration due to concerns regarding coastal erosion, loss of sea ice, etc.).

Likewise, cumulative effects on Infrastructure are likely to occur but are difficult to predict. Increases in vessel activity, tourism, and offshore renewable or oil and gas activities may act cumulatively to place additional demands on existing infrastructure within the ISR communities, and an influx of outside workers may affect the capacity of hotels and temporary accommodations, grocery stores, service centres, healthcare, and fire and emergency services. However, such needs may result in upgraded marine and air transport infrastructure, as well as accommodations and associated services, office space and industrial areas, leading to an improvement in capacity and quality of infrastructure. Meanwhile, climate change is predicted to adversely affect existing built infrastructure within ISR communities, which is not currently resilient to effects such as sea level rise, increased storm surges, coastal erosion, and melting permafrost. The extent to which climate change effects on infrastructure would be avoidable would depend on the amount of investment in resiliency works and projects. The labour force needed to implement such resiliency works would itself place demands on infrastructure and services within the ISR, and may necessitate additional infrastructure investments, such as workforce housing.

Cumulative effects on Traditional Activities, Cultural Vitality and Public Health are predicted to be adverse. The direct and indirect effects of construction activities, offshore structures and increased vessel and air traffic could lead to a decrease in traditional harvesting, or Inuvialuit may need to change patterns of access or harvesting locations to accommodate these changes. In turn, this could affect the success of traditional harvesting and participation rates in these activities. In addition, while participation in the wage economy is likely to adversely affect the overall time available for hunting and fishing activities, wage incomes may provide a beneficial effect through more money being available for financing of hunting and fishing equipment, supplies and travel. Human-associated effects in combination with climate change could incrementally change the distribution and abundance of species harvested for traditional purposes and access to the traditional harvesting areas.

These residual cumulative effects may act synergistically affect Cultural Vitality by reducing the amount of traditional food per household, and the transmission of harvesting knowledge between generations, thereby weakening the important cultural link between Inuvialuit and traditional harvesting activities. Cultural Vitality also could be affected through increases in direct and indirect employment for Inuvialuit that could take individuals away from their home community (e.g., work rotations, travel on vessels), and limit opportunities for Inuvialuit to participate in traditional activities such as hunting and fishing. The intake of large numbers of non-local workers to support projects could further have effects on the use of Inuvialuktun and other Indigenous languages, further adding to cumulative effects concerns.

Public health is a complex response to a variety of circumstances and is, thus, susceptible to potential cumulative effects. Changes in baseline health indicators described in the Status Quo scenario could compound with effects related to changes in household income and rates of harvesting and consumption of traditional foods associated with activities in scenarios 2 to 4. Climate change could further influence the cumulative effects on Public Health by reducing on-ice harvesting time and contributing to additional human health risks related to food spoilage and northward migration of insect and mammal disease vectors.

8.7 Influence of Climate Change on Valued Components and Environmental Effects

The assessment of potential environmental effects of industrial and human use over the next 30 years requires a consistent approach for consideration of climate change. As described in Chapter 6, RCP 8.5 was chosen as the most realistic future trajectory in the BRSEA Study Area over this timeframe. Predicted changes in key physical, oceanographic and coastal variables deemed most important for physical and biological processes in the BRSEA Study Area are summarized in Table 6-2, and fully described in Appendix C.

These predicted changes were used to inform the types and seasonal timing of activities and choice of equipment for the Status Quo scenario and the three oil and gas scenarios, and to describe the effect that climate change might have on the VCs and on the potential residual effects on VCs under each scenario. The main effects of climate change on VCs are summarized; Appendix D provides detailed information on effects of climate change on VCs, environmental effects and scenario-specific information.

8.7.1 Effects of Climate Change on the Physical Environment

The physical environment in the BRSEA region has undergone substantial changes in response to climate change, most of which are predicted to continue over the 30-year time frame for the BRSEA (see Table 6-2 for currents and future projections). Western science and TLK holders in the BRSEA Study Area have observed substantial changes in weather patterns and ice conditions over the last few decades, several of which could affect how industry may conduct their activities; specifically:

- more open water in the winter
- rougher ice
- delayed snowfall and freeze up
- greater numbers of icebergs
- larger and rougher pressure ridges
- thawing permafrost
- warmer winter temperatures
- shifting winds, including stronger northwest winds
- increased coastal erosion
- strong summer storms
- shorter winter seasons

In the context of this assessment and methodology, climate change is expected to have a relatively small indirect effect on atmospheric indicators such as air contaminants, GHG emissions, noise, and light emissions by leading to more marine vessel activity (longer Open Water Season in the BRSEA Study Area and the Arctic overall) and more petroleum fuel being burned in the ISR. As the length of season during which ship traffic increases so does the timeframe over which routine discharges from vessels may occur. Scenarios 2 to 4 would be year-round operations, with increases expected in the number of vessels or vessel movements if open water conditions are extended due to climate change.

The effects on the other physical VCs are expected to be greater. The combined changes in sea ice extent, dynamic processes, and timing of sea ice formation and breakup are key effects of climate change that would directly affect ongoing industrial and socioeconomic activities throughout the ISR. There is potential for climate change to delay the onset of sea ice formation (timing of freeze-up), which may encourage longer operating seasons for Status Quo activities. Furthermore, climate change may lead to delayed refreezing of vessel tracks following icebreaking, especially if air temperatures are delayed in becoming very cold (e.g., <-10°C). Sea ice mobility is expected to continue to increase throughout the Ice Season, thereby potentially enhancing sea ice dynamic processes. It is presently unknown how climate change might affect the extent and duration of landfast ice cover in the Canadian Arctic within this 30 year period; however, it is likely in the future that there would be less landfast ice for shorter portions of the year.

From a coastal dynamics perspective, climate change is already resulting in coastal erosion along all parts of the coastline of the BRSEA Study Area at varying rates depending on local and regional geological, permafrost and oceanographic conditions. Loss of permafrost is anticipated to increase due to coastal slumping and mass loss. Loss of sea ice would lead to larger waves, which would accelerate coastal erosion and effects to coastal habitats. Habitat may also be lost through sea level changes. Loss of habitat could result in increased pressure on ecosystems. Climate change is also resulting in reduction of the permafrost below the seafloor due to increased water temperatures of near-bottom waters as the duration of the Open Water Season increases.

The longer Open Water Season is resulting in more heating of the water column due to solar radiation, along with increases in air temperatures. Water temperatures are also rising due to warm water inputs to the Beaufort from the Pacific Ocean. With climate change, there is a concern that further warming of water in the Chukchi Sea from its current temperature of 11 C to 13 C could affect water temperatures in the Beaufort Sea and affect subsea permafrost.

8.7.2 Effects of Climate Change on the Biological Environment

From a biological perspective, climate change effects are likely to overwhelm effects on VCs from human activities (with the exception of a large oil release; Scenario 5). Climate change effects may make biological VCs less resilient to human pressures overall. Physical stressors on marine species (e.g., altered ocean temperature, reduced extent and quality of sea ice, increased ocean acidification) has, and is continuing to shift species assemblages and distributions, affecting species fitness, and may reduce the general resiliency of individual species and communities. In addition, this shift in distributions and a potential seasonal lengthening or intensification of human activities could lead to more spatial and temporal overlap of the cumulative effects described in Section 8.6. This is expected to be the case for the Marine Fish and Habitat, Migratory Birds, Seabirds, Marine Mammals, polar bears and caribou VCs.

There remains uncertainty about responses of lower trophic levels to changing environmental conditions in the Arctic. Potential changes could include increases in primary production due to a longer Open Water Season, a new or stronger fall phytoplankton bloom, to a collapse of phytoplankton stocks due to a lack of sea ice edge induced blooms and increased occurrence of fungal parasites.

For most arctic fish species, reproductive strategies are linked to the melting of sea ice and they are, therefore, susceptible to changes in timing of ice melt. Lengthening of the Open Water Season may have a negative effect on some arctic fish species such as arctic cod. Fish populations that are already stressed by climate change-induced changes to habitat may be more sensitive to potential effects of human activities in the region. Ice breaking activities may contribute more substantially to these effects on ice in the future as ice habitat becomes scarcer. Expected changes in contaminant levels in the water column due to climate change and increasing acidification of the Arctic Ocean may also increase sensitivity of fish to effects from human activities. If climate change effects such as increasing light availability (due to less or thinner sea ice or snow cover) and temperature in surface waters benefit primary productivity, bottom-up food web processes may benefit some fish and perhaps make them more resilient to effects from human activities. Conversely, a warming Arctic could drive northward range expansions of species currently limited to more southerly latitudes by ice (e.g., the forage fish capelin, or Pacific sand lance), and promote new or more pervasive interspecific interactions with unknown consequences, especially among fish species with similar dietary preferences like capelin and arctic cod, which could favour productivity of some fish species at the expense of others.

For the Migratory Birds VC, the effects of climate change would primarily be felt onshore, including effects on distribution of nesting habitat, earlier onset of spring, and changing food peaks. For migratory birds that use offshore leads during the Spring Transition Season (e.g., loons), the increasing extent and duration of the length of the Open Water Season and thinner ice may decrease the need for ice-breaking and thus decrease effects on those species; however, the corresponding increase in vessel traffic and an extended period of open water would generally alter migratory bird use of offshore and coastal habitats (e.g., geese, brants, shorebirds). Likewise, increases in vessel traffic and marine uses associated with climate change might lead to an increase in the frequency and, potentially, magnitude of disturbances of the Seabirds VC and their marine habitat, causing residual effects on health and mortality risk for murres, gulls and eiders. Increases in foraging habitat disturbance would put pressure on seabird populations and potentially result in shifts in range, migration routes, habitat use, or prey sources. Increases in the frequency of storms and storm surges would increase habitat disturbance in nearshore areas and could affect nesting and feeding for eiders and gulls later in the breeding season with potential residual effects on behaviour, health and fitness. Climate-related changes in sea temperature and food web structure along the continental slope would occur later than on the shelf or along the shore; therefore, the additive effect of habitat disturbance for Seabirds is expected to occur toward the end of the 30 year period examined in this study. Increased fog in the region due to climate change could increase the probability of collisions of seabirds with offshore structures and vessels, with a direct effect on seabird mortality. At the same time, larger open water areas may increase open water foraging habitat in space and time for some species. The quality of such potential new habitat is unknown. A recent study suggests that increased warming might also facilitate an increase in intertidal mussel abundance across the Arctic, which may benefit eiders in the region.

The shift in the distribution of sea ice and open water habitat is also likely to affect Marine Mammals directly by altering the timing of migration and length of time spent in the BRSEA Study Area by whales, the distribution of prey species, and the availability of suitable sea ice habitat for seal breathing holes and birthing lairs. A longer Open Water Season and increased access to the region via the Bering and Chukchi seas may result in more frequent occurrences of southern species like killer whale, grey whale or humpback whale, introducing more predation pressure and/or competition for food resources. In marine mammal populations that are already vulnerable to climate change (e.g., beluga, ice seals, polar bear), resilience to effects from human activities is likely to be reduced. It is uncertain what the ultimate impact of climate change on marine mammal populations may be, which makes difficult the prediction of potential effects of human activities over such a long temporal scale.

A shift in the distribution of sea ice habitat also is likely to affect polar bears directly (through loss and alteration of available sea ice habitat) and indirectly (through effects on ice dependent prey species). Bears from the Arctic Basin and Northern Beaufort Sea would likely remain on the sea ice as it recedes and become geographically separated from human activities. More southerly distributed bears may be forced onto land for longer periods of time during the Open Water Season and face reduced access to their primary food source (ice dependent seals) and increased pressure to replace that source with alternate (usually less energy rich) prey species on land. The increased abundance and duration of polar bears on land would also increase the geographic overlap between bears and human activity, resulting in a greater potential for bear-human interactions and mortality. Recent studies have indicated that as sea ice becomes increasingly short-lived annually, polar bears are likely to experience increasingly stressful conditions, shifting habitat (e.g., increased use on land based denning habitat) and higher mortality rates. The combined effects from climate change and human activities is likely to make polar bears less resilient to individual pressures in the future.

Changes in sea ice conditions have the potential to affect Peary caribou and the Dolphin and Union caribou populations that rely on sea ice to move seasonally between islands. More open water would create barriers to movement and reduce the ability for these caribou to move between islands or the mainland to avoid predators or seek more favorable foraging conditions. Island connectivity is important to maintain genetic diversity, particularly among caribou populations on the smaller islands within the Bathurst complex.

8.7.3 Effects of Climate Change on the Human Environment

The predicted effects of climate change on Human Environment VCs and the effects from scenario related activities are mixed. Climate change effects on the Economy, Demographics and Infrastructure could be both beneficial or adverse, and effects on Traditional Activities, Cultural Vitality and Public Health are expected to be adverse. As for the biological VCs, the direct and indirect effects of climate change are likely to overwhelm any effects from human activities on the Human VCs, except for the Economy.

While commercial shipping activities are predicted to increase, this is expected to have a marginal economic benefit because most commercial ships would not stop at ISR communities. There would be a longer tourist season resulting in more opportunities for visiting cruise ships, but the remoteness and high cost to access the BRSEA Study Area would likely cause tourism in this area to remain a niche market activity. Moreover, cruise ship tourism potential could be adversely affected by climate change due to a likelihood of increased fog and extreme storm events and thus affect cultural experiences (i.e., greater difficulty accessing communities from the cruise ships) and causing changes in wildlife viewing opportunities (as a result of weather and changing distributions and abundance of wildlife species).

In contrast, climate change is a driver for ongoing development of renewable energy generation and storage, and lowering costs of offshore wind-based energy generation and other renewable energy sources could make the installation of such facilities within the ISR more economically attractive and lower household energy costs. At the same time, the increase in number of ice-free days associated with climate change could reasonably be expected to also improve the financial viability of the natural gas and condensate export facility due to lowered operating costs associated with ice-breaking activities, less risk of ice-related infrastructure damage, and extended ice-free shipping season. While predicted increases in ocean waves, wind, and storm surges associated with climate change could pose risks to the hypothetical natural gas and condensate export facility (Scenario 2) or the offshore oil facilities (Scenarios 3 and 4), and result in shipping delays, the oil and gas industry has extensive experience operating in offshore environments that can experience extreme weather (e.g., Gulf of Mexico, North Sea, and Newfoundland and Labrador).

The prospects of employment associated with developments in Scenarios 1 to 4 may motivate some individuals to move into the ISR permanently; other individuals may be employed temporarily on a FIFO basis. In addition to scenario related employment, a substantial workforce may be needed to undertake maintenance and resiliency works to address climate change effects on infrastructure. On the other hand, climate change may exacerbate the current demographic decline through displacement of coastal communities due to increasing permafrost degradation and coastal erosion, as well as due to a decline in traditional activities and cultural vitality.

Climate change effects such as sea level rise, increases in storm surge frequency and strength, waves, sea ice extent and location, and permafrost degradation are predicted to adversely affect Infrastructure in the BRSEA Study Area. For example, changing permafrost conditions can alter the strength and integrity of the ground and cause buildings, roads, runways and other foundations to shift and become unstable. While engineering and construction practices are being developed to build on changing permafrost, most existing infrastructure is vulnerable to the effects of climate change. In Tuktoyaktuk, people are already taking steps to protect their community, such as moving homes and buildings away from the areas with the greatest erosion. Addressing climate change challenges in ISR would involve substantial investment in equipment and materials, plus considerable labour both to address infrastructure deterioration (such as from melting of permafrost) and address other environmental changes, such as rising sea level. The substantial workforce needed to undertake such maintenance and resiliency works would also need to be accommodated and transported and would place other demands on infrastructure within the ISR. However, if economic benefits were re-invested in the communities, then new and upgraded infrastructure and other resiliency works could ensue and support the long-term functioning of infrastructure needed to support industrial development within the ISR. Such activities would, in turn, result in jobs and other economic benefits, such as goods and service contract opportunities. Given an increased need for resilient infrastructure to support the development activities detailed under the different scenarios, such benefits might not occur in the absence of such development.

Given the adverse effects of climate change on important traditional resources such as fish, birds and mammals, traditional hunting, fishing and related activities would also be adversely affected. Inuvialuit are reliant on sea ice for the practice of many traditional harvesting and cultural activities. An increase of ice-free days, associated with climate warming, could affect Inuvialuit ability to access and harvest key species. The abundance of key species may also be affected by decreased ice presence in the region. Reduced ice in the ISR could lead to an increase in shipping traffic and greater use of icebreakers (as in Scenario 1) that could further decrease access to harvesting areas, and potentially change the timing and location of harvest, travel routes, and access to harvest areas. Increased vessel and aircraft traffic, as well as increased human activity and noise, is likely to exacerbate the effects of climate change on traditional harvesting. Changes in access and availability of harvested species would consequently contribute to a reduction in traditionally harvested foods consumed by ISR households and an increased reliance on market foods, potentially contributing to adverse health effects associated with dietary changes.

In addition to climate change effects on harvested species, reduced ice cover and a shorter duration of ice cover is expected to affect the ability of the Inuvialuit to travel safely over ice, reach traditional or cultural sites, and engage in traditional activities during the late Fall Transition, Ice and early Spring Transition seasons. In turn, this could affect Inuvialuit cultural knowledge transfer (e.g., harvesting sites and methods, cultural activities, and use of Indigenous languages).

These changes have a corresponding effect on Inuvialuit cultural vitality; less sea ice and reduced opportunities for activities on the ice can also change or reduce the number of opportunities for families and communities to be on the land and, thereby affecting cultural expression and the language link between the Inuvialuit and traditional activities.

9 FUTURE CONSIDERATIONS FOR INFORMATION AND MANAGEMENT DIRECTIONS

As described in the Terms of Reference (Appendix A), the BRSEA is intended to support informed decision-making, consistent with the Inuvialuit Final Agreement, around possible future resource development and management, including offshore oil and gas development, as well as environmental conservation programs, community sustainability and subsistence activities, and other complementary commercial activities (Terms of Reference, Appendix A).

During the preparation of the Data Synthesis and Assessment Report, opportunities were identified to proactively manage adverse risk and improve positive benefits by applying concepts and outcomes of the assessment to future planning programs, policy directions, management approaches and perhaps legal instruments. In addition, information needs – pertaining to TLK and western science – were identified in relation to baseline data gaps, effect pathways, monitoring the effectiveness of mitigation measures and best practices, the influence of climate change on biophysical and human systems, and approaches to adaptive management. Recommended management directions and information needs are described for:

- management of human, commercial and industrial activities in the Beaufort Region
- research and monitoring needs
- effects management
- planning, preparedness and response to a Large Oil Release Event

Considerations for potential future initiatives or programs for these subject areas are described below. Details on how to implement or fulfill these initiatives or programs are not provided in this report as implementation will be complex and require collaborative input and direction from Inuvialuit, the Federal government and agencies, Territorial governments and agencies, and other stakeholders.

Of direct relevance to the BRSEA, a number of collaborative initiatives, involving the federal government, the IRC and other Inuvialuit organizations, the GNWT and Yukon Government, are currently underway to address a wide range of policy, planning and regulatory instruments; these include:

- jurisdictional controls
- vessel management
- management of cruise and coastal tourism
- use and management of renewable and non-renewable resources, including commercial fishing, renewable energy, and oil and gas activities
- marine planning and marine conservation and protected areas
- socio-cultural resiliency
- revenue sharing and benefits

These combined actions will support informed decision-making around future development and management that balance risks and benefits at local, regional and national scales (see Terms of Reference, Appendix A), with an end goal of social and environmental sustainability, cultural vitality, complementary commercial activities and associated economic sustainability.

9.1 Management of Human, Commercial and Industrial Activities in the Beaufort Region

A variety of human, commercial and industrial activities will continue to occur within the BRSEA Study Area over the next three decades, including traditional and local use, recreational use, community resupply, infrastructure development, tourism, research, military and Coast Guard patrols and exercises, cruise ship activities, and shipping traffic within or across the Beaufort Sea, and aircraft activity. Potential industrial projects in offshore areas also could include renewable energy generation, subsea mining and/or oil and gas development.

Regardless of whether existing activities continue (e.g., Status Quo), new types of industrial projects are proposed (e.g., offshore wind energy, subsea mining), or some level of oil and gas development proceeds, the effective management of impacts will require enforcement of existing federal and territorial legislation, regulations and permitting requirements; the Inuvialuit Final Agreement and associated regulatory processes (i.e., EISC, EIRB, FJMC) and municipal requirements, as well as ongoing evolution of these instruments to adapt to changing conditions and technology. Adherence to international agreements (e.g., MARPOL) will also be required. There also will be a need to monitor performance and compliance of regulatory requirements and address deficiencies if identified.

Given that separate processes from the BRSEA are underway and ongoing to address these interjurisdictional aspects, no specific recommendations in these areas are provided as part of the Data Synthesis and Assessment Report. However, these policy, planning and regulatory instruments are strongly linked to the success and effectiveness of mitigation and management measures for potential environmental effects from human activities to the biophysical and human environment within the BRSEA Study Area. As such, the current interjurisdictional aspects, and appropriate policy, legislation and management guidelines should be completed in a timely manner to allow for proactive management that safeguards the environment and the Inuvialuit way of life.

9.2 Research and Monitoring Needs

As is evident in the State of Knowledge (Chapter 7), the marine ecosystem in the BRSEA Study Area has been the subject of study by Inuvialuit for thousands of years, and by western scientist for many decades. A wealth of information has been gathered on the status and trends of its valued ecosystem components. From a TLK perspective, these were most recently updated in the various Community Conservation Plans (ACCP 2016, ICCP 2016, OCCP 2016, PCCP 2016, TCCP 2016, SCCP 2016). From a western science perspective, the most recent summaries include a report on climate change effects on the Canadian Beaufort Sea marine ecosystem published in 2015 (Fortier et al. 2015), a 2019 Fisheries and Oceans Canada Technical Report on the State of Canada's Arctic Seas (Niemi et al. 2019), and several research projects funded recently through BRSEA that used traditional knowledge and strong community engagement to help fill several research gaps on the Beaufort Sea bio-physical environment.

Notwithstanding information in these scientific reports and the rich sources of TLK, an assessment of environmental effects, such as described in this report, require specific types of information and understanding that is either not easily observed or not a frequent focus of scientific research. In summarizing relevant baseline information in Chapter 7 and conducting the detailed effects assessment (Appendix D), targeted research and monitoring needs were identified. As such, these are not meant to be an all-inclusive list of everything that should be known or measured. Instead, it is a targeted list of research and monitoring needs that require further attention to:

- establish a better baseline for key VCs
- improve understanding of effects of certain activities on VCs
- detect potential effects

Research and monitoring needs are summarized in this section of the report, following the VC structure in Chapter 7 (Physical, Biological and Human Environment) and include Baseline (Chapter 7) and Effects (Appendix D) needs; the reader is referred to those respective sections for more details and context.

Consistent with the approach to the BRSEA, future research and monitoring programs should be co-lead by the IRC and the Government of Canada. Collaboration of Inuvialuit and western science specialists should occur throughout the full life cycle of each study or program to gain the greatest benefit from these two knowledge systems. Inuvialuit TLK holders and western scientists should be co-involved in the study scope and design, execution of the work, analysis and interpretation of information, reporting and communication of findings, and follow-up actions. In addition, Inuvialuit communities must have opportunities to be informed of the studies or programs and provide input during the planning stages, with regular updates and input as the study or program progresses. The Inuvialuit communities also must be provided with a final presentation on findings and conclusions (including providing digital and hard copies of materials and a public language summary).

9.2.1 Physical Environment

9.2.1.1 Atmosphere

For some physical VCs, there is almost no baseline data and there is a general need for more spatially explicit information and more recent and continuous data collection given rapid shifts resulting from climate change. For example, information on ambient air quality is sparse or absent in the BRSEA Study Area and the dispersion of air contaminants within the cold Arctic troposphere is not well understood. Estimates around possible methane releases from thawing terrestrial permafrost are only beginning to be understood, but the likelihood of occurrence and quantities of methane release from subsea permafrost remains largely unstudied. Likewise, there is no baseline monitoring of in-air noise levels and artificial light intensities. As a result, efforts to quantitively assess potential impacts of human activities (e.g. vessel, aircraft, and offshore structure related activities) on air quality, noise, or light is difficult either because there is no sense of long-term or spatial variability of these variables in the BRSEA Study Area, or because the potential effects of in-air noise and lighting on people and biological resources in the Arctic have not been well studied. Additional ambient monitoring in coastal communities (involving local community monitors) and at sea would help to better understand and characterize the existing conditions.

9.2.1.2 Climate and Weather

From a climate change and management of GHGs perspective, the regulatory regime in Canada is changing. The present requirement is to establish and demonstrate the ability of a given project to help meet Canada's commitments to reduce GHG emissions by 30% below 2005 levels by 2030 and help achieve a low carbon economy by 2050. Additional information and guidance may be available in the future to assess the potential environmental effects of a particular project on climate change directly. In addition, the GHG implications of a specific offshore oil and gas development should take into account carbon leakage and the potential for Beaufort petroleum products to displace higher GHG energy sources both domestically and internationally (i.e., natural gas and other light hydrocarbons could displace the use of coal from another jurisdiction). While this displacement is probable, it is difficult to establish the likelihood of this occurring in the near term. As governments develop and refine policies and regulations to slow or eliminate the use of higher GHG energy sources (such as coal), it is expected that approaches will be developed to estimate displacement benefits for higher GHG energy sources both domestically and internationally.

In terms of weather, information needs are related to the analysis and prediction of extreme events in the context of a relatively sparse network of monitoring stations. A solid understanding of the threat of weather to projects requires an assessment, often quantitative, of the probabilities and consequences of severe weather. With the changing open water conditions, seasonal weather systems (on weekly to monthly scales) are expected to have a greater impact on human uses and infrastructure. While seasonal forecasting is becoming more relevant, predictions are less reliable. Mathematical techniques in forecast science are evolving and can be adapted to a changing climate; however, the database of observations, particularly of extremes, is changing so that the statistical methods are starved for current data. Additional weather stations in locations throughout the region are needed, as are further efforts in long-term modelling to improve risk forecasting (i.e., probability and consequence) necessary to support developments in this region. Inuvialuit monitors could operate and maintain this system of stations.

9.2.1.3 Oceanography

More comprehensive data for the physical oceanographic environment below the surface water layers on the shelf and slope are required to better understand the distribution and variability of the biomass of zooplankton, marine fishes, and benthic communities. This data also would allow an analysis of the underlying biophysical and biochemical mechanisms that could be used to support the development of marine ecosystem models in the BRSEA Study Area. Continued monitoring of ocean currents and water masses (e.g., seasonal changes in speed, depth, temperatures, etc.) would also contribute to an improved and up to date understanding of how climate change has and might affect the biophysical, socio-cultural and economic conditions in the BRSEA Study Area.

The Mackenzie River is the dominant source of suspended sediments in the region. Satellite imagery provides a historical record of the surface extent of the sediment plume when there is daylight and clear conditions. To understand acceptable levels of suspended sediment concentrations during human activities that may increase suspend sediment concentrations (e.g. dredging), an understanding of the natural background suspended sediment concentrations is required.

Data on sediment is also of value in understanding possible adsorption of oil by sediment to form oil-mineral aggregates and the movement and deposition of oil-mineral aggregates. To understand the effect of a large oil release event on water quality and organisms that depend on good water quality and assist in deciding when it would be safe to resume harvesting activities, baseline data of PAHs in water, sediment, and biota are required.

9.2.1.4 Sea Ice

Changes in sea ice dynamic processes in the BRSEA Study Area are key factors that have substantially affected and will continue to affect the Inuvialuit and human and industrial uses. There are large gaps in our understanding of how dynamic and thermodynamic sea ice processes might shift with the change from a multi-year sea ice regime to a seasonal sea ice regime. There also is a need to better understand the interannual variability of sea ice characteristics within the seasonal Arctic sea ice regime and whether year-to-year variability is expected to change, thereby affecting predictability. This information is needed by ISR community members to safely use the changing sea ice, and is also required to plan, design, install and operate renewable energy or oil and gas infrastructure in offshore areas.

From an effects monitoring and impacts assessment perspective, information is needed on baseline contaminants levels in sea ice in areas that have the potential for active industrial projects in the future. Information is also required on how repeated icebreaking vessel tracks can affect ice roughness and integrity (both of which can affect marine mammal habitat and traditional ice routes).

An improved understanding of ocean currents (see above) and ice movements would be beneficial to properly plan oil spill response and to predict potential trajectories of released oil and dispersion.

Finally, lateral melting and growth of cavities in ice floes from *in situ* burning represents a potential complication for spill response measures in sea ice and should be reviewed further to determine acceptable thresholds of spill size and infiltration into the ice surface to permit effective mitigation by *in situ* burning.

9.2.1.5 Coastal Dynamics and Sea Floor Geology

There is a need for continued and more detailed studies of coastal erosion processes to be able to determine the present and future rates of coastal erosion at a higher resolution for specific coastal segments than is presently possible. This information should be used to update key planning documents such as Community Conservation Plans and the Beaufort Regional Coastal Sensitivity Atlas last updated in 2015 (see below). There is also a gap in the availability of information on the long-term near bottom ocean temperatures from the coastline to the outer continental shelf. In combination with more knowledge on sub-surface oceanographic processes (see above), this information is needed to better understand potential future changes to subsea permafrost and to support the design and safe deployment and operations of offshore infrastructure.

9.2.1.6 Coastal Habitat

Outside of a few focus areas, little information is available about coastal and terrestrial habitats in specific stretches of coastline in the BRSEA Study Area. Potential impacts of development and selection of best management practices would be better informed by an inventory of coastal and terrestrial habitat with a multi-factorial quantitative assessment of the physical, biological, ecological and socio-cultural values for each microhabitat. Such information would also be crucial to the development of oil spill response strategies for the coastline and regular updating of the Beaufort Regional Coastal Sensitivity Atlas.

9.2.2 Biological Environment

9.2.2.1 Marine Lower Trophic Levels

There are large knowledge gaps regarding the location and seasonal timing of areas of high primary productivity within the BRSEA Study Area (e.g., hotspots off Cape Bathurst extending into the mouth of Amundsen Gulf), as well in areas that are within the influence of the Mackenzie River plume, especially during the spring break-up and freshet period and extending into summer and early fall. The is a lack of understanding about how climate change will affect primary producers and possibly change the location, timing and intensity of phytoplankton blooms and related zooplankton production. Regional long-term data for zooplankton is also required to establish a robust baseline. Similarly, there is a lack of data on local and regional scales for both epifauna and infauna species distribution and abundance. Almost no information is available on the microbial community in BRSEA Study Area, a key component of nutrient cycling for this system which is being subjected to changes due to warming ocean temperatures and changes in river discharges. Given the rapid rate of change that is being observed in Arctic systems, acquiring a robust and continuous dataset on marine lower trophic levels would be important to understanding and predicting implications for higher trophic levels and the human environment.

From an effects assessment perspective, recent studies have noted some effects of underwater noise on invertebrates, challenging the belief that such effects can generally be dismissed; further research to understand how human activities (i.e., seismic, vessel noise, dredging, drilling) could affect plankton and benthic macroinvertebrates is warranted. Also, bacteria could play an important role during the biological breakdown of oil spills, even in the Arctic environment. More research on this topic is needed for the Arctic.

9.2.2.2 Marine Fish and Habitat

There is a general gap in our baseline understanding of non-harvested fish species (e.g., arctic cod) and their essential habitat within the BRSEA Study Area. In addition, there is uncertainty in our understanding about the effects of climate change on fish distribution and abundance within the BRSEA Study Area. This includes changes to fish species that are already part of the arctic marine ecosystem (e.g. arctic cod), as well as new arrivals (e.g. salmon). For arctic cod, a keystone species in arctic marine environments, there is a lack of information on regional abundance and population structure. It is unknown what their winter distribution is and whether the apparent genetic split between east and west populations created around the Mackenzie River inflow is important for future population sustainability.

Several other information gaps remain to better understand the effects from industrial activities on Marine Fish and Habitat including: the distribution of key fish habitats (e.g. kelp beds); potential indirect effects of ice-breaking on arctic cod via impacts on ice algae growth and associated zooplankton communities; establishing populations and geographic boundaries for arctic char and Dolly Varden; and life-stage specific distribution, habitat needs and potential effects. To help address these data gaps, it is recommended that the fish component of the Inuvialuit harvest study be reinstated and include baseline studies of contaminants in marine and anadromous fish. Inuvialuit fishers should also be engaged in other studies for fish and fish habitat with the BRSEA Study Area.

9.2.2.3 Migratory Birds and Seabirds

Updated information is needed on the location, status and population number of migratory birds and seabirds nesting in the BRSEA Study Area. Most of the ‘current’ information is from surveys conducted in the 1990s. Foraging ranges, diets and migration routes of thick-billed murres and Sabine’s gulls in the BRSEA Study Area are also unknown: their determination would allow for better assessment of spatial and temporal overlaps with human activities in the area. As noted for fish and marine invertebrates, there is a similar lack of baseline data on contaminant levels in migratory birds and seabirds. The lack of such up-to-date baseline data makes prediction of potential effects difficult.

It is recommended that monitoring of migratory and seabird bird population densities and breeding success, seasonal migration patterns, and sensitive breeding and foraging habitat be undertaken to allow for a better assessment of the potential effects of human activities. Tracking technology could be used to address some of these gaps and provide data to model habitat use and residency time within potential human activity areas. Inclusion of these species in the Inuvialuit community monitoring plans and harvesting surveys (e.g. measuring eider body condition) would also provide a wealth of information on populations, seasonal habitat use and health of migratory birds and seabirds.

9.2.2.4 Marine Mammals

Marine mammal populations within the BRSEA Study Area have been extensively studied and monitored in recent decades, providing a good understanding of ecology and important habitat. However, given the rapidly shifting conditions in the Arctic, habitat use is expected to shift especially for ice dependent species like seals. The ultimate implications for population dynamics resulting from changing environmental conditions remain uncertain, especially within specific areas, and a better understanding is needed about ongoing changes in body condition, prey availability, key habitat availability, and abundance and distribution, including that of ‘new’ species (e.g. killer whales). Such information will be critical to understanding how populations are adapting to their changing environment and managing and maintaining long term sustainability in the face of climate change and human activities.

Specific data for beluga whale has been collected during recent tagging studies and includes: relationship to and behaviour of beluga pods in estuarine regions; philopatry to specific areas of the Beaufort Sea region (e.g., shallow and deep water sites); the ecological purpose of estuarine regions such as Kugmallit Bay; and female and juvenile behaviour on leaving the estuary. This and new data on beluga whale should be considered in relation to future projects and human activities. Bowhead feeding habitat should be identified and the physical and biological variables that influence the location of these areas assessed. Integration of TLK and traditional harvest data on animal distribution, abundance, behaviour and health into the management of marine mammal populations in the region will continue to be important.

9.2.2.5 Polar Bear

Polar bear populations are well studied within the BRSEA Study Area, but ongoing measurement of population abundance estimates of the Southern Beaufort population are needed to confirm current and future population trends and resolve discrepancies between quantitative estimates and TLK. Accurate assessment of population abundance using TLK and western science will be critical in managing the long-term sustainability of polar bear in the region. Given their close association with sea ice habitat, ongoing monitoring of shifting habitat use, prey availability and body condition will contribute to the understanding of how polar bears are responding to shifting habitat conditions and climate change. Ongoing monitoring programs that measure the viability of the population and identify drivers of potential threats to that viability would be key to an adaptive management approach targeted at limiting residual effects of human activity on polar bear and maintaining the population’s ability to adapt to ecosystem changes that are predicted to occur. TLK and western science methods should be used to plan and execute these studies, analyse data and interpret the results.

9.2.2.6 Caribou

Although caribou migration and habitat use are well known, continued research and monitoring, including the incorporation of TLK, on population status, distribution (including seasonal distribution, migration patterns), and habitat use is highly recommended. Such baseline information is critical to understanding how human activity and climate change are influencing caribou populations in the region, particularly the Peary caribou and Dolphin and Union caribou populations. As onshore oil and gas operations and infrastructure would be expected to have more important interactions with seasonal habitat use and movements and have greater potential to result in important effects on caribou than offshore developments, the priority for this species should be monitoring the effects of future onshore activities. As part of monitoring in coastal areas, caribou use of coastal areas and islands for insect relief, calving and post-calving could also be assessed to better understand spatial and temporal distribution and inter-annual variation.

9.2.2.7 Invasive Species

There is a lack of information on the occurrence and prevalence of invasive species in the BRSEA Study Area. Given potential ecological, cultural and economic implications, a long-term monitoring program for invasive species should be considered to determine baseline ecological conditions and apply techniques for early detection of the presence of non-native species and proactive management.

9.2.3 Human Environment

9.2.3.1 Economy

Recent community specific information is available for the ISR community workforce, household income, and food prices. However, statistical information on the breakdown of the economy is limited. Such information would help inform predictions of how ISR communities may respond to different economic development scenarios. Specifically, it is recommended that a labour force analysis be undertaken to better understand the capabilities, interests, and requirements of ISR communities to participate in various development scenarios. Similar information for the NWT and Yukon also would be useful. In addition, future socio-economic monitoring programs should take into account indicators related to gender and sexual identity, and other relevant identity factors to support an assessment of socio-economic impacts on vulnerable population groups that may be disproportionately affected by industrial development (note: the new Canada Impact Assessment Act requires this type of assessment).

9.2.3.2 Demographics

Statistical data from 2016 are available on demographics within ISR communities, including population and demographic breakdowns, Inuvialuit and other Indigenous populations, population changes and net migration. Such data gathering should continue. Future monitoring should be designed to also provide a more detailed understanding of why people migrate to or from the ISR to aid in predictions of how the ISR population and communities may respond to different economic scenarios.

9.2.3.3 Infrastructure

The most recent available information and studies on infrastructure are one to two years old. However, information on specific regional or community infrastructure is either not publicly available or missing. More detailed information on infrastructure and service capacities within the ISR would inform an assessment of how community infrastructure and services may be affected by activities included in the different scenarios. It is recommended that an infrastructure inventory survey be undertaken in all ISR communities to better understand capacities, utilization, and upgrade/maintenance requirements. The survey should also identify required new and upgraded infrastructure for climate change resiliency, including cost estimates and timing. Given the speed with which climate is affecting local infrastructure, such a survey should be repeated at regular intervals to track changes in use, status and resiliency.

9.2.3.4 Traditional Activities

The ISR Community-Based Monitoring Program (CBMP) already provides a basis for ongoing monitoring of traditional harvesting. The Inuvialuit Harvest Study reports on how many of which species are harvested when and where. The ongoing effort could be expanded to include information on travel routes and a measure of effort and cost involved in traditional harvesting. The detailed harvest locations from the initial 10-year Inuvialuit harvest study (1988-1997), which were not digitized, could now be digitized and analyzed to provide a detailed historical database of Inuvialuit harvesting for comparison with current harvesting. Such comparison would be useful in assessing effects of industrial and human activities.

Collection of other environmental information by Inuvialuit during traditional activities could be added to a field-based, rather than a door-to-door, digital data collection program. As an example, the Paulatuk Community Conservation Plan concerns itself with the activities in the MPA that are likely to result in the disturbance, damage, destruction, or removal of a living marine organism or any part of its habitat. Additional metrics such as measurements of ice thickness, months of open water, numbers of polar bears visible at ice leads and in open water, number of vessels or aircraft passing through or over, would be helpful. Continuation of the beluga monitoring program is also recommended, as it collects important whale metrics, including body condition.

As noted at the start of this section, future research and monitoring within the BRSEA Study Area must involve Inuvialuit throughout the full life cycle of each study or program. Inuvialuit TLK holders and western scientists should be co-involved as equal partners in the study scope and design, execution of the work, analysis and interpretation of information, reporting and communication of findings, and follow-up actions.

9.2.3.5 Cultural Vitality

Potential knowledge gaps for the Cultural Vitality VC include a need for Inuvialuit feedback to determine the appropriateness of the proposed parameters, effects pathways and mitigation. For example, key indicators of Cultural Vitality should be identified by Inuvialuit communities, including areas of creative expression such as dancing, singing, and visual art (e.g., printing, painting and carving). Community-led reviews of traditional practices would likely provide more meaningful data, which could be used to monitor changes and identify trends. In addition, potential effects on Cultural Vitality can be synergistic with both adverse and positive effects that can be perceived differently by individuals or groups in the community. Validation by the Inuvialuit communities of the residual effects on traditional and cultural practices and associated mitigation and monitoring would strengthen this and other assessments; this could include review of the residual effects described here or community-based research on residual effects.

9.2.3.6 Public Health

The most current population health data within the ISR dates from the 2014 Canadian Community Health Survey and the 2014 NWT community surveys. The Inuvialuit should lead public health research to obtain more up to date information that reflects the latest trends and developments in population health in ISR communities (e.g., the Inuit Health Survey, the ISR Addictions and Mental Health Study). In addition, prior to the commencement of major industrial development activities in the ISR, the Inuvialuit should lead a region wide community health impact assessment to serve as a baseline for the project assessment and support mitigation and management plans. In addition, the current survey structure and questions should be re-examined to provide a more detailed understanding of linkages between environmental and socio-economic factors and health outcomes and behaviours. Such a study would better inform the development of activity specific mitigation measures.

9.3 Effects Management

Effective management of potential effects requires knowledge about activities that could result in potential effects to VCs, an understanding of effect pathways in time and space, measures that could be taken to avoid or reduce potential effects, and a system whereby activities and effects are monitored (e.g. compliance monitoring, effects monitoring, follow-up programs). These programs can be used to better understand the dynamics and relationships of effects, evaluate the effectiveness of mitigations in an ongoing and integrated fashion, and adapt to meet established management goals.

Mitigation measures that are identified in the detailed effects assessment (Appendix D) are summarized in this section. Suggested approaches for establishing an Adaptive Integrated Management Framework (AIMF) are also provided. An AIMF for the BRSEA would help to address the interplay between societal choices and the associated environmental effects on biophysical, socio-cultural and economic aspects. An AIMF would also help integrate processes to address uncertainties while progressing toward the fulfillment of management and monitoring goals within the BRSEA Study Area (Section 9.3.2).

9.3.1 Summary of Mitigation and Environmental Management Measures by Type of Activity

The effects assessment detailed in Appendix D and summarized in Chapter 8 assumes that standard mitigation measures, best industry practices and environmental management requirements and conditions under operating permits and licenses are followed to reduce environmental impacts from specific routine activities (e.g., vessels, seismic surveys, offshore activities, aircraft activities, routine discharges).

In this section of the report, mitigation measures and environmental standards are summarized for routine activities (as described in Section 8.4.2) in the five scenarios as well as for specific VCs. In addition, general measures are described to mitigate adverse effects of socio-cultural and economic aspects and improve benefits for residents and communities in the ISR, NWT and Yukon as applicable (more information is provided in Section 2.11). A full list of mitigation measures from the detailed effects assessment is provided in Appendix F. Environmental Standards such as waste management regulations are described in Section 2.4 and Section 2.5. Oil spill preparedness and response management standards are discussed separately in Section 2.13.1 and Section 9.4.

It should be noted that in addition to the monitoring needs discussed in Section 9.2 and mitigation measures summarized below, there also international regulations to which Canada is signatory that apply to certain activities (e.g. IMO and MARPOL regulations for vessels), as well as international standards developed by the International Organization for Standardization (ISO) that could be adopted by potential operators in this area to further safeguard against potential environmental effects (e.g. ISO standard 35103:2017 – petroleum and natural gas industries – Arctic operations – environmental monitoring (ISO 2017a) and to safeguard human health (ISO standard 35101:2017 – petroleum and natural gas industries – Arctic operations – working environment (ISO 2017b).

9.3.1.1 Vessels

The presence and movement of commercial, recreational and ice-breaking vessels in the BRSEA Study Area have the potential to adversely affect Traditional Activities, and most biological and several physical VCs examined in this report by emitting noise, light, GHGs and other air pollutants; disturbing habitat and displacing animals from preferred locations needed for reproduction or foraging; causing wildlife mortality through collisions; and interfering with or disturbing traditional harvesting, travel on ice or water, and other cultural activities (see Section 8.4.2). Therefore, mitigation measures to address these concerns are directed at limiting spatial and temporal overlap of vessel activities with human and biological resources and avoiding sensitive areas and times of year. Where such measures are not practical (e.g. product may need to be shipped once a week and its transport cannot be interrupted), other measures to limit effect pathways (e.g. reduce light emissions, reduce vessel speed) could be implemented. Appendix F includes over forty measures and considerations related to vessel activity, as described in the detailed assessment (Appendix D), some of which are specific to one or more VCs. Notable types of mitigation measures include:

- follow stringent fuel standards to reduce air pollution and GHG emissions
- establish low-impact shipping corridors that increase the distances between vessel and receptors to reduce exposure to air, noise, and light emissions, and minimize disturbances of traditional use areas and sensitive habitats during specific times of the year
- avoid icebreaking of landfast ice and around sensitive areas, including near coastal communities, where possible and practical, particularly during the spring and fall transition seasons
- adhere to reduced vessel operating speeds in harbours and the approaches to harbours; keep vessel speed at less than 10 knots in these areas and at times when marine mammals are present
- implement a wildlife monitoring program on commercial vessels and icebreakers to identify marine mammals in the area and maintain safe operating distance
- implement community-run, industry-supported communication centers that publicly broadcast vessel activity in the area

- establish safety exclusion zones around offshore structures and sensitive coastal habitats
- maintain search and rescue capabilities

9.3.1.2 Seismic Surveys

Underwater noise emitted during seismic operations has the potential to adversely affect Marine Fish and Habitat, Seabirds and Marine Mammals and, in turn, have indirect adverse effects on Traditional Activities and Cultural Vitality. The latest version of *The Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment* published by DFO in 2007 specifies the mitigation requirements that must be met during the planning and conduct of marine seismic surveys to reduce impacts on marine life (DFO 2007). These requirements are set out as minimum standards, and specific regional oceanographic, geomorphologic and biological characteristics may require modified or additional mitigative measures to be applied. Because seismic surveys are conducted during the open water season in specified permitted areas, mitigation measures are less about avoiding specific areas (as that would already have been addressed in the planning and permitting process) and more about specific operational protocols that help reduce or avoid potential environmental effects; these include:

- temporal restrictions or use of alternate monitoring technology (e.g., passive acoustic monitoring) may be required if operating within specific habitat zones (e.g., bowhead feeding aggregations)
- prescribed marine mammal observation and detection measures
- establishment and monitoring of a safety zone around the sound source for the duration of the survey
- prescribed start-up and shut-down procedures

9.3.1.3 Offshore Structures and Related Activities

The presence of offshore structures and their related activities have the potential to adversely affect most physical and biological VCs through increases in noise, light, and air emissions, effects on water quality, and habitat disturbance at the ocean surface and the ocean floor. Where traditionally harvested species and locations could be affected, the Traditional Activities VC also could be adversely affected. Offshore activities are tightly regulated, and operating permits usually include a series of mitigation and monitoring requirements or conditions. Appendix F includes over forty measures and considerations related to offshore structure and activities across the different VCs; these include:

- implement proven measures to reduce increases in suspended sediments and their dispersion
- implement geotechnical engineering designs that reduce heat transfers from offshore structures and subsea assets to the marine environment, including the sea floor
- implement best practices with regard to light and noise emissions to avoid or reduce sensory disturbance or collisions of marine wildlife
- use technologies during the installation and operation of offshore infrastructure (e.g. directional drilling, modeling of the potential for erosion of bottom sediments and coastlines) that reduce or avoid disturbances to coastal habitat

- use of least-risk work windows for in-water construction (e.g., dredging, installation) to avoid overlap with sensitive life history stages of marine wildlife and traditional uses
- design and implement an Environmental Effects Monitoring program to establish baseline health information for water quality, marine fish, benthic habitat and marine mammals and monitor and evaluate potential effects

9.3.1.4 Aircraft Activities

Aircraft activities emit noise, light and air pollutants that adversely affect the Atmospheric Environment and Sea Ice VCs, and can cause sensory disturbance to Migratory Birds and Seabirds, Marine Mammals and Caribou. Where harvested resources are affected, adverse effects could be expected on Traditional Activities and Cultural Vitality; air pollutants could adversely affect Public Health. Mitigation measures that were identified through the effects assessment focus primarily on reducing sensory disturbance to humans and wildlife, several of which were previously recommended by EIRB (EIRB 2011); they include:

- develop and implement a management plan that specifies an allowed number and type (i.e., fixed wing vs. helicopter) of low-level overhead flights along the coastlines and in nearshore areas to reduce effects to Inuvialuit hunters and fishers, coastal camps and wildlife
- adhere to a minimum flight altitude of 300 m depending on the flight location and time of year, but remain at a minimum altitude of 610 m when close to caribou
- use the existing co-management processes with Inuvialuit groups to help protect traditional and cultural activities and sites during specific time periods by implementing overflight exclusion zones

9.3.1.5 Routine Discharges and Waste Management

Routine discharges and waste management from vessels and offshore structures are heavily regulated on an international and national basis and monitored, such that few potential effects are expected if mitigation measures and regulations are adhered to. Adverse residual effects on water quality and marine lower trophic level habitat near offshore structures may still occur through the permitted discharge of grey water, bioaccumulation of permitted discharge levels of heavy metals and PAHs, or changes in habitat from the permitted discharge of clean cooling water, drilling muds and cuttings. Mitigation measures to avoid or reduce residual effects from routine discharges and waste management from vessels and offshore structures include:

- use water-based muds whenever possible
- implement a zero-discharge policy for synthetic and oil-based muds and hazardous waste
- develop and implement a detailed water management plan that specifies appropriate measures for the handling, transportation, and onshore disposal of solid and hazardous wastes
- prohibit discharge of bilge water and other waste streams where possible and practical; otherwise, implement and enforce treatment and monitoring of grey water, sewage, and food waste discharges from vessels and offshore structures

- treat water-based muds and associated wastes (e.g., sand and cuttings), produced water, and deck drainage to meet minimum thresholds for oil content before discharge
- where multiple environmental discharge and waste management policies apply (e.g., operational, regional, national, international), carry out a regional effort to consolidate these into a single guide for the marine portion of the ISR
- where possible, use self-contained service and supply bases, including workforce accommodations
- undertake regional monitoring and enforcement of ballast water management

9.3.1.6 Logistical and Administrative Facilities

The potential development and use of logistical and administrative facilities could adversely affect Cultural Vitality through an increased presence of resident non-Inuvialuit workers and possibly living in work camps away from home. These facilities could also contribute to increases in light pollution and possible disturbance or destruction of Coastal Habitat. Suggested mitigation measures focus primarily on Human VCs, and include:

- use TLK in design, planning, construction, and operations of buildings and other project components
- combine new infrastructure developments with efforts to address current housing shortages in the ISR
- provide ownership and investment opportunities for Inuvialuit such as infrastructure, service and supplies businesses, transportation businesses and equipment supply
- design, build, and maintain climate change resilient infrastructure
- monitor effects of industrial and other activities on infrastructure and services as part of broader socio-economic monitoring and use information to support decision-making systems for existing mitigation measures, future projects and co-management processes
- provide health and counselling services to Inuvialuit and other workers within project work camps
- implement provisions for country food in project work camps, including allowing Indigenous employees to bring their own traditional foods to project facilities and camps, and providing appropriate storage and cooking facilities in the project camp to prepare traditional foods for Indigenous workers

9.3.1.7 Mitigation and Management of Socio-cultural and Economic Effects

General mitigation measures and management approaches that would help reduce socio-cultural and economic effects and improve benefit for communities throughout the ISR, independent of the development scenario, include:

- allow flexible working shifts for Inuvialuit employees, such that participation in culturally valued traditional and cultural activities can continue (e.g., Inuvialuit Games, cultural celebrations, trips to seasonal harvesting camps)
- use cultural advisers to provide support for Inuvialuit employees, including cross-cultural training of non-local workers and contractors

- increase the number of opportunities to use Inuvialuktun and other Indigenous language in the workplace (e.g., use of Inuvialuktun on signage and in training materials and courses; cross-cultural training for non-local workers). This also could involve language preservation and terminology workshops, development of technical dictionaries, and ongoing initiatives to identify needs for Inuvialuktun words or phrases for new technical terms.
- manage hunting and fishing activities by non-local workers while on work rotations in the North
- allocate some of the financial benefits of development to fund Inuvialuit culture and language programs in local communities and schools.
- for specific projects, develop a benefits plan with the IRC, including commitments for employment, training, and education of Inuvialuit, as well as use of local services and suppliers (note that under the IFA and federal law, benefits plans are required for major projects)
- implement supplier development initiatives to help local businesses prepare to support potential industrial activities
- provide funding to address the indirect effects of a project on community services, including increased demand for childcare and Elder care that result from the increased employment of ISR residents
- provide lifestyle, diet, and money management counselling to workers and their families in both Inuvialuktun and English
- develop and implement health and medical response plans that include prevention, control, and management of communicable disease outbreaks; provision of medical services and infrastructure; and medical evacuation protocols

9.3.2 Adaptive Integrated Management Framework

The State of Knowledge presented in Chapter 7 and the detailed effects described in Appendix D illustrate the interconnectedness of the physical, biological and human environment in the BRSEA Study Area. The assessment and description of the effects of climate change through this report and in Appendix C make it clear that this interconnected system is changing and that these changes often reflect multiple causes. Systems with such characteristics are called complex adaptive socio-ecological systems (Levin and Möllmann 2015, Milkoreit et al 2016), and from a system understanding and management perspective, this means that not all the individual interactions between the system components are known or can be predicted with high degrees of certainty. As a result, a management approach is needed that can address the interplay between societal choices and the associated social and ecological cumulative impacts and integrate processes to address uncertainties while still meeting established environmental management goals. An Adaptive Integrated Management Framework is such an approach. It aims to address the interplay between societal choices and the associated social and ecological cumulative impacts, allowing for the integration of uncertainty and robust decision making to reduce undesirable outcomes while evaluating complex situations involving short-term and long-term environmental, ecological, economic, and technological changes. As such, it includes targeted research on, and monitoring of, key physical, biological, socio-economic and cultural parameters linked to specific questions and needs, accompanied by a management decision framework.

Managing complex adaptive systems is ultimately not about managing the ecological system (e.g., fisheries ecosystem-based management; Levin and Möllmann 2015), or even one component of it (e.g., caribou), but about managing the human interactions with the ecological system. In this section we discuss development and implementation of an AIMF, which has the following seven principal elements:

1. goals
2. governance
3. indicators
4. limits and thresholds
5. monitoring
6. actions
7. evaluations

9.3.2.1 Goals

As the Inuvialuit Final Agreement (IFA) already provides the fundamental guiding principles and regulatory mandates, the Inuvialuit are well positioned to implement an AIMF which reflects the most important values and goals of the Inuvialuit people. The mandates of the ISR's regulatory, management and advisory bodies implicitly or explicitly provide additional goals. The main goals currently defined within the existing regulatory and management system of the ISR can be grouped and listed as follows:

Socio-cultural

1. preserve Inuvialuit cultural identity and values within a changing northern society
2. conduct sustainable terrestrial wildlife, fish, and marine mammal harvests

Economic

3. enable Inuvialuit to be equal and meaningful participants in the northern and national economy and society
4. confirm that approved projects have liability for clearly stated compensation responsibilities associated with a worst-case scenario

Ecological

5. maintain sustainable arctic terrestrial wildlife, fish and marine mammal populations, including the quality of their habitats to support such sustainability
6. approve only development projects that during normal operations will not have a significant negative impact on Inuvialuit cultural identity, the environment, wildlife, wildlife productivity, or harvesting; where significant is defined as threatening one or more of goals 1-3, and 5
7. keep within the recommended levels of development activities established for each community's area within the ISR communities

There are many specific goals that are or could be articulated under each of these or in addition to these main goals; additional specific goals should be established and agreed upon cooperatively within the existing institutional framework. The importance of setting clear, concise, and achievable goals and associated actions cannot be overstated. They present the guide from which everything else flows (e.g., causes of change, effect pathways, indicators, thresholds, monitoring, management actions). Their evaluation and regular re-evaluation is key as the environment and the level of human activity changes over time. For example, a goal that aims to maintain a certain level of harvest may, at some point in the future, be at odds with meaningful participation in the northern and national economy for which disposable income is used as an indicator for monitoring. This may be because climate change has already reduced the abundance and distribution patterns for species of interest and harvest goals need to be adjusted to this new reality and therefore reprioritized vis-à-vis the goals of economic benefits and participation, which in turn may alter the associated indicators and monitoring efforts. Notice that the objective is not to measure whether the goals are being met, because except for perhaps goal 3 and 7, they are not end points, but fluctuating states in a complex system whose quantitative properties change and differ over time and in space.

The point is that the goals set for ISR in the IFA, like future goals, have complex social-ecological and economic dynamics and drivers whose underlying forces and rules are constantly changing. As a result, these goals should be periodically re-examined- so that they remain clear, concise, achievable, and current as the environmental and socio-economic conditions change over time.

9.3.2.2 Governance

To implement such a framework and adaptively manage the stated goals from the IFA, there would be value under the BRSEA to identify to what degree the ISR regulatory and management system already meets the following four key adaptive governance principles (Serrao-Neumann et al. 2016):

- *"connectivity*: the institutional ability to undertake timely and coordinated action across multiple scales and ensure timely information about feedbacks occurring within human-nature systems to avoid surprises
- *adaptability*: the ability of governance structures to deal with change and reorganize if considered beneficial or necessary
- *reflexivity*: the presence of governance arrangements encompassing abilities for awareness, deep reflection and recursive responsiveness to changing conditions that enables learning, new knowledge and feedback signals to be incorporated into adaptive management action
- *transformability*: the potential for the governance regime to navigate a shift to a new system direction when the existing system becomes untenable"

Further, adaptive governance should combine these four principles with traditional principles of good governance, including *legitimacy, accountability, transparency, fairness, and inclusiveness* (Lockwood et al 2010).

Once evaluated, the current system could be validated or amended, as applicable, so that there is confidence in the key mechanisms that make the overall framework successful.

9.3.2.3 Indicators

Goals set, the next task is to establish a meaningful way to discern whether natural or anthropogenic factors are threatening those goals, and if management actions and decision making are having the desired effects. This is generally done through the use of indicators.

In relation to policy-making and resource management, environmental indicators are generally used for three major purposes:

- supply information on environmental problems so that policy-makers can evaluate if some action needs to be taken (see *Actions* below)
- identify key factors that cause pressure on the environment for which we may have some decision-making power
- monitor the effects of policy responses (Smeets and Weterings 1999)

In the context of environmental assessments, the term Valued Components is sometimes used interchangeably with indicators, the idea that Valued Components, or some aspect of the VC (for example a specific species of marine mammal) are the indicator with which we evaluate a potential impact. Although this is how the term indicators is used in Chapter 7 and Appendix D, here we make the distinction that indicators from an adaptive management perspective ideally are actual variables that can be measured (e.g., the indicator is the population size rather than an individual species).

From an environmental management perspective, there is a need for clear and specific information on driving forces, the resulting environmental pressures on the state of the environment, impacts resulting from changes in environmental quality and the societal response to these changes in the environment (Smeets and Weterings 1999). This relationship is implicit in the effects assessment presented in this report and has been formalized with the Driver-Pressure-State-Impact-Response (DPSIR) framework (Figure 9-1), where indicators may be needed or can be defined for all these components and their relationships (arrows in Figure 9-1).

Indicators can be classified into four simple categories (Smeets and Weterings 1999), each aiming to answer a question:

- *descriptive*: what is happening to the environment and to humans?
- *performance*: does it matter?
- *efficiency*: are we improving?
- *total welfare*: are we on the whole better off?

Indicators in each of the categories should be chosen to span a wide range of processes (with different associated rates), biological groups, and indicator types (“tactical” and “strategic,” “early warning,” and “integrated system state”) (Fulton et al 2005).

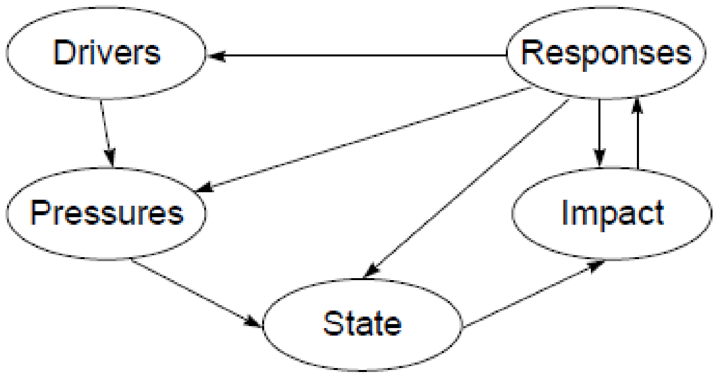


Figure 9-1 The DPSIR Framework for Analyzing and Reporting on Environmental Issues[53]

Dillon and Salmo (2005) interpreted the current ISR management goals and vision noting that indicators should reflect the strong linkage between environmental conditions and community well-being and should be selected to help integrate environmental and socio-economic assessment, resource management, economic development, social service provision, and cultural programs. Indeed, many social, ecological and environmental indicators have been suggested within the ISR or other northern regions, and are documented in previous reports, most notably in AXYS (2001), Dillon and Salmo (2005), and Antoniuk et al. (2009), and reflected in the data currently being collected (http://inuvialuitindicators.com/).

Although these indicators may be appropriate for a specific use, not all of them are clearly aligned to a management objective. For example, it may not always be understood what the indicators reflect in terms of states or dynamics within this social-ecological system and they may not easily be used to inform an action. As a result, not all the suggested indicators may be needed within this AIMF. However, the cumulative compilation of the indicators from these multiple studies is a comprehensive candidate list from which to evaluate and choose a small sub-set of indicators that fulfil key criteria within the categories and frameworks laid out above.

Indicator-based decision-making can give managers structured insight into the likely effects of alternative actions, which is essential in integrated management approaches. However, this is only true if the performance characteristics of the indicators are understood, and if their trends and current values relative to reference points can be interpreted correctly (Rice and Rochet 2005). There is also a compelling reason to formally screen and evaluate indicators following the criteria put forth by Rice and Rochet (2005). Initial screening criteria of indicators include: directly observable and based on well-defined theory, understandable to the general public, cost-effective to measure, supported by historical time series, sensitive and responsive to changes in ecosystem state (and management efforts), and responsive to properties they are intended to measure.

53 Initially developed by RIVM, National Institute of Public Health and Environment, Bilthoven, Netherlands as a recommendation to the European Environment Agency (EEA) on how to develop a strategy for Integrated Environmental Assessment.

Once a set of indicators that have passed these screening criteria have been chosen, they should be formally evaluated based on the following steps (the first two were already discussed above):

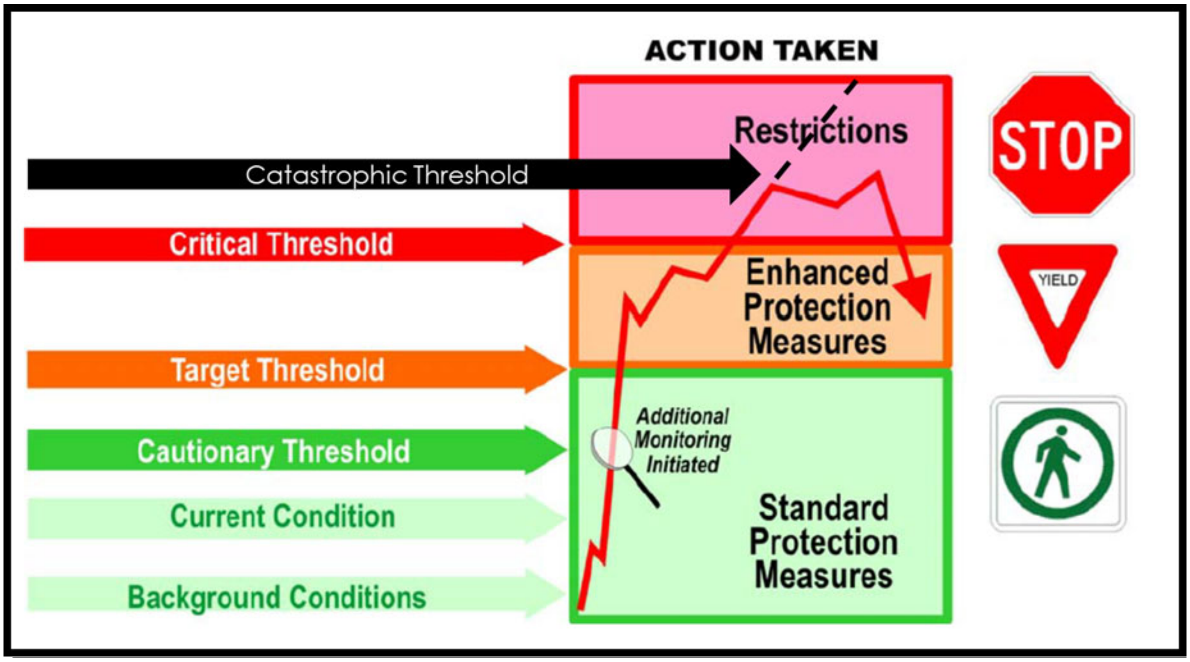
1. identify user groups and their needs, featuring the setting of operational objectives (goals)
2. identify a corresponding list of candidate indicators
3. assign weights to the screening criteria for the candidate indicators; should be done collaboratively with community members, stakeholders, scientists, and managers as it is key to help select the final suite of indicators
4. score the indicators against the screening criteria
5. summarize the scores by weights assigned to the screening criteria for each user group, as well as by scores for each candidate indicator for each criterion
6. decide how many indicators are needed based on the balance between wanting the fewest possible number of indicators to serve all uses, while having the key system components featured in the objectives covered
7. make a final selection of complementary suites of indicators
8. report on the suite of chosen indicators in a clear manner to users (community members, scientists, managers, regulatory agencies)

Steps 6 and 7 should be done interactively with community members, stakeholders, scientists, and managers. The process should be regularly re-evaluated as the underlying system changes, new management rules get implemented or Limits of Acceptable Change (LAC) are reached (see below).

Despite this robust evaluation process, the question of how to carry the information from the indicators into the overall decision-making process remains unless all the decision rules associated with each indicator require the same management response (see *Actions* below).

9.3.2.4 Limits and Thresholds

To be actionable, there must be some ecologically or socially defined value where an indicator changes to an unacceptable condition, triggering some level of management action. These values are often referred to as thresholds, which may be a quantitative threshold (e.g., in the mathematical sense of a non-linear response) or otherwise a value, limit or state at which some management response is required to not jeopardize established management goals. In simple systems such limits may be established through scientific experimentation and it is those well-informed values (i.e. LACs) that lead to air, water, or soil quality regulations for specific contaminants. However, in complex adaptive systems, limits and thresholds are more challenging to quantify and predict and thus the use of a series of signposts for the chosen indicators relative to each management goal is recommended; these signposts can be thought of as Tiered Action Thresholds, or TATs (Dillon and Salmo 2005; Figure 9-2).



SOURCE: adapted from Dillon and Salmo, 2005.

Figure 9-2 Example of a Tiered Action Threshold approach

Tiered thresholds have been recommended for fisheries management, resource management in the NWT, cumulative impact management in northeastern British Columbia and the Deh Cho territory, and activities in the Alberta oil sands. They have also been developed for marine and aquatic environment in Australia (Serrao-Neumann, 2016).

As with the goals above, TATs (and associated actions) should be arrived at and agreed on cooperatively by residents and managers and be based on regulatory mandates, TLK, scientific information, and the guiding principles, values, and goals of its people. This is a key element of adaptive frameworks since responses to, and perceptions of, change differ among individuals, communities, stakeholders, organizations, and cultures. Overall, this tiering process provides an opportunity to evaluate the management goal, the performance of the chosen indicator, and the action associated with reaching the tiered value, and thus forms an integral part of the AIMF. The use of TATs provides a buffer in the face of uncertainty given that the underlying system dynamics are continuously changing and there is often uncertainty whether the changes are being adequately captured or understood based on the data collected through established monitoring programs.

Four tiered action thresholds (adapted from Dillon and Salmo 2005) are suggested, listed in order of increasing risk of threatening the maintenance of management goals, and defined qualitatively as:

- *cautionary:* established to indicate the point at which some changes are occurring that require more intense monitoring to reduce uncertainty in the indicator values

- *target:* established to indicate the LAC
- *critical:* established to indicate the maximum continuous amount of stress the monitored system can sustain without long-term negative implications on the management goal
- *catastrophic:* established to indicate significant harm to the social-ecological system and define a worst-case scenario resulting in a potentially mid to long-term inability to meet the management goal

To implement this approach, each TAT needs to be quantitatively defined to the extent possible for each of the established indicators. One of the best approaches to determine whether a system of interest (be it social, economic, ecological or a combination thereof) is approaching a TAT can be to examine key processes involved in proper functioning and integrity of the system, rather than those that have a delayed response to disturbance effects (e.g. biodiversity) (Laurance et al. 2011). In natural systems, key observations of that system approaching a critical threshold can be a significant slowing of ecosystem dynamics evidenced as a slower recovery from disturbances, increased variance (e.g. in population counts or harvest success), and/or increased spatial auto-correlation (e.g. in spatial patterns of vegetation). However, none of the assessment of TATs is possible without an appropriate monitoring system for each indicator (e.g., as those suggested in Section 9.2).

9.3.2.5 Monitoring

Integrated adaptive management demands that key aspects (indicators) of human activities and the potentially affected environment are monitored across multiple temporal and spatial scales (Huntington et al. 2015b), and that managers learn from the consequences of their decisions and alter their decisions (or implement new decisions) and management practices accordingly (see *Actions* below).

The availability and maintenance of long-term data (i.e. availability of historical time series) for indicators is one of the criteria in the evaluation of suitable indicators. Long-term data are important for improved understanding (decreased uncertainty) and management of complicated ecological systems, including evaluating responses to climate change, providing baselines to evaluate change, and detecting and evaluating changes in ecosystem structure and function (Lindenmayer and Likens, 2009). Key to a useful indicator is not only its relationship to the defined goal, but also that the indicator is able to answer a tractable question vis-à-vis one or more of the established thresholds. This implies an *a priori* established rigorous statistical design by which the data are collected; otherwise a change or effect could be missed (false negative), natural variability and a directional change or effect may not be detected (non-conclusive result), or a change is an artifact of sampling rather than a true change or effect (false positive).

Part of the indicator evaluation process described in Section 9.3.2.3 speaks specifically to these monitoring fallacies, which can be avoided (i.e., the temporal and spatial scale of the question and the concomitant scales of the indicator and its drivers can be used to improve the validity of the monitoring program) (Rice and Rochet 2005).

As is the case for all other parts of this integrated adaptive management framework, the monitoring design should be re-evaluated in concert with the regular evaluation of the indicators and be modified if it is found that underlying forces, such as variability, vulnerability, and spatial and temporal scales have changed due to environmental or anthropogenic effects. The different TATs (cautionary, target, critical, catastrophic) will require separate monitoring plans as the type of changes leading up to them differ and pressures on the system increase cumulatively.

9.3.2.6 Actions

Regulatory agencies worldwide accept that there is a *de minimis* risk level below which no management or regulatory action is warranted (Felter et al. 2009). However, above that level, different levels of action may be required and need to be clearly defined. The definition of actions, sometimes also called decision-based rules, is arguably the second most important element of the adaptive framework after setting and evaluating goals. The reason for defining TATs is so that actions can be taken to avoid further increase in risk of not meeting the stated management goals (see Figure 9-2 above). These actions should be reviewed and agreed on by the communities, stakeholders, managers and policy makers within the ISR, and specified (i.e., the specific actions to be implemented) *a priori* so there is little delay in their implementation when a TAT is reached.

The following describes a sequential (in time) approach to pragmatic (in support of decision making) implementation of the TATs (adapted from Dillon and Salmo 2005):

- When **cautionary** TATs are reached, more intense monitoring is required to reduce uncertainty in the indicator values. No other management or mitigation actions may be required, but it should be confirmed that all human activities in the area are complying with established regulatory guidelines and best industry management practices.
- When **target** TATs are reached, enhanced management practices should be formally adopted to reduce risk and further increase understanding of the system. This may include expanded monitoring to provide additional environmental or social context to understand the observed change, initiation of applied research on the applicable topic, voluntary use of new 'best available technology', or the implementation of more restrictive regulations (e.g. reduce emission levels, reduce harvest levels, limit access to previously open areas).
- When **critical** TATs are reached, restrictive management practices are formally adopted to reduce risk. This may include required retrofitting of 'best available technology', cessation of certain activities, temporary or long-term closure of land use areas, implementation of buffer zones, or active restoration of damaged habitats, all of which can play vital roles in maintaining ecosystem viability (Laurance et al., 2011).
- When **catastrophic** TATs are reached, an emergency response (e.g. spill cleanup, evacuation) is needed, followed by new or established restrictive management measures to facilitate recovery of the affected system.

One important issue that needs to be resolved once the TATs and associated specific management and regulatory actions have been defined is conflicts between different actions. Step 6 in the indicator evaluation process (Section 9.3.2.3) points to an optimal number of indicators that balance the need between wanting the fewest possible number of indicators to serve all uses, while having all key system components in the management objectives covered. This will result in at least one, but typically more than one indicator per objective.

Whereas the decision rules and associated actions described above appear straight forward for each TAT once established, it is likely that some TATs needing attention at the same time could lead to suggested actions that are at conflict with each other. Conversely, there may be synergies across TATs, where one management action may affect the probability of achieving several objectives at once. A single or group of actions may cause new problems (e.g., area closures can cause redistribution of harvesting effort, affecting other previously untouched areas or species). Such conflicts should be envisioned in advance and a family of meta-rules developed to determine which management response is appropriate and takes precedence (Rice and Rochet 2005). Another possible strategy to help inform the resolution of such emergent inter-action conflicts is to build an overall risk profile across all indicators, and manage that combined risk, instead of each component.

9.3.2.7 Evaluations

An integral feature of the AIMF is the process of continuous evaluation of its elements, relationships, feedbacks, processes, and underlying assumptions. It is this continuous re-evaluation that makes the adaptive framework work. However, it is not intended that all elements must be re-evaluated all the time or all at the same time. Instead, the different elements and its controlling processes should be considered, and an appropriate regular evaluation schedule established. More frequent evaluation may be needed if there is a major unforeseen alteration to the system (e.g., a natural or man-made disaster).

In summary, the AIMF integrates key ecological, cultural and management principles whose implementation would capitalize on all the substantial work and monitoring to date, and progresses to an actionable tool that would help to adaptively safeguard the social-ecological integrity and values in the BRSEA Study Area in the face of inevitable future changes.

9.4 Planning, Preparedness and Response to a Large Oil Release

Effects of an accidental oil spill in the BRSEA Study Area on marine ecosystems, human uses and cultural vitality are of high concern to the Inuvialuit, other northern residents, government agencies and a broad range of public stakeholders in Canada and internationally. While an accidental large oil release may occur in association with offshore oil and gas activities, a similar event could result from a collision or accident involving large ocean-going vessels.

While a large oil release is a low probability event, rapid deployment of an initial local response to contain and remove released oil, followed by deployment and management of appropriate spill response tiers, is critical to the overall success for spill containment, oil removal, site cleanup and site restoration, as well as reducing and managing effects of released oil on the biophysical and human environment. The following discussion addresses a number of considerations for the BRSEA Study Area related to the command structure, the spill response organization, spill response planning, spill response preparedness, and adoption of new technology and tactics.

9.4.1 Command Structure

As discussed in Section 2.13.3, there are two critical components for a spill response operation:

- a Unified Command (UC) which provides overall leadership and direction on a response that is shared among several agencies or organisations. This approach allows for the involvement of local communities and residents in the leadership for the decision process.
- an Incident Command System (ICS) which provides a common hierarchy or organization within which the spill response can be delivered

The combination of a UC with the ICS allows each organization or agency to carry out their own responsibilities while working cooperatively within a single leadership system. Although the ICS is used to organize and deliver oil spill response in Canada, the UC tends to be less prescriptive and formal than in in the United States[54] (E. Owens 2019, pers. comm.).

Because vessel operations and other offshore industrial activities (e.g., installation of wind turbines, dredging) in the BRSEA Study Area present a risk for spills and may require emergency response capabilities, and there is a high likelihood that these activities will increase with longer and more extensive open water conditions, there is an immediate need to establish a strong and effective response system for the region, regardless of how the oil and gas industry proceeds in the BRSEA Study Area. Based on the experience from the US in developing a fully-functioning UC/ICS management system, it is expected that it could take more than 5 years to establish a similar capability in the ISR.

It should be noted that through previous and current planning processes, training and drills, the major oil and gas proponents are well versed and experienced in UC/ICS, whereas some vessel owners (e.g., cruise ships, other commercial vessels) and other industrial operators may not be. As a result, the learning curve for the latter groups will be greater than for oil and gas operators.

A UC/ICS structure could be considered for the marine areas of the ISR to respond to a variety of marine spill incidents, including vessel collisions and incidents, icebreaker incidents, oil and gas releases, and other industrial releases in shoreline, nearshore, moderate and deep water environments over the full cycle of seasonal conditions.

A government agency working group should lead this initiative[55]. Members might include Transport Canada and the Canadian Energy Regulator (the current regulators for ship-based and offshore oil and gas related spills), in collaboration with the IRC, and the GNWT, Yukon and Nunavut governments.

[54] The US Oil Pollution Act of 1990 mandated that a UC/ICS system be standard practice for oil spill response; effective implementation of a UC/ICS organization requires considerable planning and training.

[55] This working group could be similar to the existing Northwest Territories/Nunavut Spills Working Group.

9.4.2 Oil Spill Response Organizations

The current response capability for spills associated with offshore oil and gas exploration and marine spills from vessels is ~ 1,000 tonnes of oil in total (Section 3.10.5.3). A certified oil spill response organization should be considered for the BRSEA Study Area which can provide a minimum of a 10,000 tonne capability for a marine Tier 1 response using pre-positioned equipment at one or more sites within the ISR. The government agency working group should lead this initiative.

Inuvialuit organizations and communities should be engaged in the planning of the spill response organization and spill responses plans. They also should be directly involved in spill preparedness, including establishment and maintenance of equipment caches, ongoing training, and regular participation in spill response drills. The Inuvialuit also should be provided with opportunities for possible ownership of the spill response organization. Regional organizations such as the Mackenzie Delta Spill Response Corporation, Canadian Rangers, and Canadian Coast Guard Auxiliary might also be involved.

9.4.3 Spill Response Planning

As discussed in Section 2.13.2, spill response planning in the Beaufort Region should include:

- development of a regional plan for long-term preparedness, management and operational spill response, including development of specific management, operational and training plans to complement the regional plan
- implementation of the plans based on existing needs and risks

The needs for emergency and spill response capabilities should be re-assessed on a regular basis (e.g., annually) by the government agency working group to determine if new or modified proposed projects and activities are likely in the region and/or if climate change has resulted in substantial shifts in physical and seasonal conditions that require modification of the existing plans. Advances in technology (e.g., remote sensing, spill response methods; Section 9.4.5) also should be regularly evaluated for consideration in the regional plan. Appropriate modifications or additions of new programs and best available technology should then be incorporated into the regional spill response plan to ensure a sustained capability with continuous improvement.

9.4.4 Spill Response Preparedness

In conjunction with the preparation and finalization of a regional spill response plan for the BRSEA Study Area, the government agency working group should identify priorities for spill preparedness in the BRSEA Study Area; these might include:

- identification or development of infrastructure to support the spill response operations, including a command centre or centres, communication services, one or more logistical bases, marine facilities and ports, aircraft facilities, equipment stores and maintenance
- acquisition and commissioning of equipment and resources

- identification of local first responders in each Inuvialuit community and regular training of these individuals as first responders
- conduct of exercises in spill response that bring together the local first responders with a designated Response Organization (RO), as well as various federal and territorial agencies. Oil and gas companies that own ELs or SDLs in the Canadian Beaufort Sea might also be invited to participate.
- equipment maintenance

Auditing procedures should eventually be put in place to regularly assess that adequate human and equipment capacity and capability is in place and is maintained.

9.4.5 New Technology and Tactics for Spill Response

As described in Section 2.13 and Section 3.10.5.3, technologies and tactics for offshore oil spill response and cleanup are advancing rapidly, including measures for response in arctic conditions and, of note, transitional ice periods. To stay abreast of advances that are applicable to the BRSEA Study Area, the government agency working group should actively track research and development in two specific areas:

- spill response equipment and tactics (in both marine and shoreline environments)
- decision support tools

9.4.5.1 Spill Response Equipment and Tactics

Areas of current high potential for improved response capability and capacity in remote marine areas and during the ice transition seasons include:

- use of fixed wing and rotary-wing herding/burning strategies (i.e., aerial application of herders using aircraft followed by in-situ burning methods)
- remotely-operated, aerially-deployed, ice-strengthened surface water vehicles (Unmanned Surface Vehicles that are similar to jet skis) to safely deliver herders, ignition systems, and dispersants to remote marine areas in open water or during the ice transition seasons
- collection of command-and-control data by Unmanned Aerial Systems (UASs) and other remote sensing methods
- use of Oil Detection Canines for detection and delineation of oil in and under ice/snow (an important gap in current technology and tactics)

9.4.5.2 Decision Support Tools

Decision-support tools for spill responses are vital in assisting the Unified Command in assessing spill conditions and evaluating preferred options for spill response. Decision-support tools that might be considered for the BRSEA Study Area include:

- the "Oiled Shoreline Response Program (SRP) Decision Support Tool for Canadian Marine Coastal Environments" currently being developed by Concordia University includes coverage for the Resolute area in Nunavut (Owens et al. 2020) and could be extended to the Beaufort Sea Region
- development of a Response Viability Analysis (RVA) tool that is specific to the Canadian Beaufort Sea region (EPPR 2017). The RVA is intended to quantify the windows of opportunities for oil spill response (e.g., percentage of time that marine conditions might be favorable, marginal, or not favorable for defined oil spill response systems).
- the Beaufort Regional Coastal Sensitivity Atlas (Environment Canada 2015)
- multi-factorial quantitative assessment of the physical, biological, ecological and socio-cultural values for each microhabitat

To support the selection of decision-support tools, a comparison of existing marine decision-support and operating systems could be undertaken (e.g., comparison of systems currently used by Alaska, the Norwegian Barents Sea, North Sea, and the Canadian East Coast). Such an undertaking could provide a range of options and approaches to inform development of marine decision-support tools and an operating systems for the BRSEA Study Area.

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APPENDIX A

Terms of Reference: Beaufort Region Strategic Environmental Assessment (BRSEA), Synthesis and Report Package

SECTION II
TERMS OF REFERENCE

1. PROJECT IDENTIFICATION

Project Title:	**Beaufort Region Strategic Environmental Assessment (BRSEA), Synthesis and Report Package**
Location:	**Inuvik**
Issuer:	**Inuvialuit Regional Corporation**

2. BACKGROUND

The Beaufort Regional Strategic Environmental Assessment (BRSEA) is a multi-stakeholder undertaking that aims to promote engagement, education, monitoring, and research projects in the Western Arctic to support informed decision-making around possible future resource development and management, environmental conservation programs, community sustainable and subsistence activities, and other complementary commercial activities. The BRSEA is led by two (2) parties: the Inuvialuit (represented by the Inuvialuit Regional Corporation and the Inuvialuit Game Council) and Canada (represented by Crown-Indigenous Relations and Northern Affairs Canada). Project support to the BRSEA is jointly provided by IRC for the Inuvialuit Settlement Region and by the Northern Affairs Organization of CIRNAC.

To support the Government's commitment to a clean environment and a strong economy, decisions around potential resource development and conservation plans involve balancing risks and benefits at project-specific, regional and national scales. Government, Indigenous communities, industry and local stakeholders have an interest in understanding and assessing the balance of potential development and conservation scenarios. In particular, the detection, management and monitoring of cumulative effects of resource development is at the interface of project-specific and regional concerns and is often raised as a priority by all stakeholders.

The delicate nature of the Arctic ecosystem and the unique logistical and scientific challenges associated with potential offshore oil and gas activities were key considerations in prohibiting the issuance of new offshore oil and gas licences of all Arctic Canadian waters. This prohibition allows time for the risks and benefits of potential oil and gas activities in the Beaufort Sea to be assessed ahead of review of the 5-year review decision (in 2021).

The purpose of the Beaufort Regional Strategic Environmental Assessment (BRSEA) is to assess the potential effects, including cumulative effects, on the human and environmental systems of the Beaufort Sea Region as monitored through the Valued Ecosystem Components, of alternative strategic initiatives, plans or programs (collectively "Scenarios"), associated with potential offshore oil and gas activities in the Beaufort Sea Region. This assessment is therefore, not simply expanding the scope of the spatial and temporal boundaries of a particular project, rather, it encompasses a comprehensive examination of the interrelationships between the environment, social, cultural and economic conditions, the traditional use and wildlife harvesting of natural resources and decision-making by Inuvialuit, regulatory and planning authorities. The outputs of the BRSEA do not represent decisions, but rather the results of a systematic evaluation of options such that a strategic direction can be identified, and informed regional policies, plans, programs and project development decision can be made.

This requirement is for a Contractor to support the BRSEA through the development and delivery of an Assessment, Synthesis and Report Package for the Strategic Environmental Assessment for the Beaufort Sea Region. Leveraging knowledge gathered and studies completed to date and on-going, the Contractor's work will take into account the various Valued Ecosystem Components of the Beaufort Sea Area, with respect to Local Traditional Knowledge (LTK), biophysical, environmental, socio, cultural, subsistence economy and economic impacts and benefits, as further detailed in section 4. Scope, below, and will require subject matter expertise in a number of disciplines aligned to the Valued Ecosystem Components as further detailed in section 5. Disciplines below. The Contractor will provide the knowledgeable and coordinated project management function, oversight and quality assurance of the delivery of its services together with the services of a complement of recognized and competent subject matter experts required to finalize the Assessment and develop the Report Package for the BRSEA to be delivered to the Inuvialuit Regional Corporation (IRC), Inuvialuit Game Council (IGC) and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) [together the "Co-Chairs" of the BRSEA] for review with Regional stakeholders. The completed BRSEA Report Package will also form part of the Prime Minister announced science-based review, taking into account marine and climate change science that will inform future decisions on offshore Arctic oil and gas.

This Terms of Reference sets out the required scope of work, options, required input information, deadlines, and deliverables for each phase of the work. *[Note to Proponents: Proponents are requested to specify in their Proposal the specific methodology and work plan for the conduct of the work, including proposed work schedules, milestones, review, reporting and communications structure. The final work plan, schedule, milestones, review, reporting and communications structure will be subject to negotiation between the IRC and the successful Proponent prior to execution of any contract and will form part of any resulting contract.]*

3. OBJECTIVES

The Contractor's work shall support the BRSEA in achievement of the following:

- Leveraging the considerable body of knowledge gathered and work undertaken to date within the Beaufort Region and ensuring the appropriate consideration of Traditional Local Knowledge (TLK), and "Western"/scientific knowledge, on behalf of and working in close collaboration with the Co-Chairs, analyze and synthesize quantitative and qualitative data and findings, to compile and build-out the Regional Strategic Environmental Assessment Report and associated knowledge transfer and engagement materials ("the Report Package") for the Beaufort Sea Region.
- Employing an established and rigorous methodology for Strategic Environmental Assessment, that will contribute to preserving Inuvialuit cultural identity and values, enable Inuvialuit to be equal and meaningful participants in the northern and national economy and society, and to protect and

preserve Arctic wildlife, environment and biological productivity while guiding future development, based on the best available knowledge of environmental (human and natural) thresholds and limits.

- Ensuring the Report Package provides a comprehensive examination of the interrelationships between the environment, social, cultural and economic conditions, the traditional use and wildlife harvesting of natural resources and decision-making by Inuvialuit, and regulatory and planning authorities for all “Valued Ecosystem Components” (as further defined in section 5 below).
- Providing a completed BRSEA Report Package (comprised of a comprehensive BRSEA Final Report, addressing all topics identified in the Report Table of Contents as affirmed by the Co-Chairs – see Appendix A for a draft Table of Contents; a summary of findings; a plain language synthesis report suitable for distribution within the ISR; and presentation materials suitable for use by Co-Chairs in presentation to Regional stakeholders). The completed BRSEA Report Package shall be suitable to inform Regional participants, the public in the Beaufort Region, as well as to inform the Prime Minister’s announced science-based review.
- Ensuring the completed BRSEA Report Package includes the following outcomes:
  - recommends desired economic and environmental outcomes and thresholds for offshore oil and gas development in the Beaufort Region while respecting the Inuvialuit Final Agreement and relevant regulatory processes;
  - advances the baseline understanding of the state of knowledge around the Beaufort Sea; and
  - supports informed decision-making around possible future resource development and management, environmental conservation programs, community sustainable and subsistence activities, and other complementary commercial activities; ensuring Indigenous knowledge, local/community knowledge and western science will be utilized and included equally whenever possible.

4. SCOPE OF WORK

The work will be conducted in six (6) phases from Award to March 31, 2020, as detailed below.

The Contractor shall deliver the following services and outputs on a milestone basis, in accordance with the Work Plan as proposed by the Contractor within its Proposal and refined with the Co-Chairs during Phase 1 below. The Contractor shall ensure its work methods provide for effective and iterative presentation and validation of concepts, draft and updated component documentation for each Valued Ecosystem Component as well as for the overall components of the BRSEA Report Package with the Co-Chairs.

Phase 1 - Work Plan Finalization

Within **two (2) weeks of Contract Award**, the Contractor shall meet with the Co-Chairs to review the preliminary Work Plan provided in its Proposal, including any proposed adjustments to the BRSEA Report Table of Contents (see Appendix A to this Terms of Reference) and the Contractor’s proposed source list (see Appendix B to this Terms of Reference for a preliminary listing), work methodology, activities, effort, milestones and schedule; to present ideas, gather feedback and changes from the Co-Chairs in order to refine and confirm a finalized Work Plan for the conduct of the Work.

In accordance with the feedback received from the Co-Chairs, **within two (2) weeks following the meeting with the Co-Chairs** the Contractor shall deliver for review and approval, a finalized Work Plan including an updated methodology and approach, updated description of any data collection instruments (if required), updated detailed BRSEA Report Table of Contents, confirmed source list and annotated bibliography for use in the conduct of the Work. The Contractor's updated Work Plan shall include finalized dates for completion of each activity and deliverable/sub-deliverable and a detailed meeting and reporting schedule.

Phase 2 – Background Assessment and Synthesis

Upon written approval from the Co-Chairs, the Contractor shall implement its Work Plan.

The Contractor shall undertake a review, analysis and synthesis of the relevant and available background information and data pertaining to the Beaufort Sea Region, including consideration of related work previously undertaken in the Region such as, but not necessarily limited to, the foundational studies and background information identified in Appendix B attached to this Terms of Reference.

The Contractor shall review the studies and literature confirmed by the Co-Chairs to be used in the Work with respect to the BRSEA, analyze the state of knowledge, and identify any gaps.

This shall include, identification, in collaboration with the Co-Chairs, the baseline knowledge, ecological thresholds (including the basis for establishment of these thresholds, e.g. nature of impact, magnitude, probability, temporal and/or spatial extent, reversibility, etc.), management limits and maximum limits for each of the Valued Ecosystem Components together with targets for each of the Valued Ecosystem Components.

Phase 3 – Development of Components for Draft Report

The Contractor shall work collaboratively with the Co-Chairs in review and refinement of the Contractor's Work. The Contractor shall ensure that it presents each component of the draft Report to the Co-Chairs in iterative phases, including an initial presentation of the component's proposed concept, gathering of feedback from the Co-Chairs, followed by the Contractor's refinement and development of the draft Report component, gathering of feedback from the Co-Chairs, and update to the Report component, and review of the updated/refined draft Report component for approval and use in the compiled Draft Beaufort Region Strategic Environmental Assessment (BRSEA) Report.

Working in collaboration with the Co-Chairs, the Contractor shall:

- **Synthesize data and findings from BRSEA activities** completed to date and those on-going over the term of the Contract (as agreed upon by the Co-Chairs) for integration into the BRSEA Draft and Final Report. This shall include identification of the drivers of change in the Beaufort Region, including changes in policy directions and management approaches, external and natural drivers of change;

and development of change metrics for the BRSEA.

- **Establish and document a TLK Framework** which shall highlight the method of Traditional Knowledge inclusion within the cumulative effects and Scenario portions of the Assessment. This document shall provide methodology and guidelines specifically associated with data types and themes provided by IRC.

- Based on the synthesis of data and findings and using the TLK Framework, **identify and develop**, in collaboration with the Co-Chairs, **strategic alternative Scenarios** for offshore oil and gas development activities in the Beaufort Large Ocean Management Area and ways to proceed vis-à-vis development and conservation in the Beaufort Region (collectively, the "Scenarios"). The Scenarios shall provide clear, focused descriptions of the plausible projected development futures and the associated co-evolutionary pathways of combined human and environmental systems. The Scenarios shall be based on community and ISR organization perspectives on offshore oil and gas development and other activities in the Region; ensuring each Scenario fully considers community and Inuvialuit perspectives.
    - This Work shall include identification and description of, at a minimum, five (5) Scenarios:
        - one (1) establishing the status quo – conservation or "the baseline Scenario";
        - at a minimum, three (3) Scenarios of varying levels of development activity – 'low', 'medium' and 'high'; and
        - one (1) 'worst case Scenario', or most severe potential outcome that can reasonably be projected.

- **Construct the Scenarios** of what each Scenario would consist of in the Regional environment relative to each and all Valued Ecosystem Components, while accounting for the influence of external policies/regulations, actions and natural changes.
    - The **Valued Ecosystem Components** are as identified in the Report Table of Contents, and include:
        - Physical
            - Weather and climate
            - Air quality
            - Water quality
            - Oceanography
            - Ice conditions
            - Icebergs, drift and distribution
            - Coastal dynamics and sea floor geology
        - Biological
            - Lower trophic level
            - Fish and fish habitat
            - Sea birds
            - Marine mammals
            - Migratory Birds
            - Invasive Species
            - Caribou
        - Human
            - Demographics

- Cultural Vitality
- Subsistence activities
- Sociocultural systems
- Economy
- Public health
- Infrastructure

- **Identify the cumulative effects for each Scenario** by identifying potential effects on, threats to, or changes under each Scenario for each and all Valued Ecosystem Components.

- Provide analysis and advice to support the Co-Chairs in their **identification of the anticipated preferred strategic Scenario** based on, but not limited to, community and ISR organization perspectives on: implications for sustainability of the Regional environment, potential to exacerbate, improve, or forge new Regional cumulative impacts or impact pathways, distributional consequences of change under the Scenario with regard to the effects on each and all Valued Ecosystem Components, and consistency and compatibility with policy and regulations.

- Based on community and ISR organization perspectives on offshore oil and gas development and other activities in the Region, provide analysis and advice to **identify and develop mitigation needs and management actions**; to enable the Co-Chairs to come to a final decision on the preferred strategic Scenario.

- Informed by the identification of the preferred strategic Scenario, and in consideration of community and ISR organization perspectives **develop a follow-up and TLK, science-research and monitoring program**, including post decision effect monitoring, performance evaluation of the implementation of the preferred strategic Scenario and its associated mitigation and management actions, and reporting of the monitoring results and of the preferred strategic Scenario's performance. This shall include sustainable, reusable and evolutive tools to ensure that data collected and analysis methods remain relevant and usable over time; applicable as conditions change over time.

Phase 4 – BRSEA Draft Report

Incorporating each of the above components, as conceptually validated, reviewed in draft(s) and finalized in consideration of the Co-Chairs input and decisions, the Contractor shall collate and deliver an integrated version of the BRSEA draft Report. The BRSEA draft Report shall be delivered **at least four (4) months prior to contract completion** (i.e. no later than November 30, 2019) for review and comment by the Co-Chairs.

The Contractor shall review the BRSEA draft Report with the Co-Chairs to gather feedback and revisions using the same iterative approach as in the development of the Report components. (e.g., initial review by Co-Chairs, gather feedback, revise).

Phase 5 – BRSEA Final Report

Incorporating the feedback received in Phase 4, the Contractor shall provide the BRSEA final Report – to be delivered **one (1) month prior to contract completion** (i.e. no later than February 28, 2020).

Phase 6 – BRSEA Final Report Package - Knowledge Transfer Materials

Based on the Final Report, the Contractor shall develop and provide material to assist the Co-Chairs with communications, engagement and knowledge transfer on the BRSEA Report Package, collectively the "Knowledge Transfer Materials", including:

- A BRSEA summary of findings;
- A plain language synthesis report suitable for distribution within the ISR; and
- Presentation materials (e.g. presentation decks, fact sheets, etc.) suitable for use by the Co-Chairs in presentation to Regional stakeholders.

The Contractor shall review the Final Report Package Knowledge Transfer Materials with the Co-Chairs, and incorporate their feedback and comments, and re-submit in final form, to be delivered **prior to contract completion**, and no later than March 31, 2020.

5. REQUIRED DISCIPLINES

In delivering the Services, the Contractor shall provide the requisite subject matter expertise in the Streams and disciplines identified below to ensure the BRSEA incorporates Traditional Local Knowledge, available scientific information and public feedback; and to ensure the knowledgeable analysis and incorporation of the required content for all Value Ecosystem Components into the final BRSEA Report Package.

The Contractor shall provide and manage the Services of an integrated and multi-disciplinary team of qualified Resources that overall shall address the following discipline subject matters at the level of experience and expertise required to complete the work. Each discipline may be addressed by one (1) or more persons, and one (1) person may fulfill multiple roles/disciplines; depending upon their background and experience. In addition, the Contractor shall provide overall project management and quality assurance of the delivery of the Work, to ensure an integrated and cohesive outcome for the project.

Stream #1 – Project Management:

- Project Management;
- Quality Assurance;

Stream #2 - Traditional Local Knowledge (experience working with Traditional Local Knowledge, including local natural resource knowledge):

- Socio, cultural, subsistence economy and economic;
- Biophysical environment;

Stream #3 – Socio, cultural, subsistence economy and economic disciplines – "Western"/scientific knowledge (including experience working with complex scientific data, large data systems, identification of patterns or trends and modelling):

- Socio-Cultural:
    - Cultural vitality, infrastructure, food security, ability to harvest, education;
- Indicator development and analysis, socio-economic impacts and benefits and analysis, including:

- Economic Measures;
- Economic Impact/Potential (e.g., Tourism, Labour, Commercial, Tradition, Manufacturing, etc.);
- Statistics;

***Stream #4 – Biophysical and environmental disciplines* - Scientific Knowledge** (including experience working with complex scientific data, large data systems, identification of patterns or trends and modelling):

- Marine Biology;
- Ecology;
- Sea ice and Oceanography;
- Coastal dynamic and sea floor geology;
- Contaminants;
- Climate Change Modelling;
- Oil and Gas Industry (Understanding of risks and safety with respect to Oil and Gas, experience in the Oil and Gas sector including working with industry participants);
- Indicator development and analysis for biological systems, air, water and terrestrial quality, socio-economic impacts and benefit and analysis; and
- Cumulative impacts and environmental interactions.

6. REPORTING AND PROJECT MANAGEMENT

For the matters pertaining to the content of the Work and deliverables, the Contractor shall report to the Co-Chairs for the duration of the contract, as set out in the Contractor's Work Plan and approved by the Co-Chairs.

This shall include, at a minimum:

- Bi-weekly reports, in writing, on the subject contents of the Contractor's work and findings – in a format suitable for sharing with other members of the BRSEA (e.g. technical working papers, etc. to provide informative updates on the content of the Work and associated next steps);
- Bi-weekly Progress/Project Management updates, providing the status of the Contractor's deliverables (including percentage completed, cost to date, time and budget status).

For matters pertaining to the administration of the contract, the Contractor shall report to the IRC Contact as identified in the Form of Agreement.

7. LOCATION OF WORK AND TRAVEL

It is anticipated that the majority of the work will be undertaken at the Contractor's place of business and delivered to the Co-Chairs via electronic means.

The Contractor shall meet in person with the Co-Chairs in Inuvik to undertake:

- a Kick-off meeting and review of the Contractor's methodology and Work Plan at the commencement of Phase 1;
- comprehensive review and gathering of feedback on the Contractor's Draft BRSEA Report in

Phase 4; and

- formal presentation of the Final Report to and review of the draft Final Report Package Knowledge Transfer Materials with the Co-Chairs at the conclusion of Phase / commencement of Phase 6.

The reasonable and actual cost associated with the Contractor's / Resources' travel to participate in the above three (3) meetings shall be reimbursed, in accordance with the Travel Directive (https://www.njc-cnm.gc.ca/directive/d10/en), subject to the provision of receipts. The Contractor shall confirm its provided estimates for eligible travel expenses with the IRC prior to undertaking any travel.

Other meetings may take place virtually (e.g. by teleconference, web presence) or in person, at the Co-Chairs' discretion. In the review of the Contractor's preliminary Work Plan in Phase 1, the Contractor shall confirm with the Co-Chairs any additional in-person meetings and travel requirements, beyond the above three (3) meetings, as contained within the Contractor's Proposal. In-person meetings where travel is required and authorized by the Co-Chairs will be reimbursed, in accordance with the Travel Directive (https://www.njc-cnm.gc.ca/directive/d10/en) as set out above.

Except as expressly set out in the Contractor's Work Plan as approved by the Co-Chairs, the Contractor is responsible for all costs related to its own and its deployed Resources' personal expenses, including the cost of travel between their place of business and the Co-Chairs' facilities, regardless of the location of the Resources conducting the work. No other expenses will be reimbursed for any required travel.

8. METHODOLOGICAL CONSIDERATIONS

In synthesizing and developing the Report Package Components the Contractor shall follow:

- the BRSEA Draft Table of Contents, as detailed in Appendix A and with any revisions as confirmed with the Co-Chairs in Phase 1;
- the Contractor's methodology and Work Plan – as confirmed with the Co-Chairs in Phase 1; and
- this Terms of Reference.

In the conduct of the Work, the Contractor shall consider and implement practicable measures to enhance the participation of Inuvialuit participants, including but not limited to, Inuvialuit Businesses, in support of the Contractor's service delivery. This could include: capacity development, on-the-job training, employment or contracting (supplies or services), as set out in the Contractor's Work Plan and approved by the Co-Chairs. The Contractor shall provide priority to the delivery of supplies and services to Inuvialuit Businesses (see: https://irc.inuvialuit.com/business/inuvialuit-business-list-ibl).

In the completion of the Work, the Contractor and its Resources shall abide by the terms of a Non-Disclosure Agreement (NDA) and Data Sharing Agreement that shall be provided after the contract is awarded and will compliment Part V Form of Agreement. In so doing, the Contractor and its Resources shall keep in confidence and not use or disclose without the express written instruction of the Co-Chairs, any proprietary or confidential information obtained in the course of its Work. This information includes any business confidential information. The Contractor must obtain written permission from the Co-Chairs prior to the use of any materials and knowledge gained from this project in the

Contractor's other work or business, including presentation at conferences. All NDAs and Data Sharing Agreements will remain valid at least for a period equal to the length of the project, or longer, as indicated in the executed Agreement.

9. SUPPORT TO THE CONTRACTOR

As required for the conduct of the work, the Co-Chairs will provide:

- access to available data, studies and foundational works pertinent to the project in possession of the Co-Chairs;
- timely review, comment and approvals on the Contractor's milestones and deliverables;
- organization, conduct of, and outputs from any Stakeholder engagement sessions conducted by one (1) or more of the Co-Chairs that are relevant to the conduct of the Contractor's Work. It is not expected that the Contractor will be involved in any Stakeholder engagement during the course of the contract.

10. BUDGET

The maximum budget for the work is $600,000.00 CAD, inclusive of all taxes and expenses.

11. TERM OF THE PROJECT

The term of the contract will be from date of execution to March 31, 2020.

APPENDIX A   DRAFT BRSEA REPORT TABLE OF CONTENTS

The following provides the draft Table of Contents for the BRSEA Final Report, as developed jointly by the BRSEA Co-Chairs. This Table of Contents shall inform and be reflected in the work completed by the Contractor, and may be added to or adjusted as recommended by the Contractor and authorized by the Co-Chairs.

1. Context of the RSEA
    a) Context of the RSEA and the 5-years science review
    b) Management regimes in the region
        i. Inuvialuit Final Agreement
        ii. Inuvialuit Regional Corporation
        iii. Inuvialuit Game Council
        iv. GNWT
        v. INAC
        vi. Others
    c) RSEA governance, coordination and consultation (i.e. RSEA Terms of Reference)
    d) Temporal and spatial limit
    e) Goal of the RSEA
2. State of baseline knowledge
    a) Physical
        i. Weather and climate
        ii. Oceanography
        iii. Ice conditions
        iv. Icebergs, drift and distribution
        v. Coastal dynamics and sea floor geology
        vi. Gaps
    b) Biological
        i. Lower trophic level
        ii. Fish and fish habitat
        iii. Sea birds
        iv. Marine mammals
        v. Invasive species
        vi. Migratory birds
        vii. Caribou
        viii. Polar Bear
        ix. Gaps
    c) Human
        i. Demographics
        ii. Cultural Vitality
        iii. Public health
        iv. Economy

v. Subsistence activities
vi. Infrastructure
vii. Gaps

d) Oil and Gas
i. History
ii. Emissions
iii. Sound generation
iv. Drilling, support vessels, etc.
v. Oil discharge prevention
vi. Etc.
vii. Gaps

3. Scenarios and projections (drivers of change)
   a) Environmental (climate change)
   b) Technology
   c) Economic development
4. Risks and benefits assessment
   a) Scenario 1 – Baseline / No action
      i. Air quality
      ii. Water quality
      iii. Lower trophic level
      iv. Fish and fish habitat
      v. Sea birds
      vi. Marine mammals
      vii. Terrestrial animals (Polar Bears, caribou, migratory birds)
      viii. Subsistence activities
      ix. Sociocultural systems
      x. Economy
      xi. Public health
   b) Scenario 2
      i. Air quality
      ii. Water quality
      iii. Lower trophic level
      iv. Fish and fish habitat
      v. Sea birds
      vi. Marine mammals
      vii. Terrestrial animals (Polar Bears, caribou, migratory birds)
      viii. Subsistence activities
      ix. Sociocultural systems
      x. Economy

        xi. Public health

    c) Scenario 3
        i. Air quality
        ii. Water quality
        iii. Lower trophic level
        iv. Fish and fish habitat
        v. Sea birds
        vi. Marine mammals
        vii. Terrestrial animals (Polar Bears, caribou, migratory birds)
        viii. Subsistence activities
        ix. Sociocultural systems
        x. Economy
        xi. Public health
    d) Scenario 4
        i. Air quality
        ii. Water quality
        iii. Lower trophic level
        iv. Fish and fish habitat
        v. Sea birds
        vi. Marine mammals
        vii. Terrestrial animals (Polar Bears, caribou, migratory birds)
        viii. Subsistence activities
        ix. Sociocultural systems
        x. Economy
        xi. Public health
    e) Scenario 5 – 'worst case' Scenario
        i. Air quality
        ii. Water quality
        iii. Lower trophic level
        iv. Fish and fish habitat
        v. Sea birds
        vi. Marine mammals
        vii. Terrestrial animals (Polar Bears, caribou, migratory birds)
        viii. Subsistence activities
        ix. Sociocultural systems
        x. Economy
        xi. Public health

5. Preferred Scenario and mitigation
    a) Recommended development Scenario(s) and mitigation

b) On-going monitoring planning
c) Research gaps

6. Summary and conclusions

APPENDIX B   POTENTIAL SOURCE MATERIAL

The following documents and links provide access to some of the known available data and information related to the Beaufort Sea Region and potentially relevant to the conduct of the BRSEA. This Appendix is provided to support the development of the BRSEA Report Package Source List and annotated bibliography, and may be added to or adjusted as recommended by the Contractor and authorized by the Co-Chairs during the course of the Phase 1.

Foundational Works shall be incorporated into the BRSEA and shall inform and be reflected in the work completed by the Contractor.

Other Available Source Material may provide pertinent background or additional information.

Foundational Works

Arctic Offshore Drilling Review. National Energy Board. Available online at: https://www.neb-one.gc.ca/nrth/rctcffshrdrllngrvw/index-eng.html

Beaufort Sea Strategic Regional Plan of Action and Appendices. Available online at: http://www.bsstrpa.ca/

Beaufort RSEA Oil and Gas Life Cycle Activities Scenario. Canadian Association of Petroleum Producers. To be provided following Award.

Traditional and Local Knowledge studies completed as part of the BRSEA work plan, including but not limited to:

- Inuvialuit Land Use and Occupancy and Harvest Studies. To be provided following Award.
- Inuvialuit Place Names - a consolidated and quality-controlled map of place names within the ISR. To be provided following Award.
- Inuvialuit Cultural Life—Out On The Land. To be provided following Award.

Integrated Oceans Management Plan for the Beaufort Sea: 2009 and beyond. Department of Fisheries and Oceans Available online at: http://www.dfo-mpo.gc.ca/Library/350719.pdf

2011 Beaufort Regional Environmental Assessment (BREA) Data Mining Project. ArcticNet. Available online at: http://www.arcticnet.ulaval.ca/pdf/research/brea_arcticnet2011.pdf

2012 State of the Ocean Report for the Beaufort Sea Large Ocean Management Area. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2977. Available online at: http://www.dfo-mpo.gc.ca/oceans/publications/soto-rceo/2012/beaufort-eng.html

March 2016 Beaufort Regional Environmental Assessment: Key Findings: Research and Working Group Results 2011 - 2015. Available online at: https://rsea.inuvialuit.com/docs/NCR10615510-v1-BREA_FINAL_REPORT.PDF

Other Available Source Material

2009 Regional Strategic Environmental Assessment in Canada Principles and Guidance PN 1428 ISBN 978-1-896997-84-1 PDF Available online at: https://www.ccme.ca/files/Resources/enviro_assessment/rsea_principles_guidance_e.pdf

2013 Advancing Regional Strategic Environmental Assessment in Canada's Western Arctic: Implementation Opportunities and Challenges Article (PDF Available) in Journal of Environmental Assessment Policy and Management 15(01) · March 2013

Beaufort Regional Environmental Assessment Working Group Reports and Publications (various). Available online at: https://www.beaufortrea.ca/publications/

Various Studies available on ArcticNet, available online at: http://www.arcticnet.ulaval.ca/research/current.php

Various Publications made possible through the Environmental Studies Research Fund, available online at: https://www.esrfunds.org/174.

The outcomes of completed BRSEA program activities, available online at: https://rsea.inuvialuit.com/Activities and as contained within the work plan for the Beaufort Regional Strategic Environmental Assessment 2018-2020, available online at: https://rsea.inuvialuit.com/docs/Inuvialuit%20Workplan%20RSEA%202018-21%20Website.pdf.

APPENDIX C GLOSSARY

The following terms used in the Terms of Reference have the following meanings, whether capitalized or not, unless the context requires otherwise:

BRSEA	Beaufort Region Strategic Environmental Assessment.
Beaufort Sea Large Ocean Management Area	Approximately 1,107,694 km2, located in the extreme northwestern corner of Canada, and includes the marine portion of the Inuvialuit Settlement Region. The Beaufort Sea Large Ocean Management Area is one of five priority areas identified for integrated ocean management planning by the Government of Canada.
Beaufort Region	See 'Inuvialuit Settlement Region'
Beaufort Sea	The Canada Basin of the Arctic Ocean north of Alaska, Yukon and the Mackenzie Delta coast, bounded on the east by Banks Island and Prince Patrick Island.
BRSEA	Beaufort Region Strategic Environmental Assessment
CAPP	Canadian Association of Petroleum Producers
CIRNAC	Crown Indigenous Relations and Northern Affairs Canada
Co-Chairs	Means the Co-Chairs of the BRSEA, who are: the Inuvialuit (represented by IRC and IGC) and Canada (represented by CIRNAC).
GNWT	Government of the Northwest Territories
Inuvialuit Business	Has the meaning set out in the Inuvialuit Final Agreement.
Inuvialuit Settlement Region	Has the meaning set out in the Inuvialuit Final Agreement.
IFA	Inuvialuit Final Agreement
IGC	Inuvialuit Game Council
IRC	Inuvialuit Regional Corporation
ISR	Inuvialuit Settlement Region
MPA	Marine Protected Area
NEB	National Energy Board
RSEA	Regional Strategic Environmental Assessment
Resource	Means the persons providing services on behalf of the Contractor, whether employees or sub-contractors.
TLK	Traditional and Local Knowledge
Valued Ecosystem Components	Have the meaning as set out in section 5. of the Terms of Reference.
Western Arctic	For the purpose of this Terms of Reference means the Canadian Beaufort Sea and the Inuvialuit Settlement Region.
Work Plan	

APPENDIX D GOVERNANCE FRAMEWORK

The following Acts, Regulations, Policies and Standards apply to the conduct of the BRSEA. Please refer to the hyperlinks embedded below for additional background and context on the requirements and conduct of the work:

Canadian Environmental Assessment Act, 2012 and associated regulations, available online at: https://laws-lois.justice.gc.ca/eng/acts/C-15.21/

Inuvialuit Final Agreement 2005, available online at: http://www.irc.inuvialuit.com/sites/default/files/Inuvialuit%20Final%20Agreement%202005.pdf

Oceans Act S.C. 1996, c. 31 and associated regulations, available online at: https://laws-lois.justice.gc.ca/eng/acts/O-2.4/

Terms of Reference for the Beaufort Regional Strategic Environmental Assessment. Available online at: https://rsea.inuvialuit.com/About/TermsofReference

APPENDIX E   RESOURCE TEAM QUALIFICATIONS

The following tables describe the anticipated roles and level of experience/expertise required for each of the disciplines identified in Section 5. of the Terms of Reference:

Discipline	Description (Anticipated Role)	Desired Level of Experience / Expertise
Stream #1 - Project Management:		
Project Management	The Project Management discipline of the Project Team is responsible for planning and coordinating project management activities including financial, planning and contracting aspects; giving briefings on progress and concerns of the project; coordinating and preparing documentation in response to scheduled and unscheduled reports, returns and observations to update management on project progress; planning and coordinating the activities of project Resources, including any sub contractors and other support providers.	8+ years as a project manager in the field of environmental analysis; University degree in an environmental or business field; Experience as a Project Manager on projects related to resource development. Additional preference will be given to Experience within federal, territorial, or provincial governments. Experience working with Indigenous organizations or communities.
Quality Assurance	The Quality Assurance discipline of the Project Team is responsible for developing, deploying and evaluating policies, procedures, standards, initiatives, metrics, forms and tools for the quality management system; Verifying and confirming if the quality management system's process assets (policies, procedures and standards) are being adhered to; Leading process improvement initiatives, and facilitating/coaching teams which are performing process improvement initiatives; Managing and monitoring all aspects of the Quality Management System; Conducting conformance audits of the Quality Management System. Reporting results and recommending appropriate corrective actions to deal with the non-conformances.	One (1) + project(s) experience delivering Quality Assurance services in the field of environmental analysis. Additional preference will be given to: Experience within federal, territorial, or provincial governments delivering Quality Assurance services relevant to environmental analysis. Experience in project management of an environmental assessment or Strategic Environmental Assessment.

Discipline	Description (Anticipated Role)	Desired Level of Experience / Expertise
Stream #2 - Traditional Local Knowledge (experience working with Traditional Local Knowledge, including local natural resource knowledge):		
Socio, cultural, subsistence economy and economic	Responsible for providing expertise in Traditional Local Knowledge relevant to socio, cultural, subsistence economy and economic factors to and applying that knowledge to planning and decision-making processes relevant to the Strategic Regional Environmental Assessment.	One (1) + project(s) experience working with Traditional Local Knowledge, current social and economic issues. Demonstrated understanding, through experience, of Traditional Knowledge collection methods, pedagogy and Inuit perspectives. Additional preference will be given to: Project working with Arctic TLK, current social and economic issues and local community or regional experience; with a preference for experience relevant to the Western Arctic; Indigenous language fluency, with a preference for languages within the ISR.
Biophysical environment	Responsible for providing expertise in Traditional Local Knowledge relevant to biophysical environment (natural resources) factors to and applying that knowledge to planning and decision-making processes relevant to the Strategic Regional Environmental Assessment.	One (1) + project(s) experience working with Traditional Local Knowledge, current social issues and natural resources. Demonstrated understanding, through experience, of Traditional Knowledge collection methods, pedagogy and Inuit perspectives. Additional preference will be given to: Project working with Inuvialuit TLK, current social issues and natural resources in the Arctic; Project experience relevant to environmental analysis; Indigenous language fluency, with a preference for languages within the ISR.

Discipline	Description (Anticipated Role)	Desired Level of Experience / Expertise
Stream #3 - Socio, cultural, subsistence economy and economic disciplines - "Western"/scientific knowledge (including experience working with complex scientific data, large data systems, identification of patterns or trends and modelling):		
Socio-Cultural	Responsible for providing input into the Strategic Regional Environmental Assessment relevant to the impacts and potential affecting Local communities' customs, lifestyles, values, businesses, social organizations, etc. from a socio-cultural perspective.	Post secondary education in a relevant field One (1) + project(s) demonstrating experience providing services relevant to socio-cultural research in an environmental assessment. Additional preference will be given to: Experience with local community or region.
Cultural vitality, infrastructure, food security, ability to harvest, education	Responsible for providing input into the Strategic Regional Environmental Assessment relevant to the impacts and potential affecting Local communities' customs, lifestyles, values, businesses, social organizations, etc. from the perspective of the discipline.	Post secondary education in a relevant field One (1) + project(s) demonstrating experience providing services relevant to socio-cultural research in the discipline in an environmental assessment. Additional preference will be given to: Experience in the discipline with local community or region.
Indicator development and analysis, socio-economic impacts and benefits and analysis, including:		
Economic Measures	Responsible for providing input into the Strategic Regional Environmental Assessment relevant to the impacts and potential affecting economic measures in the Region.	Advanced postsecondary education in a relevant field (e.g. economics). One (1) + project(s) demonstrating experience providing services relevant to economic measures in an environmental assessment. Experience in the Northern economy. Additional preference will be given to: Experience with oil and gas economic potential impact on regional economies.

Discipline	Description (Anticipated Role)	Desired Level of Experience / Expertise
Economic Impact/Potential (e.g., Tourism, Labour, Commercial, Tradition, Manufacturing, etc.)	Responsible for providing input into the Strategic Regional Environmental Assessment relevant to the impacts and potential affecting Local tourism, labour, tradition and manufacturing, etc. from an economic perspective.	Advanced postsecondary education in a relevant field (e.g. economics). One (1) + project(s) demonstrating experience providing services relevant to economic impact/potential in an environmental assessment. Experience in the Northern economy. Additional preference will be given to: Experience with oil and gas economic potential.
Statistics	Responsible for providing input into the Strategic Regional Environmental Assessment on applied statistics that concerns the collection, processing, compilation, dissemination, and analysis of economic data. Analyses within economic statistics both make use of and provide the empirical data needed in economic research, whether descriptive or econometric.	University degree in (applied) mathematics, (applied) statistics, or a related field. One (1) + project(s) demonstrating experience and familiarity with standard and advanced statistics concepts and methodologies. At least one project experience with economic potential of an exploration/resource development project within the last five years.
Stream #4 - Biophysical and environmental disciplines - Scientific Knowledge (including experience working with complex scientific data, large data systems, identification of patterns or trends and modelling):		

Discipline	Description (Anticipated Role)	Desired Level of Experience / Expertise
Marine Biology	Provide subject matter expertise in Marine to provide input into the Strategic Regional Environmental Assessment focusing on the ecology and behavior of microbes, plants, and animals inhabiting oceans, coastal waters, and saltwater wetlands and their interactions with the physical environment in Canada's North.	University Science degree with post graduate education in Marine Biology or Oceanography. One (1) + projects demonstrating experience providing advisory services relevant to Marine Biology. One (1) + projects demonstrating experience with an environmental project within the last five years. Experience in the North or Arctic. Additional preference will be given to: Experience related to oil and gas development in a marine/ocean environment.
Ecology	Provide input into the Strategic Regional Environmental Assessment focusing on ecological processes in the environment and particular ecosystems.	University Science degree with a specialization in Ecology. One (1) + projects demonstrating experience providing advisory services relevant to ecology, using a variety of landscape scales and development spatial patterns. One (1) + projects demonstrating experience with an environmental project within the last five years.

Discipline	Description (Anticipated Role)	Desired Level of Experience / Expertise
Sea ice and Oceanography	Provide subject matter expertise relevant to Ice and Coastal Regions to provide input into the Strategic Regional Environmental Assessment focusing on the monitoring of coasts in cold climate regions in Canada's North.	University Science degree with post graduate education relevant to Ice and Coastal Environments. One (1) + project(s) demonstrating experience providing advisory services relevant to Ice and Coastal Regions. One (1) + project(s) demonstrating experience with an environmental project within the last five years. Experience in the North or Arctic. Additional preference will be given to: Experience related to oil and gas development in an Arctic marine/ocean environment.
Coastal dynamic and sea floor geology	Provide subject matter expertise relevant to Coastal Regions and sea floor geology to provide input into the Strategic Regional Environmental Assessment focusing on the monitoring of coasts and seabeds in cold climate regions in Canada's North.	University Science degree with post graduate education relevant to Sea floors and Coastal Environments. One (1) + project(s) demonstrating experience providing advisory services relevant to Sea floors and Coastal Environments. One (1) + project(s) demonstrating experience with an environmental project within the last five years. Experience in the North or Arctic. Additional preference will be given to: Experience related to oil and gas development in an Arctic marine/ocean environment.

Discipline	Description (Anticipated Role)	Desired Level of Experience / Expertise
Contaminants	Provide subject matter expertise relevant to Contaminants associated with offshore oil and gas development in cold climate regions in Canada's North.	University Science degree with post graduate education relevant to major resource development contaminants. One (1) + project(s) demonstrating experience providing advisory services relevant to Contaminants associated with offshore oil and gas development. One (1) + project(s) demonstrating experience with an environmental project within the last five years. Experience in the North or Arctic. Additional preference will be given to: Experience related to oil and gas development in an Arctic marine/ocean environment.
Climate Change Modelling	Provide Climate Change Modelling subject matter expertise relevant to environments in Canada's North.	University Science Degree with a specialization relevant to Climate Change. One (1) + project(s) demonstrating experience and knowledge of computational physics and/or climate modeling, with analysis of model output. One (1) + project(s) demonstrating experience with a climate related project in Canada's North or the Arctic within the last five years.

Discipline	Description (Anticipated Role)	Desired Level of Experience / Expertise
Oil and Gas Industry (Understanding of risks and safety with respect to Oil and Gas, experience in the Oil and Gas sector including working with industry participants)	Responsible for providing input into the Strategic Regional Environmental Assessment with respect to the Oil and Gas industry including the understanding of risks and safety and working with industry participants.	One (1) + projects demonstrating experience in the field of environmental analysis providing input relevant to the Oil and Gas industry. One (1) + projects demonstrating experience in the use of legislation, regulations, policies and institutions relevant to oil and gas activities in the NWT. One (1) + projects demonstrating experience in the use of technical knowledge of the fundamentals of oil and gas exploration, production, processing and transportation activities. Demonstrated Project experience incorporating the environmental review process applicable to oil and gas activities in the NWT, cumulative environmental effects assessment, protected areas strategy land use planning processes and initiatives and sustainable development concepts. University degree in an environmental, scientific, or business, field.
Indicator development and analysis for biological systems, air, water and terrestrial quality, socio-economic impacts and benefit and analysis	Provide indicator development and analysis for biological systems, air, water and terrestrial quality and associated socio-economic impacts and benefit analysis relevant to the Strategic Regional Environmental Assessment.	University degree in (applied) mathematics, (applied) statistics, environmental statistics, environmental science or a related field. One (1) + projects demonstrating experience providing indicator development and analysis relevant to environmental projects. One (1) + projects demonstrating experience with an environmental project within the last five years.

Discipline	Description (Anticipated Role)	Desired Level of Experience / Expertise
Cumulative impacts and environmental interactions.	Responsible for providing subject matter expertise and analysis input into the Strategic Regional Environmental Assessment with respect to the cumulative impacts and environmental interactions of potential offshore oil and gas development on the Region.	University degree in (applied) environmental science, environmental studies, environmental statistics or a related field. One (1) + projects demonstrating experience assessing cumulative impacts and interactions relevant to environmental projects. One (1) + projects demonstrating experience with cumulative impacts and interactions relevant to oil and gas development. One (1) + projects demonstrating experience with an Arctic environment.

APPENDIX B List of Traditional and Local Knowledge (TLK) Source used in the TLK Inventory

B.1 Beaufort Region Strategic Environmental Assessment

9. Inuvialuit Community Based Monitoring Program. 2017. Inuvialuit Harvest Study Annual Newsletter January to December 2016. Inuvialuit Regional Corporation, Inuvik, NWT.
10. Inuvialuit Community Based Monitoring Program. 2018. Inuvialuit Harvest Study Annual Newsletter January to December 2017. Inuvialuit Regional Corporation, Inuvik, NWT.
11. Inuvialuit Community Based Monitoring Program. 2019. Inuvialuit Harvest Study 2018 Partner Report. 2019. Joint Secretariat, Inuvik, NWT.
12. FJMC and IRC. 2019a. Inuvialuit Cultural Life Out on the Land - A Traditional Knowledge Project. Beaufort Sea Regional Strategic Environmental Assessment. Prepared by C. Elliot for the Fisheries Joint Management Committee and the Inuvialuit Regional Corporation.
13. FJMC and IRC. 2019b. The Importance of Ice - A Traditional Knowledge Project. Beaufort Sea Regional Strategic Environmental Assessment. Prepared by C. Elliot for the Fisheries Joint Management Committee and the Inuvialuit Regional Corporation.
14. FJMC and IRC. 2019c. Traditional Knowledge Assessment for the Key Species of the Beaufort Sea - A Traditional Knowledge Project. Beaufort Sea Regional Strategic Environmental Assessment. Prepared by C. Brogan for the Fisheries Joint Management Committee and the Inuvialuit Regional Corporation.
15. Inuvialuit Regional Corporation (IRC). 2020. Inuvialuit indicators. Available at: https://indicators.inuvialuit.com/

B.2 Inuvialuit Community Conservation Plans

16. ACCP (Aklavik Community Conservation Plan). 2016. Aklavik Community Conservation Plan, Akaqvikmiut Numamikini Nunutailivikautinich. Prepared by the Aklavik Trappers Committee, Aklavik Community Corporation, The Wildlife Management Advisory Council (NWT), The Fisheries Joint Management Committee and the Joint Secretariat. Inuvik NWT, 2016.
17. ICCP (Inuvik Community Conservation Plan). 2016. Inuvik Community Conservation Plan, Inuuvium Angalatchivingit Niryutinik. Prepared by the Inuvik Hunters and Trappers Committee, Inuvik Community Corporation, The Wildlife Management Advisory Council (NWT), The Fisheries Joint Management Committee and the Joint Secretariat. Inuvik NWT, 2016.
18. OCCP (Olokhaktomiut Community Conservation Plan). 2016 Olokhaktomiut Community Conservation Plan, Ulukhaqtuum Angalatchivingit Niryutinik. Prepared by the Olohaktomiut Hunters and Trappers Committee, Ulukhaktok Community Corporation, The Wildlife Management Advisory Council (NWT), The Fisheries Joint Management Committee and the Joint Secretariat. Inuvik NWT, 2016.
19. PCCP (Paulatuk Community Conservation Plan). 2016. Paulatuk Community Conservation Plan, Paulatuum Angalatchivingit Niryutinik. 2016. Prepared by the Paulatuk Hunters and Trappers Committee, Paulatuk Community Corporation, The Wildlife Management Advisory Council (NWT), The Fisheries Joint Management Committee and the Joint Secretariat. Inuvik NWT, 2016.

20. TCCP (Tuktoyaktuk Community Conservation Plan). 2016. Tuktoyaktuk Community Conservation Plan, Tuktuuyaqtuum Angalatchivingit Niryutinik. Prepared by the Tuktoyaktuk Hunters and Trappers Committee, Tuktoyaktuk Community Corporation, The Wildlife Management Advisory Council (NWT), The Fisheries Joint Management Committee and the Joint Secretariat. Inuvik NWT, 2016.
21. SCCP (Sachs Harbour Community Conservation Plan). 2016. Sachs Harbour Community Conservation Plan, Sachs Harbour Angalatchivingit Niryutinik. 2016. Prepared by the Sachs Harbour Hunters and Trappers Committee, Sachs Harbour Community Corporation, The Wildlife Management Advisory Council (NWT), The Fisheries Joint Management Committee and the Joint Secretariat. Inuvik NWT, 2016.

B.3 Inuvialuit Co-Management Organizations

22. Fabijan, M.F., N. Snow, J. Nagy and L. Graf. 1993. Inuvialuit Harvest Study. Atlas of Wildlife Species Harvest Locations Reported During: July 1987-December 1992. Reported for the Joint Secretariat, Inuvik, Northwest Territories. 80 pages
23. KAVIK-AXYS Inc. 2012. Traditional and local knowledge workshop for the Paulatuk area of interest. Prepared for Fisheries and Oceans Canada, Inuvik. NWT
24. Joint Secretariat. 2015. Inuvialuit and Nanuq: A Polar Bear Traditional Knowledge Study. Joint Secretariat, Inuvialuit Settlement Region. xx + 304 pp
25. Joint Secretariat. 2003. Inuvialuit Harvest Study: Data and Methods Report 1988-1997. Inuvik, NWT. March 2003.
26. Slavik, Dan. 2010. Inuvialuit Knowledge of Nanuq: Community and Traditional Knowledge of Polar Bears in the Inuvialuit Settlement Region. Published by Wildlife Management Advisory Council NWT, Wildlife Management Advisory Council - North Slope and Inuvialuit Game Council
27. Wildlife Management Advisory Council (North Slope) and Aklavik Hunters and Trappers Committee. 2018. Inuvialuit Traditional Knowledge of Wildlife Habitat, Yukon North Slope. Wildlife Management Advisory Council (North Slope), Whitehorse, Yukon. vi + 74 pp.
28. Wildlife Management Advisory Council (North Slope) and Aklavik Hunters and Trappers Committee. 2018. Yukon North Slope Inuvialuit Traditional Use Study. Wildlife Management Advisory Council (North Slope), Whitehorse, Yukon. 124 +xvi pp.
29. Wildlife Management Advisory Council (North Slope) & the Aklavik Hunters and Trappers Committee. (2009). Aklavik local and traditional knowledge about Porcupine Caribou: Final Report. Whitehorse, Yukon: Wildlife Management Advisory Council (North Slope
30. Wildlife Management Advisory Council (North Slope) & the Aklavik Hunters and Trappers Committee. (2008). Aklavik local and traditional knowledge about grizzly bears of the Yukon North Slope: Final Report. Whitehorse, Yukon: Wildlife Management Advisory Council (North Slope).

B.4 Industry Program

B.4.1 BP - Deep Water Exploration Drilling Program

31. IMG Golder and Golder Associates. 2011a. Traditional Knowledge Collection Program, Aklavik Community Report submitted to BP Exploration Operating Company Limited, 240-4 Avenue SW Calgary Alberta T2P 2H8. Report number 09-1334-1034
32. IMG Golder and Golder Associates. 2011b. Traditional Knowledge Collection Program, Inuvik Community Report submitted to BP Exploration Operating Company Limited, 240-4 Avenue SW Calgary Alberta T2P 2H8. Report number 09-1334-1034
33. IMG Golder and Golder Associates. 2011c. Traditional Knowledge Collection Program, Tuktoyaktuk Interviews submitted to BP Exploration Operating Company Limited, 240-4 Avenue SW Calgary Alberta T2P 2H8. Report number 09-1334-1034
34. IMG Golder and Golder Associates. 2011d. Traditional Knowledge Collection Program, Paulatuk Community Report submitted to BP Exploration Operating Company Limited, 240-4 Avenue SW Calgary Alberta T2P 2H8. Report number 09-1334-1034
35. IMG Golder and Golder Associates. 2011e. Traditional Knowledge Collection Program, Ulukhaktok Community Report submitted to BP Exploration Operating Company Limited, 240-4 Avenue SW Calgary Alberta T2P 2H8. Report number 09-1334-1034
36. IMG Golder and Golder Associates. 2011f. Traditional Knowledge Collection Program, Sachs Harbour Community Report submitted to BP Exploration Operating Company Limited, 240-4 Avenue SW Calgary Alberta T2P 2H8. Report number 09-1334-1034

B.4.2 BP - Offshore Seismic Program

37. KAVIK-AXYS Inc. in association with ASL Environmental Services and JASCO Research. 2009. BP Exploration Pokak 3D Seismic Program Project Description submitted by BP Exploration Company Limited submission to the Environmental Impact Screening Committee. 794p.

B.4.3 Imperial Oil - Deep Water Exploration Drilling

38. IMG Golder and Golder Associates. 2014. Tuktoyaktuk Traditional Ecological Knowledge Collection Program, Beaufort Sea Joint Venture Drilling Program. Submitted to Imperial Oil Resources Limited, 237 Fourth Avenue S.W., P.O. Box 2480, Station M, Calgary, Alberta, T2P 3M9. Report number -12-1334-0067

B.4.4 Devon - Nearshore Drilling Program

39. Devon Canada Corporation. August 2004. Devon Beaufort Sea Exploration Drilling Program – Technical Assessment Report. Prepared for Devon Canada Corporation Calgary, Alberta by KAVIK-AXYS Inc. Calgary, Alberta. Section 18-Traditional Knowledge and Land Use

40. KAVIK-AXYS Inc. December 2004a. Aklavik Traditional Knowledge and Land Use Studies. Devon Canada Corporation Beaufort Sea Drilling Application
41. KAVIK-AXYS Inc. December 2004b. Inuvik Traditional Knowledge and Land Use Studies. Devon Canada Corporation Beaufort Sea Drilling Application
42. KAVIK-AXYS Inc. December 2004c. Tuktoyaktuk Traditional Knowledge and Land Use Studies. Devon Canada Corporation Beaufort Sea Drilling Application

B.4.5 Mackenzie Gas Pipeline Project

43. Inuvik Community Corporation, Tuktuuyaqtuuq Community Corporation, Aklavik Community Corporation. August 2006. Inuvialuit Settlement Region Traditional Knowledge Report Submitted to the Mackenzie Project Environmental Group, Calgary, Alberta

APPENDIX C Climate Change Predictions for the Strategic Assessment

Beaufort Region Strategic Environmental Assessment

Foundational Element: Climate Change Predictions for the Strategic Assessment

July 31, 2020

Prepared for:
Inuvialuit Regional Corporation,
Inuvialuit Game Council
and
Crown-Indigenous Relations and Northern Affairs Canada

Prepared by:
KAVIK-Stantec Inc.
Inuvik, NT

Project Number: 123513135

KAVIK-STANTEC

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1 INTRODUCTION AND BACKGROUND

During the January 31, 2019 meeting with the Inuvialuit Regional Corporation (IRC), the Inuvialuit Game Council (IGC) and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC), it was agreed that a single climate change emissions scenario (IPCC scenario), based on a realistic set of assumptions, would be applied to the BRSEA and downscaled to the BRSEA Study Area. The resulting atmospheric, oceanographic, and coastal predictions over the next 30 years will then be used in the assessment phase to:

1. describe how climate change might modify the types and seasonal timing of activities and choice of equipment for each oil and gas development scenario (e.g., effects of longer open water seasons and increased potential for storm impacts)
2. describe how climate change might affect the distribution, seasonal movements and populations of marine species (e.g., the effects of a longer open water season and changes in sea-ice on the distribution and activities of a species), as well as socioeconomic and cultural conditions (e.g., how changes in sea ice might affects the timing and location of harvesting)
3. describe how climate change might modify the effect pathways or mechanisms for each valued environmental or social component (e.g., how climate might change the magnitude, duration or geographic scope of effects on a biological species, traditional use, or socio-economic values). For example, if a longer open water period allows longer industrial activities, as well as longer occupancy of the area by a marine species, effects may occur over a larger geographic area for a longer period of time).

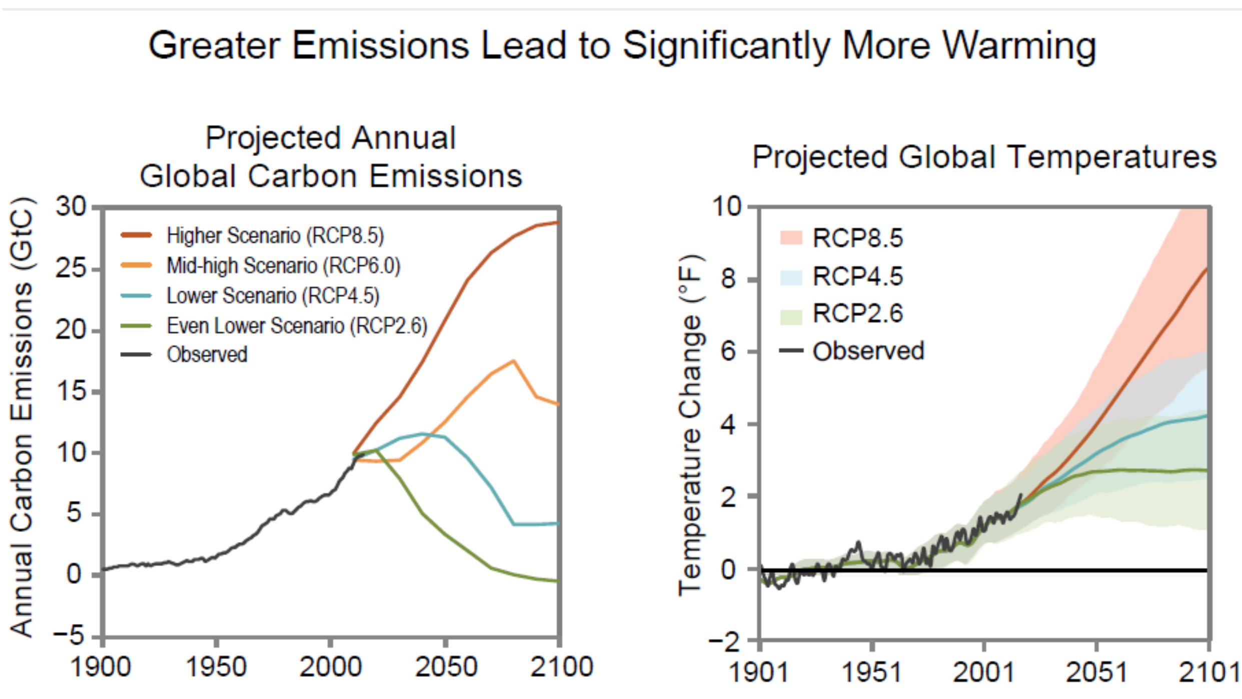
In this report, we first describe our approach to choosing one IPCC scenario to base our environmental predictions on, list the chosen set of environmental variables, and then provide predictions for these variables within the BRSEA region.

2 METHODOLOGY

2.1 Selection of the BRSEA Climate Change Scenario

The key consideration to determine the environmental effects of climate change is to choose a climate scenario for context. Given the uncertainty in future human behavior regarding national and global fossil fuel use, and within and across climate prediction models, the approach generally taken is to present a range of models with different emission scenario assumptions, called Representative Concentration Pathways (RCPs) (Figure 2-1). The number behind each RCP represents a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6.0, and 8.5 W/m^2, respectively). The RCPs are consistent with a wide range of possible changes in future human greenhouse gas (GHG) emissions and aim to represent their atmospheric concentrations. Assumptions differ substantially; RCP 2.6, for example, assumes that global annual GHG emissions peak between 2010–2020, with emissions declining substantially thereafter. Emissions in RCP 4.5 peak around 2040, then decline, RCP 6 emissions peak around 2080, and in RCP 8.5, emissions continue to rise throughout the 21st century.

One way to help us chose the one IPCC scenario that is to form the basis for the BRSEA, is to investigate how current data match the predictions these models have made thus far starting in 2005. For this purpose, we present data on GHGs, temperature and Arctic sea-ice.



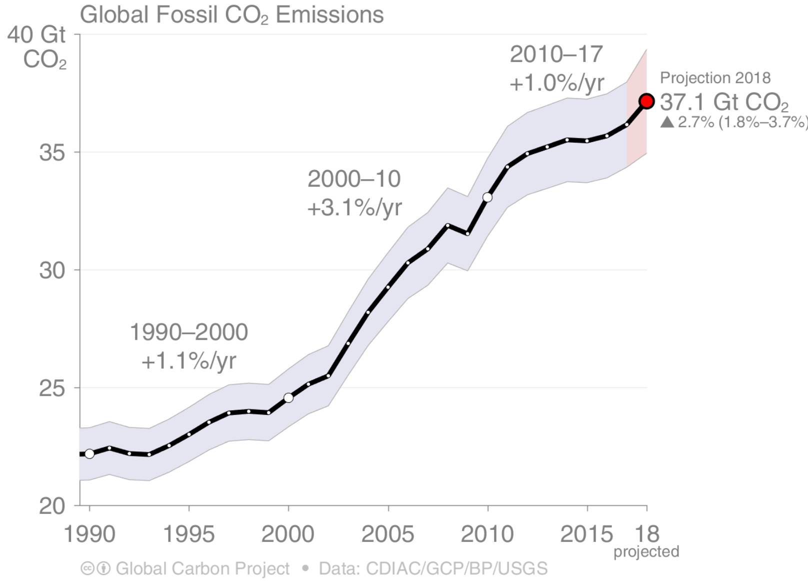
SOURCE: USDCRP 2017: Climate Science Special Report: Fourth National Climate Assessment, Volume I

Figure 2-1 Annual historical and range of plausible future carbon emission

2.1.1 Global Fossil Fuel Emissions

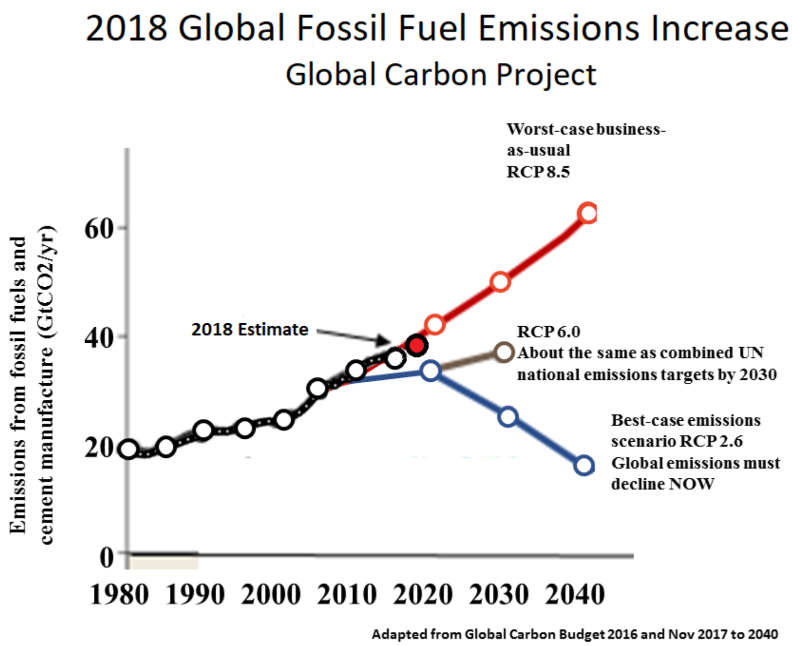
On the broadest scale, we can look at global fossil fuel emissions, which for 2018 show 37.1 ± 2 Gigatons of Carbon Dioxide ($GtCO_2$), 2.7% higher than 2017 (Figure 2-2).

If we overlay that this information with the RCP scenarios, we find that actual emissions are tracking closer to RCP8.5, compared to the other RCPs (Figure 2-3).



NOTES: Estimates for 2015, 2016 and 2017 are preliminary; 2018 is a projection based on partial data.
SOURCE: CDIAC; Le Quéré et al. 2018a; Global Carbon Budget 2018

Figure 2-2 Global fossil CO_2 emissions from 1990-2018



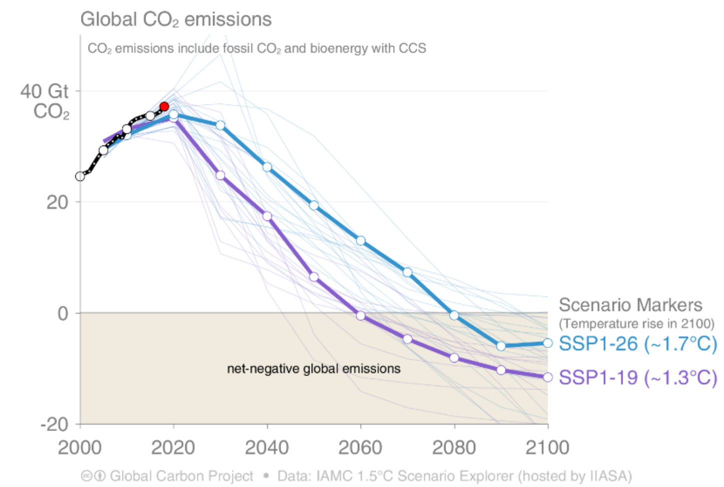
SOURCE: Le Quéré et al. 2018a

Figure 2-3 Historical and current global fossil fuel emissions relative to three RCP predictions that started in 2007

2.1.2 Temperature

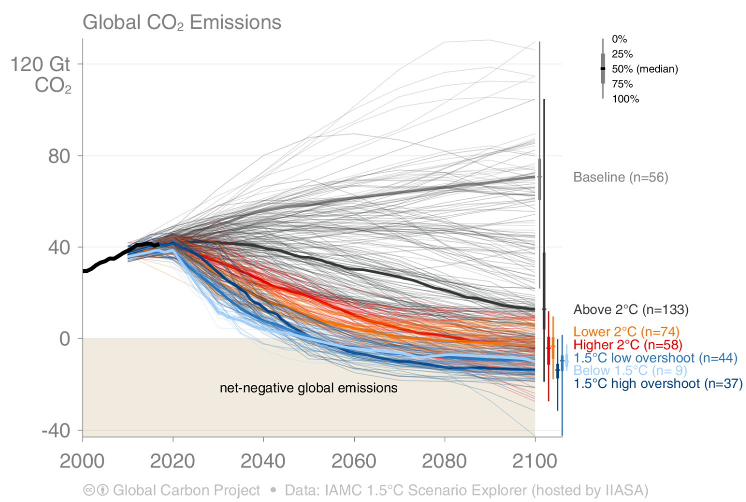
Another indicator of global change is temperature. The Paris Climate Accord stipulated a target in global temperature rise of no more than 1.5°C by 2100. To reach this ambitious goal, CO_2 emissions would need to rapidly decline to follow pathways consistent with the Paris targets, and current data do not seem to support this (

Figure 2-4, Figure 2-5 and Figure 2-6). Furthermore, the IPCC Special Report on “Global Warming of 1.5°C” presented new scenarios, noting that the 1.5°C scenarios require halving emissions by ~2030, net-zero by ~2050, and negative thereafter (Figure 2-5), yet current conditions seem to be more on track with an increase of 3-6°C, which would be more consistent with predictions made under RCP 6.0 or 8.5 (Figure 2-6).



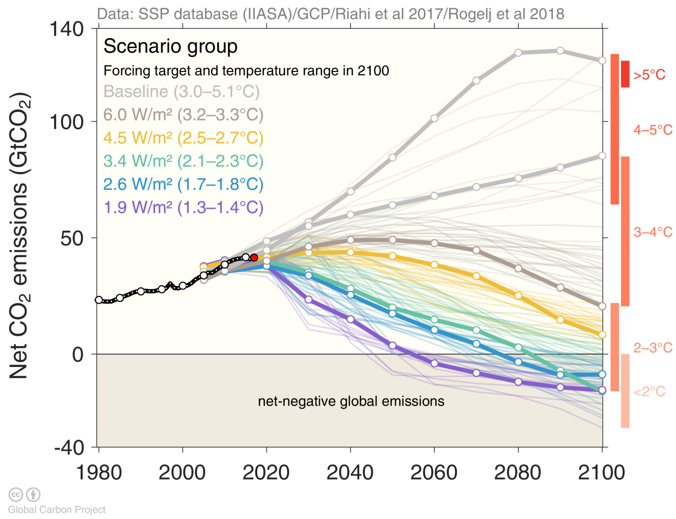
SOURCE: Huppmann et al. 2019IPCC 2018; Jackson et al. 2018; Le Quere et al 2018b.

Figure 2-4 Shared Socioeconomic Pathways (SSP) analyses for keeping with a 1.5°C target increase by 2100 compared to current observations (in black. Red dot is the 2018 preliminary estimate)



SOURCE: Huppmann et al. 2018; IAMC 1.5C Scenario Database; IPCC 2018; Jackson et al. 2018;

Figure 2-5 SSPs lead to a broad range in baselines (grey), with more aggressive mitigation leading to lower temperature outcomes (grouped by colours)



NOTE: Net emissions include those from land-use change and bioenergy with CCS.
SOURCE: Riahi et al. 2017; Rogelj et al. 2018; IIASA 2018. ; IAMC; Le Quere et al 2018b

Figure 2-6 Set of quantified SSPs based on the output of six Integrated Assessment Models (AIM/CGE, GCAM, IMAGE, MESSAGE, REMIND, WITCH)

2.1.3 Arctic Sea-Ice

Finally, relevant for the Arctic and linked to both GHG and temperature, are sea-ice conditions. Winter and summer sea-ice extent and thickness has been declining since the satellite record began in 1979 (e.g., Figure 2-7).

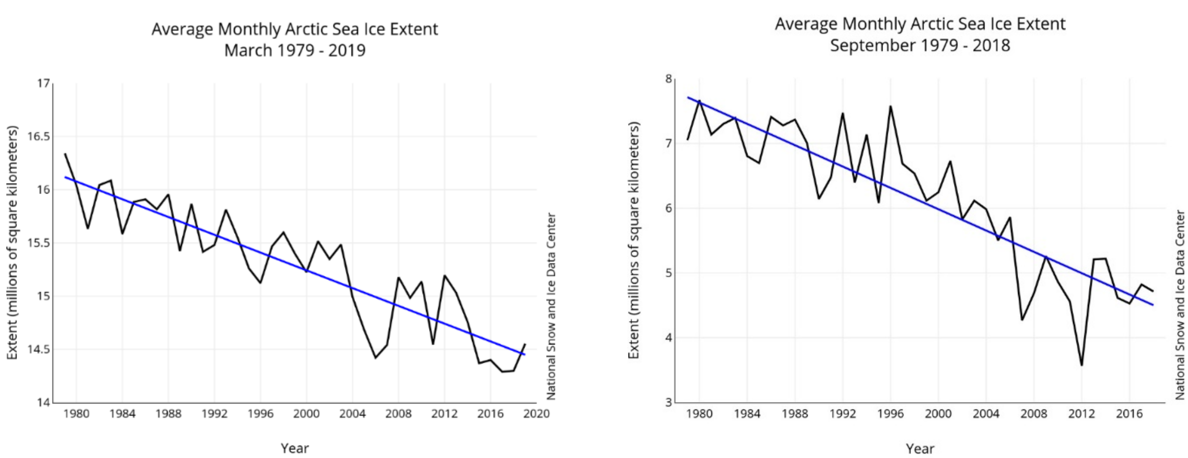
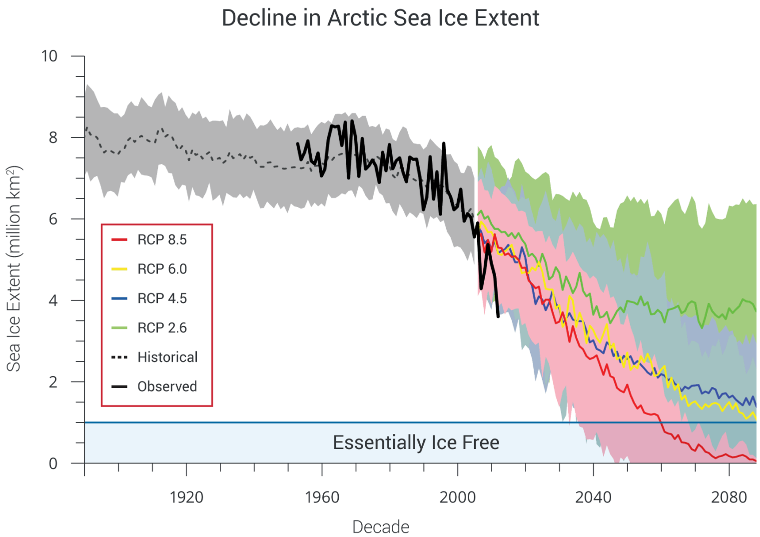


Figure 2-7 (left) Change in average March Arctic sea ice extent from 1979 – 2019, (right) Change in average September Arctic sea ice extent from 1979 – 2018

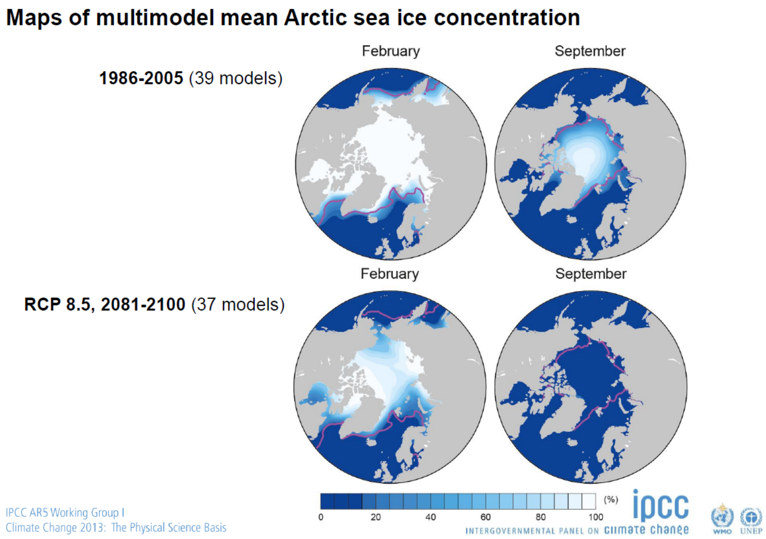
Projections for year-round reductions in Arctic sea ice extent range from 43% for RCP2.6 to 94% for RCP 8.5 in September, and from 8% for RCP 2.6 to 34% for RCP 8.5 in February. Current sea-ice observations seem to be most in line with RCP 8.5 (Figure 2-8). Under that scenario, a nearly ice-free Arctic Ocean (sea ice extent < 10^6 km^2) for at least five consecutive years in September is likely to occur before mid-century (Figure 2-8 and Figure 2-9).



NOTES: Colored lines for RCP scenarios are model averages (CMIP5) and lighter shades of the line colors denote ranges among models for each scenario. Dotted gray line and gray shading denotes average and range of the historical simulations through 2005. The thick black line shows observed data for 1953-2012.

SOURCE: Adapted from Stroeve et al. 2012

Figure 2-8 Model simulations of Arctic sea ice extent for September (1900-2100) based on observed concentrations of heat-trapping gases and particles (through 2005) and four scenarios



SOURCE: IPCC 2013c

Figure 2-9 Spatial sea ice extent and concentration historically (1986-2005) and for the last 2 decades of this century based on RCP 8.5

2.1.4 Emission Scenario for BRSEA

Although it is reasonable to expect that we will eventually see emissions level off somewhere between RCP 6.0 and RCP 8.5 levels, that the biosphere and hydrosphere may end up being better buffers of CO_2 than we expected, and that the state of global political affairs and emissions cutting appears to be gaining traction in some major industrial countries, global emissions continue to rise and actions to curb climate change have not been swift and severe enough. In addition, the BRSEA is located in the region of the globe that is experiencing the most rapid and severe changes, substantially above the global average. Indeed, Christensen et al (2018) noted that "*our results indicate that there is a greater than 35% probability that emissions concentrations will exceed those assumed in RCP8.5."*

Based on all three lines of evidence presented, and from further consultations with our colleagues in the climate modeling community, we conclude that the most robust climate prediction to choose for BRSEA at this time is RCP 8.5 (Riahi et al. 2011). We note, however, that in choosing this scenario for the purposes of our project, there remains a range of variability and uncertainty. Some of these variabilities and uncertainties have been characterized, but really require further scientific investigation by the broader scientific community (see e.g., Swart et al. NCC 2015). Beyond this are the "unknown unknowns" present in this very complex coupled system of the atmosphere with the ocean, cryosphere and terrestrial components of the earth. In providing our atmospheric, oceanographic, and coastal predictions over the next 30 years (2020-2050) under this scenario, we will therefore aim to include measures of variability and uncertainty where possible and appropriate.

2.2 Selection of Physical Attributes

Climate change is the primary factor in predicting future consequences of both natural changes and anthropogenic effects on valued ecosystem components. To help frame these effects in the assessment phase of BRSEA, we plan to predict and describe:

- atmospheric changes for the BRSEA Study Area
- changes in physical and chemical oceanography
- changes in coastal processes and associated changes in coastal formations and habitats

Specifically, the following variables deemed important for physical and biological processes in the BRSEA Study Area were investigated and characterized (Table 2-1).

Some of these physical attributes, including those involving physical and chemical oceanographic variables and coastal erosion/permafrost variables, are not addressed by IPCC model results. For these variables, results from scientific papers and reports that describe current trends and predictions of future conditions are reviewed and documented, in relation to the underlying physical mechanisms. For many of the variables, this approach made use of the BREA Climate Change Report in Relation to Oil and Gas Activities in the Beaufort Sea (Stantec 2013) which were then updated based on a review of the scientific literature that are now available since the 2013 timeframe of the BREA Report.

Table 2-1 Key physical parameters investigated during this study

Variable	Metric	Rationale/Effect
Air temperature (means, maxima, variability)	Change in air temperature relative to climate normals	Influences melting of sea ice and snow, timing and length of seasons, open water, thawing permafrost.
Precipitation (rain, fog and snow)	Change in amounts of rain and snow relative to climate normals	May enhance melting of sea ice and access for shipping; negatively affect offshore operations and coastal infrastructure; increase rates of coastal erosion; reduced snow cover on ice can influence ice algal and under ice phytoplankton blooms.
Frost-free days	Probability of frost-free days	Influences accumulation and duration of snow cover, as well as timing and length of seasons.
Wind (direction, speed, variability, frequency of extreme events)	Changes in wind speed, wind direction, storminess and storm frequency relative to climate normals	Influences storm surge, waves, sea ice extent and location, with effects on shipping, offshore operations and coastal infrastructure; and rates of coastal erosion. Compounded by effects of storm surges, water column structure, upwelling events, and fate of Mackenzie plume.
Sea level rise (including frequency and severity of storm surges)	Changes in relative mean sea levels (m), probabilities of storm surges >1.5m and > 2.0m	Implications for coastal communities, infrastructure, marine operations, coastal ecology, and erosion rates; increased likelihood of damaging storm surges; increased likelihood of permafrost thaw through inundation
Ocean temperature and heat content (including bottom water temperature)	Water Temperature	Influences dissolved oxygen and sea ice extent. In turn, each of these parameters have effects on the food web and coastal communities.

Table 2-1 Key physical parameters investigated during this study

Variable	Metric	Rationale/Effect
Sea ice (extent, thickness, type, timing, including landfast ice)	Areal extent (m^2), thickness (m), stage of development (age), changes in seasonal timing (days)	Influences the duration of the offshore exploration Open Water Season, navigability, and fetch; timing of breakup of pack and landfast sea ice near coastal communities; effects of sea ice on seasonal ocean physical attributes; ecological and coastal processes; and weather; decreased sea ice extent and duration increase probability of coastal erosion and exposure to storm surges
Glacial ice (ice islands: frequency of occurrence and dimensions)	Numbers and frequency of occurrence of marine glacial ice in the Beaufort Sea	The presence of massive marine glacial ice features can have a major effect on offshore oil and gas, shipping and other activities.
Waves (height, direction, speed, variability, frequency of extreme events)	Mean and maximum significant wave (H_S) height (m), peak period (T_P), mean direction	Effects on small craft, shipping activities, offshore operations, and coastal infrastructure; physical forcing on remaining sea ice cover; and rates of coastal erosion, compounded by increased likelihood of storm surges,
Currents and water column structure (physical and chemical)	Salinity Mixed layer depth pH and alkalinity Dissolved oxygen	Affects density and, in turn, ocean ventilation and mixed layer depth. These parameters then can affect the food web (e.g., primary production, crustaceans), coastal communities, and the overall health of the Beaufort, including through transportation of nutrients and contaminants
Permafrost conditions	Extent of permafrost (km^2) Permafrost quality including temperature (°C) and active layer thickness (m)	Permafrost sediment holds enormous amounts of carbon (carbon dioxide and methane) which would otherwise be in the atmosphere. Extent and quality can affect ground stability – public safety and infrastructure hazard (e.g., land-based logistical centres). Active (freeze/thaw) layer thickness affects construction projects – depth of foundations, insulation characteristics. Drainage and erosion can be altered, thereby further altering ground conditions and altering ecosystems. Some metals and contaminants held by permafrost sediment may be released during thaw
Freshwater runoff from Makenzie River (timing, volume and water quality)	Discharge volume (m^3), changes in baseflow (m^3), sediment volume (kg), freshet timing, water quality ($N0_3$)	Freshwater input into Beaufort Sea prior to and following landfast ice breakup; thermodynamics (relatively warm water); discharge of sediments and contaminants; and freshwater impacts on coastal ocean attributes, sedimentation in the harbours and estuaries, flooding, freshwater influence at the ocean interface
Coastal exposure and erosion	Changes in coastlines Loss of land (hectares)	Effects on important cultural and historical sites and coastal communities (housing) and ways of life. Changes in coastlines requires special provision for nearshore infrastructure and areas where offshore pipelines or cables make landfall, as well as effects of sediment discharge from erosion on the ocean environments, ecosystems and infilling harbours/bays

2.3 Use of down-scaled IPCC Model results

Trends and RCP 8.5 scenario projections for climate variables presented in this report were assessed from the IPCC's Fifth Assessment Report (Church et al. 2013), the Canada's Changing Climate Report (Bush and Lemmen 2019), and academic journal publications, published in 2014 or later. Preference was given to literature employing data from the Coupled Model Intercomparison Project (CMIP5), with regionally downscaled results for the southern Beaufort Sea were the primary. The Climate Change Hazards Information Portal (CCHIP) database was also used via the Risk Sciences International (RSI) data portal (RSI 2018). CCHIP provides visualized historical and projected climate data and analysis for both active and inactive weather monitoring stations in Canada (RSI 2018).

Studies using Global Climate Model output for the Arctic were assessed for physical attributes where regionally-downscaled results were unavailable. For variables where limited information was found using CMIP5 data (e.g., Mackenzie River Discharge), studies following an AR4 climate scenarios using CMIP3 data were employed. Specifically, the CCSR-SRES-A1FI scenario is equivalent to the RCP8.5 scenario of the AR5 (Riahi et al. 2011). Projections specific to coastal communities and geographic sites in the southern Beaufort Sea and Amundsen Gulf are presented, along with author interpretations of Arctic-wide and regional scale projections for physical attributes presented in Section 3.

2.4 Assessing uncertainties in IPCC Model results

We will aim to include measures of variability and uncertainty in our predictions of the chosen variables where possible and appropriate. To do this, we use the same calibrated uncertainty language as in the IPCC's Fifth Assessment Report (e.g., (Church et al. 2013). Specifically, where possible, we will aim to lay out the predicted conditions under RCP 8.5 at the end of each decade (2030, 2040, 2050), and describe the uncertainties for each variable according to the IPCC levels of confidence (very low, low, medium, high, very high) and likelihood (exceptionally unlikely (<1%), extremely unlikely (<5%), very unlikely (<10%), unlikely (<33%), about as likely as not (33–66%), likely (>66%), very likely (>90%), extremely likely (>95%) to virtually certain (>99%)).

To estimate the level of uncertainty, the model results under RCP 8.5 derived for recent past and present conditions are compared with observed conditions, as presented in papers available in the scientific literature. In addition, differences in the many different models operated under the IPCC studies provide a measure of the potential variability inherent in the model outputs for the particular variable being examined. When model results are not available for a particular variable, scientific papers which provide analyses of existing trends and the natural variability around these trends are examined, as well as consideration of the projected future changes in the variables based on analysis of relevant physical mechanisms and their potential responses to climate change. From this review, an assessment of the variability and uncertainties is made based on the results and conclusions of these papers.

3 CURRENT AND FUTURE TRENDS OF KEY PHYSICAL ATTRIBUTES

3.1 Air temperature

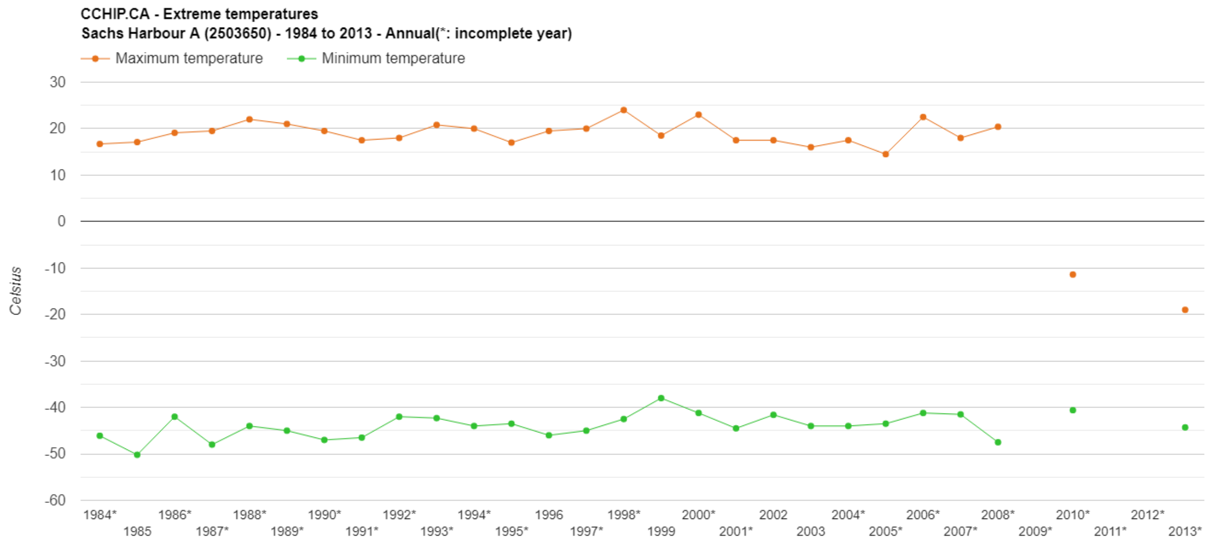
3.1.1 Current trends

Air temperatures in the region typically range between lows near -28°C in the winter and highs near 12°C in the summer (ECCC 2019a), although locations specific extremes exceed these. For example, as shown in Table 3-1, the lowest average daily minimum temperature at Sachs Harbour is -32.1°C, occurring in February and the highest average daily temperature is 6.6°C, occurring in July. Extreme temperatures at Sachs Harbour range between -52.2°C in January and 24.2°C in July. Figure 3-1 shows a profile of the minimum and maximum daily temperatures experienced at the Sachs Harbour A weather station for over a 30-year timespan (1984 – 2013).

Table 3-1 Climate Normals - Sachs Harbour and Tuktoyaktuk

Sachs Harbour - 1981 to 2010 Climate Normals													
Temperature	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Daily Average (°C)	-28	-28.3	-26.7	-18.3	-7.6	3.1	6.6	3.7	-1.2	-10.7	-20.5	-25.1	-12.8
Daily Maximum (°C)	-24.4	-24.5	-23.1	-14.6	-4.6	6.1	10	6.5	1.2	-7.7	-17.1	-21.5	-9.5
Daily Minimum (°C)	-31.7	-32.1	-30.3	-22	-10.5	0.1	3.1	0.9	-3.4	-13.7	-23.9	-28.5	-16
Extreme Maximum (°C)	-4.4	-4.5	-4	2.2	10	20.5	24.2	21.5	15.6	4.4	1.7	-4	-
Date (yyyy/dd)	1974/02	1989/05	1988/13	1960/25	1994/25	1977/21	1982/06	2000/01	1957/06	1969/11	1970/01	1983/24	-
Extreme Minimum (°C)	-52.2	-50.2	-48.4	-43	-26.7	-16.5	-5	-11	-22.8	-35.5	-42.8	-45	-
Date (yyyy/dd)	1975/10	1985/15	1979/04	1997/01	1958/03	1978/05	2002/31	1995/28	1975/30	1996/28	1972/20	1957/23	-
Tuktoyaktuk - 1981 to 2010 Climate Normals													
Temperature	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Daily Average (°C)	-26.6	-26.4	-25.1	-15.7	-4.7	6.4	11	8.9	3.3	-7.4	-20.7	-23.8	-10.1
Daily Max (°C)	-23	-22.4	-21.1	-11.3	-1.1	11	15.1	12.3	5.8	-4.7	-17.3	-20.1	-6.4
Daily Min (°C)	-30.4	-30.6	-29.2	-20.1	-8.2	1.7	6.9	5.4	0.7	-9.9	-24	-27.5	-13.8
Extreme Max (°C)	0.6	0.7	-0.5	4.8	20.9	28.2	29.4	27.6	20.9	17.4	2.2	0.8	-
Date (yyyy/dd)	1974/04	1982/04	1988/11	1989/25	1985/31	1982/28	1973/26	1989/08	2006/08	2003/02	1976/10	1992/02	-
Extreme Min (°C)	-48.9	-46.6	-45.5	-42.8	-28.9	-8.9	-1.7	-2.5	-12.8	-28.5	-40.1	-46.7	-
Date (yyyy/dd)	1975/13	1985/19	1979/10	1971/01	1992/03	2000/04	1974/05	1985/26	1974/27	1983/27	1988/19	1974/30	-

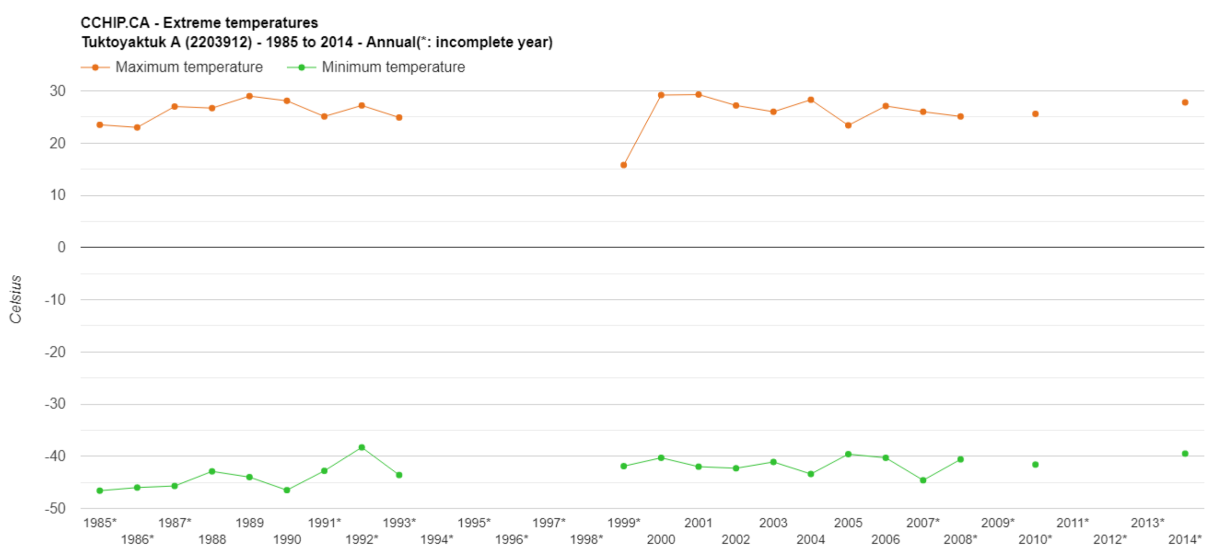
Source: ECCC 2019a



Source: ECCC 2019a

Figure 3-1 Annual extreme daily maximum and minimum temperatures at the Sachs Harbour A weather station from 1984-2013

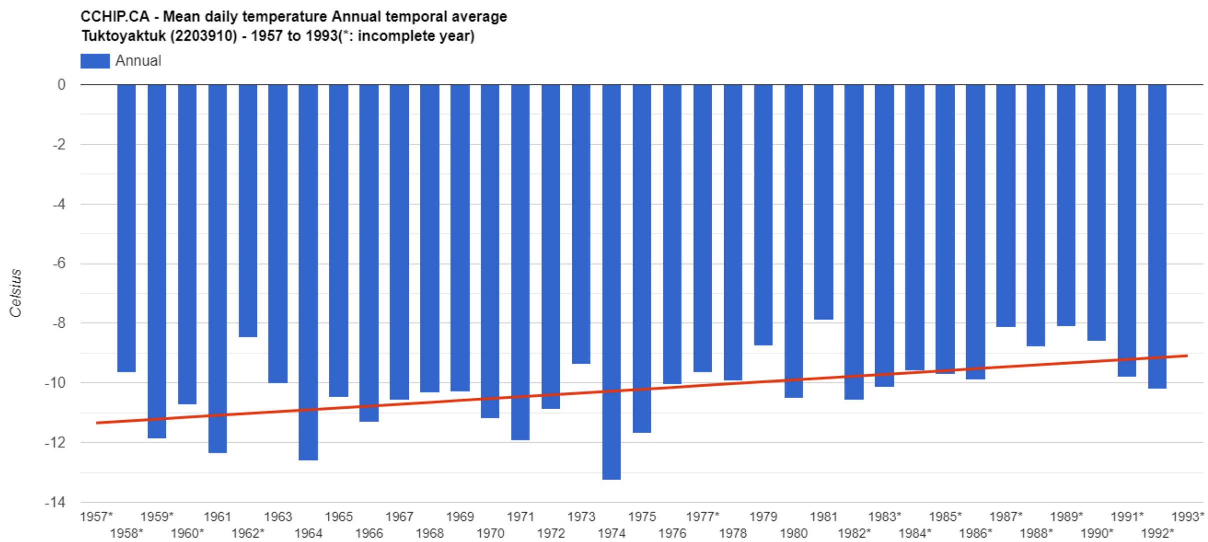
At Tuktoyaktuk, the air temperatures in the region typically range between lows near -31°C in the winter and highs near 15°C in the summer. For example, as shown in Table 3-1 data from the climate normals indicate that the lowest average daily minimum temperature at Tuktoyaktuk is -30.6°C, occurring in February and the highest average daily temperature is 6.6°C, occurring in July. Extreme temperatures at Tuktoyaktuk range between -48.9°C in January and 29°C in July. A plot of minimum and maximum daily temperatures experienced at the Tuktoyaktuk A weather station over the past 30-years (1985-2014) is provided in Figure 3-2.



Source: ECCC 2019a

Figure 3-2 Annual extreme daily maximum and minimum temperatures at the Tuktoyaktuk A weather station from 1985-2014

Historical mean temperature data at the Tuktoyaktuk A weather monitoring station are presented below in Figure 3-3. Data here shows a generally increasing trend in mean annual temperature within the timespan of the dataset of +0.06°C per year.



Source: ECCC 2019a

Figure 3-3 Historical mean daily temperature as annual temporal average for the Tuktoyaktuk (ID: 2203910) from 1957 to 1993

3.1.2 Predictions

3.1.2.1 Arctic

A review of the latest IPCC assessment (IPCC 2014a; Kirtman et al. 2013; Collins et al. 2013) was conducted to ascertain the potential changes in climate for the Arctic Region and where available, specifically for the Beaufort Sea region associated with the offshore. Highlights of the findings, taken largely from the IPCC reports, are provided here.

Polar amplification, is defined as the warming that occurs in the Arctic and Antarctica, caused by greenhouse gas emissions of human origin, and changes in surface reflectivity. Arctic amplification is warming of the Arctic at high latitudes generally between 67.5°N and 90°N. The timeframes for looking at the future and comparing projections to the present are 2081-2100 for future, with comparisons to 1986-2005.

There is a strong seasonality to the expected warming in the Arctic. Warming is projected to peak in early winter (November-December) and the rate of warming is projected to exceed the global average by a factor of about 4. Warming would be lowest in summer, when more heat is taken up in the melting of ice and snow, and in warming the ice water and sea water.

There is likely to be some feedback due to changes to ice and snow cover related to change in the reflecting ability (also known as albedo) of both the ice and snow. The ice extent and snow cover changes as the melt season progresses, as it changes from (~0.90 – 0.95 for new snow cover) white to an average of ~0.6 for partially melted ice surfaces comprised of meltponds, exposed hummocks and ridges, and small expanses of open sea water. The shift to lower albedos results in less reflection of solar and longwave radiation, thereby increasing the rate of energy absorption at the surface.

A comprehensive atlas of global and regional climate projections has been presented as Annex I to the IPCC report and includes the Arctic as a special region (IPCC 2013a). Using the Maximum Concentration Pathway (RCP8.5), the change in annual surface air temperature is projected for the Arctic region (land) to be a mean of +3°C and as high as +9°C, and a mean of +5°C and as high as +7.5°C for Arctic (sea), i.e., the Arctic Ocean.

Using the 50% percentile of the climate models distribution, the change in surface air temperature on an annual basis is projected for the Beaufort Sea region to be +2°C to +3°C for 2016-2035, and +4°C to +5°C for 2046-2065. (IPCC 2013a - Figure AI.SM8.5.12).

The same metrics for the 4 seasons of the year are provided in Table 3-2.

Table 3-2 Projected Temperature Change relative to 1986-2005 – in the Atmosphere (RCP8.5)

Location	Timeframe		Temperature Change (°C) Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
Arctic (land)	2050	mean	5	3	2.5	4.5
		maximum	10	7.5	5	7.5
Arctic (sea)	2050	mean	7.5	4	2	6.5
		maximum	14	7.5	2.5	11
Beaufort Sea	2016-2035	range	3-4	1.5-2	1-1.5	4-5
Beaufort Sea	2046-2065	range	5-7	4-5	1.5-3	5-9
SOURCE: from IPCC 2013a – Atlas of Global and Regional Climate Projections – Figures AI.SM8.5.13, .14, .15, .16						

In the Arctic, the IPCC projections for 2050 indicate that the biggest change from 1986 – 2005 is expected to occur on land during the December to February period with a mean change of +5°C and a maximum of +10°C. The most warming in the atmosphere over the Arctic sea at year 2050 will occur during the December to February period with a mean change of +7.5°C and a maximum of +14°C.

Regarding extremes in temperature, while there is some uncertainty in the specific projections, IPCC states *that it is virtually certain* that there will be more hot and fewer cold temperature extremes, as global temperatures rise. Extremes may occur for a single day or a few consecutive days and may constitute a heat wave (spells of days with temperatures above a threshold from climatology). For the Maximum Concentration Pathway (RCP8.5), the minimum temperature during the coldest day of the year is expected to rise by 7-9^{o}C in 2081-2100. It is very likely that heat waves will occur with higher frequency and duration, mainly because of the increase in seasonal temperatures.

3.1.2.2 Beaufort Sea

For the Beaufort Sea, the IPCC projections indicate that the most warming is expected in the September-November period; around +4-5^{o}C during the period 2016-2035, and an increase in the range of +5 to +9^{o}C for the period 2046-2065 (IPCC 2013a).

The average changes in the mean surface air temperatures projected in this study for the Tuktoyaktuk A and Sachs Harbour weather monitoring stations are provided in Table 3-3 and Table 3-4, for the RCP 8.5 scenario. These are projected for 3 time periods – 2020s, 2050s and 2080s.

Table 3-3 Average Change in Mean Temperature Relative to 1981 – 2010 - Tuktoyaktuk A

Season	1981-2010 (°C)	Average Change in Mean Temperature from 1981-2010 Baseline (°C)		
		2020s	2050s	2080s
Annual	-10.0	2.2	5.2	8.5
Winter	-25.7	2.9	7.7	13.3
Spring	-15.2	1.9	4.3	7.3
Summer	8.8	1.1	2.7	4.7
Autumn	-8.1	2.9	6.2	8.9

Table 3-4 Average Change in Mean Temperature Relative to 1981 – 2010 - Sachs Harbour A

Season	1981-2010 (°C)	Average Change in Mean Temperature from 1981-2010 Baseline (°C)		
		2020s	2050s	2080s
Annual	-12.9	2.2	5.3	8.8
Winter	-27.3	2.9	7.8	14.1
Spring	-17.4	1.9	4.4	7.4
Summer	4.3	0.9	2.3	4.1
Autumn	-11.0	3.0	6.8	9.8

The projection information complied here shows a warming trend throughout the region. The largest changes observed in the data presented above are for the winter months. Both the annual and winter average projected changes have been summarized in a series of plots (Figure 3-4 and Figure 3-5) for a comparative analysis among the four assessed stations. These results suggest that there is limited variability in projected mean temperature change within the region, based on information provided at the selected stations.

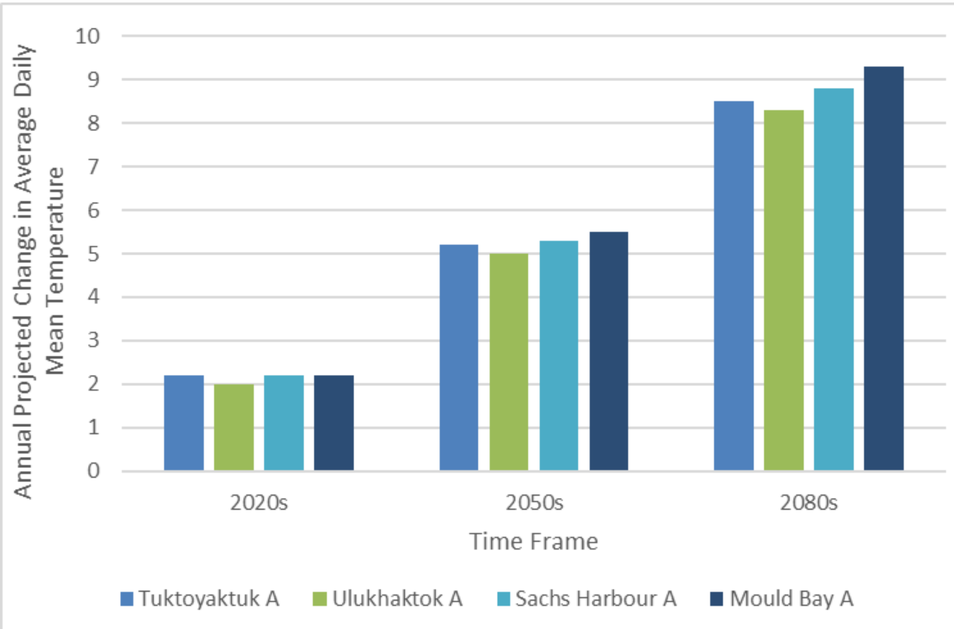


Figure 3-4 Projected Changes in Average Daily Mean Annual Temperatures for Tuktoyaktuk A, Ulukhaktok A, Sachs Harbour A, and Mould Bay A

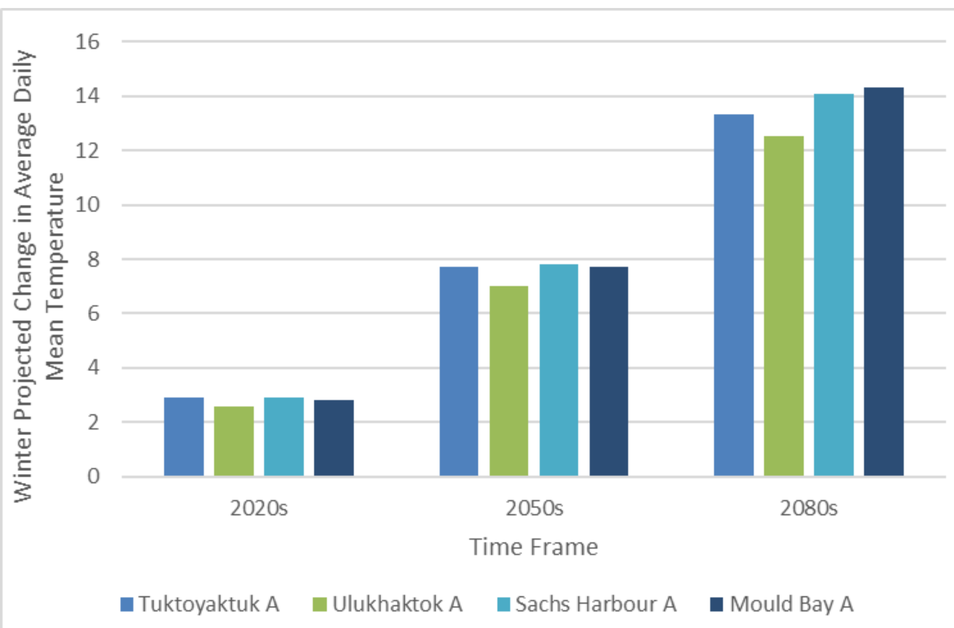
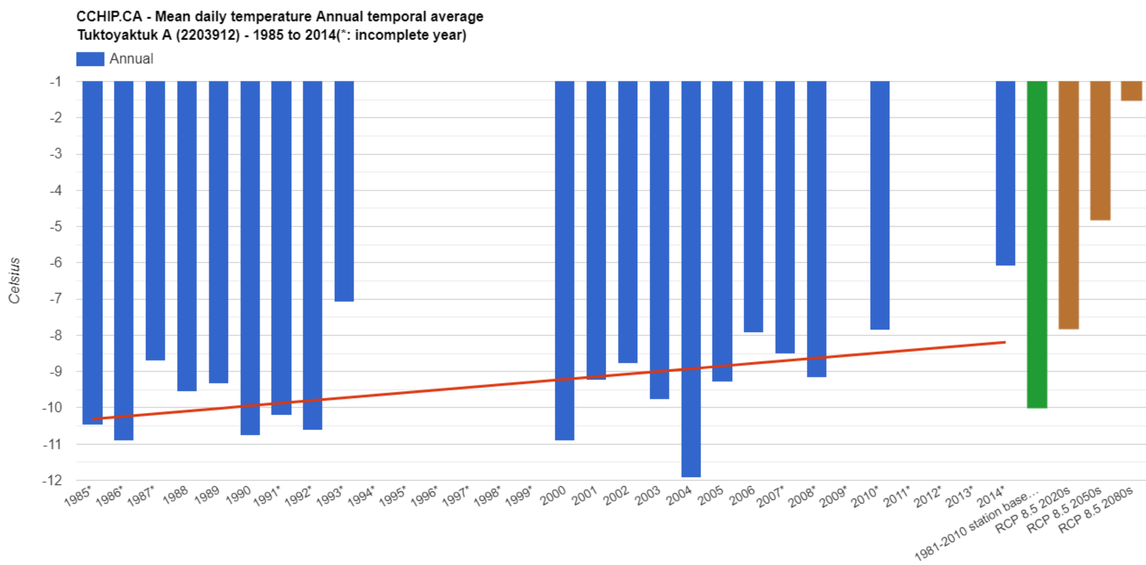


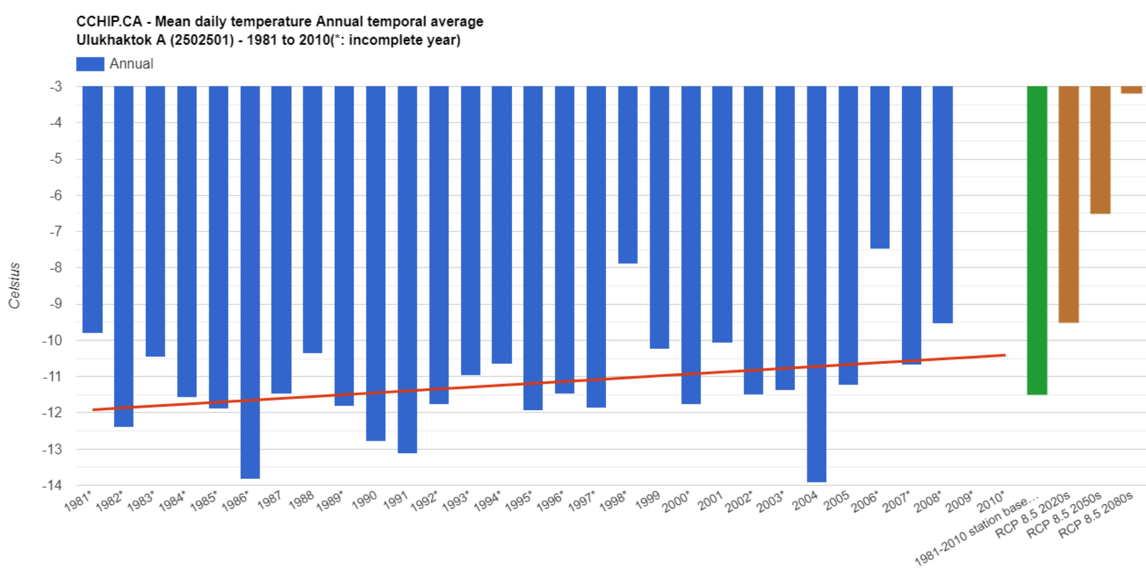
Figure 3-5 Projected Changes in Average Daily Mean Winter Temperatures for Tuktoyaktuk A, Ulukhaktok A, Sachs Harbour A, and Mould Bay A

Figure 3-6 to Figure 3-9 provide a more detailed visualization of the historical and projected mean temperature values at the four weather monitoring stations. These plots highlight the general warming trend that has been observed in the region and large change expected by the 2050s and 2080s.



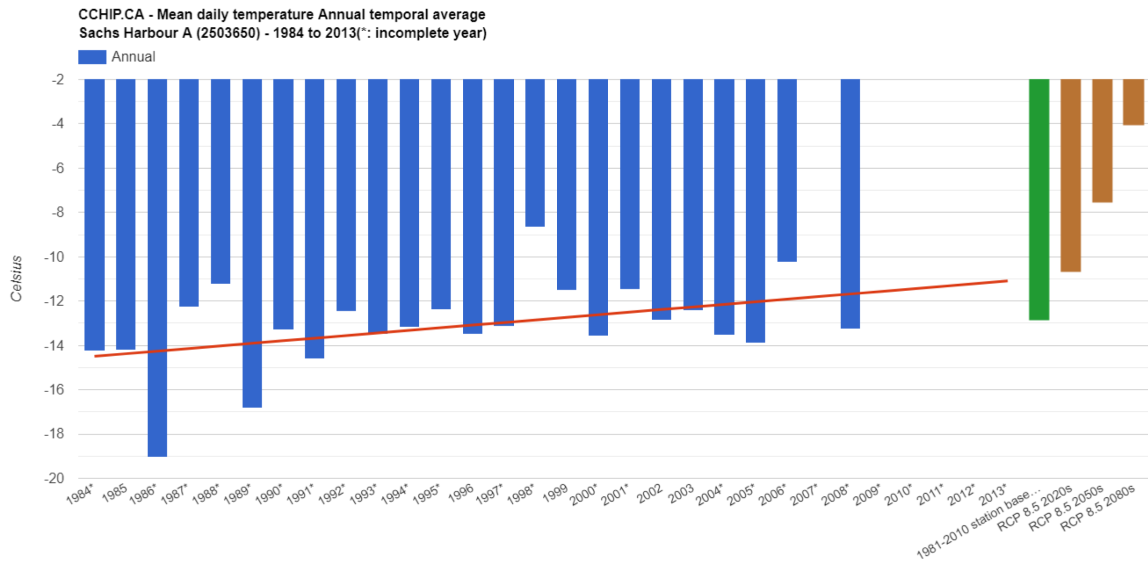
NOTES: Observed changes in mean daily temperature are shown by the blue bars. The trend in those data are plotted as the red line (0.07ºC/year). The average value for the reference period of 1981-2010 is shown as the green bar. Climate projections for the 2020s, 2050s, and 2080s, are represented by the brown bars.

Figure 3-6 Annual Temporal Average – Mean Daily Temperature – Tuktoyaktuk A



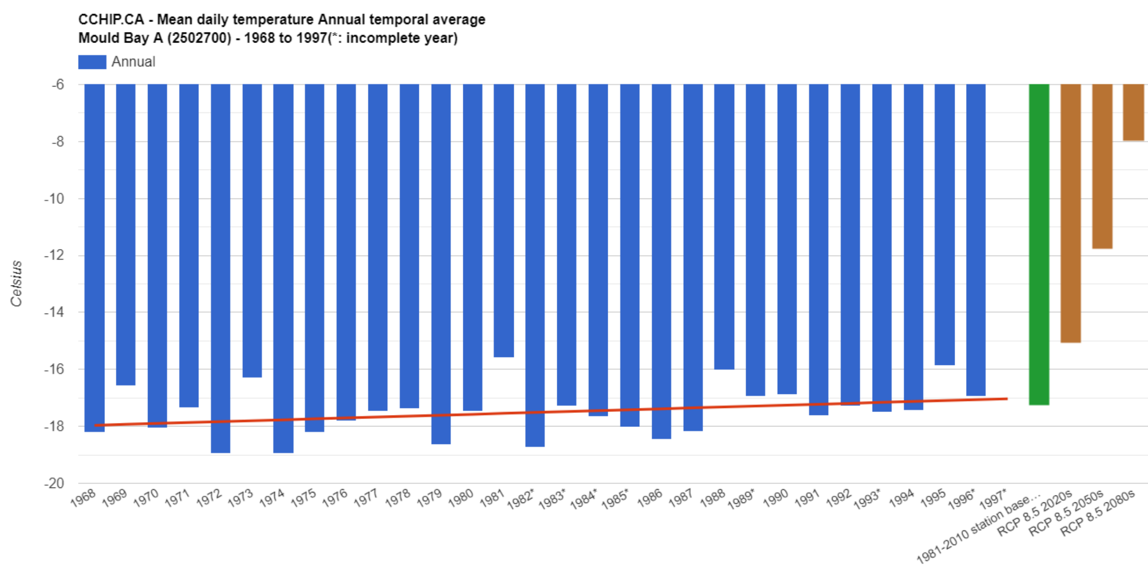
NOTES: Observed changes in mean daily temperature are shown by the blue bars. The trend in those data are plotted as the red line (0.05ºC/year) . The average value for the reference period of 1981-2010 is shown as the green bar. Climate projections for the 2020s, 2050s, and 2080s, are represented by the brown bars.

Figure 3-7 Annual Temporal Average – Mean Daily Temperature – Ulukhaktok A



NOTES: Observed changes in mean daily temperature are shown by the blue bars. The trend in those data are plotted as the red line (0.12ºC/year). The average value for the reference period of 1981-2010 is shown as the green bar. Climate projections for the 2020s, 2050s, and 2080s, are represented by the brown bars.

Figure 3-8 Annual Temporal Average – Mean Daily Temperature – Sachs Harbour A



NOTES: Observed changes in mean daily temperature are shown by the blue bars. The trend in those data are plotted as the red line (0.03ºC/year). The average value for the reference period of 1981-2010 is shown as the green bar. Climate projections for the 2020s, 2050s, and 2080s, are represented by the brown bars.

Figure 3-9 Annual Temporal Average – Mean Daily Temperature – Mould Bay A

The average change in the maximum surface air temperatures projected for Tuktoyaktuk A and Sachs Harbour A weather stations are provided in Table 3-5 and Table 3-6, for the Maximum Representative Concentration Pathway (RCP 8.5). These are projected for 3 time periods – 2020s, 2050s and 2080s.

Similar to the results to the changes in mean temperature, maximum temperatures are projected to increase into the coming decades, the largest changes occurring during the winter months.

Table 3-5 Average Change in Maximum Temperature Relative to 1981 – 2010 Baseline for Tuktoyaktuk A

Season	1981-2010 (°C)	Average Change in Maximum Temperature from 1981-2010 Baseline (°C)		
		2020s	2050s	2080s
Annual	-6.4	2	4.7	7.6
Winter	-21.9	2.7	6.9	11.8
Spring	-11.1	1.7	3.8	6.3
Summer	12.8	1	2.6	4.5
Autumn	-5.2	2.5	5.5	7.9

Table 3-6 Average Change in Maximum Temperature Relative to 1981-2010 Baseline for Sachs Harbour A

Season	1981-2010 (°C)	Average Change in Maximum Temperature from 1981-2010 Baseline (°C)		
		2020s	2050s	2080s
Annual	-9.5	2	4.9	8.1
Winter	-23.6	2.7	7.3	13
Spring	-13.8	1.7	3.9	6.5
Summer	7.5	0.9	2.3	4.1
Autumn	-7.9	2.7	6.1	8.7

Including Ulukhaktok A and Mould Bay A weather stations projections for annual and winter temperatures are showing similar warming trends across the Beaufort Sea region, with little variability among sites relative to the magnitude of change (Figure 3-10 and Figure 3-11).

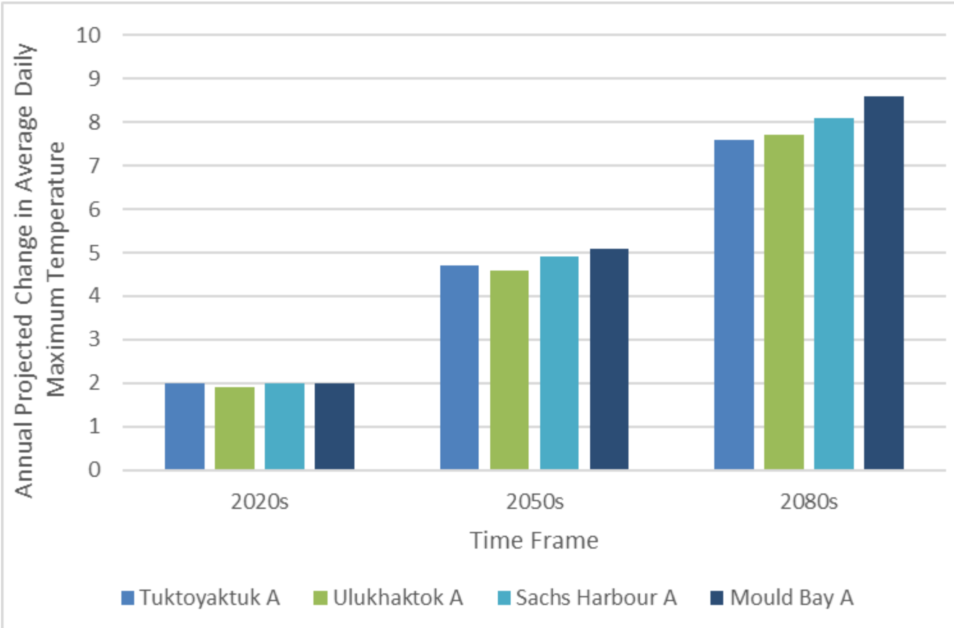


Figure 3-10 Projected Changes in Average Daily Maximum Annual Temperatures for the Tuktoyaktuk A, Ulukhaktok A, Sachs Harbour A, and Mould Bay A weather monitoring stations

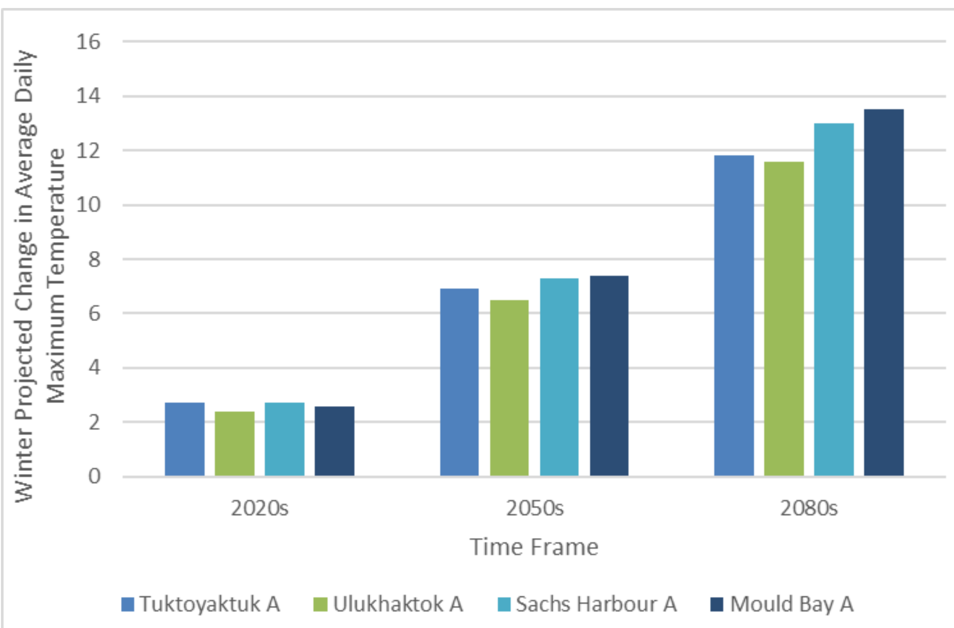


Figure 3-11 Projected Changes in Average Daily Maximum Winter Temperatures for the Tuktoyaktuk A, Ulukhaktok A, Sachs Harbour A, and Mould Bay A weather monitoring stations

The average changes in the minimum surface air temperature projected for Tuktoyaktuk A and Sachs Harbour A weather monitoring stations are provided in Table 3-7 and Table 3-8, for RCP 8.5. These are projected for 3 time periods – 2020s, 2050s and 2080s.

Similar to the previous analyses, general warming in the Beaufort Sea region is projected to occur, with the highest period of warming being during the winter months.

Table 3-7 Average Change in Minimum Temperature Relative to 1981-2010 Baseline for Tuktoyaktuk A

Season	1981-2010 (°C)	Average Change in Minimum Temperature from 1981-2010 Baseline (°C)		
		2020s	2050s	2080s
Annual	-13.7	2.4	5.6	9.1
Winter	-29.6	3.1	8.0	13.9
Spring	-19.2	2.1	4.8	8.0
Summer	4.8	1.1	2.7	4.7
Autumn	-10.9	3.1	6.8	9.6

Table 3-8 Average Change in Minimum Temperature Relative to 1981-2010 Baseline for Sachs Harbour A

Season	1981-2010 (°C)	Average Change in Minimum Temperature from 1981-2010 Baseline (°C)		
		2020s	2050s	2080s
Annual	-16.2	2.3	5.7	9.3
Winter	-31.0	3.0	8.1	14.6
Spring	-21.0	2.2	4.9	8.2
Summer	1.3	0.9	2.3	4.1
Autumn	-14.0	3.2	7.3	10.5

Expanded to all four weather stations previously used, data corroborate the conclusions that the region is experiencing general warming, and that there is no evidence of significant geographic variability in projected changes in minimum temperature extremes in the Beaufort Sea region (Figure 3-12 and Figure 3-13).

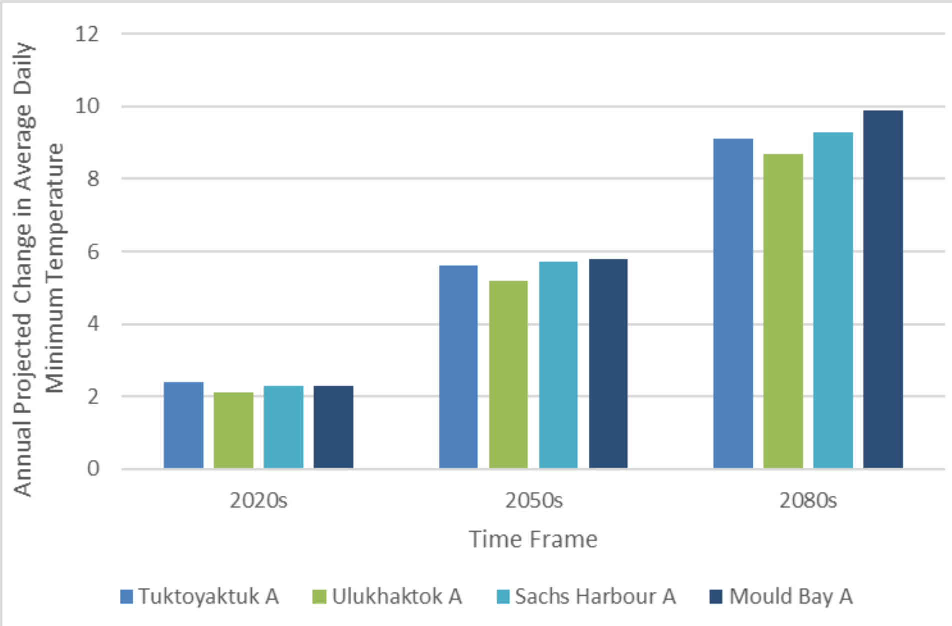


Figure 3-12 Projected Changes in Average Daily Minimum Annual Temperatures for the Tuktoyaktuk A, Ulukhaktok A, Sachs Harbour A, and Mould Bay A weather monitoring stations

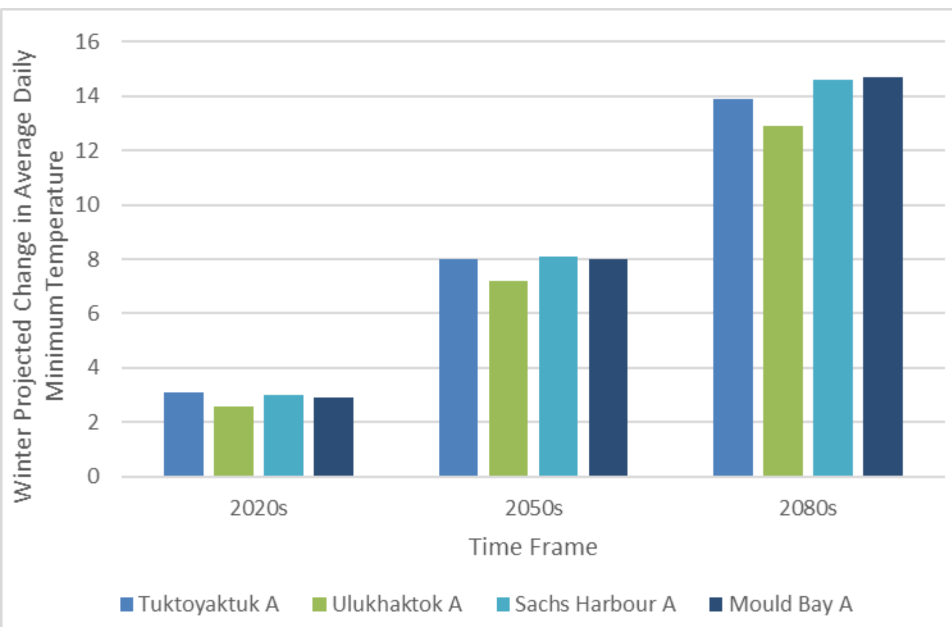


Figure 3-13 Projected Changes in Average Daily Minimum Winter Temperatures for the Tuktoyaktuk A, Ulukhaktok A, Sachs Harbour A, and Mould Bay A weather monitoring stations

3.1.3 Uncertainties

The Climate Change Hazards Information Portal (CCHIP) was used for projection analyses and plots provided in this section. This analysis tool runs a total of 40 global climate models (GCMs), i.e., those included in the AR5 Fifth Coupled Model Intercomparison Project (CMIP5). This study used the 50th percentile results of the spread of these 40 GCM model outcomes to represent estimated projection values and assumes progression towards the RCP 8.5 scenario. Actual future climate changes will largely depend on the speed at which certain global phenomena unfold and on the scale of global efforts to reduce greenhouse gas emissions in the coming decades. However, the methods used for these projection calculations are accepted as being a reasonable representation of potential future climate outcomes.

One key atmospheric unknown that affects air temperature is uncertainty over the vertical structure of the future Arctic atmosphere over the Beaufort Sea under the absence of summer sea ice cover, and delayed freeze-up. There is a vertical structure to the projected warming of the atmosphere, where warming is projected to be greatest near the surface, and less so aloft. Several factors which complicate climate projections are acknowledged, including:

- initial ice state and timing
- inversion strength, in a stable future Arctic atmosphere
- ocean heat transport, between south and north
- albedo feedback, where the rate of warming goes up as the surface darkens
- short wave and long wave radiative forcings, and associated feedback
- clouds and associated feedback

These complications lead to a medium confidence in the specific climate projections.

3.1.4 Limitations

Although the Beaufort Sea region is represented by a fair number of active and historical weather monitoring stations, data availability within these stations is, at times, limited. (Table 3-9). Data availability is presented as the percentage to which the dataset is complete within the listed time range. The data availability and time range, including the age of the data are factors in choosing which data to use for which application.

Table 3-9 Summary of weather stations considered in this study (grey highlight) as well as nearly complimentary stations and their respective data ranges and the availability of data within the time range.

Station	Station ID	Data Range	Temperature Data Availability	Station Status
Tuktoyaktuk A	**2203912**	**1970-2014**	**72% complete**	**Inactive**
Tuktoyaktuk	2203914	1994-2017	91% complete	Active
Tuktoyaktuk	2203910	1957-1993	97% complete	Inactive
Ulukhaktok A	**2502501**	**1979-2010**	**85% complete**	**Active**
Holman Cs	2502505	2000-2018	91% complete	Inactive
Holman	2502500	1941-1969	NA	Inactive
Sachs Harbour A	**2503650**	**1955-2013**	**85% complete**	**Inactive**
Sachs Harbour Climate	2503648	1993-2017	89% complete	Active
Mould Bay A	**2502700**	**1948-1997**	**96% complete**	**Inactive**
Mould Bay Cs	250M001	1997-2018	80% complete	Active
Mould Bay Camp	2502G00	1994-1997	NA	Inactive

NOTE:
A temperature data availability of 'NA' means that data availability statistics are not available.

3.1.5 Summary

The observed air temperatures in the Arctic and specifically for the Beaufort Sea show a clear upward trend. The climate projections by the IPCC and those provided this study for the Beaufort Sea show an upward trend in air temperature. The rate of change is projected to increase over time. The most warming in the atmosphere over the Arctic sea at year 2050 will occur during the December to February period with a mean change of +7.5°C and a maximum of +14°C.

Similar magnitudes were projected for changes in the annual mean, the daily mean, the annual maximum and the annual minimum values, with values ranging from +5 to +6°C as an annual average, and +7 to +9°C in the winter season, with low geographic variability.

3.2 Precipitation

3.2.1 Current trends

The climate normal for precipitation are shown in Table 3-10 (ECCC 2019a,b). Precipitation in the Arctic is lower than over most regions at lower latitudes. The average annual precipitation at Sachs Harbour is 151.5 mm, for the 30-year climate normal period of 1981 – 2010.The annual average total rainfall over the 1981 – 2010 period is 58.3 mm, with most rain falling in July August September timeframe. The annual average total snowfall for the same period is 97.7 cm (ECCC 2019a). At Tuktoyaktuk A, the annual precipitation is 160.7 mm, with 74.9 mm rain and 103.1 cm of snow. The data are similar at both stations, and the maximum snow fell in October at both locations.

Table 3-10 Climate Normals 1981 – 2010 - Precipitation - Sachs Harbour, Tuktoyaktuk A

Sachs Harbour - 1981 to 2010 Climate Normals													
Precipitation	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Rainfall (mm)	0	0	0	0	0.1	5.1	16.7	24.7	11.2	0.5	0	0	58.3
Snowfall (cm)	5.2	7	7.7	12.4	9.3	2.4	0.9	4.1	10.9	20.2	9.4	8.3	97.7
Precipitation (mm)	4.9	6.6	7.1	12.1	9.1	7.5	17.6	28.9	22	20	9	7	151.5
Snow Depth Month-end (cm)	15	15	18	16	9	0	0	0	3	10	12	14	9

Tuktoyaktuk - 1981 to 2010 Climate Normals													
Precipitation	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Rainfall (mm)	0	0	0	0	1.4	9.7	22.2	24.4	15.5	1.3	0	0.3	74.9
Snowfall (cm)	13.4	10.2	9	9.4	6.2	1.3	0.1	1.2	8.9	20.1	12.1	11.2	103.1
Precipitation (mm)	10.5	8.9	7.2	8.3	6.8	11	22.3	25.7	23.3	18.4	9.6	8.7	160.7
Avg Snow Depth (cm)	25	28	34	35	18	1	0	0	0	6	13	18	15
Median Snow Depth (cm)	25	28	34	36	19	0	0	0	0	5	13	17	15
Snow Depth-Month-end (cm)	28	31	36	31	5	0	0	0	1	10	15	20	15

Data on precipitation over a longer period of record at Tuktoyaktuk A are shown in Figure 3-14 to Figure 3-16. There is considerable variation in the data on both rainfall and snowfall, with a slight increase in total annual precipitation from 1970 to 2014 (0.53 mm/year). Rainfall has increased a small amount as well (0.28 mm/year). Snowfall has steadily increased from about 70 to 110 cm per year, with a trend of 1.16 cm/year as shown by the red trend line in Figure 3-16. As shown by the blue bars, the year-to-year variability is fairly high.

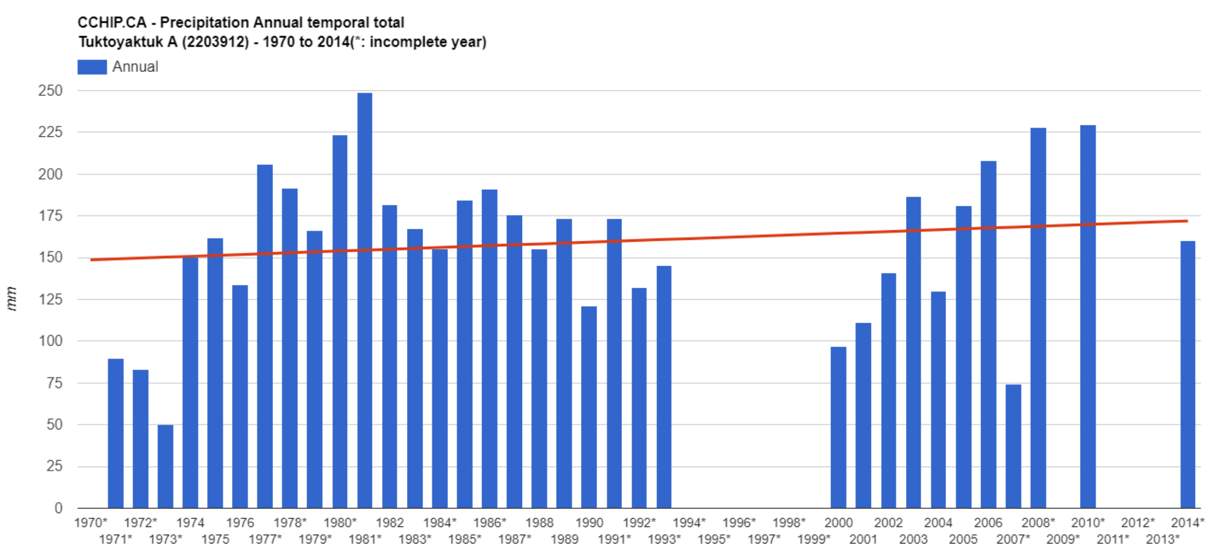


Figure 3-14 Historical annual total precipitation at the Tuktoyaktuk A weather station from 1970 to 2014

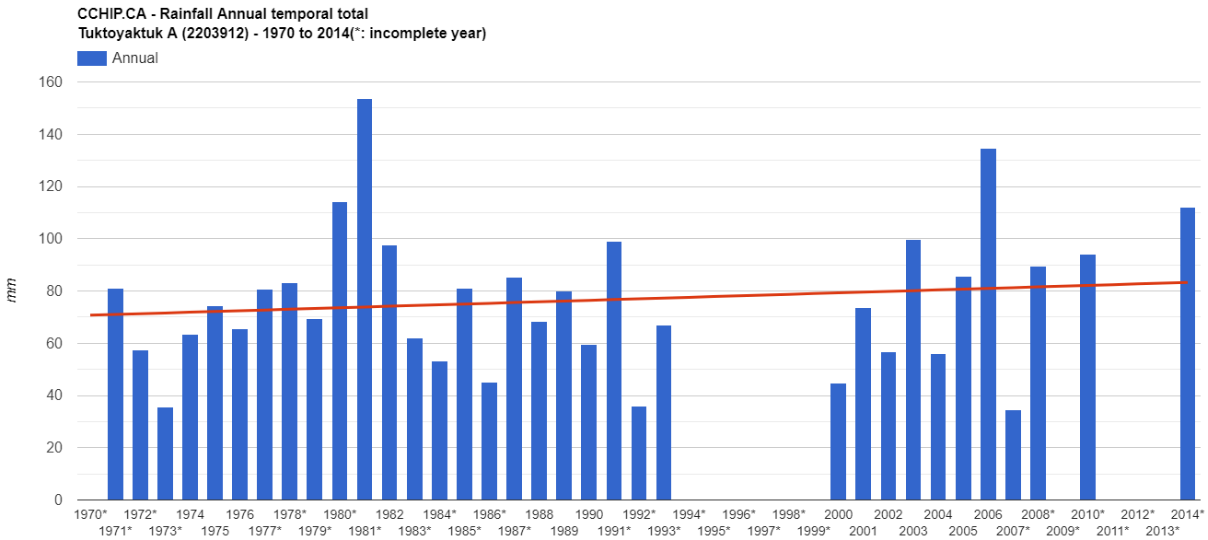


Figure 3-15 **Historical annual total rainfall at the Tuktoyaktuk A weather station from 1970 to 2014**

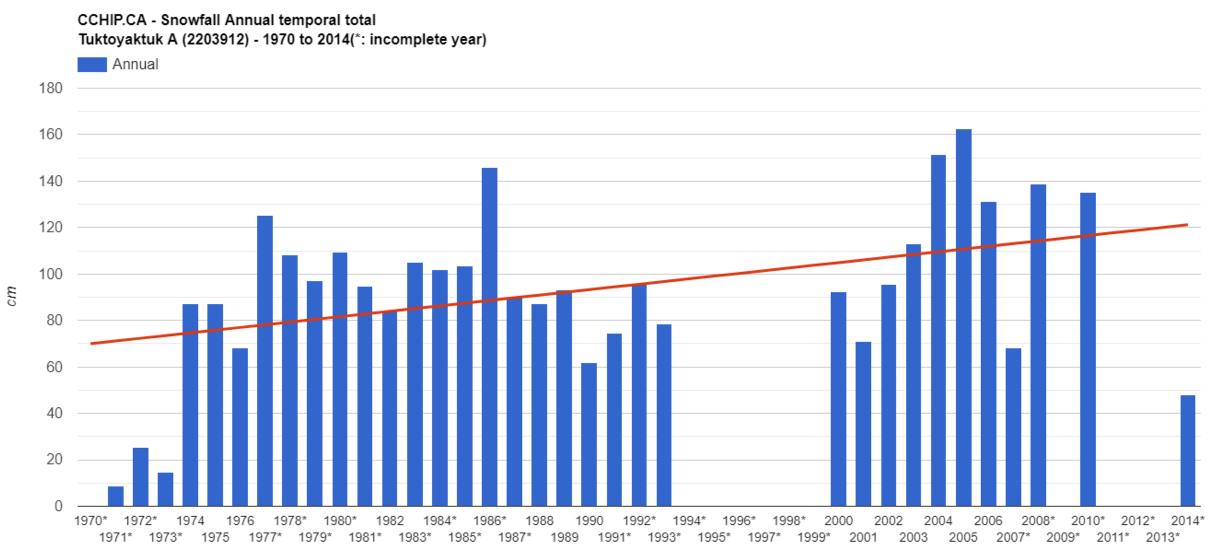


Figure 3-16 **Historical annual total snowfall at the Tuktoyaktuk A weather station from 1970 to 2014**

3.2.2 Predictions

3.2.2.1 Arctic

Observations and conclusions presented in this section are taken largely from the Intergovernmental Panel on Climate Change (IPCC) most recent reports (IPCC 2013b; Christensen et al. 2013; Collins et al. 2013; IPCC 2014). Changes in the quantities of precipitation tend to scale with change in mean surface temperature, for the Maximum Concentration Pathway (RCP8.5). The presence of black carbon and stratospheric ozone also influence precipitation, and these in turn are related to changes in heating and atmospheric circulation.

Projections for precipitation for specific geographies are presented in the atlas of global and regional climate projections, referred to as Annex I to the IPCC report (IPCC 2013a). Using the Maximum Concentration Pathway (RCP8.5), the increase in annual precipitation for the Arctic region (land) at year 2050 relative to 1986-2005 is projected to be a mean of 18%, and as high as 43%. For the Arctic Ocean, this increase is projected to be a mean of 20%, and as high as 38%. Seasonally, this change in more pronounced in the fall as compared to spring (Table 3-11; IPCC 2013a).

Table 3-11 Projected Precipitation Change - relative to 1986 – 2005

Location	Timeframe		Precipitation Change (%)	
			Oct-Mar	Apr-Sep
Arctic (land)	2050	mean	20	18
		maximum	52	42
Arctic (sea)	2050	mean	20	12
		maximum	46	40
Beaufort Sea	2016-2035	range	10-20	0-10
Beaufort Sea	2046-2065	range	30-40	10-20
SOURCE: from IPCC 2013a – Atlas of Global and Regional Climate Projections – Figures AI.SM8.5.18 and .19				

The distribution of events associated with large amounts of precipitation is projected to change considerably as the climate warms. A shift to more intense, individual storms is projected. However, changes in extreme precipitation do not seem to be related to the total precipitation. Rather, extreme events are influenced by changes in maximum water vapour concentration, as this may increase the intensity, but not necessarily the frequency of heavy snow or rain events.

Little information is available in current climate models on the change in frequency of the heavy precipitation events, however, episodes of more intense precipitation are projected to occur in the wet seasons especially at high latitudes. The daily extreme precipitation is projected to increase with temperature, but seemingly only at higher latitudes. However, the natural variability in extreme events is substantial, and this affects the quality of the projections.

3.2.2.2 Beaufort Sea

Using the 50% percentile of models' distribution, the change in annual precipitation projected for the Beaufort Sea region is +10 to +20% for 2016 – 2035, and +20 to +30% for 2046 – 2065. (IPCC 2013a - Figure AI.SM8.5.17).

For the Tuktoyaktuk and Sachs Harbour the largest annual projected changes are to occur during the winter months (Table 3-12 and Table 3-13). When considering annual and winter precipitation, it should be noted that snowfall depth equates to a liquid depth of precipitation by a factor of about 10 mm snow to 1 mm precipitation.

Table 3-12 Change in Annual and Seasonal Precipitation for Tuktoyaktuk - relative to 1981 – 2010

Season	1981-2010 (mm)	Average Change in Total Precipitation (%)		
		2020s	2050s	2080s
Annual	167.1	7.9	19.2	34.9
Winter	30.2	7.4	23.5	48.8
Spring	22.8	5.7	13.0	27.0
Summer	60.3	7.8	20.2	33.9
Autumn	53.8	11.9	22.8	38.8

Table 3-13 Change in Annual and Seasonal Precipitation for Sachs Harbour - relative to 1981-2010

Season	1981-2010 (mm)	Average Change in Total Precipitation (%)		
		2020s	2050s	2080s
Annual	147.9	9.6	23.3	42.4
Winter	17.7	9.1	30.7	69.4
Spring	27.3	6.6	17.0	33.9
Summer	54.9	9.0	17.8	30.0
Autumn	48.0	14.0	30.6	50.1

The percent changes from the baseline data (1981-2010) to the projected future cases are shown in Figure 3-17 and Figure 3-18 for each of the four stations assessed in this study. Firstly, these plots solidify the observation that there is projected to be an annual increase in total precipitation in the region. Second, comparing the trends among the different stations shows that there appears to be a positive trend of increasing projected change with latitude. This relationship is strong in Figure 3-18 (winter projected change), however, the projected change for Ulukhaktok A in Figure 3-20 (annual projected change) are lower that what might be expected. This lower value for the annual average is due to the fact that, unlike the other four stations, the Ulukhaktok station is projected to experience a summer-time decrease in precipitation. This could be a result of geographic differences, for example, the Ulukhaktok station is located in an area that is more sheltered than the other stations from the open Beaufort Sea.

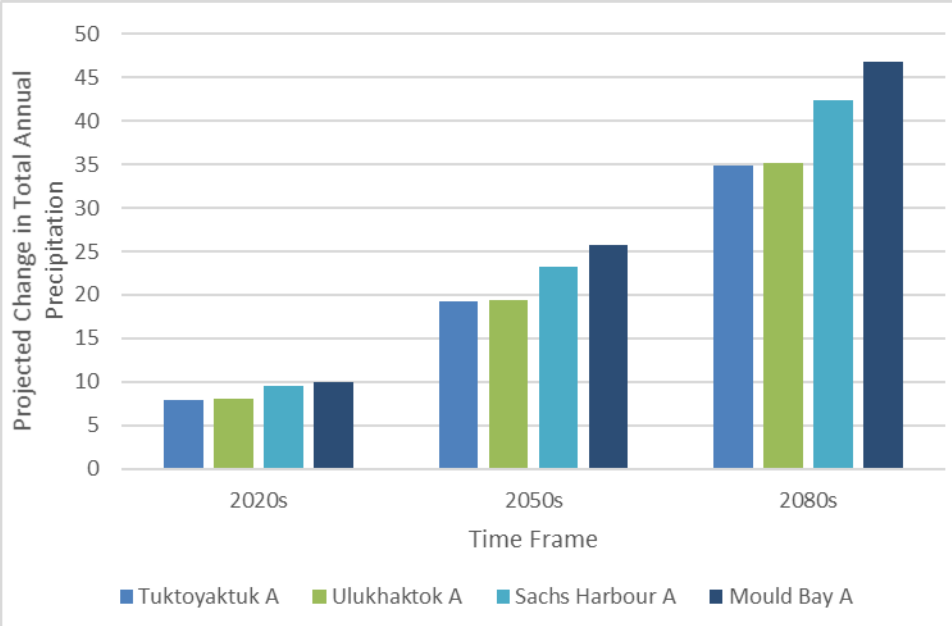


Figure 3-17 Projected Changes in Total Annual Precipitation – 4 Arctic weather monitoring stations

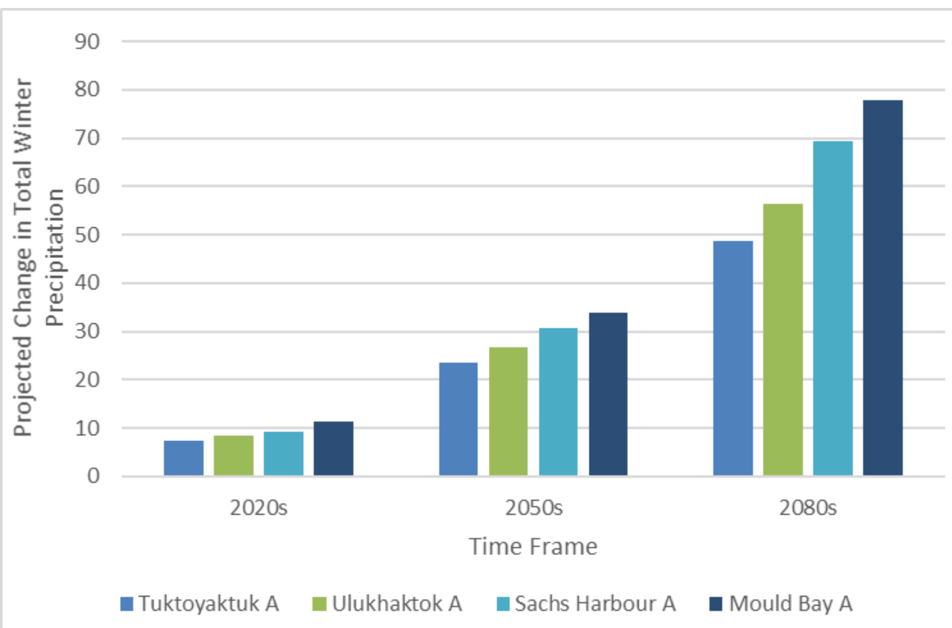


Figure 3-18 Projected Changes in Total Winter Precipitation – 4 Arctic weather stations

Additional details in the climate projections for precipitation are shown in Figure 3-19 through Figure 3-22. The trend in those data are plotted as the red line. The average value for the reference period of 1981-2010 is shown as the green bar. The climate projections for the 2020s, 2050s, and 2080s, are represented by the brown bars.

In all cases, the trends in projected change in precipitation are upward. Historical data, presented as annual averages for the past 30 years, is noted to be on an increasing trend as well at all stations with exception to the Sachs Harbour A. In this case, however, looking further back in the historical records, there is a noticeable decreasing trend from 1955 to 2013. The negative slope presented in Figure 3-21 is possibly a product of incomplete records from this station.

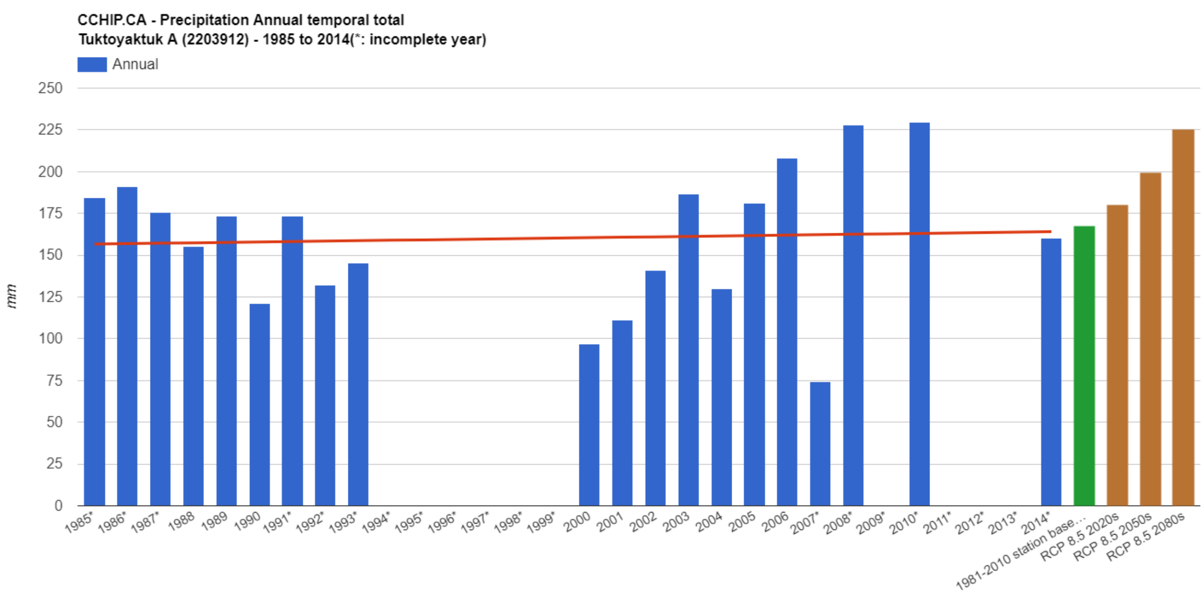


Figure 3-19 Annual Precipitation Temporal Total – Tuktoyaktuk A (trend shown by red line = 0.26 mm/year)

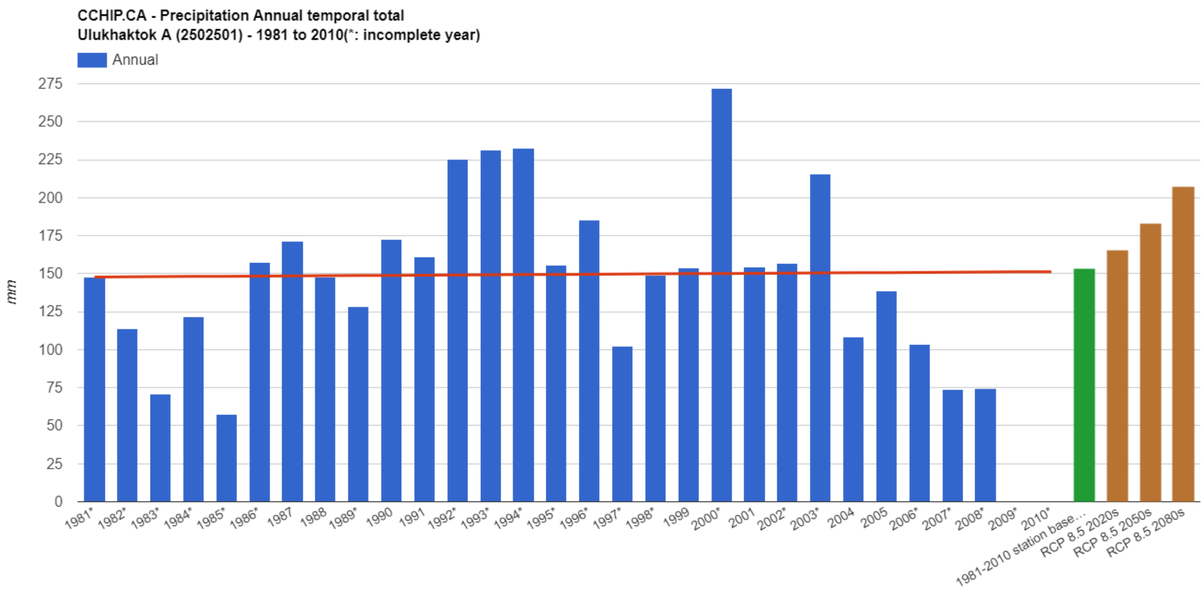


Figure 3-20 Ulukhaktok A - Total annual precipitation values (1981 – 2008), period trend (trend shown by red line = 0.12 mm/year), and mean total annual precipitation amounts (right) for 2018 – 2010, RCP 8.5 2020s, RCP8.5 2050s, and RCP8.5 2080s.

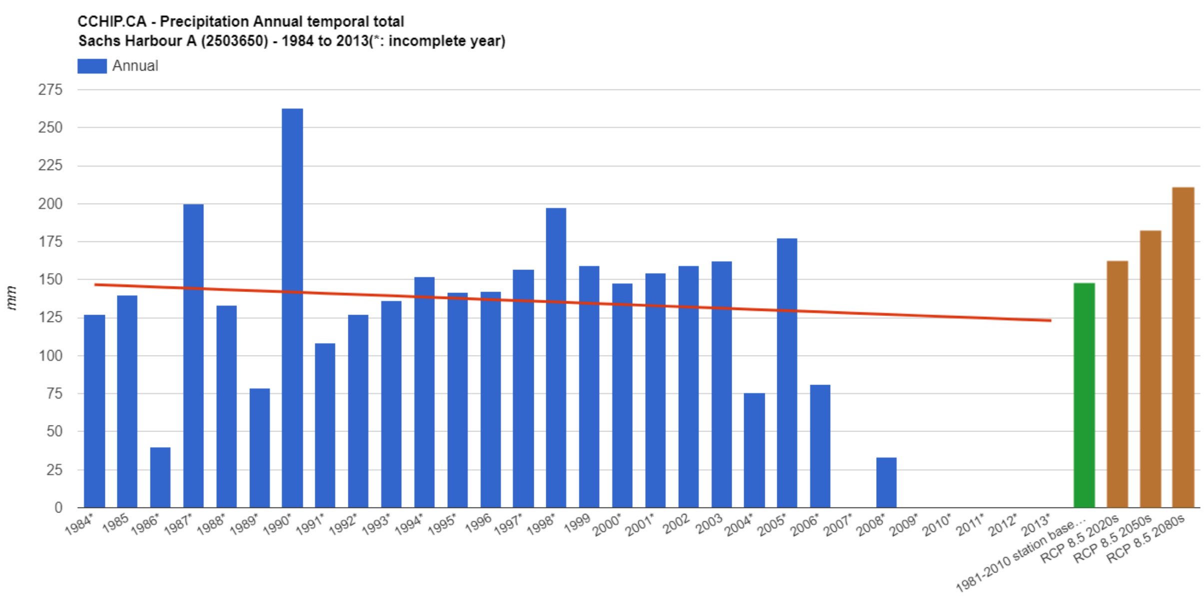


Figure 3-21 Annual Precipitation Temporal Total – Sachs Harbour A (trend shown by red line = - 0.81 mm/year)

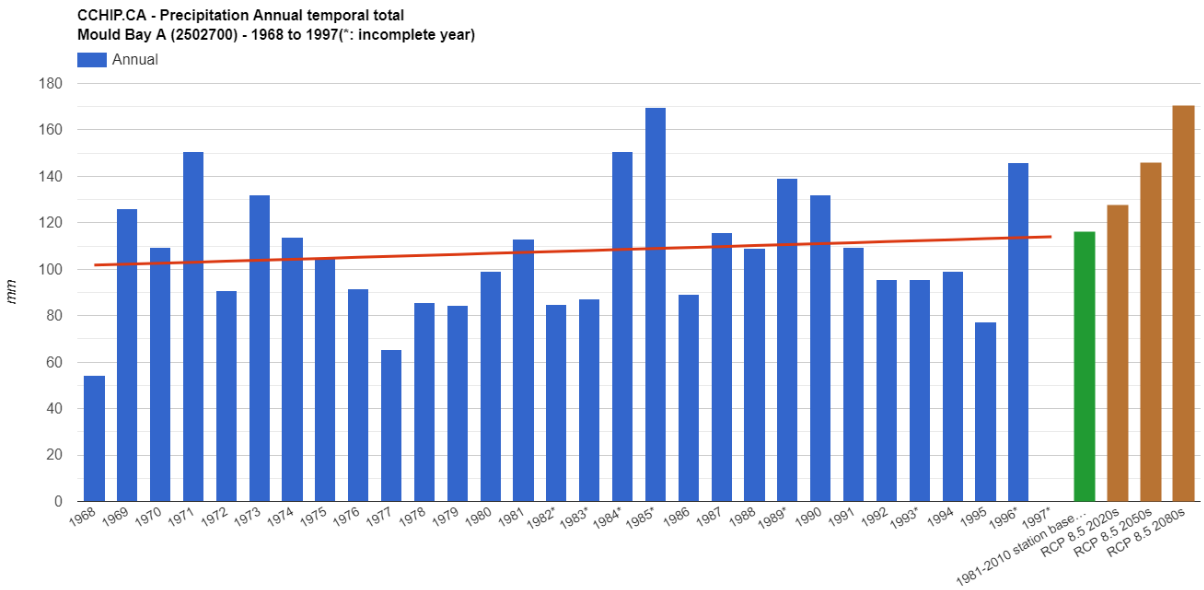


Figure 3-22 Annual Precipitation Temporal Total – Mould Bay A (trend shown by red line = 0.42 mm/year)

The projected percent increases in rainfall intensity, presented for various return periods and storm durations, are provided in Table 3-14 and Table 3-15 for the Tuktoyaktuk and Sachs Harbour A locations. The projection data from the stations in the region shows, significant increases in rainfall intensity, on the order of 40-70% in 2050.

Table 3-14 Projected Change in Rainfall Intensity - Tuktoyaktuk – 2041-2100 relative to 1981-2010, RCP 8.5 - Various Return Periods and Durations.

Event	Return Period						
	2	5	10	20	25	50	100
5 min	38.7%	49.3%	63.0%	70.5%	72.3%	78.1%	84.5%
10 min	38.7%	49.3%	63.0%	70.4%	72.3%	78.1%	84.5%
15 min	38.7%	49.3%	63.0%	70.5%	72.2%	78.1%	84.5%
30 min	38.7%	49.3%	63.0%	70.4%	72.2%	78.1%	84.5%
1 h	38.7%	49.4%	63.0%	70.4%	72.3%	78.1%	269.3%
2 h	38.6%	49.2%	62.8%	70.4%	72.2%	78.1%	84.6%
6 h	38.9%	49.5%	63.1%	70.5%	72.2%	78.0%	84.7%
12 h	38.5%	49.7%	62.7%	70.6%	72.0%	78.1%	84.7%
24 h	37.7%	49.0%	62.3%	69.8%	72.1%	78.1%	84.3%

Table 3-15 Projected Change in Rainfall Intensity – Sachs Harbour – 2041-2100 relative to 1981-2010, RCP 8.5 - Various Return Periods and Durations.

Event	Return Period						
	2	5	10	20	25	50	100
5 min	35.5%	33.4%	33.5%	39.3%	41.2%	47.5%	52.3%
10 min	35.6%	32.9%	35.5%	43.6%	46.3%	55.0%	59.8%
15 min	39.8%	34.8%	34.9%	42.5%	45.1%	53.5%	57.6%
30 min	35.7%	33.4%	34.0%	40.5%	42.8%	49.9%	53.2%
1 h	35.8%	33.4%	33.8%	39.9%	42.0%	48.8%	51.8%
2 h	35.5%	33.2%	34.2%	40.7%	42.6%	49.6%	53.0%
6 h	36.0%	33.2%	34.3%	41.2%	43.6%	51.1%	54.7%
12 h	36.7%	33.6%	35.5%	42.4%	45.1%	54.4%	61.4%
24 h	34.8%	32.3%	36.5%	43.9%	46.4%	55.6%	60.0%

One metric used to assess extreme weather events related to precipitation is a measurement of the precipitation that occurs over a period of 5 consecutive days, and the maximum value of this metric over a given time period of 10 or more years. The projected change in the maximum 5-day precipitation for Beaufort Sea for 2081-2100, relative to 1980-2000, is 20-25% for the Maximum Concentration Pathway (Collins et al. 2013).

3.2.3 Uncertainties

Thunderstorms, large hail, high winds, tornadoes, are part of the Earth's water cycle. As reported by IPCC, in the formation of these events, there are two main competing factors: i) the overall general increase of energy in the system and ii) the decrease in shear in the atmosphere. There is a large variability in these factors – and this makes it difficult to produce projections that are accurate. There is still not enough research done to draw firm solid conclusions on projected changes to these extreme weather events (Collins et al. 2013).

The IPCC states that at the high latitudes and over the northern land masses, *increased precipitation is likely* under the RCP8.5 scenario (Collins et al. 2013). Overall, projections suggest a trend toward more thunderstorms, but few details on variables such as frequency are provided.

The Climate Change Hazards Information Portal (CCHIP) was used for projection analyses and plots provided in this section. This analysis tool runs a total of 40 global climate models (GCMs), i.e., those included in the AR5 Fifth Coupled Model Intercomparison Project (CMIP5). This study used the 50th percentile results of the spread of these 40 GCM model outcomes to represent estimated projection values and assumes progression towards the RCP 8.5 scenario.

Actual future climate changes will depend largely on the speed at which certain global phenomena unfold and on the scale of global efforts to reduce greenhouse gas emissions in the coming decades. However, the methods used for these projection calculations are accepted as being a reasonable representation of potential future climate outcomes.

3.2.4 Limitations

Although the Beaufort Sea region is represented by a fair number of active and historical weather monitoring stations, data availability within these stations is, at times, limited. The four weather monitoring stations selected within the region to comprise the main data base for this study as well as the nearby complementary stations, have a data availability within these climate data sets ranging from 72-96% complete. Some stations that have operated over a long timeframe are not being operated today. This represents an opportunity for extending the meteorological monitoring in an area where climate is changing faster than most other locations.

3.2.5 Summary

The precipitation in northern latitudes is expected to increase and is strongly seasonal. The largest changes at high latitudes are expected to occur in winter and spring, including an increase in snowfall in colder regions and a decrease in snowfall in warmer regions, corresponding with fewer frost days. As may be expected, the change is not expected to be uniform across the region. Precipitation in the Beaufort Sea is expected to increase by approximately 20% by the middle of the 21st century (2050). Increases are expected to occur during all 4 seasons, with the largest increases in the autumn and winter periods. The change in rainfall intensity for a 20-year return period (that is the change in mm/hour of rainfall) is projected to be close to 40% at Sachs Harbour and as high as 70% at Tuktoyaktuk for the mid-21st century.

3.3 Frost-free days

3.3.1 Current trends

The frost-free season In the Beaufort Sea begins on the first day in spring when temperatures remain above freezing. It ends on the first day in autumn when freezing temperatures return. A frost-free day is therefore one where the air temperature stays above 0^{o}C. As a specific region warms over time, such as the Beaufort Sea, the frost-free season would likely be extended, i.e., there will be more days with no frost. In the mid to lower latitudes, the increase is important as it relates to the length of the growing season.

As part of this study, the frost data were accessed from the CHHIP portal and historical frost profiles were plotted for the Tuktoyaktuk A and Sachs Harbour A weather monitoring stations, as shown in Figure 3-23 and Figure 3-24. These plots present the percent probability of frost occurring on any given day throughout the year. In comparing the frost profile for Tuktoyaktuk and Sachs Harbour, it is evident that there are differences between the probability of frost occurring during the summer months at each location.

Sachs Harbour (latitude of 72.00°N) also has a generally higher daily probability of frost than Tuktoyaktuk (latitude of 69.45°N) (Figure 3-23 and Figure 3-24).

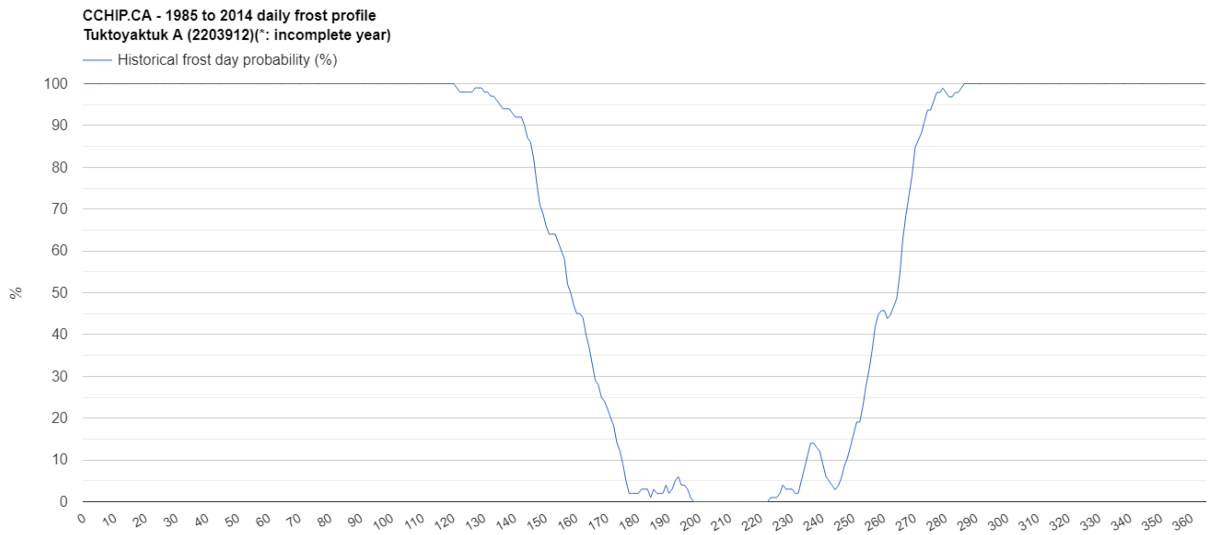


Figure 3-23 **Daily frost profile for the Tuktoyaktuk A weather station from 1985 to 2014, expressed as % probability of frost on any given day of the year**

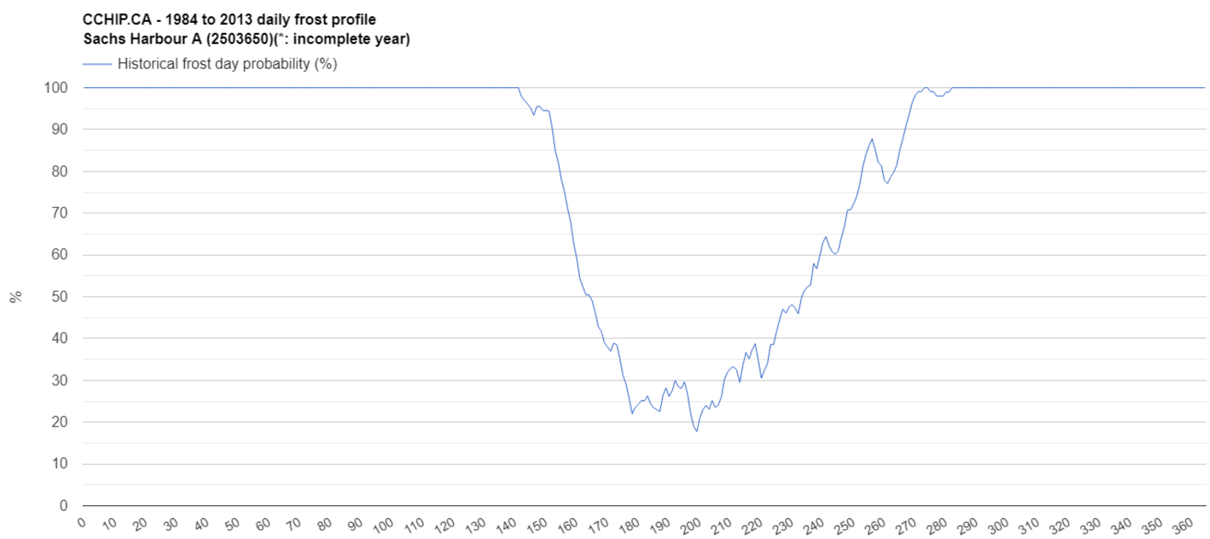


Figure 3-24 **Daily frost profile for the Sachs Harbour A weather station from 1985 to 2014, expressed as % probability of frost on any given day of the year**

3.3.2 Predictions

The projected frost-free day probabilities and for the 2020s, 2050s and 2080s periods for Tuktoyaktuk A and Sachs Harbour are shown in Figure 3-25 and Figure 3-26. The differences in the results at the two locations suggests that there is a natural variability in the region's propensity for frost conditions.

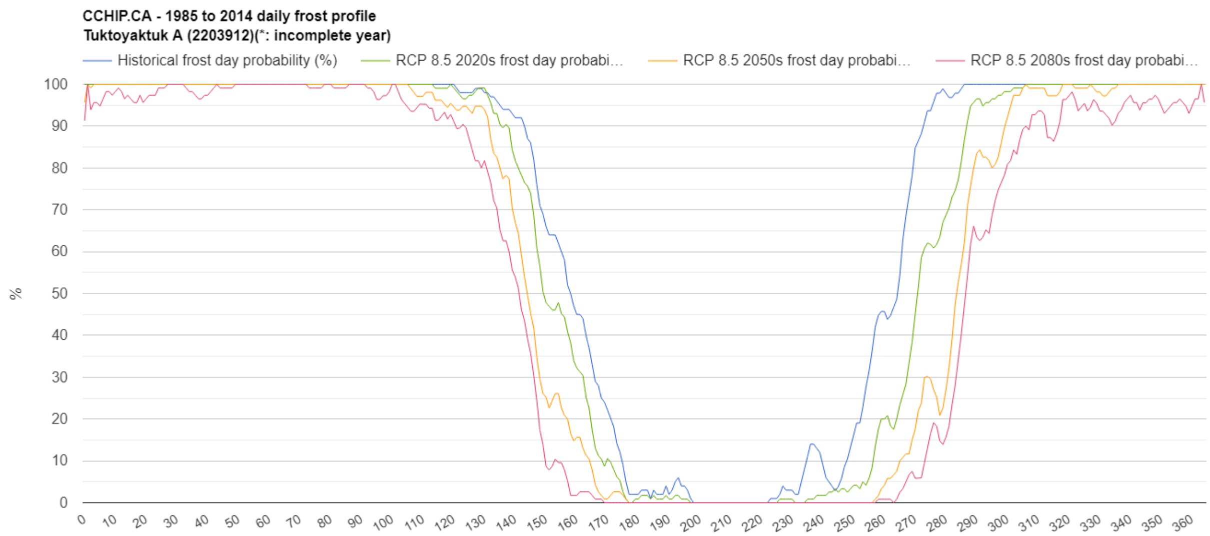


Figure 3-25 Daily frost profile for the Tuktoyaktuk A weather station based on historical (1985-2014) and projected data, expressed as % probability of frost on any given day of the year

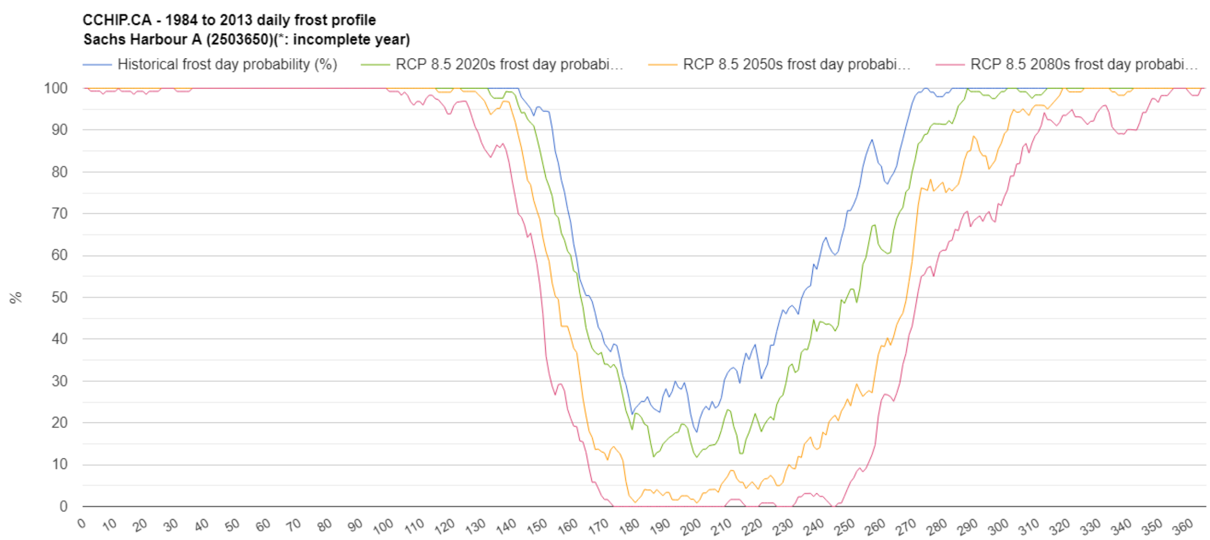


Figure 3-26 Daily frost profile for the Sachs Harbour A weather station based on historical (1985-2014) and projected data, expressed as % probability of frost on any given day of the year

The resulting numbers of projected number of frost-free days are summarized for all four communities in Table 3-16 and Table 3-17. The data demonstrate a negative relationship between latitude and frost-free days per year where those stations near the mainland coast are notably lower than for those stations that are located on the northern islands.

Table 3-16 Average frost-free days for baseline and projected scenarios at each representative location

Location	Tuktoyaktuk	Ulukhaktok	Sachs Harbour	Mould Bay
Latitude	**69.45°N**	**70.76°N**	**72.00°N**	**76.23°N**
Baseline (1981-2010)	67	74	38	34
Projected: 2020s (2011-2040)	92	92	63	30
Projected: 2050s (2041-2070)	106	109	87	43
Projected: 2080s (2071-2100)	119	125	107	55

The projected changes in frost-free days per year for 2050s relative to 1981-2010 are provided in Table 3-17 and show a range of +9 days at Mould Bay to +49 days at Sachs Harbour.

Table 3-17 Projected change in frost-free days for 2050s relative to 1981-2010

Location	Tuktoyaktuk	Ulukhaktok	Sachs Harbour	Mould Bay
Baseline (1981-2010)	67	74	38	34
Projected: 2050s (2041-2070)	106	109	87	43
Change in Number of Frost free days (Projected 2050s relative to 1981-2010)	+39	+35	+49	+9

These data are also presented as a latitudinal transect in Figure 3-27 through the four stations represented in this study. It is acknowledged that the varying longitudinal placement of these stations adds biases to this analysis, however it is presented here as a course-level demonstration of the potential latitudinal variation in the occurrence of frost-free days. This trend is disrupted at Ulukhaktok, likely due to the fact that its location is more sheltered from the open Beaufort Sea than the other locations.

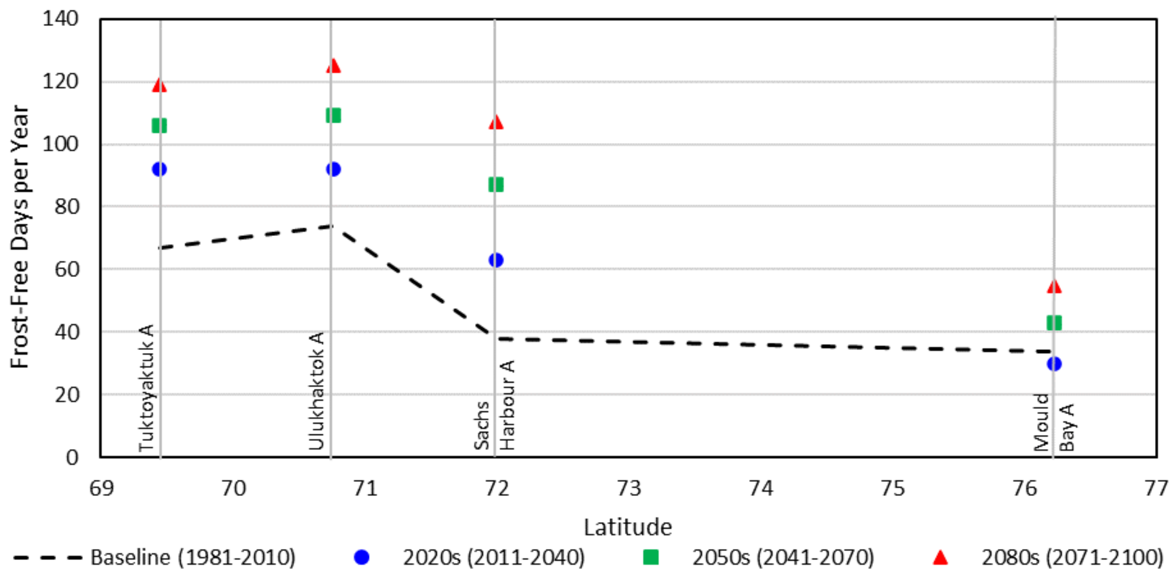


Figure 3-27 Frost-free days presented as a latitudinal transect for baseline and projected values

3.3.3 Uncertainties

The Climate Change Hazards Information Portal (CCHIP) was used for projection analyses and plots provided in this section. This analysis tool runs a total of 40 global climate models (GCMs), i.e., those included in the AR5 Fifth Coupled Model Intercomparison Project (CMIP5). This study used the 50th percentile results of the spread of these 40 GCM model outcomes to represent estimated projection values and assumes progression towards the RCP 8.5 scenario. Actual future climate changes will depend largely on the speed at which certain global phenomena unfold and on the scale of global efforts to reduce greenhouse gas emissions in the coming decades. However, the methods used for these projection calculations are accepted as being a reasonable representation of potential future climate outcomes.

Since about 1950 it is *very likely* that the numbers of cold days and nights have decreased and the numbers of warm days and nights have increased overall on the global scale, that is, for land areas with sufficient data. It is likely that such changes have also occurred across most of North America (Hartman et al. 2013).

3.3.4 Limitations

Although the Beaufort Sea region is represented by a fair number of active and historical weather monitoring stations, data availability within these stations is, at times, limited. For the four weather monitoring stations selected within the region to comprise the main data base for this study as well as the nearby complementary stations.

The data availability and time range, including the age of the data are factors in choosing which data to use for which application.

3.3.5 Summary

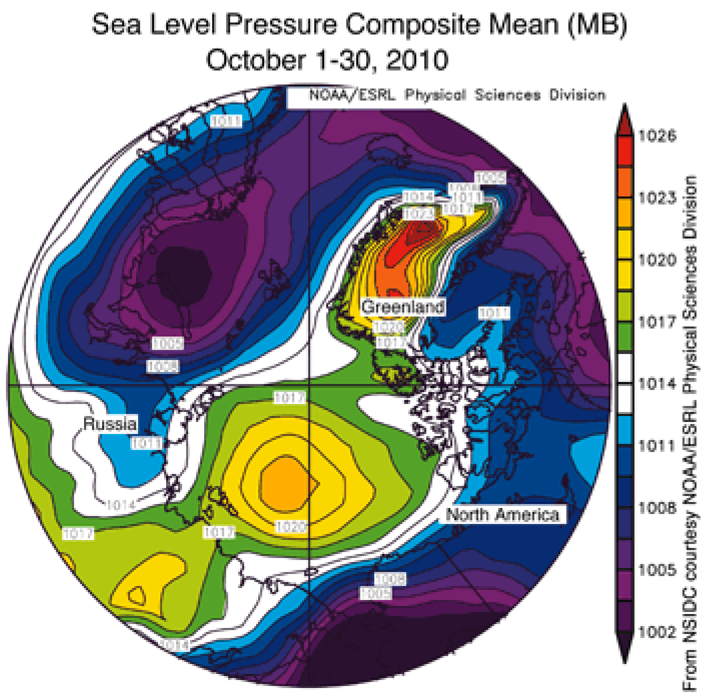
As might be expected, the number of frost-free days decreases with increase in latitude. The projected changes in frost-free days per year for 2050s relative to 1981-2010 range from +9 days at Mould Bay to +49 days at Sachs Harbour, and is +39 days at Tuktoyaktuk.

3.4 Wind

Atmospheric circulation in the Arctic Ocean is complex, varying from a baroclinic environment during the late summer and autumn with differences in temperature between the ocean, sea ice and land masses driving strong winds and storms, to a predominantly barotropic environment in the winter, dominated by a stable boundary layer and high atmospheric pressure. Synoptic-scale, semi-permanent atmospheric features that drive sea level pressure (SLP) patterns and surface wind climatology are the Aleutian Low, Siberian High, Icelandic Low and Beaufort Sea High, also known as the Beaufort High. An example is shown in Figure 3-28.

The Aleutian Low is a large, semi-permanent low-pressure center located near the Aleutian Islands, near the Bering Sea. It is most intense in winter, and dynamically drives the formation of many strong migratory surface cyclones. Traveling cyclones formed in sub-polar latitudes in the North Pacific usually slow down and reach maximum intensity in the area of the Aleutian Low. The position and intensity of the Aleutian low is influenced by atmosphere-ocean teleconnections, such the Pacific Decadal Oscillation (PDO), and El Nino Southern Oscillation (ENSO). A deepened Aleutian Low, linked to positive phases of the PDO and ENSO, may increase poleward transport of moisture and energy, thereby enhancing storm development (Newman et al. 2016).

The Beaufort High is a high-pressure center over the Beaufort Sea present mainly in winter (Figure 3-28). This feature typically builds over the winter pack ice in the Arctic in late winter and persists throughout spring into early summer. Surface winds from the Beaufort High tend to force anticyclonic circulation within the Beaufort Sea Ice Gyre throughout much of the year, however the incursion of low pressure over the region during the summer months may lead to wind-forced reversals of the sea ice gyre, thereby affecting sea ice dynamic processes (Asplin et al. 2009).



SOURCE: from NSIDC 2019

Figure 3-28 Sea level pressure in the Arctic, featuring the Beaufort and Greenland Highs, and low pressure over the Barents Sea – an example

Polar lows refer to smaller intense cyclones that form over open ocean during the cold season and are sometimes called Arctic hurricanes, with windspeeds exceeding 20 m s^{-1}Polar lows tend to form when cold Arctic air flows over relatively warm open water. The storms can develop rapidly (12-24 hours) and last 1 to 2 days (NSDIC 2019). Polar lows are not typically common in the southern Beaufort Sea and Amundsen Gulf; however, this may change with delayed winter freeze-up of these areas in future years.

Large scale atmospheric circulation phenomena and teleconnections can affect surface wind patterns throughout the Arctic. The Arctic Oscillation or AO, also known as the northern annular mode - an annular sea level pressure (SLP) anomaly that may be present over the entire Arctic. During then positive phase, the Arctic has below normal SLP, an enhanced polar circulation, and a cyclonic wind flow. In the negative phase, it has a higher SLP, a weakened polar circulation and anticyclonic atmospheric flow (Lui et al. 2016). The Arctic Dipole anomaly or AD, is important in summer. The AD anomaly typically has 2 centers, one on the Siberian side and one on the North American side. A negative AD phase has a higher SLP on the North American side of the Arctic, and a positive SLP the opposite (Overland et al. 2012). The AO and AD modes have strong influences on the windspeeds and wind directions in the region. One example is that a change in AD mode in to a higher SLP over the Barents Sea in 2010-2011 may have blocked storms from approaching from the south and this may have caused the sharp decline in windspeed observed during that time.

Changes are noted by (NSDIC 2019):

> "Recent research led by James Overland of the National Oceanic and Atmospheric Administration (NOAA) and Jennifer Francis of Rutgers University shows that the Arctic dipole anomaly, featuring unusually high pressure over the northern Beaufort Sea and Greenland and unusually low pressure over northeastern Eurasia, has become more common in the early summer of recent years."
> From http://nsidc.org/arcticseaicenews/tag/arctic-dipole-anomaly/

Surface-level winds throughout the Arctic can vary in magnitude and direction by season, and are typically stronger when large temperature gradients are present between the atmospheric and ocean. Geographically, surface winds tend to be stronger overall in the Russian Arctic, which is commonly affected by migratory Siberian cyclones, however windspeeds can be intense during the early winter freeze-up in the southern Beaufort Sea and Amundsen Gulf. These strong winds can reach hurricane strength, and scour the snow from exposed areas and form large snow drifts in sheltered areas. This is common the southern Beaufort Sea and Amundsen Gulf Regions, characterized by strong easterly or northwesterly winds, depending on the sea level pressure patterns and storm track. During the later part of winter and early spring, strong temperature inversions can slow wind speeds near the surface. Temperature inversions are where air at the surface is cooler than the air above, often with a stable atmosphere, meaning with little vertical movement or exchange of moisture and energy. These inversions disconnect the surface air from the air above.

To assess the surface wind climatology of the study region, wind data were obtained from the Environment and Climate Change Canada (ECCC) Database on historical hourly data for the most recent data available for weather stations at Tuktoyaktuk, Sachs Harbour, Ulukhaktok A (to the east of Tuktoyaktuk) and Mould Bay (ECCC 2019b). These data are supplemented with information and conclusions from the literature and the most recent IPCC reports and climate projections, and further supplemented with current climate projections for the Beaufort Sea.

3.4.1 Current trends

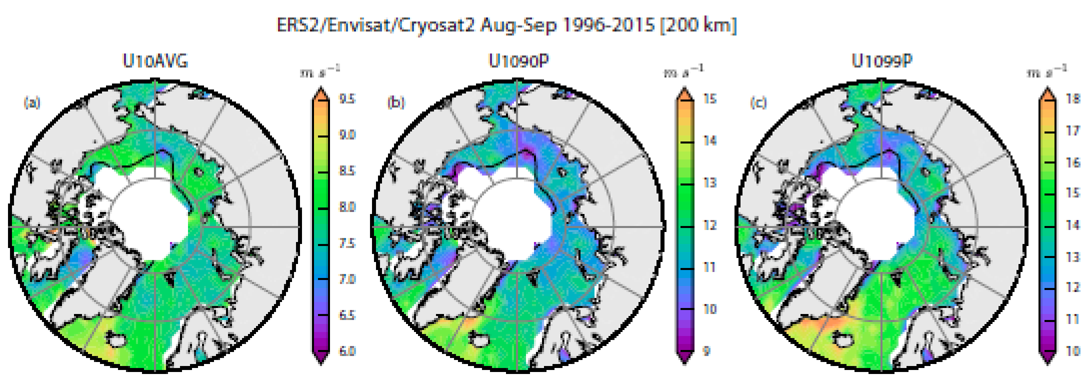
3.4.1.1 Winds

Wang et al. (2015) studied historical changes in surface windspeed and wind direction in the Beaufort-Chukchi-Bering Seas over the period 1971 – 2013 (Wang et al. 2015). Two periods were studied – 1970 – 1991 and 1992 – 2013. Findings include: the mean windspeed increased just north of Alaska over the two periods but decreased in the region off the Canadian coasts. In the area just west of the Canadian coast, the mean wind direction rotated clockwise, with the anticyclonic center displaced northeastward. The increases are not large, being 0.1 to 0.3 % per year from the climatological mean. It is noted that the changes in local wind speeds alone cannot explain the bigger trends in wave action, and suggests that the role of swells generated by non-local winds is also important in wave generation.

Zhang (2016) studied variation of surface winds and mesoscale climatology in the Chukchi–Beaufort Coastal Areas and adjacent Arctic slope region. The surface winds are driven mainly by the prevailing synoptic weather patterns including the Beaufort high and the Aleutian low-pressure systems, and the winds are influenced by local terrain features on land. The surface winds have a strong seasonality with stronger winds during the colder seasons. In summer, winds are generally calm to weak. Sea breezes are prominent in June-September and may extend to 50 km offshore at 1-3 m/s in late afternoon. In July, the area's regional scale winds are strongly influenced by the anticyclonic flow in the Beaufort Sea, related to the position of the Beaufort high. The onshore winds are strongest right at the shoreline. The sea breezes along the Beaufort coast in July are relatively weak at about 2 m/s. The synoptic winds may on occasion add to the sea breezes and can double the windspeed in the region. The increased onshore winds may influence and strengthen upwelling that may in turn affect ice local distribution. (Zhang et al. 2016).

Lui et al. 2016 reported on winds in the Arctic Ocean as measured over a 20-year period (1996-2015) with satellite radar altimeters, for the summer season (August-September). Measurements from 3 different satellite missions were used to assess the wind climate. The satellite measurements were compared to local buoy measurements for short periods, and there was good agreement. The windspeeds are shown in Figure 3-29. The windspeeds in the Beaufort Sea ranged from 8-8.5 m/s as an average. It is noted that the presence of ice may affect the quality of the measured data. The uncertainty associated with this effect has not been assessed.

It is noted that the large-scale atmospheric circulations such as the Arctic Oscillation and the Arctic Dipole have a strong influence on the winds and the waves in the region. Wind in the Barents and Kara Seas initially increased between 1996 and 2006, and then decreased.



SOURCE: Liu et al. 2016

Figure 3-29 Climatology of Windspeed in the Arctic Ocean – from altimeter measurements for August and September 1996-2015

Observations for the Beaufort Sea were similar. Trends in windspeed metrics for the Beaufort Sea are shown in Table 3-18. The metric U10 is the windspeed measured at 10 m height. The data trends are presented for the average, and the 90th and 99th percentiles. The trends in windspeed, the 90th and the 99th percentiles are different in the two periods 1996-2006 and 2007-2015. When taken together, the trends are slightly negative in windspeed (-0.12 m/s/decade), slightly positive for the 90th percentile and a bit more positive for the 99th percentile (0.28 m/s/decade).

Table 3-18 Trends - windspeed (m/s/decade) – Beaufort Sea

Metric	U10avg			U10_90			U10_99		
Timeframe	1996-2006	2007-2015	1996-2015	1996-2006	2007-2015	1996-2015	1996-2006	2007-2015	1996-2015
Trend (m/s/decade)	1.67	-1.48	-0.12	2.56	-1.05	0.04	2.64	-1.43	0.28
SOURCE : From Liu et al. 2016									

The climate normals on winds for Sachs Harbour and Tuktoyaktuk from Environment and Climate Change Canada (2019a,b) for the period 1981 to 2010 are presented in Table 3-19.

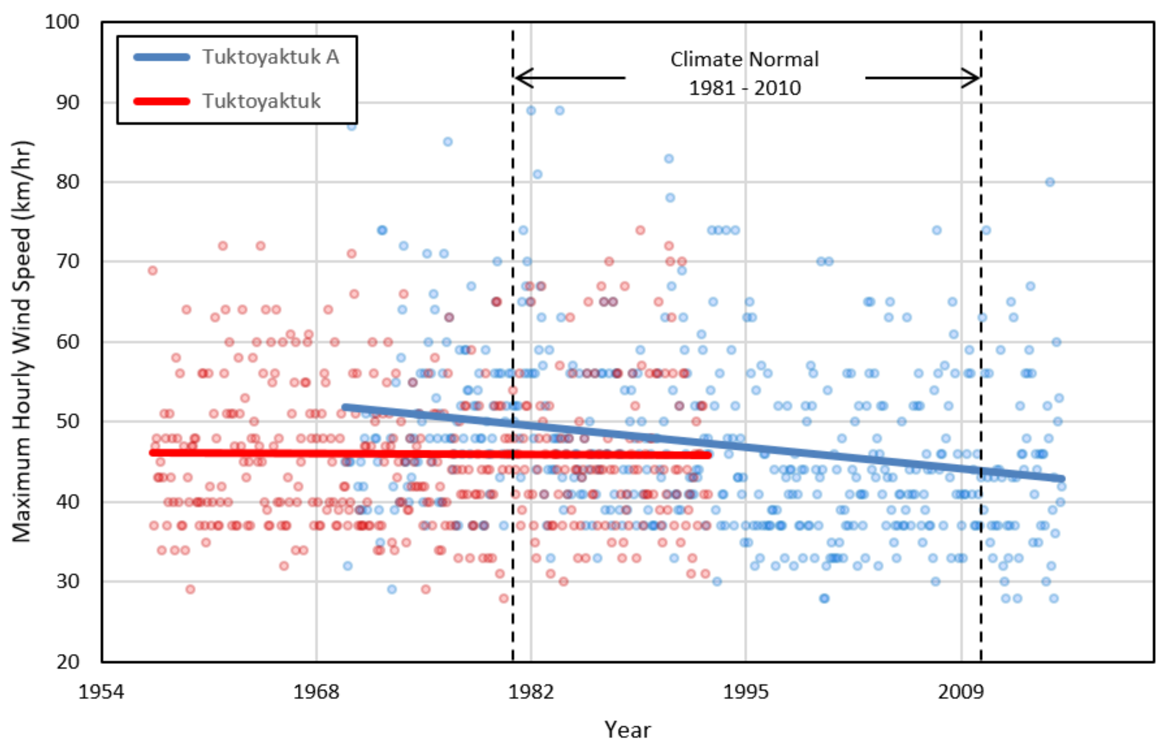
Table 3-19 Climate Normals for Sachs Harbour and Tuktoyaktuk, NWT – 1981-2010

Sachs Harbour - 1981 to 2010 Climate Normals													
Winds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Max Hourly Speed (km/h)	80	97	72	89	76	71	77	68	72	80	84	87	97
Date (yyyy/dd)	1957/17	1965/25	1971/08	1960/05	1957/04	1962/05	1964/11	1956/21	1962/04	2005/22	1965/12	1981/19	1965/25
Direction Max Hourly Speed	NW	N	SE	NE	SE	SE	N	NE	NW	SE	SE	SE	N
Max Gust Speed (km/h)	113	77	70	79	64	58	72	100	71	85	105	84	113
Date (yyyy/dd)	1973/28	1973/09	1977/25	1972/30	1973/08	1972/28	1974/28	1974/11	1974/03	1973/03	1972/29	1971/04	1973/28
Direction of Max Gust	E	N	SE	SE	SE	SE	S	S	NW	E	NW	NE	E

Tuktoyaktuk - 1981 to 2010 Climate Normals													
Winds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Max Hourly Speed (km/h)	78	89	63	59	67	54	81	74	87	69	85	89	89
Date (yyyy/dd)	1991/26	1982/13	1996/27	1979/22	1978/01	1996/04	1982/27	1972/20	1970/14	1991/23	1976/29	1983/24	1982/13
Direction of Max Hourly	NW	W	NW	NW	NE	NW	NW	W	W	W	NW	NW	W

The maximum hourly windspeeds tend to occur in the winter months and are lower in the summer months at both locations. Meteorological data from Pelly Island (just west of Tuktoyaktuk) may better represent the marine wind environment in the offshore Canadian Beaufort Sea (Fissel et al. 2009) and were included in the analysis presented in this study.

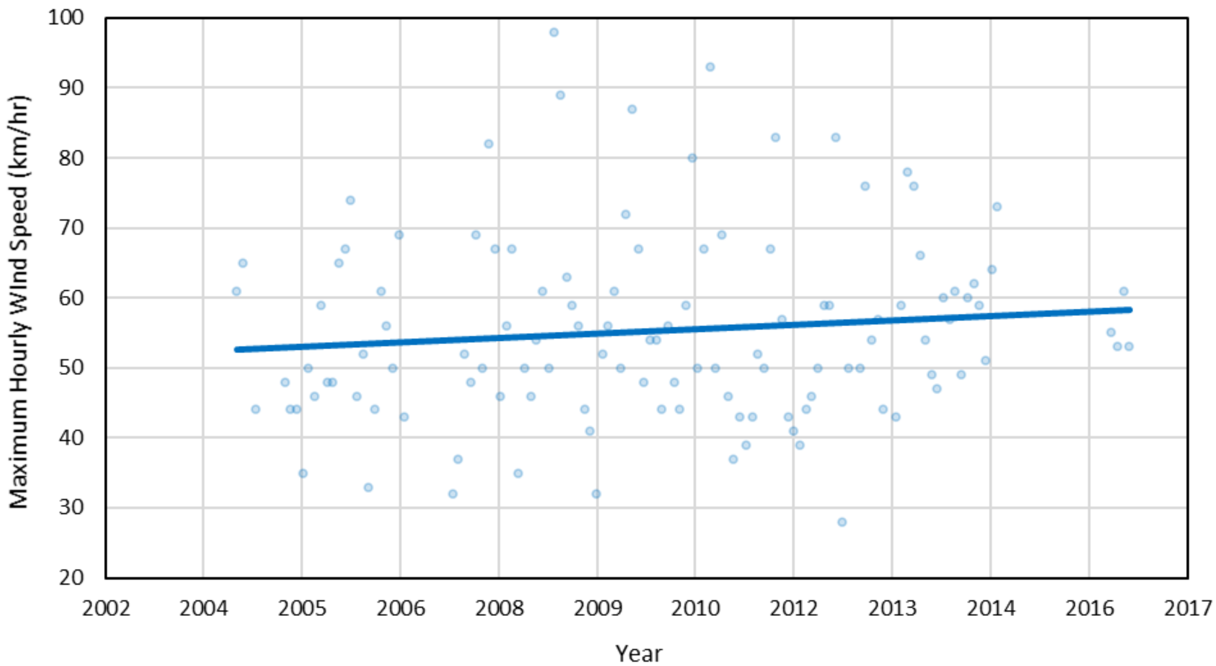
The variability in maximum hourly windspeeds at Tuktoyaktuk over the period 1954-2017 are shown in Figure 3-30. The means values are also shown, and indicate a slight but significant ($P<0.001$) negative trend from 1968 to 2012 for Tuktoyaktuk A.



SOURCE: ECCC 2019b

Figure 3-30 Wind variability at Tuktoyaktuk for 1954-2017 represented by maximum hourly wind speeds recorded monthly - trends: red line = -0.008 km/hour/year; blue line = -0.194 km/hour/year)

Maximum hourly wind speeds at Pelly Island (Figure 3-31) show a slightly increasing trend for this shorter and more recent dataset (0.504 km/hour/year or 0.140 m s^{-1} y^{-1}), i.e., over the past decade or so. Comparing these results with those from Tuktoyaktuk A suggests there is small-scale spatial variability in the windspeed trends; however, the Pelly Island data set presented here extends over a considerably shorter timespan which is likely to affect the trend.



SOURCE: ECCC 2019b

Figure 3-31 Wind variability at Pelly Island for 2004-2016 represented by maximum hourly wind speeds recorded monthly – trend = 0.504 km/hour/year

Wind roses were produced using the statistical modelling software, R (version 3.5.2), and the “openair” extension package and were based on Environment and Climate Change Canada historical hourly wind data (ECCC 2019b). Wind roses for the Tuktoyaktuk A and Pelly Island weather monitoring stations are presented in Figure 3-32 and Figure 3-34 (annual) and in Figure 3-33 and Figure 3-35 (the four seasons). To complement this, annual wind roses for the Ulukhaktok A (to the east of Tuktoyaktuk) and Mould Bay A (to the north) are presented in Figure 3-36 and Figure 3-37. The wind roses illustrate the variability in the windspeeds, and the strong easterly and northwesterly components in all seasons, and a northeasterly component in late spring and early summer (months 4 to 7). The annual wind roses for Mould Bay are different from the wind roses of Pelly Island and Tuktoyaktuk in that data from Mould Bay have a much less easterly component, a strong northly and north west component, and a strong southerly component.

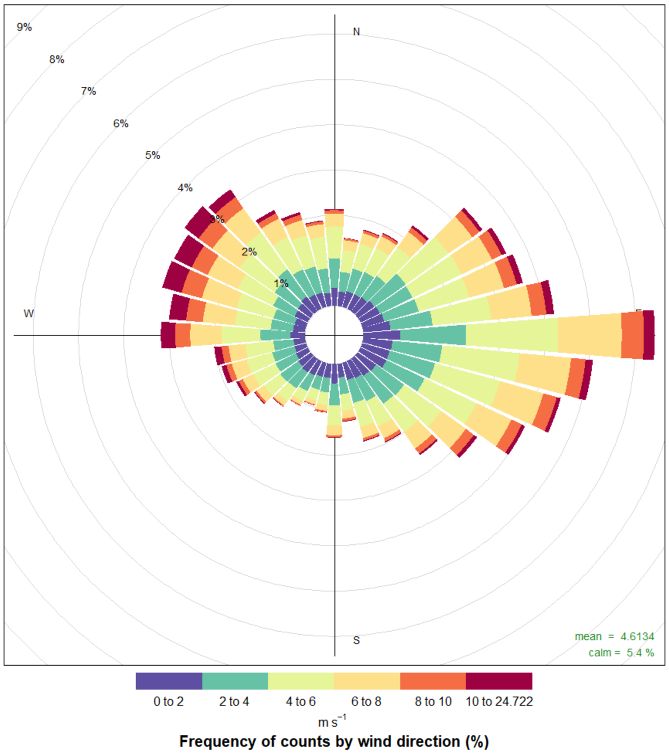


Figure 3-32 Annual wind rose for Tuktoyaktuk A hourly wind data comprising 63 years from 1954-2017

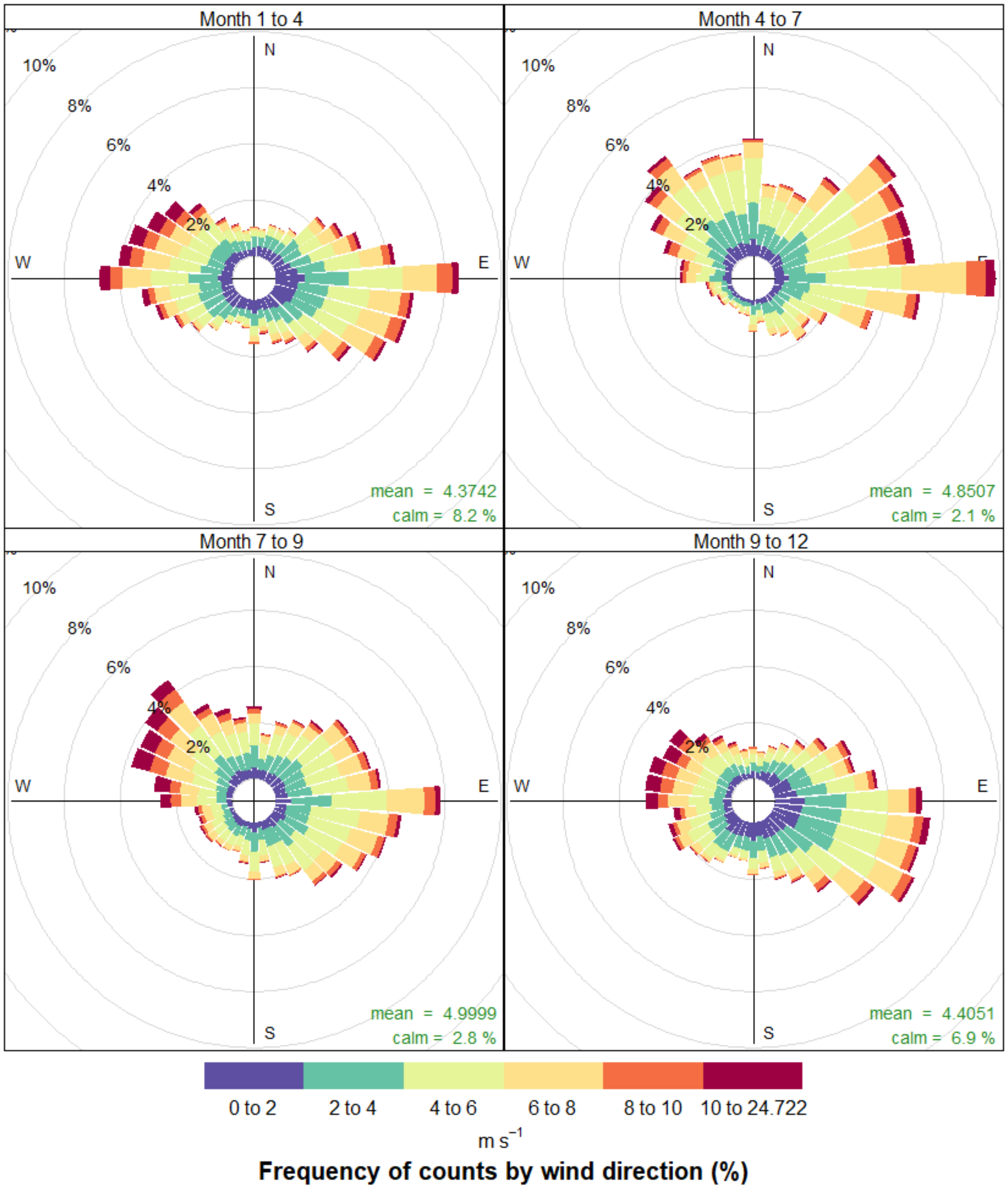


Figure 3-33 Seasonal wind roses for Tuktoyaktuk A hourly wind data comprising 63 years from 1954 – 2017, grouped quarterly

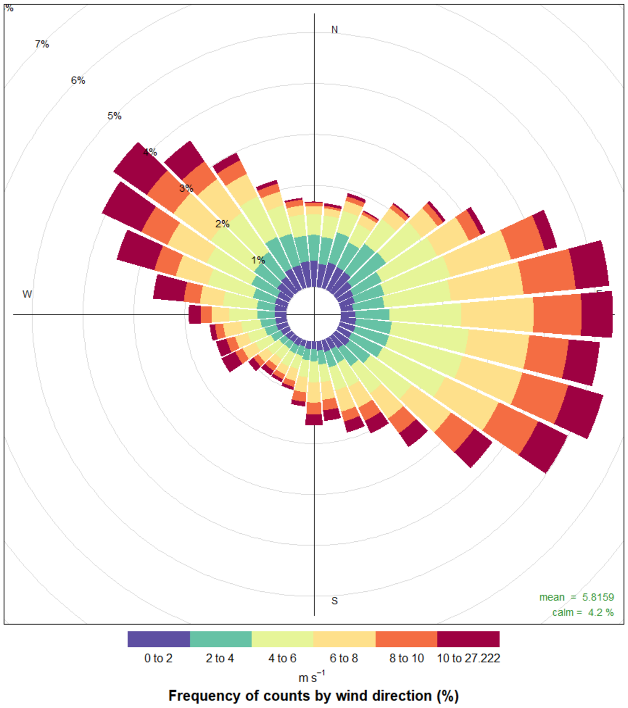


Figure 3-34 Annual wind rose for Pelly Island hourly wind data comprising 12 years from 2004 – 2016

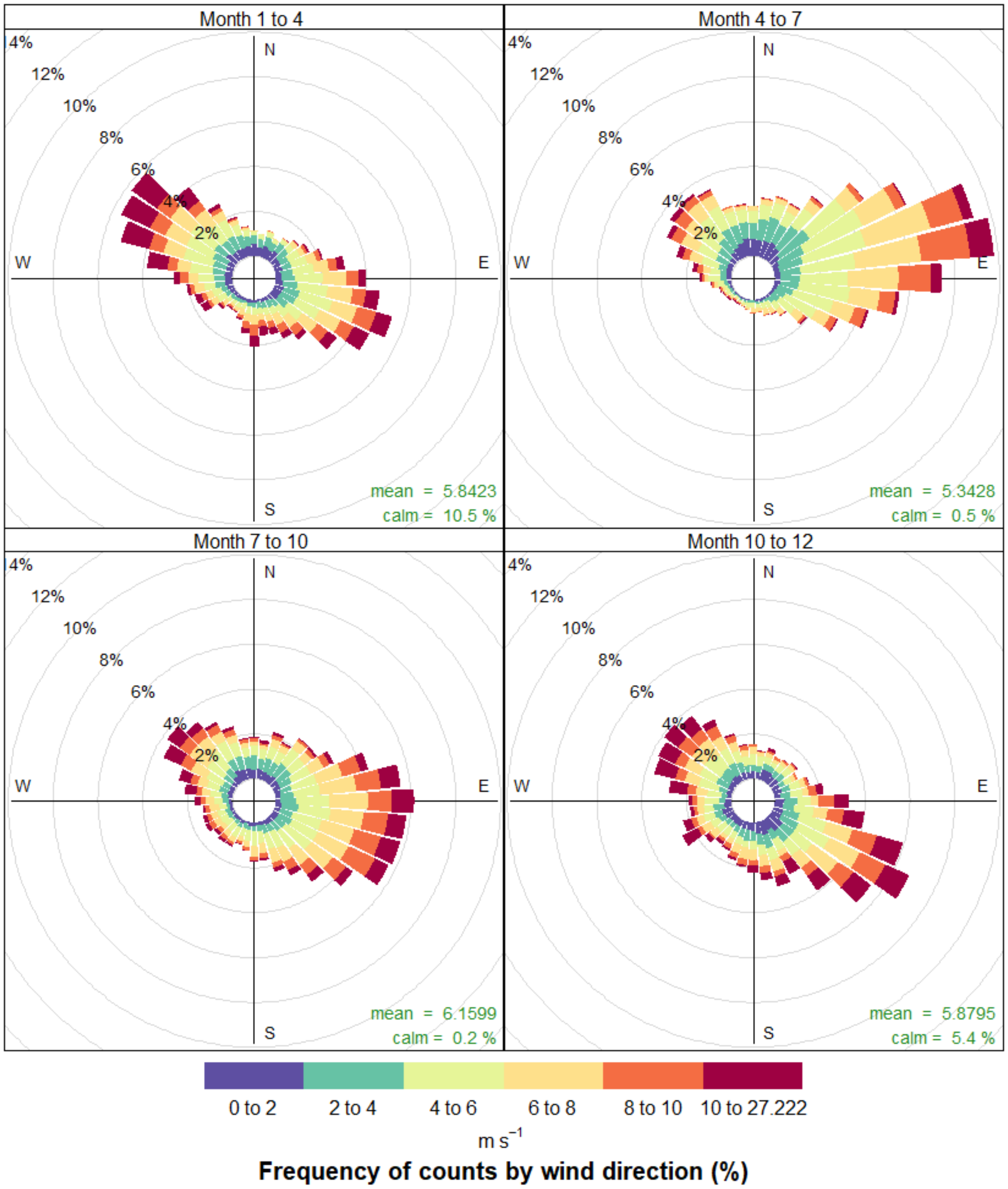


Figure 3-35 Seasonal wind roses for Pelly Island hourly wind data comprising 12 years from 2004 – 2016, grouped quarterly

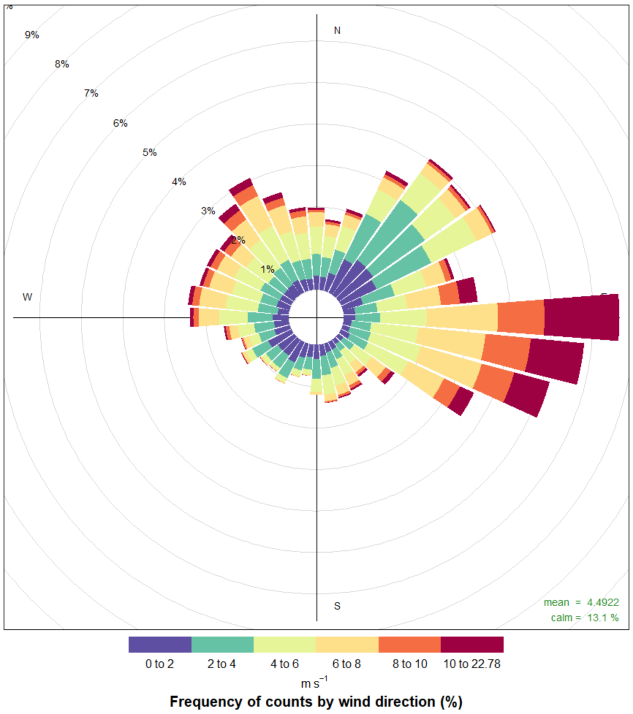


Figure 3-36 Annual wind rose for Ulukhaktok A hourly wind data comprising 27 years from 1987 – 2014

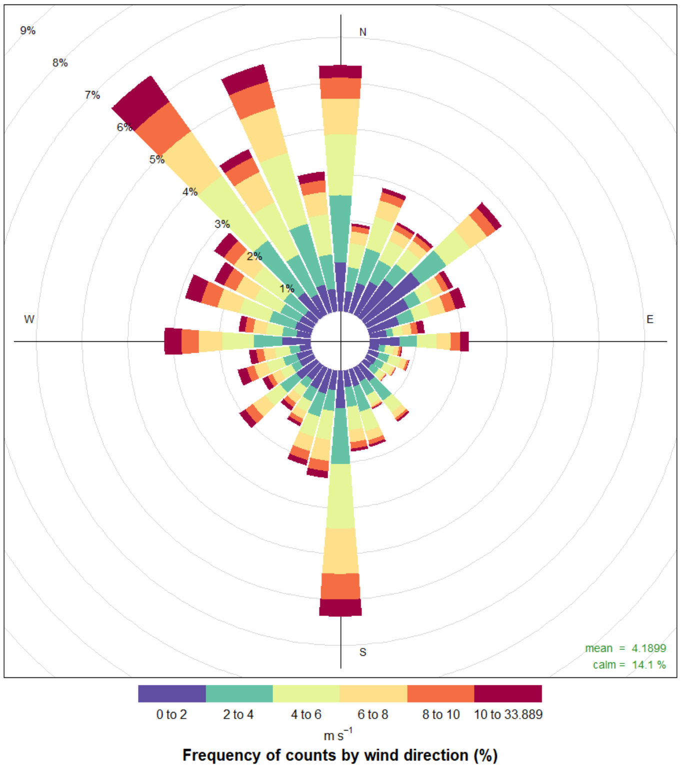
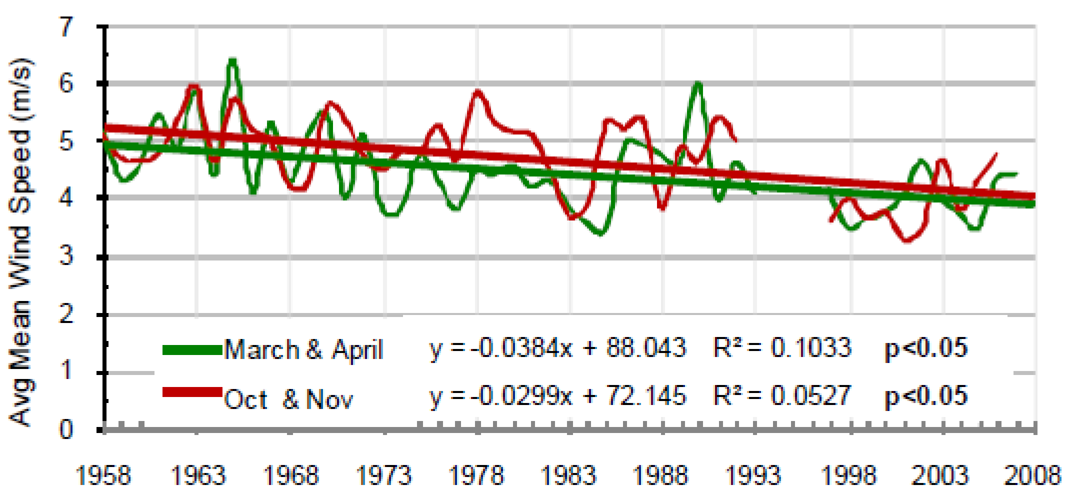


Figure 3-37 Annual wind rose for Mould Bay A hourly wind data comprising 49 years from 1948-1997

Mean wind data from Fissel et al. (2009) are provided in Figure 3-38 for Tuktoyaktuk from 1958-2008. These data show a significant (*$p < 0.05$*) negative trend of about -1.2 m/s per year.



SOURCE: adapted from Fissel et al. 2009

Figure 3-38 Wind speeds – Mean wind speeds at Tuktoyaktuk

Wind data from Pelly Island are provided in for a shorter period of record (1994-2008) in Table 3-20 and Table 3-21, showing prevailing winds from the east and east-southeast. Mean windspeeds at Pelly Island were highest in the fall at 6.7 m/s.

Table 3-20 Summary of Pelly Island wind statistics – 1994 – 2008

	Dominant		Vector Average		Mean	Max	
Month	Speed (m/s)	Direction	Speed (m/s)	Direction (deg)	Speed (m/s)	Speed (m/s)	Direction (deg)
January	4-6	ESE E	1.1	180.3	5.6	26.4	290
February	4-6	ESE E	1.0	158.1	6.5	24.7	270
March	4-6	E W	0.3	35.7	5.6	22.2	300
April	4-6	E	1.1	80.7	5.6	18.1	320
May	4-6	E	2.5	64.6	5.6	18.6	280
June	4-6	E	2.2	62.4	5.4	16.9	290
July	4-6 6-8	E	1.9	37.6	6.0	19.4	250
August	4-6 6-8	E	0.9	5.5	6.3	24.2	230
September	6-8 4-6	E	1.4	75.6	6.7	21.1	310
October	4-6 6-8	E E-S-E	1.4	88.0	6.7	19.2	120
November	4-6	E-S-E	0.7	131.4	6.6	20.6	300
December	4-6	E-S-E E	0.3	28.8	6.3	25.3	300

SOURCE: adapted from Fissel et al. 2009

The joint frequency data for Pelly Island (Table 3-21) were colour-coded to illustrate favourable winds, referring to times when ice is moving offshore. This typically occurs when winds are blowing from the east and southeast.

Table 3-21 Frequency Distribution - Pelly Island wind direction and wind speed – 1994 – 2008

Wind Direction	Wind Speed (m/s)														Total Occur. (%)
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	
N	0.62	1.20	1.35	0.82	0.51	0.12	0.15	0.01							4.78
NNE	0.43	0.62	1.14	0.66	0.37	0.15	0.11								3.48
NE	0.65	1.04	1.32	0.98	0.92	0.35	0.02								5.28
ENE	0.37	0.97	2.01	2.08	1.11	0.42	0.06	0.02							7.04
E	0.92	1.86	3.92	5.58	4.86	1.88	0.40	0.17	0.01						19.60
ESE	0.44	1.08	2.36	3.09	2.34	1.06	0.17	0.01							10.55
SE	0.27	0.61	1.91	2.29	1.43	0.66	0.14	0.01							7.32
SSE	0.24	0.31	1.25	1.53	0.63	0.14	0.05								4.15
S	0.37	0.38	1.57	1.93	0.84	0.17	0.13								5.39
SSW	0.06	0.21	0.47	0.55	0.18	0.01									1.48
SW	0.30	0.39	0.69	0.47	0.32	0.17	0.07								2.41
WSW	0.28	0.41	0.79	0.71	0.32	0.12	0.06								2.69
W	0.21	0.65	1.42	1.45	0.98	0.40	0.24	0.16	0.10	0.05					5.66
WNW	0.37	0.59	1.09	1.74	1.39	1.38	0.56	0.20	0.15	0.16					7.63
NW	0.38	0.49	1.23	1.47	1.37	1.53	0.47	0.15	0.07	0.02	0.01				7.19
NNW	0.39	0.80	1.39	1.11	0.97	0.35	0.12	0.05	0.06	0.02					5.26
Total Occur. (%)	6.30	11.61	23.91	26.46	18.54	8.91	2.75	0.78	0.39	0.25	0.01	0.00	0.00	0.00	100.00

white	Ice movement is small or along shore, or no data.
light blue	Favourable Winds - Ice moving **offshore** at moderate speeds
darker blue	Best Winds – Ice drifting **offshore** at high speeds
light orange	Unfavourable Winds - Ice drifting **onshore** at moderate speeds
darker orange	Worst Winds – Ice drifting **onshore** at high speeds

SOURCE : from Fissel et al. 2009

Mean, maximum and standard deviations for wind data at the stations considered in this study are presented in Table 3-22. These data are based on hourly historical data (ECCC 2019b).

Table 3-22 Summary of mean, maximum and standard deviations for wind data at stations considered in this study (m/s)

	Tuktoyaktuk A			Pelly Island			Ulukhaktok A			Mould Bay A		
	Mean	Max	Std Dev	Mean	Max	Std. Dev.	Mean	Max	Std Dev	Mean	Max	Std Dev
Jan	3.10	21.67	3.30	5.33	24.72	4.59	1.43	22.78	2.79	2.28	24.72	3.46
Feb	3.01	24.72	3.31	5.84	25.83	4.44	1.27	16.39	2.65	2.15	23.61	3.33
Mar	2.92	22.22	2.94	4.67	16.39	2.96	1.24	20.56	2.66	2.13	26.11	3.25
Apr	2.98	16.39	2.98	5.16	21.11	3.47	1.41	20.56	2.93	1.95	19.72	2.91
May	3.33	18.61	3.02	4.95	18.61	3.07	1.60	21.67	2.95	2.48	21.11	3.00
Jun	3.33	15.00	2.90	4.94	15.83	2.42	1.67	17.50	2.84	2.80	26.39	3.29
Jul	3.53	22.50	2.95	4.51	16.94	3.13	1.52	15.56	2.59	2.86	23.33	3.23
Aug	3.63	20.56	3.16	5.22	18.06	2.87	1.50	17.50	2.69	2.78	20.56	3.27
Sep	3.57	24.17	3.23	5.59	16.67	3.41	1.72	20.00	3.00	2.97	20.00	3.56
Oct	3.39	19.17	3.16	5.87	19.17	3.85	1.95	19.17	3.38	2.35	33.89	3.35
Nov	3.12	23.61	3.17	5.53	23.06	4.31	1.65	20.56	3.03	2.23	22.22	3.14
Dec	2.99	24.72	3.08	5.00	27.22	3.83	1.38	20.00	2.78	2.30	30.28	3.38
Annual	3.25	24.72	3.11	5.22	27.22	3.61	1.53	22.78	2.87	2.44	33.89	3.28

3.4.1.2 Storms

Storms may enter the southern Beaufort Sea Region from the Bering Strait, Northern Canada, the North Atlantic, or follow eastward migratory trajectories from the Russian Sector (Zhang et al. 2004). Atkinson (2005) studied storminess patterns in the areas surrounding the Arctic referred to as the circum-Arctic coastal regime during the open water season of June, July, August, September, October. Data from weather stations in the 7 different coastal zones for a period of 1950 to 2000 were analysed. Coastal zones of interest here are zone 5 – Chukchi Sea, zone 6 – Beaufort Sea, and zone 7 – the Canadian Arctic Archipelago. Thresholds of 37 km/hour (10 m/s) for windspeed, and 6 hours for duration, were used to define a storm event, and algorithms were set up to establish counts for each region.

The number of mean annual storm events is shown in Figure 3-39 for zone 5 (Chukchi Sea), zone 6 (Beaufort Sea) and zone 7 (the Canadian Arctic Archipelago). Similarly, the mean storm core windspeeds and the mean storm maximum windspeeds by month are shown in Figure 3-39.

It is noted that the Beaufort Sea comes under the influence of systems from the Pacific via the Bering Strait, and that increasing open water amounts align with increase in storm activity, which reaches a maximum in October. The mean storm windspeed in the Beaufort Sea ranged from 9.9 m/s in July (the lowest value) to 10.8 m/s in October. The mean storm maximum windspeed in the Beaufort Sea ranged from 11.6 m/s in July to 12.8 m/s in October. The mean duration of core winds within the thresholds in the Beaufort Sea range from 19 to 25 hours. It was concluded that the storm counts did not exhibit a steady trend but did show when it seemed that different circulations prevailed, with rapid jumps in activity and variability (Atkinson 2005).

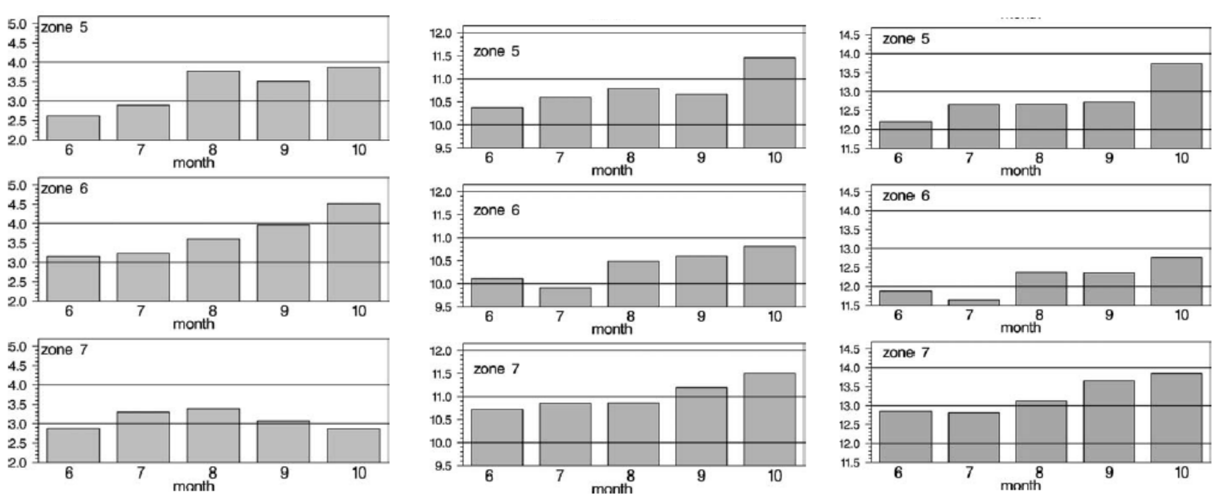


Figure 3-39 (Left) Mean annual storm events by month, by location (from Atkinson 2005), (Centre) Mean storm core windspeed (m/s) by month, by location, (right) Mean storm maximum windspeed (m/s) by month, by location

SOURCE: Adapted from Atkinson 2005

3.4.2 Predictions

3.4.2.1 Winds

Environment and Climate Change Canada (ECCC) recently published data on seasonal and annual multi-model ensembles of projected change (also known as anomalies) in surface wind speed based on an ensemble of twenty-nine Coupled Model Intercomparison Project Phase 5 (CMIP5) global climate models, and these are available for 1900-2100 (ECCC 2018). The projected change in wind speed is with respect to the reference period of 1986-2005 and expressed as a percentage (%). The 5th, 25th, 50th, 75th and 95th percentiles of the ensemble of wind speed change are available from ECCC for the historical time period, 1900-2005, and for emission scenarios, RCP2.6, RCP4.5 and RCP8.5, for 2006-2100. These data were accessed for the RCP8.5 scenario for the year 2050, for the Beaufort Sea. The projected changes for the Beaufort Sea are provided in Table 3-23.

Table 3-23 Projected Change in Near Surface Windspeed – Beaufort Sea, 2050

Climate Variable	Projected Change (%) for 2050, relative to 1986 – 2005 Period		
	Minimum	Median	Maximum
Near Surface Wind Speed	+2.0	+5.0	+6.5

IPCC has stated that wave heights and duration of the wave season will increase in the Arctic Ocean as a result of more wind stress facilitated by reduced sea ice extent (see Chapter 3.9).

3.4.2.2 Storms

For the northern hemisphere, in winter, the projections show an overall reduced frequency of storms and less of a poleward shift, than in the Southern Hemisphere. Factors that affect changes in storm tracks and storm strength include the horizontal resolution in atmospheric flows, i.e., the jet streams in the atmosphere, and the Atlantic Meridional Overturning Circulation, i.e., the change in ocean currents in the North Atlantic.

Asplin et al. (2015), Vavrus (2013), Villarini et al. (2012), Sepp and Jaagus (2011), Zhang et al. (2004), and others have reported cyclone activity and intensity have increased in the Arctic, and suggest that storm tracks have shifted northward, with stronger east winds in the Arctic during the fall season. Reasons for a slight increase seem to be related to the increased meridional atmospheric circulation in the northern hemisphere, a deepening of the Aleutian low, and a strengthening of the pressure gradient in the Beaufort region. One review stated there is strong evidence that the frequency and intensity of storms in the Arctic is increasing, and that storms will be large and stronger as sea-ice extent continues to decrease, especially in areas of significant fetch such as the Beaufort Sea (Ford et al. 2016). Others including Hudak and Young (2002), and Barber et al. (2010) have reported no trend in changes to storm frequency in the Arctic. There is therefore some support for all three: an increase, a decrease and no change in the frequency of the storms in the region.

3.4.3 Uncertainties

There is considerable uncertainty in the climate projection of changes in the winds and storm regimes at any location on the planet and it is the same for the Beaufort Sea region. The uncertainty is associated with different assumptions on future GHG emissions, the spread in the climate model predictions, and internal variability in the climate system associated with atmospheric circulation, and the challenge of downscaling future wind fields from coarse-resolution climate models (Church et al. 2013).

Future projections of surface wind characteristics in the southern Beaufort Sea region depend highly on the nature of future storm tracks. As reported by IPCC, there is substantial uncertainty in predicting winds and storm tracks in the Northern Hemisphere (Collins et al. 2013; Kirtman et al. 2013). It is suggested that this is likely because the links among surface warming, storms in the North Atlantic, and influence on and by climate are more complex than simply predicting changes in patterns and trends of atmospheric pressure, especially in the long term out to the year 2100.

In a study of Arctic sea ice loss projections, it was noted that the 3 sources of uncertainty (the magnitude of GHG forcing, model sensitivity, and internal variability) are all roughly comparable (Wettstein and Deser 2014). From IPCC 2013b regarding atmospheric circulation, there is considerable model uncertainty in the response of the storm track position in the Northern Hemisphere related to the jet streams, and further that there is only *medium confidence* in the near term projections of a northward shift of Northern Hemisphere storm track and westerlies, and an increase in the North Atlantic Oscillation (Kirtman et al. 2013).

Further from IPCC, in general there is low confidence in region-specific projections for winds and waves due to the low confidence in tropical and extratropical storm projections, and to the challenge of down-scaling future wind states from coarse resolution climate models. There is low confidence in the impact of storm track changes on regional climate at the surface (Church et al. 2013).

Actual future climate changes will depend largely on the speed at which certain global phenomena unfold and on the scale of global efforts to reduce greenhouse gas emissions in the coming decades. However, the methods used for these projection calculations are accepted as being a reasonable representation of potential future climate outcomes.

3.4.4 Limitations

Although the Beaufort Sea region is represented by a fair number of active and historical weather monitoring stations, data availability within these stations is, at times, limited. For the four weather monitoring stations selected within the region to comprise the main data base for this study as well as the nearby complementary stations, have a data availability within these climate data sets ranging from 72 - 96% complete. Data availability is presented as the percentage to which the dataset is complete within the listed time range. Some stations that have operated over a long timeframe are not being operated today. This represents an opportunity for extending the meteorological monitoring in an area where climate is changing faster than most other locations.

3.4.5 Summary

The prevailing winds in the Beaufort Sea are from the east, southeast and northeast depending on the season. Mean windspeeds are 6 - 8 m/s, with maxima on the order of 15 - 16 m/s. The wind directions vary by location. The winds for Tuktoyaktuk and Pelly Island have strong and frequent components especially for the NE, E, and SE directions, while Pelly Island has more frequent winds from the NW, and broader range from the east. Winds at Ulukhaktok are similar Tuktoyaktuk and Pelly Island, except there are stronger winds from the east and southeast. Winds at Mould Bay (the station located furthest north) exhibit different characteristics, with frequent and strong winds from the north, northwest and south, and with much less frequent winds from the eastern quadrant.

Storm activity in the Beaufort Sea reaches a maximum in October (4.5 storms per month). The mean storm windspeed in the Beaufort Sea ranged from 9.9 m/s in July (the lowest value) to 10.8 m/s in October, and the mean storm maximum windspeed was 12.8 m/s in October.

As gleaned from the literature, there is support for an increasing trend in observed winds (although modest), no change in winds, and a slight increase in winds. Similarly, with storminess, there is some support for an increasing trend in the future, but the changes to date have been modest.

An extract from recent climate projections published by Environment and Climate Change Canada (ECCC 2018), indicate that for the Beaufort Sea region, the near surface windspeed will increase by about 5% in 2050 relative to the 1986-2005 period, but could be as low as 2.0% and as high as 6.5%.

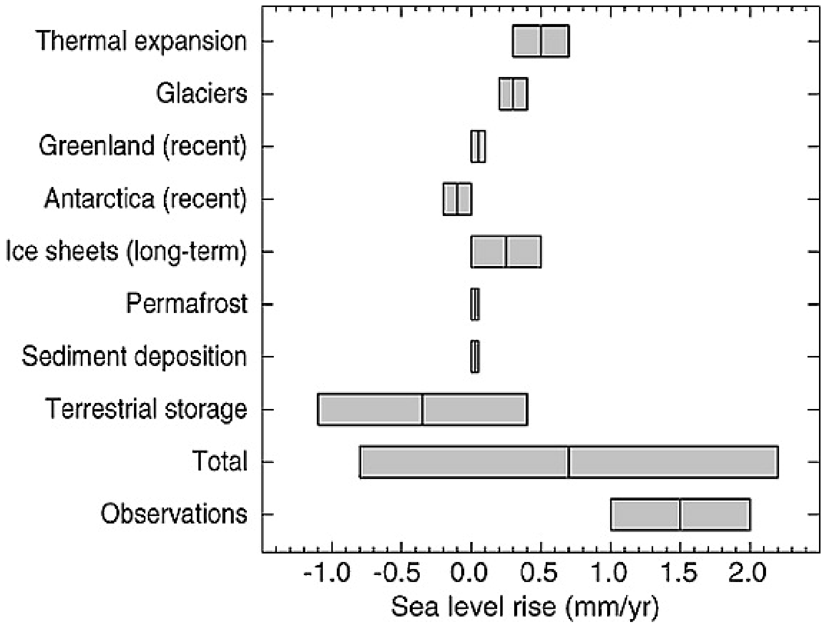
The storm track density is projected to be lower offshore in the Beaufort Sea in 2081-2100, meaning that less storms are projected for that region for that time period.

3.5 Sea Level Rise and Storm Surges

3.5.1 Current trends

3.5.1.1 Sea Level Rise

Global mean sea level (GMSL) rose at a mean rate of 1.7 (± 2) mm per year between 1901 and 2010, and this trend has been increasing throughout the 20th century (Church and White 2011). Ocean thermal expansion and freshwater inputs (glaciers and ice sheets) are the dominant contributors to the 20th century GMSL rise (Figure 3-40).

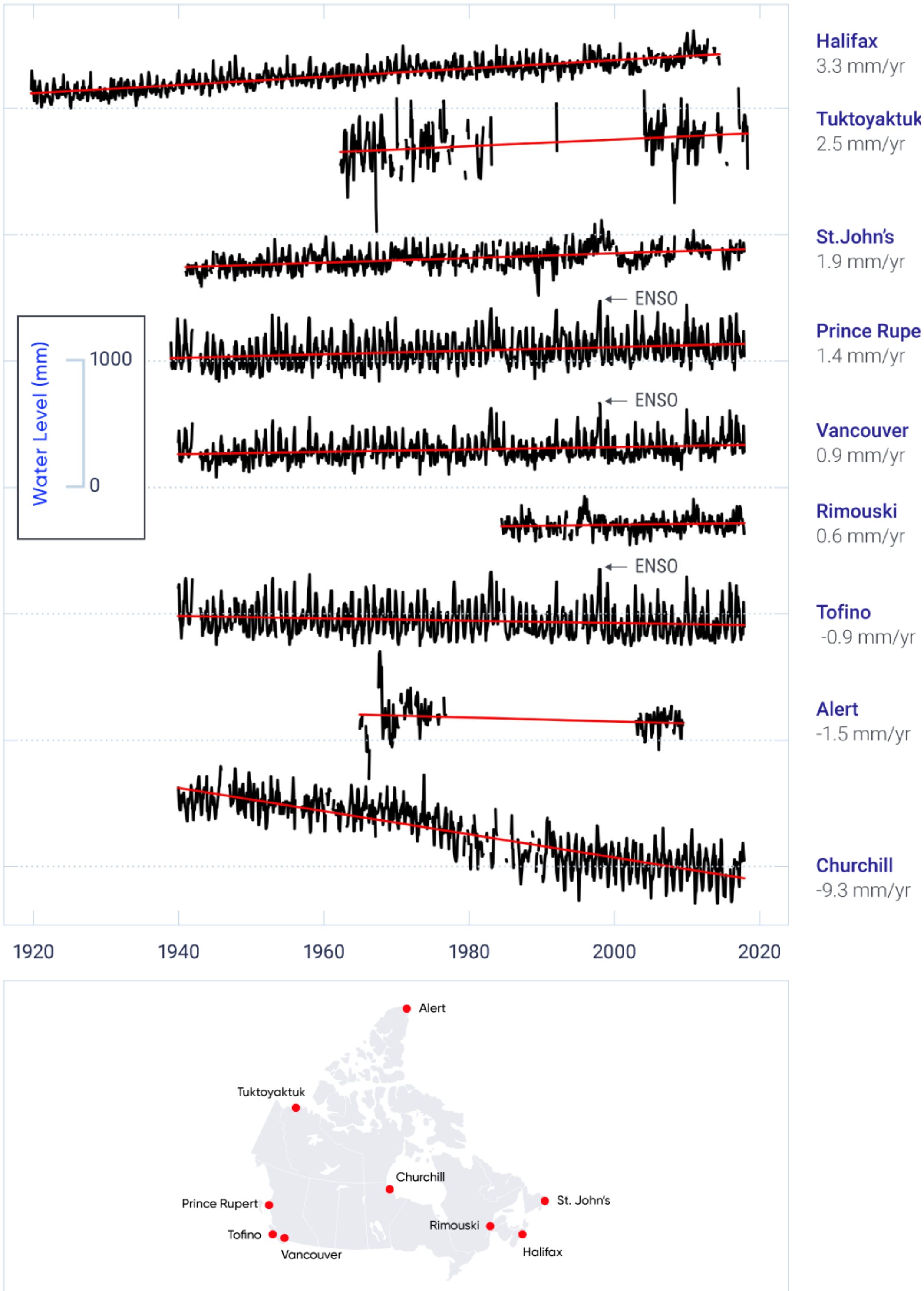


SOURCE: Adapted from Church et al. 2001

Figure 3-40 Estimates of the contributions to global sea level rise

The mean sea level (MSL) is defined as sea level at a given location averaged over a period of one year. GMSL is determined as the spatial average of MSL. Relative sea level (RSL) is defined as sea level measured with respect to land and is often measured using tide gauges. Regional ocean volume change (steric and dynamical effect) and vertical land motion can cause the rate of regional (relative) sea level (RSL) change to be considerably different from that of the GMSL (Cazenave and Nerem 2004). If the land is sinking, sea-level rise will be increased locally, and if the land is rising, sea-level rise will be decreased locally. In the Canadian Arctic, vertical land motion is occurring primarily as a delayed response to the surface unloading caused by the thinning and retreat of the continental ice sheets at the end of the last ice age. This delayed response is called postglacial rebound or Glacial Isostatic Adjustment (GIA).

There are a limited number of tidal gauges in the Western Canadian Arctic with long, reliable data records (Tuktoyaktuk data is available from 1962). Han et al. (2015) calculated a historical rate of sea level change of +1.9 mm (± 2) mm per year for Tuktoyaktuk, significantly different from zero at the 95% confidence level. Recent analysis (Bush and Lemmen 2019) identified a rate of sea level rise for Tuktoyaktuk of 2.5 mm per year (Figure 3-41).

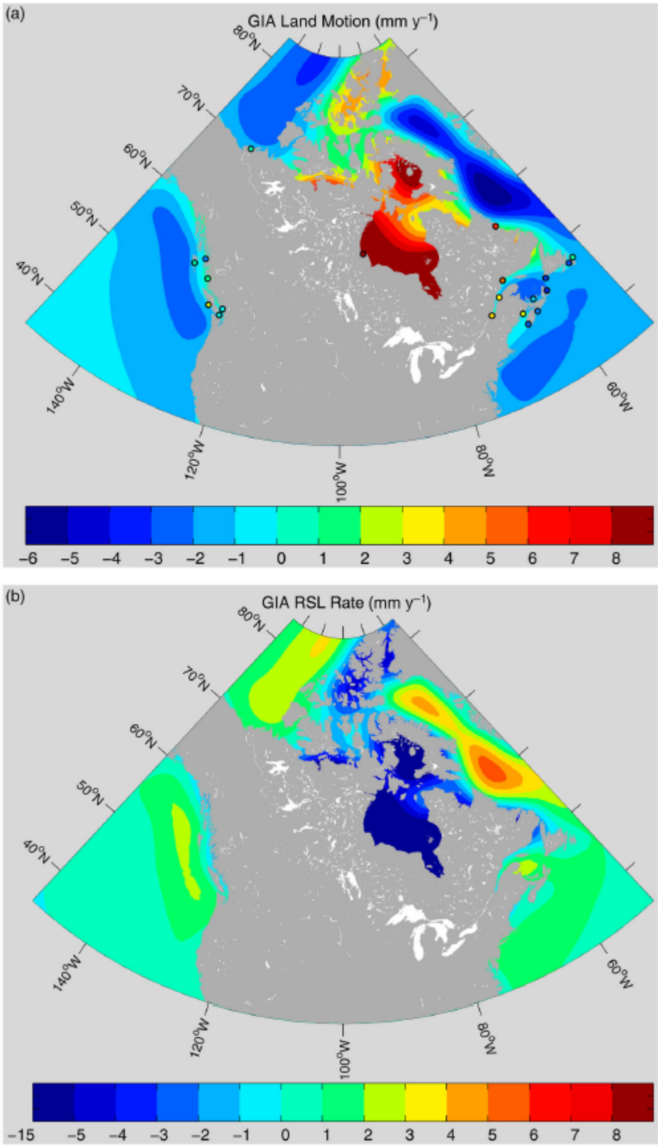


SOURCE: adapted from Bush and Lemmen 2019

Figure 3-41 Long-term trends of relative sea-level change at sites across Canada

GIA is a factor in determining the characteristics of sea level rise in coastal communities in the NWT, and is estimated using GPS-based measurements of the vertical motion of bedrock (note: these measurements do not account for plate tectonics or changing underlying permafrost conditions). Within the periphery of the former continental glacier, land was pushed downward, forcing materials deep within the Earth to be moved horizontally away from the region of loading, thereby causing uplift in areas immediately beyond the ice sheet. In the absence of the ice, depressed landmasses are rising and regions that were previously uplifted are now sinking. Positive and negative rates of GIA are affecting coastal communities in the NWT. Vertical land motion ranges from uplift of 1 (± 2) mm yr^{-1} at Ulukhaktok, to no change at Paulatuk, to subsidence of 1 (± 2) mm yr^{-1} and 2.5 (± 2) mm yr^{-1} at Sachs Harbour and Tuktoyaktuk, respectively. These communities are located near the periphery of the former ice sheet, and vertical land motion is much less than rates (10+mm yr^{-1}) found in areas such western Hudson Bay (Figure 3-42).

The changing gravitational mass of the Greenland ice sheet is also affecting rates of sea level rise in the Canadian Arctic. The uneven distribution of meltwater from glaciers, ice caps, and ice sheets is called sea-level fingerprinting (Chia-Wei Hsu 2017). Owing to the reduced gravitational attraction of a shrinking ice mass, sea level falls close to a body of ice that is shrinking and providing meltwater to the oceans. The melting Greenland glacier will affect sea levels throughout the Canadian Arctic due to this effect, albeit to a small effect in coastal NWT communities. A contribution of 1 mm yr^{-1} to sea level rise from the Greenland Glacier is estimated to contribute 0.2 mm yr^{-1} to rates of sea level rise at Tuktoyaktuk and reduce it by 0.1 mm yr^{-1} at Ulukhaktok.



SOURCE: Adapted from Han et al. 2015

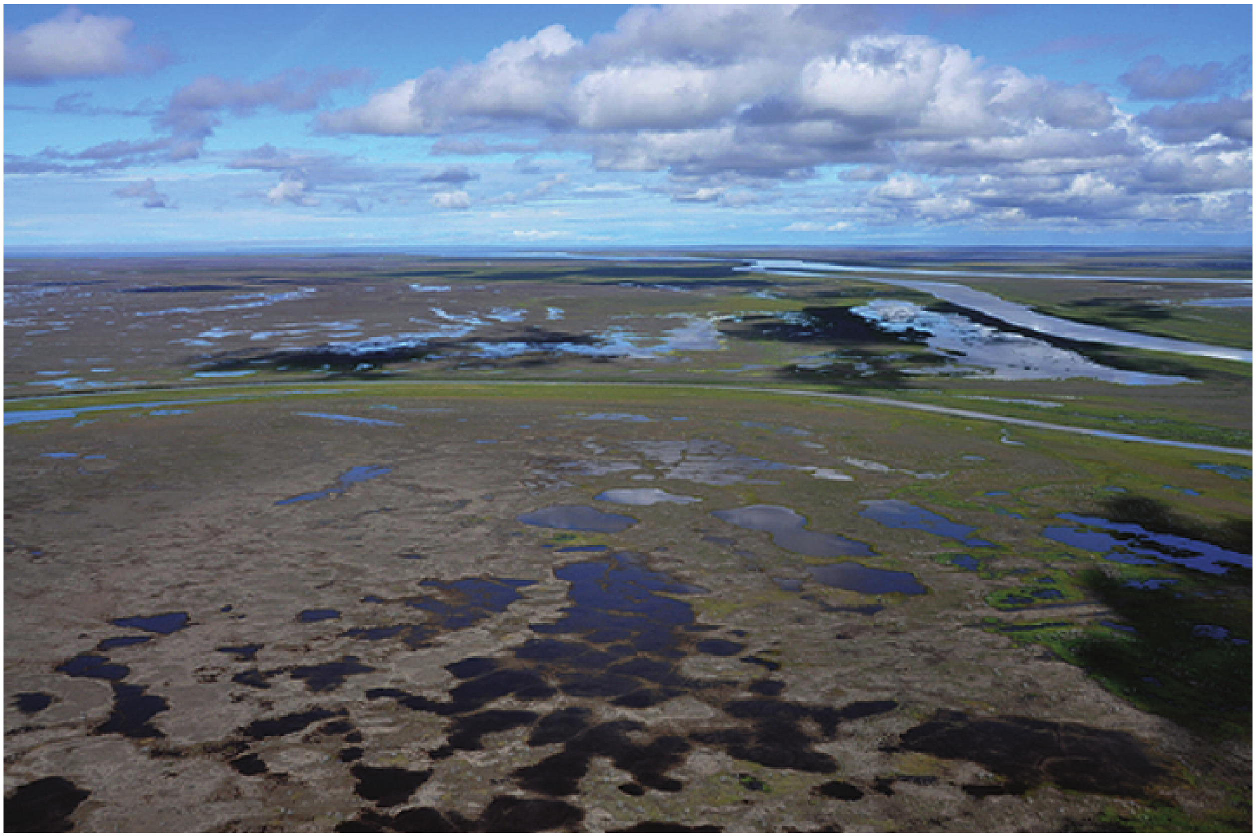
Figure 3-42 (a) 500-year average rates of vertical land motion due to GIA and (b) Rate of RSL change due to GIA. Based on Peltier's (2004) model

3.5.1.2 Storm Surges

Declines in Arctic sea ice cover and commensurate increases in fetch are elevating the potential for damaging storm surges in coastal areas of the Canadian Beaufort Sea Region (Morse et al. 2009; Vermaire et al. 2013). They can manifest as flooding (positive surge), or water-level recession (negative surge), depending on the direction and intensity of the wind forcing. The largest storm surges observed along the coastline of the Canadian Beaufort Sea Region have been recorded during the late autumn and early winter where some first-year sea ice is present.

Although coastal ecosystems are dependent on frequent sedimentation and salinization from small floods, larger storm inundations can cause salinization of freshwater ponds and non-saline meadows (Pisaric et al. 2011), increase soil salinity and damage vegetation along the margins of permafrost plateaus, and melt subterranean permafrost causing underground hollows subject to collapse (thermokarst) (Kokelj et al. 2013, 2015). For example, Pisaric et al. (2011) described the effects of a widespread storm surge inundation event in the MacKenzie River Delta (Figure 3-43) in 1999. An exceptionally high surge moved saltwater far above the normal surge lines and killed shrubs and changed the ecology of some delta lakes from freshwater to brackish lakes. Through traditional and local knowledge, dendrochronology, and analysis of lake diatoms, it was determined that this type of large-scale storm surge had not occurred in the Mackenzie Delta in the past 1000 years. Vermaire et al. (2013) investigated this event further and inferred an increase in storm surge activity in the region over the past 150 years. They linked this trend to increases in annual mean temperatures in the Northern hemisphere, and a decrease in summer sea ice extent. It is reasonable to expect this trend to continue with further declines in Arctic sea ice extent.

Tuktoyaktuk, NWT is particularly vulnerable to positive storm surges, driven by strong, northwesterly winds from migratory Arctic cyclones interacting with seasonal areas of open water (fetch). Harper et al. (1987) identified a local maximum in surge elevations of 2.4 – 2.5 m above MSL under northwesterly winds for Tuktoyaktuk, NWT where maximum surge elevations were limited to ~2.0 m above MSL in coastal areas to the north and west. No evidence was found for larger surges within the past 100 years, however the observed changes to the regional climate and sea ice cover may be increasing the risk for a surge event with an elevation > 2.5 m. The frequency and magnitude of extreme high water-level events is projected to increase (high confidence) along the Canadian Beaufort Sea coastline, resulting in increased flooding and pressure on infrastructure and coastal ecosystems (Bush and Lemmen 2019).



SOURCE: Photograph by T. Lantz in: Chappin III et al. 2013

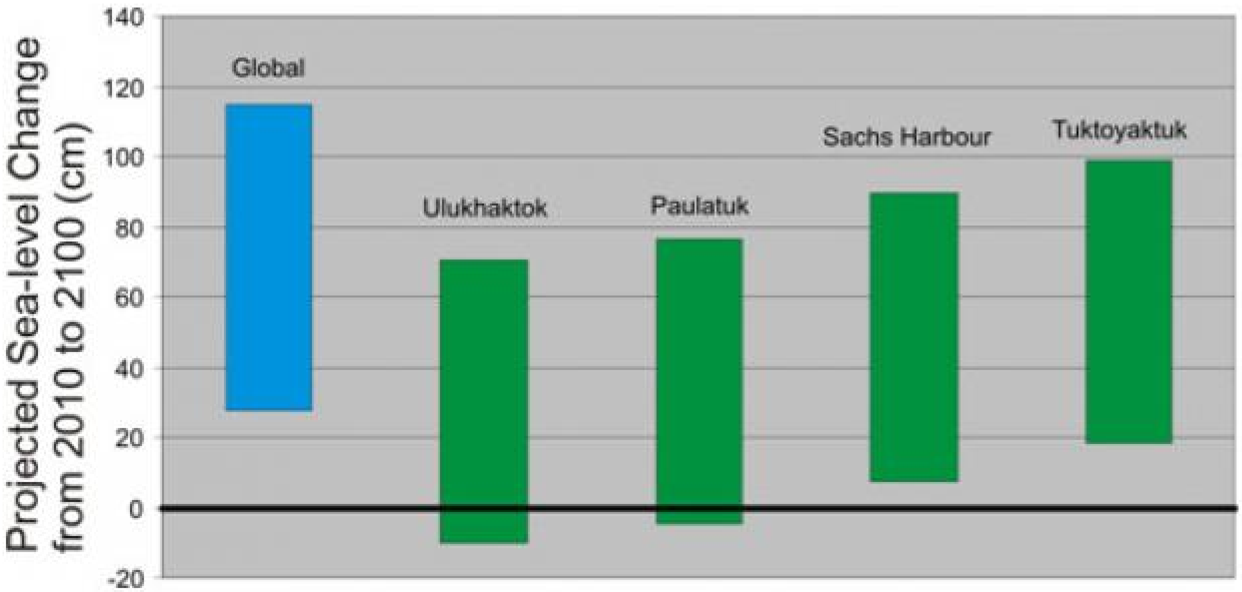
Figure 3-43 Effects of the 1999 Storm surge on vegetation of the outer MacKenzie Delta

3.5.2 Predictions

3.5.2.1 Sea Level Rise

According to the AR5 of the IPCC, the future rate of GMSL rise will very likely (90-100% probability) exceed the observed rise under all RCP scenarios. GMSL rise is likely (66 – 100%) to be in the 5 – 95% range of projections, which show GMSL rise of 0.52 – 0.98 m for RCP8.5 (Church et al. 2013). RSL change projections are very likely to have a strong regional pattern in the 21st century, following the effects of GIA to the last glacial maximum (Han et al. 2014, 2015). Slangen et al. (2014) shows a revised GMSL rise projection of 0.71 ± 0.28 m during the twenty-first century under RCP8.5.

Projections for RSL in the communities of Ulukhaktok, Paulatuk, Sachs Harbour, and Tuktoyaktuk are compared to global projections for GMSL for the RCP8.5 scenario for the end of the 21st century (Figure 3-44). These projections show a range of values for the change in mean sea level at these communities and are based on limited available information. Advances in the understanding of global sea level rise, and rates of vertical land motion will lead to future revisions of these projections.

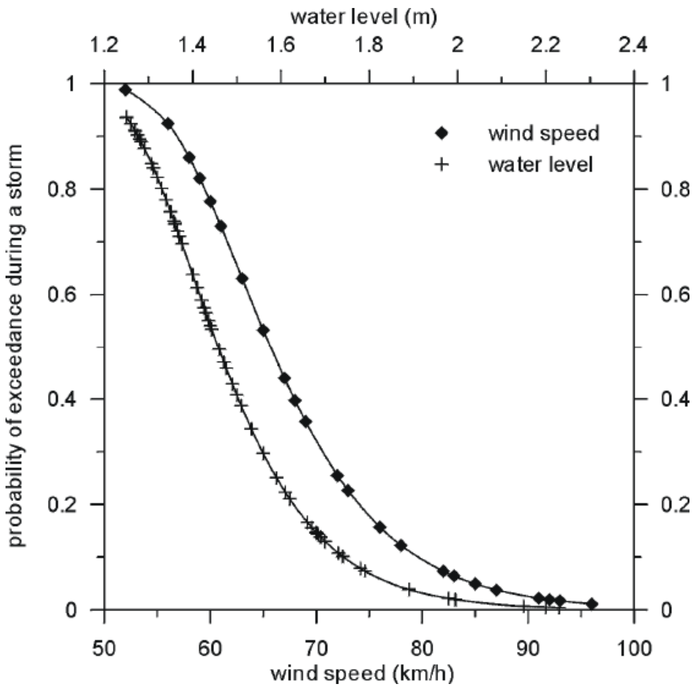


NOTE: Scenarios of sea –level rise ranging from 28 – 115cm between 2010 – 2100 were analyzed to determine RSL for each community, accounting for isostatic rebound
SOURCE : based on James et al. 2011

Figure 3-44 Sea level projections for four coastal communities of the Inuvialuit Settlement Region

3.5.2.2 Storm Surges

As storm surges are linked to winds, ocean temperatures, and fetch (less ice – more fetch), all of which are anticipated to continue to increase over the next three decades, storm surge activity in the region is also predicted to continue to increase. The potential trajectory for the duration, frequency and intensity of future storms is not well handled by current climate model projections and limited record of storm surges in the region. In the absence of changes to storm attributes, increased exposure to storm surges is anticipated due to declining sea ice cover and sea level rise. Probabilities of exceedance for winds speeds and storm surge height (Figure 3-45) calculated from a limited record (1970 – 2010) for Tuktoyaktuk by Soloman et al. (2010) using a "peaks over threshold" method can be used as a baseline for future projections depending on other physical climate factors.



NOTE: Return periods for peak wind speeds exceeding 90km/hr and water levels exceeding 2 m relative to chart datum are shown to be rare

SOURCE: adapted from Solomon et al. 2010

Figure 3-45 Probabilities of exceedance for Tuktoyaktuk wind speeds (km/h) and water levels (m)

Sea-level allowance is defined as the amount by which an asset needs to be raised to maintain the same frequency of inundation events as that site has experienced in the recent past. Zhai et al. (2014) estimated sea-level allowances for 56 tidal gauge sites along the coasts of Canada, based on the latest projections of regional sea-level rise from the Fifth Assessment Report (AR5) of the IPCC using the statistics of historical tides and storm surges. For the period 1995 – 2050 under the RCP8.5 scenario, an allowance of 0.30 m is identified for Tuktoyaktuk. Extending this period to 1995 – 2099 reveals an allowance of 0.78 m for Tuktoyaktuk.

3.5.3 Uncertainties

Additional uncertainty may be introduced to projected rates of sea level rise and future storm surge climatology if there is a collapse of parts of Antarctic ice shelves that are in direct contact with warming ocean waters. There is medium confidence that this additional contribution would not exceed several tenths of a metre of sea-level rise (Church et al. 2013), although DeConto and Pollard (2016) noted that up to a metre or more of global sea-level rise could occur from changes in Antarctica alone by 2100.

3.5.4 Limitations

Unfortunately, with fewer than two large storm surge events per year, it is not possible to determine whether the frequency of surges or their magnitude has changed over time. A key limitation in modelling storm surges in the Arctic is the presence and timing of sea ice cover. Storms are affected by the marginal ice zone, which modify the effects of wind stress on the ocean-ice surface (Salisbury et al. 2013). Greater confidence is required in our capability to simulate storm surges in marginal ice zones to improve our estimates of the variability in storm surge climate, and the possible effects of climate change on future storm surge projections.

3.5.5 Summary

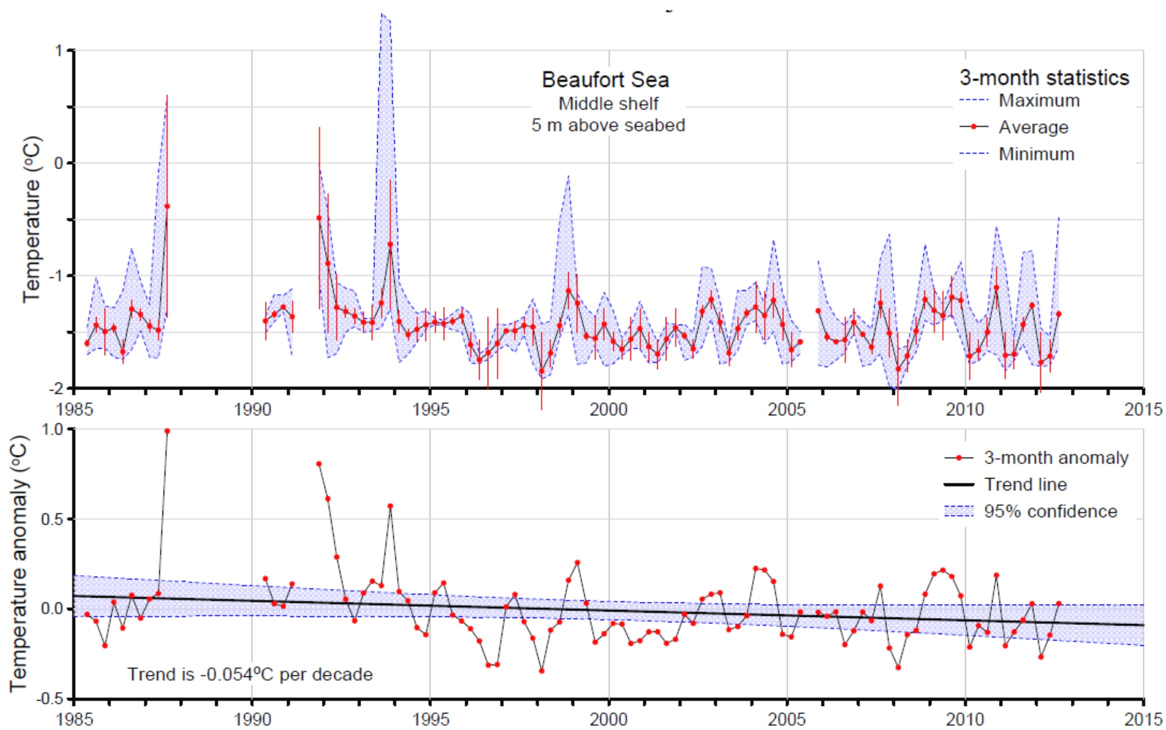
Global mean sea level has risen and is projected to continue to rise under the RCP8.5 scenario. The projected GMSL increase may exceed one metre, however RSL projections in the Beaufort Sea region of Canada are tempered somewhat by local vertical land motion due to GIA, and sea level fingerprinting effects from the changing mass of the Greenland ice sheet. The projected amount of sea level rise in the Southern Beaufort Sea is relatively lower than the projected global sea level rise projections for the 21st century with the high-end of projected mean sea levels in Ulukhaktok, Paulatuk, Sachs harbor and Tuktoyaktuk expected to increase between 70 – 100 cm by 2100 compared to 2010 levels. Rates of increase for 2050 are inferred at between 35 – 50 cm, respectively. Historical storm surge frequency is difficult to assess due to limited data, however it is anticipated that the commensurate decline of summer Arctic sea ice cover, extended periods of fetch, and delayed freeze-up will increase the risk of coastal communities in the Beaufort Sea to devastating storm surge events, such as described by Pisaric et al. (2011). Additional uncertainty in these projections may arise if additional contributions of water come from the marine-based sectors of the Antarctic Ice Sheet.

3.6 Ocean temperature and heat content

3.6.1 Current trends

3.6.1.1 Near-Bottom

The longest record of near-bottom ocean temperature within the Beaufort Sea comes from 5 m above the seabed in the middle of the Beaufort shelf within 50 m of water and spans from 1985 to 2013 (Steiner et al. 2015); Figure 3-46. The record shows substantial interannual variability but no significant long-term trend.



NOTE: The upper panel shows quarterly means and the spread between the minimum and the maximum. The bottom panel illustrates the long-term trend, but which when error bars are added, is not significant.

Figure 3-46 Mid-Beaufort shelf temperature record from 1985-2013 at 5m above bottom within 50 m of water as per Steiner et al. (2015)

3.6.1.2 Mid-Water Column Temperature Maximum

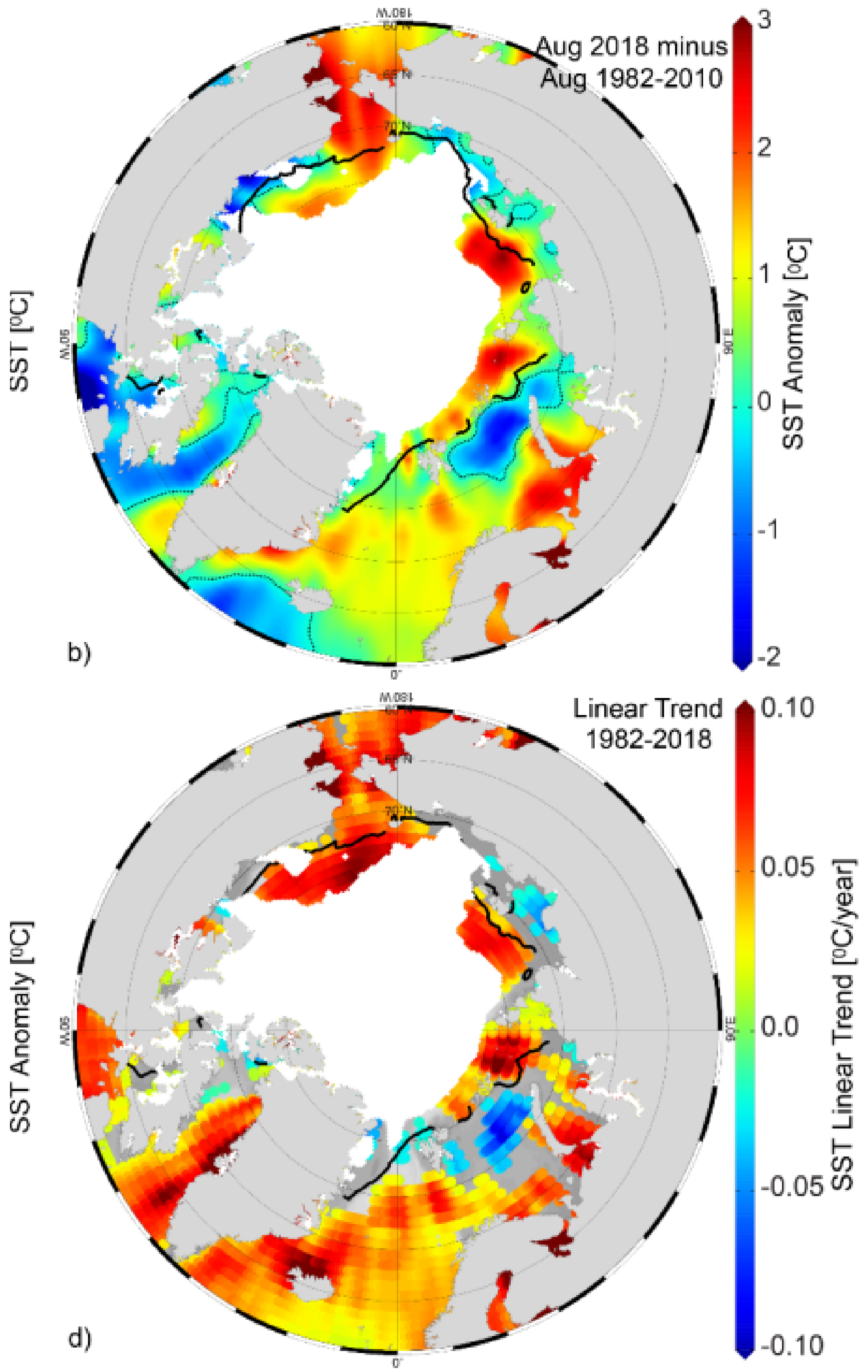
Warm salty water enters the Arctic Ocean from the Chukchi Sea. The increased density due to the saltiness causes it to reside between 50 and 150 m depth within the Beaufort Gyre. Reductions in ice cover in the Chukchi have allowed increased solar heating of these surface waters which later subduct to depth in the Beaufort. Between 1987 and 2017, the heat content these waters bring into the Beaufort Gyre has more than doubled, from $2x10^8 J/m^2$ to over $4x10^8 J/m^2$ (Timmermans et al. 2018). This increase in heat content is due to an increase in the temperatures within this layer as well as a thickening of this layer. Winter storms have not mixed through this layer, meaning this source of heat within the Beaufort Gyre remains in the ocean through the winter. The 11˚C temperatures observed in parts of the Chukchi in 2017 (Richter-Menge et al. 2018) has raised the question whether further warming to 13˚C within the Chukchi could further decrease the density of these waters to the point of shutting down the ventilation of the halocline within the Beaufort Gyre (Timmermans et al. 2018).

3.6.1.3 Sea Surface Temperatures (SST)

In 2018, persistent northerly winds through August kept the sea ice from leaving the Southern Beaufort Sea. The sea ice kept the 2018 SST values in the region below the 1982-2010 average (Timmermans and Ladd 2018). A linear trend in the near shore could not be obtained at a 95% confidence interval, but further offshore a linear trend in excess of 0.05 ˚C/year was detected. South of Banks Island, a decreasing trend of around -0.03 ˚C/year was found (Figure 3-47). Similar analyses by the Arctic Monitoring and Assessment Program for 2017 show the same pattern, but with the warming in the near shore of the Southern Beaufort being more evident (AMAP 2019).

3.6.2 Predictions

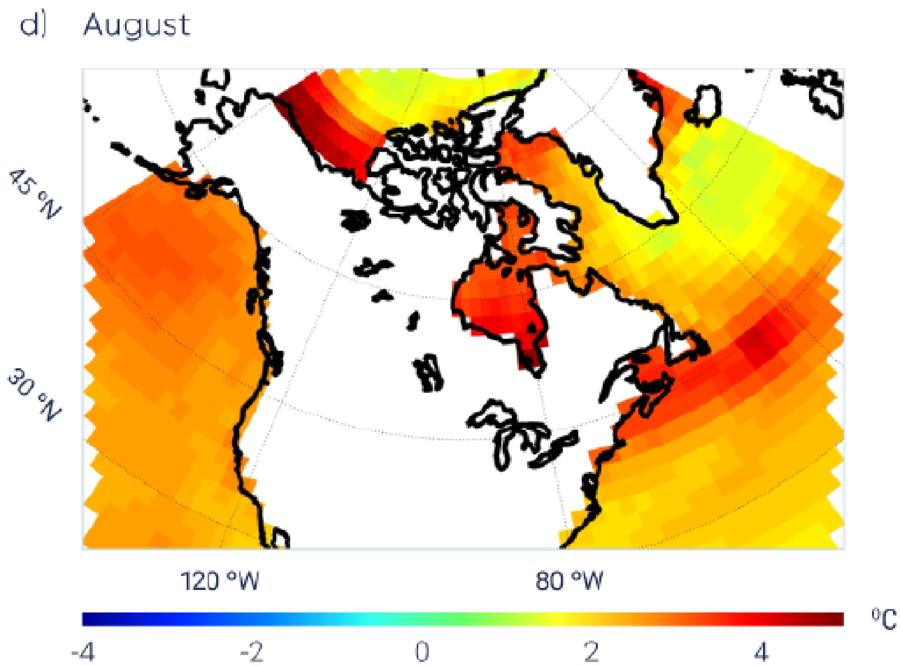
As ice is anticipated to continue to form in the Beaufort Sea through the mid-21st century, the winter SST will be at or near the freezing point of sea water. Modelling of summer SST under RCP 8.5 using models from the fifth phase of the Coupled Model Intercomparison Project (CMIP5) predict an increase of 3-4˚C in the Southern Beaufort Sea (Greenan et al. 2018) by the middle of the 21st century. The trend tends to show the largest changes in the south and the southwest (Figure 3-48). The results shown in the top panel of Figure 3-48 are based on an ensemble of model results. The standard deviation across this ensemble is provided in the bottom panel. The smaller the standard deviation with respect to the mean change, the higher the confidence level in the results. It is reassuring to see a similar trend in a pan-Arctic model which also predicts warming within the Beaufort Sea, even under RCP 6.0 forcing (Hu and Myers 2014).The probability of SST anomalies between 2040 and 2069 in the Beaufort Sea exceeding the maximum SST from 1976-2005 is around 50-70% (Alexander et al. 2018); (Figure 3-49).

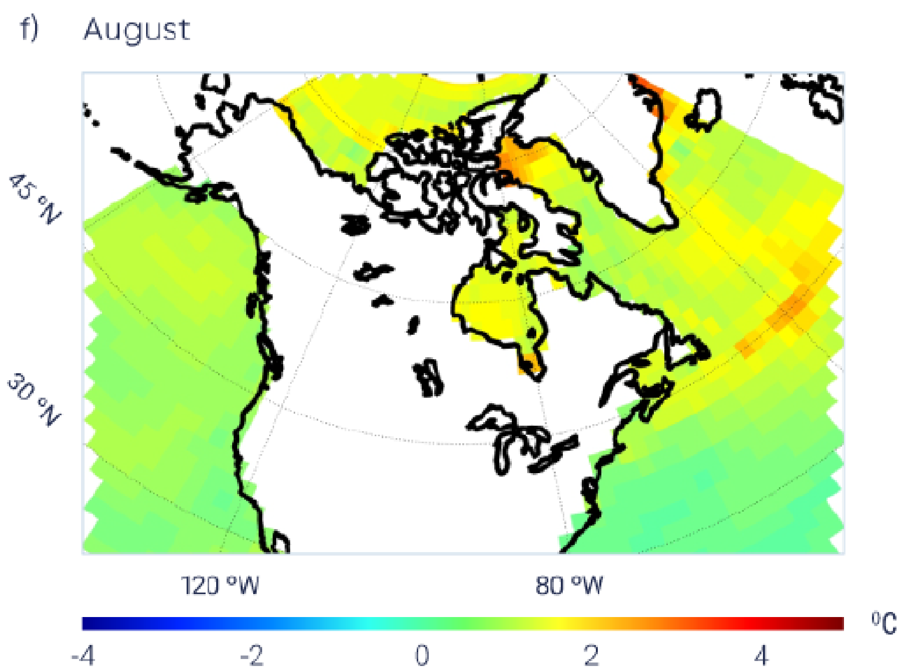


NOTES: White denotes the 2018 mean sea ice extent. The dotted black contour indicates zero trend. The solid black line indicates the mean ice extent for 1982-2010. Grey in the linear trends indicates regions where a 95% confidence level for the trend could not be found.

SOURCE: As per Timmermans and Ladd 2018

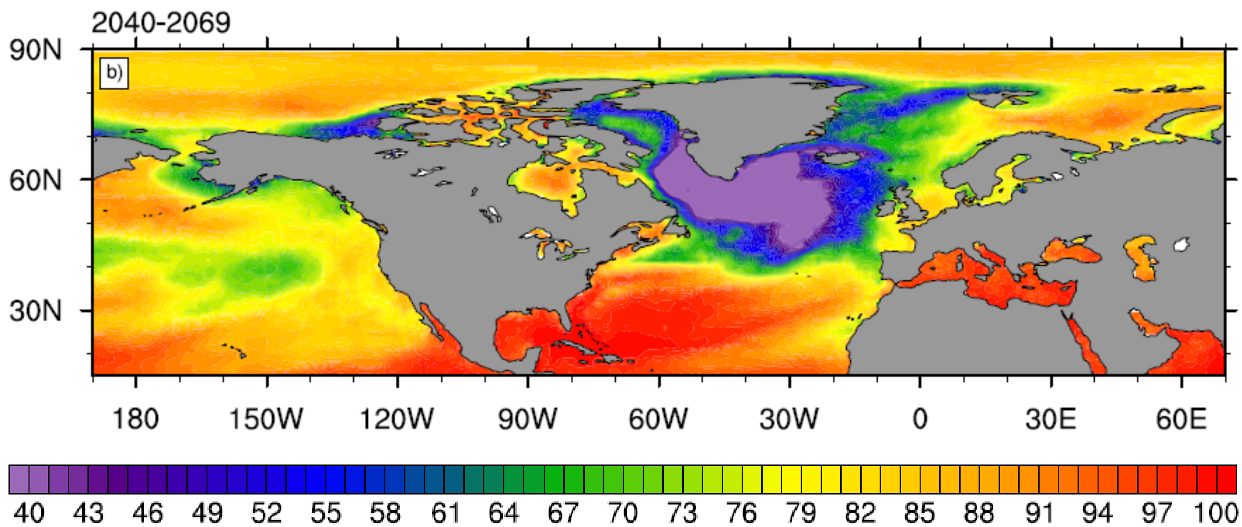
Figure 3-47 August 2018 SST anomaly (top). The linear trend in SST from 1982 to 2018 (bottom)





SOURCE: Figures are from Figure 7.8 of Greenan et al. 2018

Figure 3-48 Change in mean August SST between 1986-2005 and 2046-2065 (top). The standard deviation in the mean SST change in August (bottom).



SOURCE: Alexander et al. 2018

Figure 3-49 Probability of the SST extremes exceeding the maximum from 1976-2005

3.6.3 Uncertainties

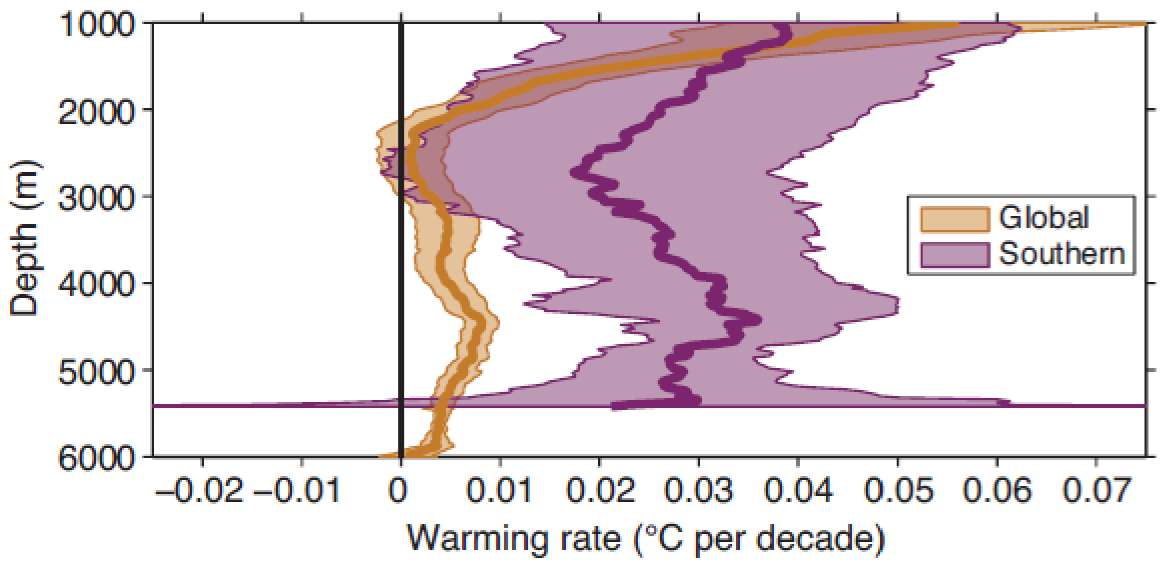
The absence of long-term moored temperature measurements limits the validation of numerical models' predictions to the sea-surface temperatures. A regional model of the Beaufort Sea Region which provides high resolution horizontally and vertically would be the ideal source of predictions for future changes in the Beaufort Sea Region, however, almost all of the predictions for this area are from global models (Steiner et al. 2015). The limited data at depth further limits any model predictions due to the limited model validation.

Sea-ice extent has substantial effects on the sea surface temperature (Peralta-Ferriz and Woodgate 2015), as does freshwater input and wind forcing which affect stratification and the mixed layer depth. The uncertainties of these variables will also affect sea surface temperature.

Studies such as the one by Alexander et al. (2018) use 26 models from CMIP5 and 30 ensemble runs from the National Center for Atmospheric Research Large Ensemble Community Project (CESM-LENS) under the RCP 8.5 scenario. Alexander et al. (2018) found more variability between different models than between the CESM-LENS ensembles (which represented the climate variability), indicating a high degree of dependence on the actual model. In all cases, the upward trends in predicted SST were due to a shift in the mean; the magnitude of the interannual variability did not seem to change during the 21st century. The CESM-LENS and CMIP5 models predicted linear increases in the Arctic Ocean in August of 0.35 ˚C/decade (CMIP5) and 0.5 ˚C/decade (CESM-LENS).

3.6.4 Limitations

Even if SST increases, and there is further increases in the halocline temperature maximum (Timmermans et al. 2018), what will happen deeper in the water column is not certain, especially during summer when a mixed layer forms which tends to insulate the deeper water column. More is said in Section 3.10 about the mixed layer depth, which has quite a lot of spatial variability within the Arctic. There are still mechanisms for heat exchange within the water column, including diffusion of heat, mixing by storms and in the Arctic, brine rejection in winter due to sea ice formation. Globally, the world's oceans have warmed by 0.015 ˚C/decade between 1971 and 2010 at 700 m depth (Rhein et al. 2013), but to put this into perspective the rate of increase in the upper 75 m is 0.11 ˚C/decade. A plot of temperature change per decade by the deeper ocean is provided in (Figure 3-50).



SOURCE: From Rhein et al. 2013

Figure 3-50 Warming rate versus depth for the world's ocean (orange), and for the Southern Ocean (purple)

3.6.5 Summary

The limited data from within the Southern Beaufort Sea at depth has not allowed the global increase in ocean temperature at depth to be confirmed in this region. Despite the variations between models, there is however agreement that the mean summer sea surface temperature will increase through to the middle of the 21st century. The continued projected formation of sea ice in the winters during this time period will tend to prevent this same upward trend from also applying in the winters. Upward warming in the summers in sea surface temperature may vary between 0.35 ˚C/decade (CMIP5) and 0.5 ˚C/decade (CESM-LENS) (Alexander et al. 2018).

3.7 Sea ice

3.7.1 Current trends

Sea ice in the Beaufort Sea is undergoing major changes in association with climate change processes. Sea ice also exhibits a great deal of natural variability especially on seasonal and year-to-year (interannual) time scales. Characterizing the effects of climate change on sea ice involves many different aspects, including its areal extent, timing of formation and break-up, ice thickness and volume, ice motion and other attributes. These are summarized individually below.

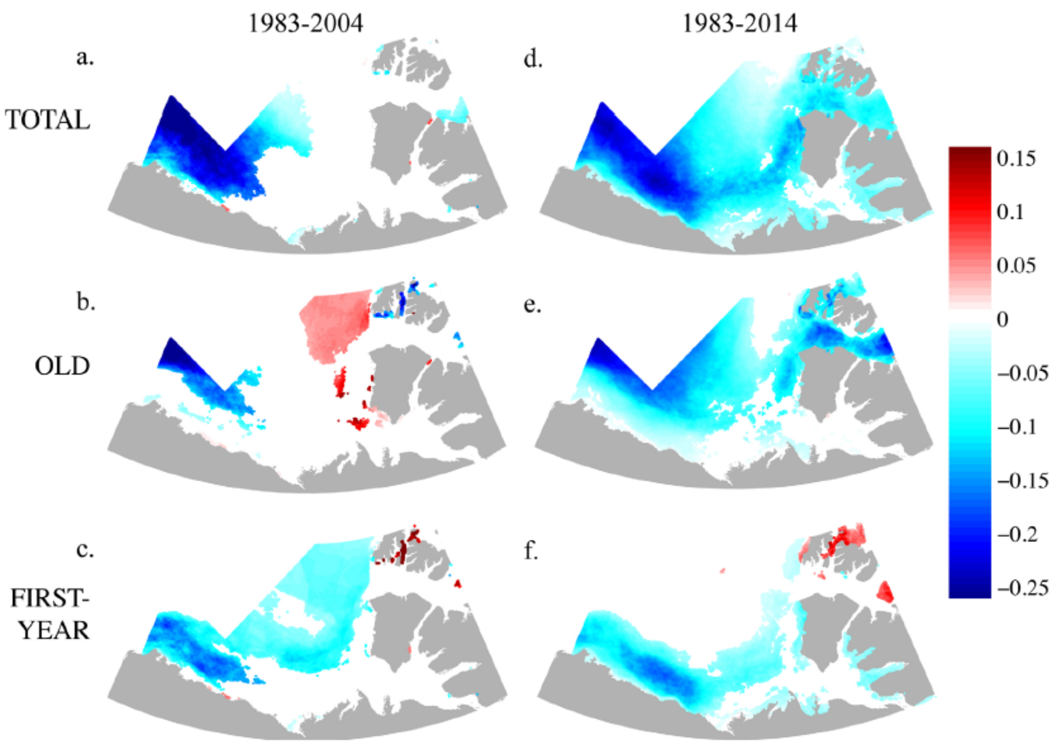
3.7.1.1 Sea Ice Thickness

The longest records of sea ice thickness anywhere in the Arctic come from measurements made in landfast ice (Polyakov et al. 2003; Brown and Cote 1992; Howell et al. 2016). Recent analyses suggest there has been a reduction in annual maximum ice thickness of around 25 cm (approximately 10%) at most locations in the Canadian Arctic Archipelago (Howell et al. 2016).

Sea ice thickness, as well as sea ice volume exhibits a trend to reductions in the deep Canada Basin waters of the Beaufort Sea (Krishfield et al. 2014). However, the trend in the shallower continental slope waters of the Canadian Beaufort Sea are much smaller as seen in the 12 years of ice draft measurements from 1991 to 2003 which suggest only a slight thinning trend (0.07 m/decade) and high variability in the seasonal pack ice zone (Melling et al. 2005).

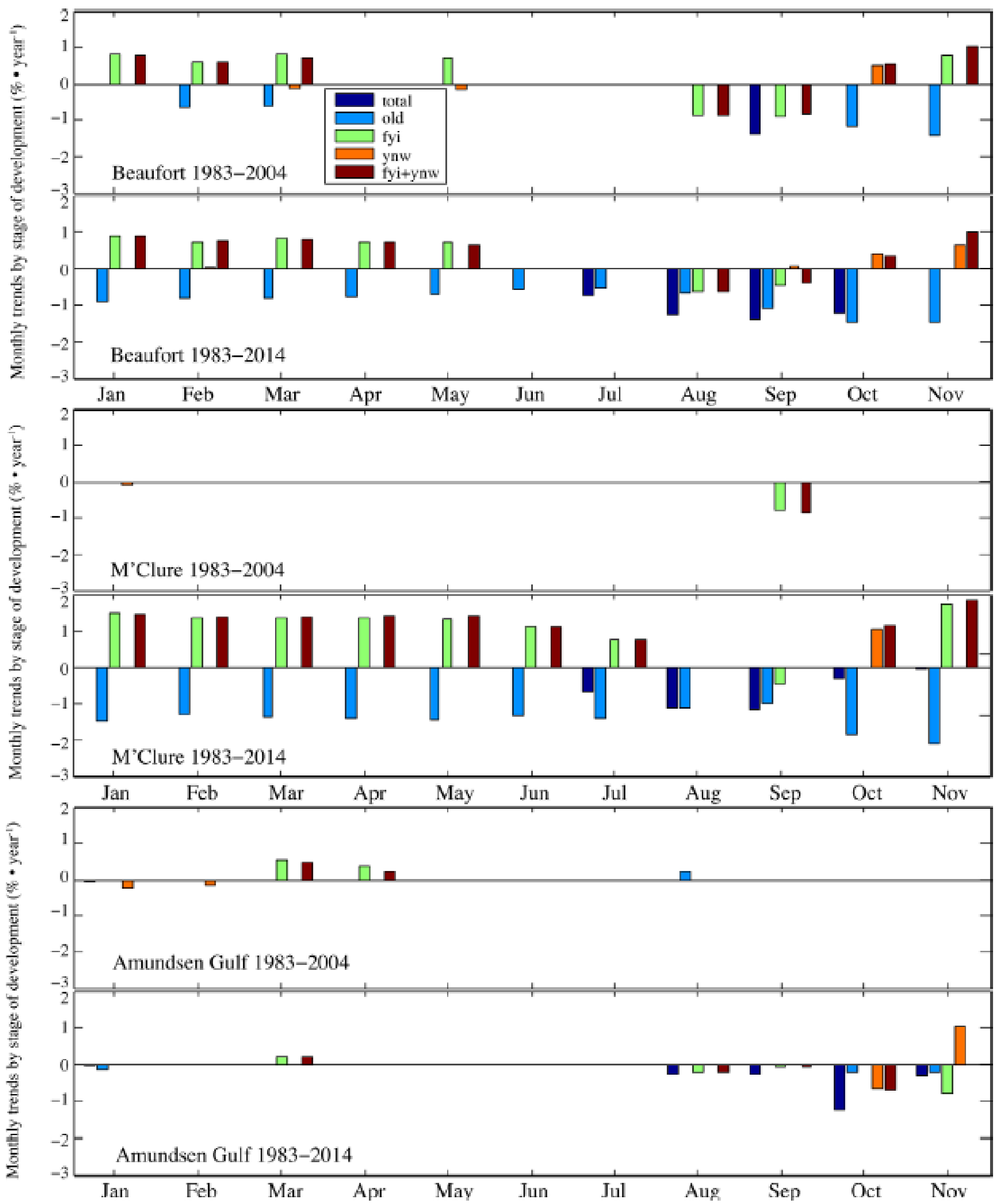
3.7.1.2 Areal Extent (Concentrations)

Statistically significant losses in total sea ice occurred from July – October between 1983 and 2014 in the southern Beaufort Sea (Galley et al. 2016). Negative trends in old sea ice also occur from July – October, with a positive first-year sea ice trend partially compensating for the loss of the old ice in July, as well as in October (Figure 3-51). The periphery of the summer sea ice pack in the study area (MacKenzie continental shelf and Banks Island) experienced large negative trends in first-year sea ice concentrations between 1983 – 2014. There are no trends in total sea ice concentration noted for January – June, or in November; however large negative trends in old ice concentration occurred monthly in M’Clure Strait between 1983 – 2014 (Figure 3-52). As a result, the old sea ice concentration is now substantially decreased year-round and is being replaced by first-year sea ice outside the July – October melt season (Galley et al. 2016).



SOURCE: from Galley et al. 2016

Figure 3-51 Trends (tenths yr -1) in mean summer (JAS) sea ice concentrations by stage of development for Left) 1983 – 2004 and right (1983 – 2014)



NOTE: Trend data are presented at the 90% significance level ($p < 0.10$)
SOURCE: From Galley et al. 2016

Figure 3-52 Trends (% yr $^{-1}$) in monthly mean sea ice concentration by stage of development in the Beaufort Sea from 1983 to 2004 and from 1983 to 2014

3.7.1.3 Timing

Breakup in this region typically begins around 15 May within the Cape Bathurst flaw lead polynya (Figure 3-53). Breakup occurs next in the Amundsen Gulf and entrance to M'Clure Strait (mid-June), followed by the nearshore landfast sea ice along the continental coast (Galley et al. 2012). Landfast sea ice in the study area begins to breakup about the same time as the periphery of mobile, old pack ice. The Cape Bathurst flaw lead polynya complex is first to reach complete breakup, typically in two weeks, indicating that breakup is controlled predominantly by sea ice dynamics (Steele et al. 2015).

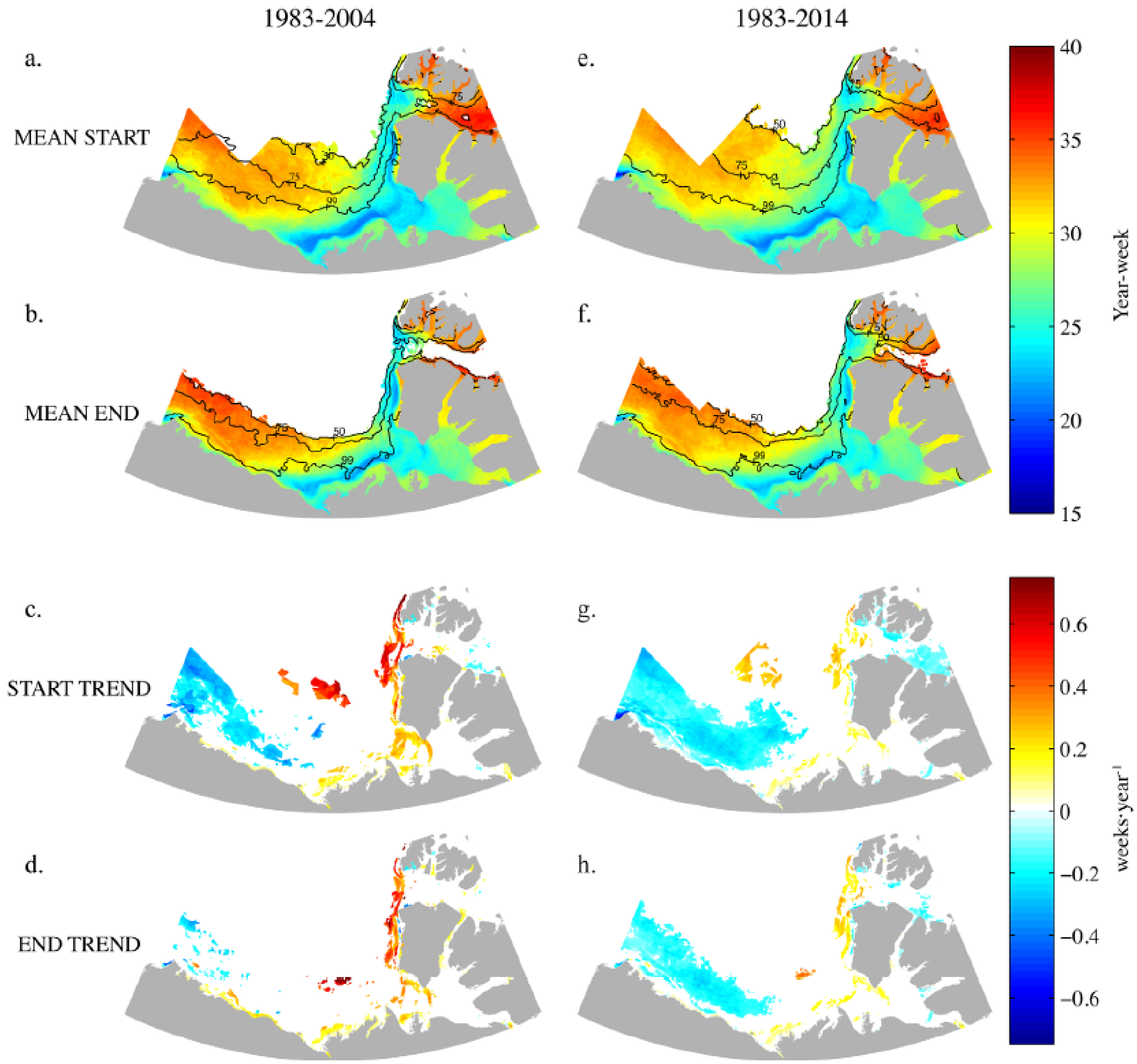
A trend towards later breakup end dates was recorded through the 32-year period across the Tuktoyaktuk Peninsula, between Cape Bathurst and Sachs Harbour, and along the west coast of Banks Island (Figure 3-53). These trends correspond with the reductions in mean old ice and increases in first-year ice concentrations. In contrast, mean breakup end timing occurred 2 weeks earlier over the same time frame in the offshore areas of the MacKenzie shelf region, and about 1 week earlier in the mouth of the Amundsen Gulf.

The end of open water (freeze up start) occurs earliest in the northern reaches of the study region, specifically in the M'Clure Strait and the northern Beaufort Sea, where the mean summer concentrations were highest and composed almost entirely of old sea ice between 1983 and 2014 (Figure 3-54).

Summer ice-free areas of the study region reached freeze up start one week later on average between 1983 and 2014 compared to 1983–2004, except along the west coast of Banks Island where the mean 1983–2014 start of freeze up occurred up to 5 weeks later than in 1983–2004 (Figure 3-54). The summer mean ice-free areas (Alaska, Mackenzie, Amundsen Mouth, Amundsen, Banks and the east side of Prince Alfred), have experienced significant ($p < 0.10$) trends toward later freeze up start date over the period 1983–2014 on the order of 1–2 weeks / decade.

The mean year-week of (a, e) freeze up start and (b, f) freeze-up end for the 1983–2004 and 1983–2014 time series. Trends in the year-week of (c, g) freeze up start and (d, h) freeze up end through the two time-series. Data shown for each grid cell where freeze up occurred at least 50% of the years in the time series interrogated. Percent occurrence contours for the start and end of freeze up (50%, 75% and 99% from north to south) are overlaid on the mean maps. Trend data only presented at 90% significance level ($p < 0.10$). (From Galley et al. 2016.)

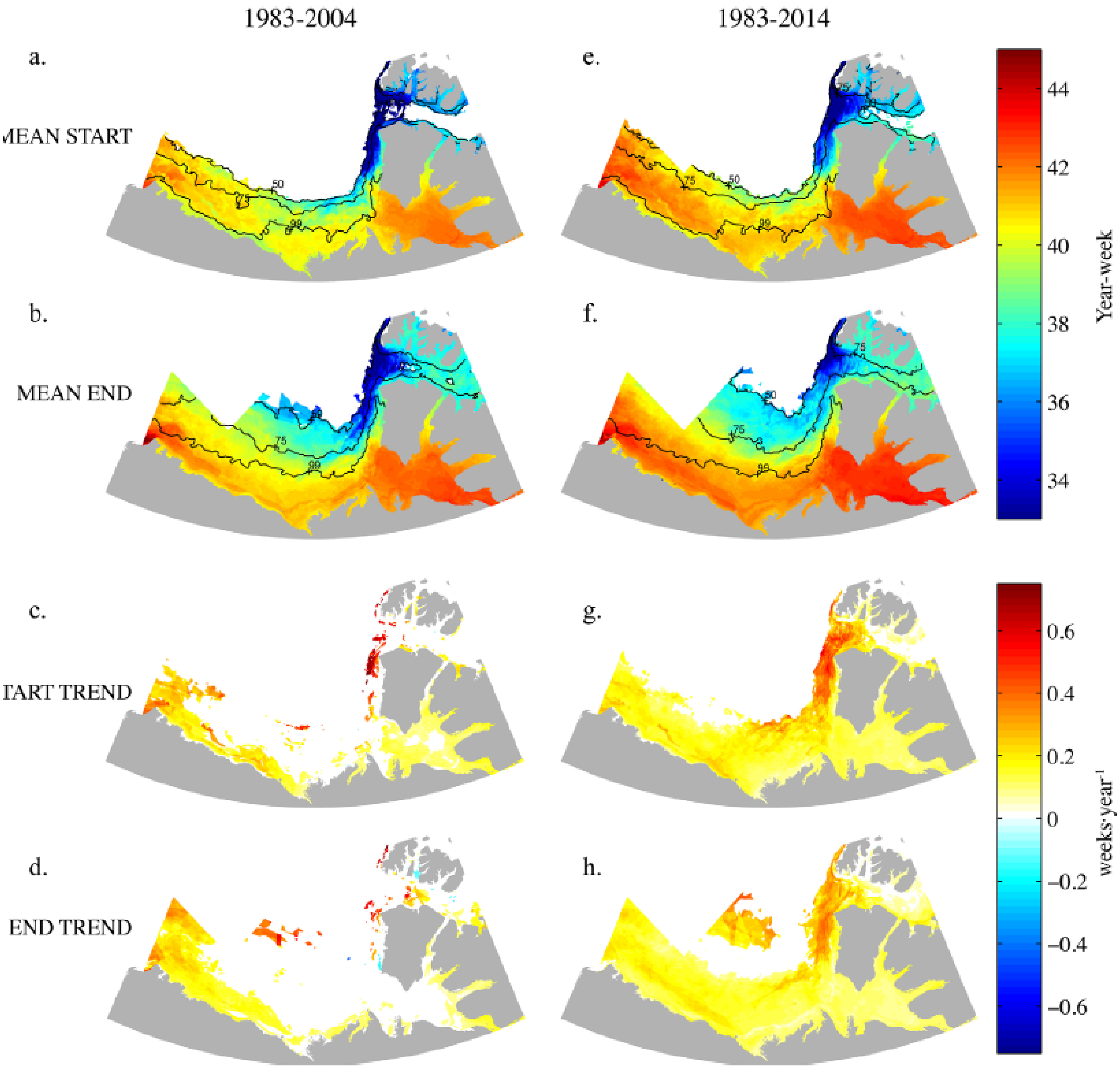
As a result of changes in freeze-up and break-up dates, linear trends are identified in the open water season duration by Galley et al. 2016 (Figure 3-55). The addition of 2005 – 2014 to the analysis extends the open water season in the study region up to 3 weeks / decade for the period of 1983 – 2014. The mean duration and trends in open water season are directly linked to the trends identified in freeze-up in the previous section.



NOTES: Data shown for each grid cell where breakup occurred at least 50% of the years in the time series. Percent occurrence contours (50%, 75% and 95%) from north to south are overlaid on the mean maps. Trend data is presented at the 90% significance level (p<0.10)

SOURCE: From Galley et al. 2016

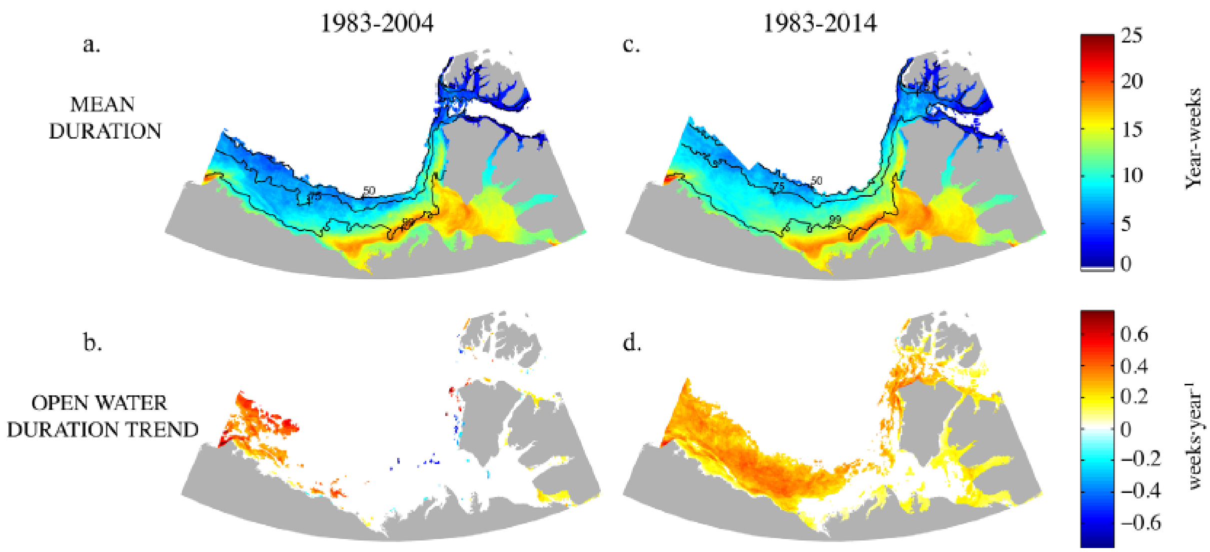
Figure 3-53 The mean year-week of (a,e) breakup start and (b,f) breakup end for the 1983-2004 and 1983-2014 time series. Trends in the year-week of breakup (c, g) start and (d,h) end through the two-time series.



NOTES: Data shown for each grid cell where freeze up occurred at least 50% of the years in the time series interrogated. Percent occurrence contours for the start and end of freeze up (50%, 75% and 99% from north to south) are overlaid on the mean maps. Trend data only presented at 90% significance level ($p < 0.10$)

SOURCE: From Galley et al. 2016

Figure 3-54 The mean year-week of (a, e) freeze up start and (b, f) freeze-up end for the 1983–2004 and 1983–2014 time series. Trends in the year-week of (c, g) freeze up start and (d, h) freeze up end through the two-time series.



NOTES: Percent occurrence contours (50%, 75%, and 99% from north to south) are overlaid on the mean duration maps. Trend data only presented at 90% significance level ($p < 0.10$).

SOURCE: From Galley et al. 2016

Figure 3-55 (a, c) Mean open water mean duration and (b, d) trends in the duration of open water between 1983 and 2004 (left column) and 1983–2014 (right column)

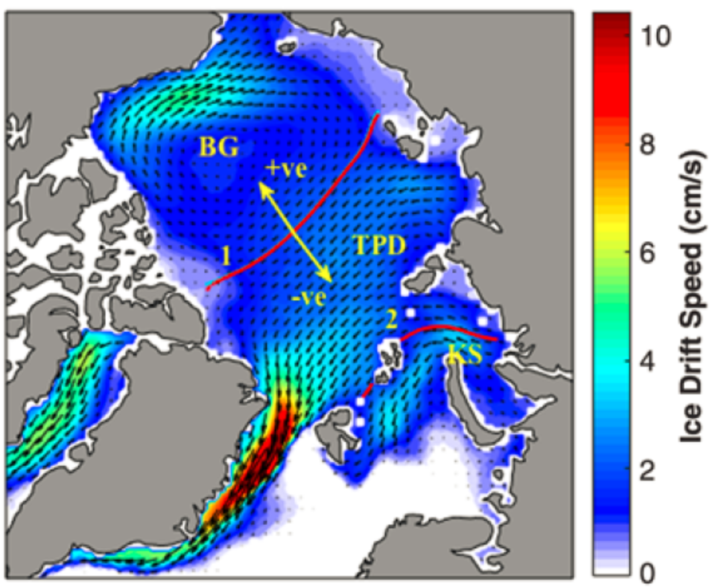
3.7.1.4 Sea Ice Motion

The motion of sea ice is primarily a response to wind forcing associated with large scale atmospheric circulation patterns. However, other physical factors can play an important role including ocean current forcing and changes in the material properties of sea ice such as contact of the sea ice keels with the seabed in shallow water areas which results in no ice motion (termed landfast ice) and ice strength, associated with internal ice stress, which inhibits ice motion in areas where sea ice is very highly concentrated. The presence of leads in the sea ice can also result in increased ice motion (Lewis and Hutchings 2019). Over the full Arctic Ocean, sea ice motion and deformation rates, has been generally increasing over recent decades (Rampal et al. 2009).

The overall sea ice drift pattern in the Beaufort Sea, exhibited on time scales of months and years is characterized by the Beaufort Gyre, which is centred on the deeper waters of the Canada Basin which involves transport between the coastal areas of Canada, Alaska and the Siberian Arctic across the Canada Basin and central Arctic to regions north of the Canadian Archipelago and returning to the coastal areas (Lewis and Hutchings 2019). The Beaufort Gyre ice motion is related to the Beaufort High anticyclonic atmospheric high-pressure system, which varies both seasonally (largest in spring) and over interannual time scales.

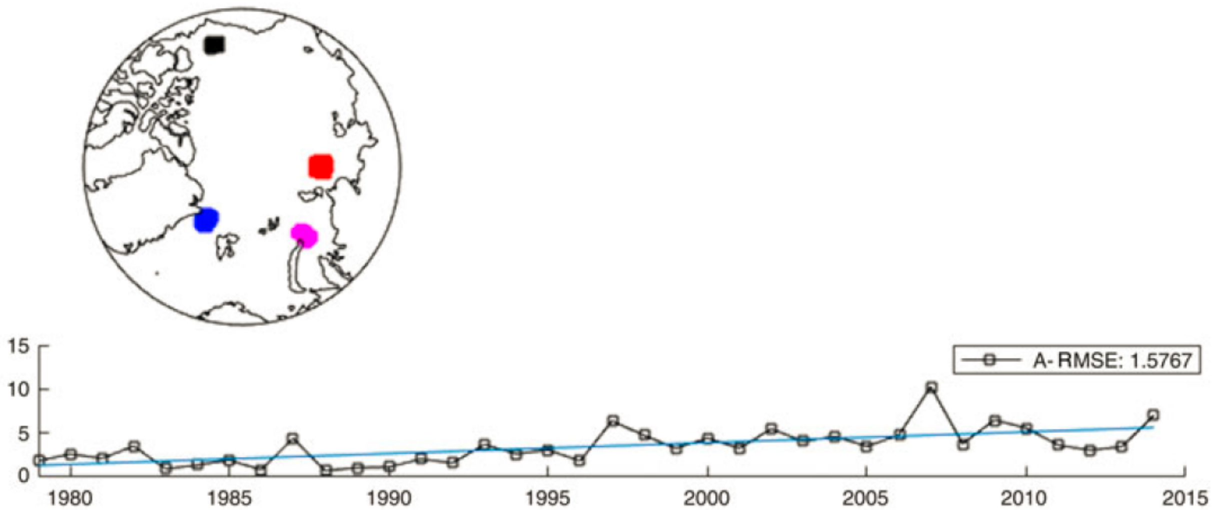
The southern Beaufort Sea has the largest sea ice velocities (Kaur et al. 2019; Lewis and Hutchings 2019; Kwok et al. 2013; Petty et al. 2016) in the western Arctic Ocean (Figure 3-56). Kwok et al. (2013) reported a trend towards strengthening of the Beaufort Gyre ice drifts over the years 1982-2009, in both winter and more prominently in summer. The multiplier that relates ice drift to wind speed exhibits an increase in the Beaufort Gyre which is attributed to reduced ice strength in this area related to thinning and less concentrated sea ice cover (Figure 3-56). The trend towards increasing winter sea ice drift speeds in the Canadian Beaufort Sea portion of the Beaufort Gyre is clearly seen in Figure 3-57 with speeds increasing from about 2 cm/s in the early 1980's to about 5 cm/s in the middle of the present decade.

Petty et al. (2016) found positive trends in the anticyclonic ice motion for the years 1980-2013 with the largest increases occurring in autumn, causing an increasing export of ice out of the southern Beaufort Sea (Figure 3-58). Changes in wind forcing may contribute to this trend but the winds increase only in the summer months and not in the fall or winter (Petty et al. 2016). The largest increase in ice motion, which occurs in autumn, appears to be related to reductions in ice strength, associated with lower ice concentrations and thinning of the sea ice, rather than due to any significant increases in wind forcing for autumn.



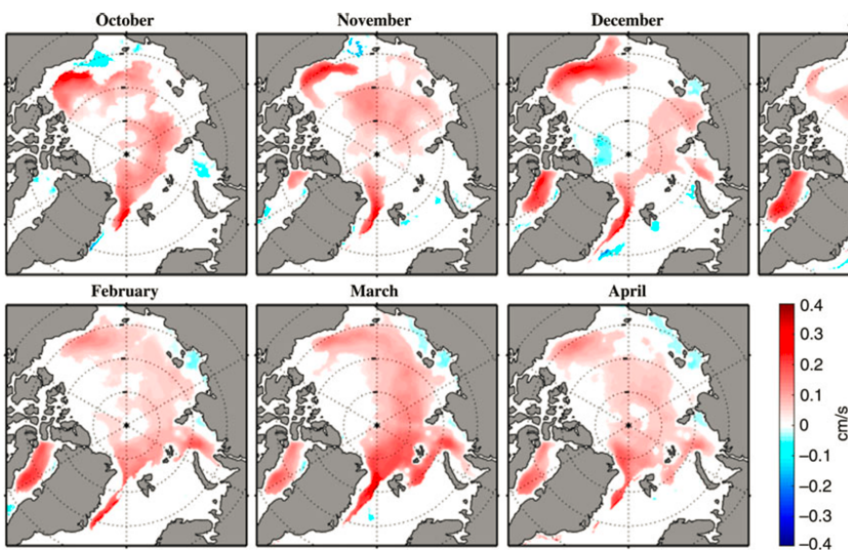
SOURCE: Kaur et al. 2019

Figure 3-56 Mean Arctic sea-ice drift patterns of the 36 winter seasons overlaid over the mean winter sea ice drift speed (cm/s) from October 1979 to April 2015



SOURCE: Kaur et al. 2019

Figure 3-57 Winter mean ice drift speed derived from passive microwave ice velocities in the Canadian Beaufort Sea (black region in map above figure) from 1979-2015



NOTE: The trends shown are statistically significant, with $P < 0.05$.
SOURCE: Kaur et al. 2019

Figure 3-58 Statistically significant trends in the sea-ice drift speed anomalies for each month for winters 1979–2015

3.7.1.5 Landfast Ice

In landlocked areas, breakup is a predominantly thermodynamic process (Melling 2002) and typically follows a consistent break-up period each year throughout the Canadian Arctic Archipelago (Galley et al. 2012). Landfast ice on open coastlines that is not heavily grounded have a higher variability in break-up dates, correlating with the cumulative amount of solar energy reaching the Earth's surface (Petrich et al. 2012). The breakup of firmly anchored Landfast ice cover along areas may be initiated by the occurrence of strong winds and currents or changes in local sea level (Divine et al. 2004; Mahoney et al. 2007; Jones et al. 2016). The break-up of landfast ice near rivers can be triggered by spring discharge (Bareiss et al. 1999; Divine et al. 2003).

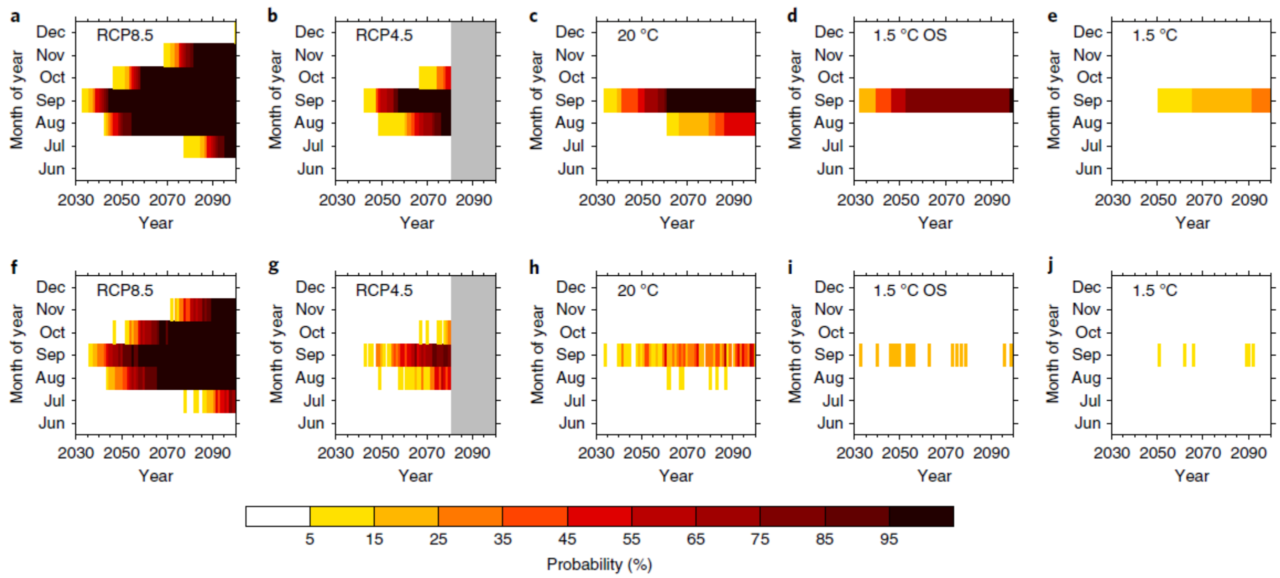
The declining seasonal average extent of Arctic landfast ice is in part caused by a later date of formation and earlier break-up, which reduces the total amount of ice growth. Over the period 1976-2007, U.S. National Ice Center (NIC) ice charts indicate that the duration of landfast ice is decreasing by approximately 0.8 d/yr on average across the Northern Hemisphere. Canadian Ice Service charts show a declining trend for landfast ice duration of almost 3 d/yr in the Alaska Beaufort Sea and Mackenzie Delta area (Galley et al. 2012). A comparison between results from studies covering the periods 1973-77 (Barry et al. 1979) and 1996-2008 shows a shortening of the landfast season of approximately 53 days (~2 d/yr) in the western Beaufort Sea and 38 days (~1.4 d/yr) in the Chukchi Sea (Mahoney et al. 2014).

Weekly ice NIC charts indicate that overall landfast ice extent in the Arctic decreased by approximately 12,300 km^2 yr^{-1} (0.7% yr^{-1}) between 1976 and 2007 (Yu et al. 2013), however the maximum extent of landfast ice in the Beaufort Sea changed little during this time. It should be noted that the NIC results represent changes in the seasonal average extent from January to May, rather than the full maximum extent at the end of the growth season.

3.7.2 Predictions

Projections for sea ice extent under the RCP8.5 scenario indicate that there is a high probability of ice-free conditions (defined here as a sea ice extent of 1 million km^2 or less) occurring within the 2020 – 2050 timeframe in the Canadian Beaufort Sea. Jahn (2018) estimates the timings of the first possible ice-free Arctic using the CESM1 model, and finds that A CESM mean global temperature increase of 1.9°C is identified for ice-free conditions in September to occur for the first time. This result is strongly affected by internal variability, evidenced by one 1.5°C warming scenario reaching ice-free conditions before the final RCP8.5 simulation does (2050 and 2053 respectively). Hence, the probability of an early ice-free Arctic increases the stronger the forcing is, as the mean sea ice extent will reduce faster to the 1 million km^2 threshold.

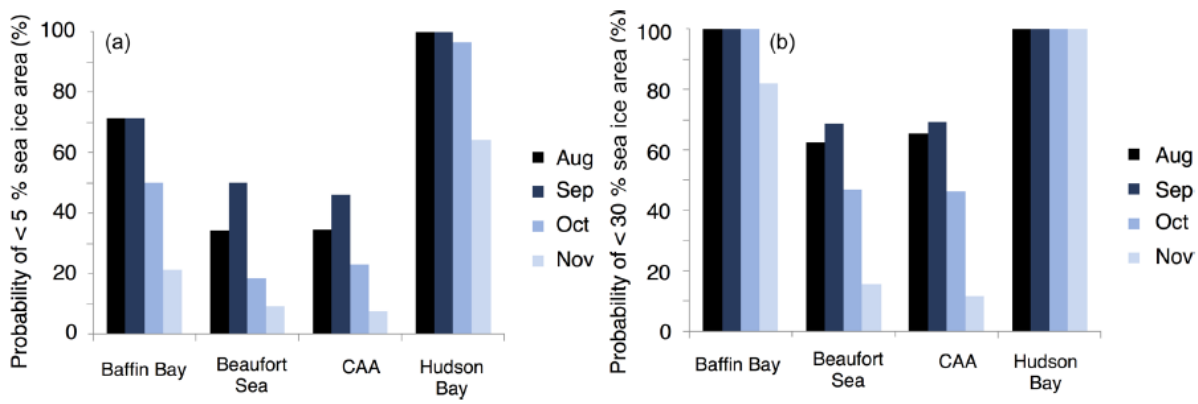
Under the RCP8.5 scenario (Figure 3-59), the ice-free season in the Arctic could extend from July to November in some years, with a 100% probability of ice-free conditions from August to November by the final decade of the twenty-first century (Jahn 2018).



NOTE: The areas shaded grey indicate no data, due to the end of the RCP 4.5 simulations in 2080
SOURCE: Jahn 2018

Figure 3-59 Probability of ice-free conditions in a given month (a – e), and how long the ice-free season could potentially be in the late twenty-first century (f-j) under different forcing scenarios

Predictions are available by region for the Canadian Arctic using the CMIP5 multi-model projections under the RCP8.5 scenario. Widespread reductions in sea ice concentrations are identified for both the melt (summer) and freeze-up (autumn) seasons (Mudryk et al. 2018). This study shows that probability of future sea ice-free conditions are sensitive to the particular definition of 'ice free' (Laliberte et al. 2016) used. The probabilities of ice-free conditions occurring in a given region are considerably higher at the <30% ice area threshold than at the <5% ice area threshold. Following the 30% ice area definition, the Beaufort Sea and Canadian Arctic Archipelago may be ice free in August and September by 2050 (Figure 3-60).



SOURCE: Adapted from Mudryk et al. 2018

Figure 3-60 Probability of sea ice-free conditions by 2050 from CMIP5 multi-model mean using a 5% (a) and 30% (b) regional sea ice area threshold

3.7.3 Uncertainties

A key physical control on the uncertainty of predictions of interannual sea ice predictability is the high degree of variability that advected atmospheric temperature fluctuations have on the sea ice cover. Olonscheck et al. 2019 estimates that upwards of 75% of natural variability in Arctic sea ice extent and volume are primarily driven by atmospheric temperature anomalies, whereas the remaining 25% is controlled by other drivers such as surface albedo, clouds, water vapour, surface wind and oceanic heat transport. The chaotic and nonlinear nature of the atmospheric climate system may represent a limit on predictability on Arctic sea ice area.

Recent work by Jahn (2018) demonstrates that the probability of ice-free summers in the Arctic Ocean vary considerably for total average global warming of 1.5°C versus an increase of 2°C. Using the CESM1 model, they showed that constraining warming to 1.5°C rather than 2.0°C reduces the probability of summer ice free conditions in 2100 from 100% to 30%. For warming scenarios above 2.0°C (such as the RCP 8.5 scenario), frequent ice-free conditions can be expected, potentially for several months per year. Prediction uncertainty in their study is estimated to be as high as six decades due to the enhanced internal variability in the low warming scenarios, but is reduced to an uncertainty of only two decades when considering only the RCP8.5 simulations.

Tropical Pacific Ocean variability is a key source of uncertainty in model projections of summer sea ice extent (SSIE) projections, particularly for the 2020 – 2050 timeframe (Wettstein and Deser 2014). Higher rates of SSIE loss were found to be associated with an atmospheric Rosby wave train over the Pacific that closely resembles that found to be connected to the Interdecadal Pacific Oscillation (IPO) pattern in Screen and Deser (2019). Thus, trajectories to an ice-free Arctic are modulated by shifts in the IPO. Screen and Deser (2019) showed that modelled trajectories towards an ice-free Arctic ocean starting in the negative phase of the IPO become ice-free 7 years earlier than those started in the positive phase of the IPO. Trajectories starting in the negative phase of the IPO transition into a positive IPO phase, which is associated with strengthening of the Aleutian Low, and consequently increased poleward energy transport and faster sea ice loss. The observed IPO began to transition away from its negative phase in the past few years. If the IPO persists, this suggests an increased likelihood of accelerated sea ice loss over the coming decades, thereby leading to a potentially sea ice-free Arctic Ocean within 20-30 years.

3.7.4 Limitations

The present trend to more benign sea ice conditions, in terms of ice areal extent and thickness/volume, longer open water season and reduced duration of landfast ice, and increased ice motion, is very clear. However, the model-based prediction results are subject to uncertainties as described above. There is also a great deal of natural variability in sea ice conditions in the Beaufort Sea with good and bad ice years often masking projected trends over short-term, sub-decadal time scales. The occurrence of ice-free conditions in late summer appears to be likely in 30 years from the present, although the presence of sea ice through late summer can still be expected in some years due to natural variability in the time frame of 30 plus years from now. The non-model derived results for the longer open water season, reduced duration of landfast ice and increased sea ice motion are more uncertain and also subject to the large levels of natural variability in the sea ice environment.

3.7.5 Summary

The Arctic sea ice cover appears to have transitioned from a multi-year sea ice regime to a predominantly first-year sea ice regime. This is evident in the Southern Beaufort Sea where total sea ice extents are declining following significant trends for July – October in the Southern Beaufort Sea between 1983 – 2014 (Galley et al. 2016). The concentrations of old sea ice in the Southern Beaufort Sea and Amundsen Gulf are decreasing, and being replaced by higher concentrations of thinner, first-year ice. Significant trends are identified in the timing of sea ice breakup, freeze-up and open water duration in the Southern Beaufort Sea and Amundsen Gulf, suggesting that the freeze-up season is occurring ~2 weeks later, with a concomitant increase in the length of the open water season (Table 3-24).

Table 3-24 Trends in timing of sea ice breakup, freeze up, and open water duration from Galley et al. 2016 ($p < 0.10$) in weeks yr -1 for the 1983 - 2014 study period as follows:

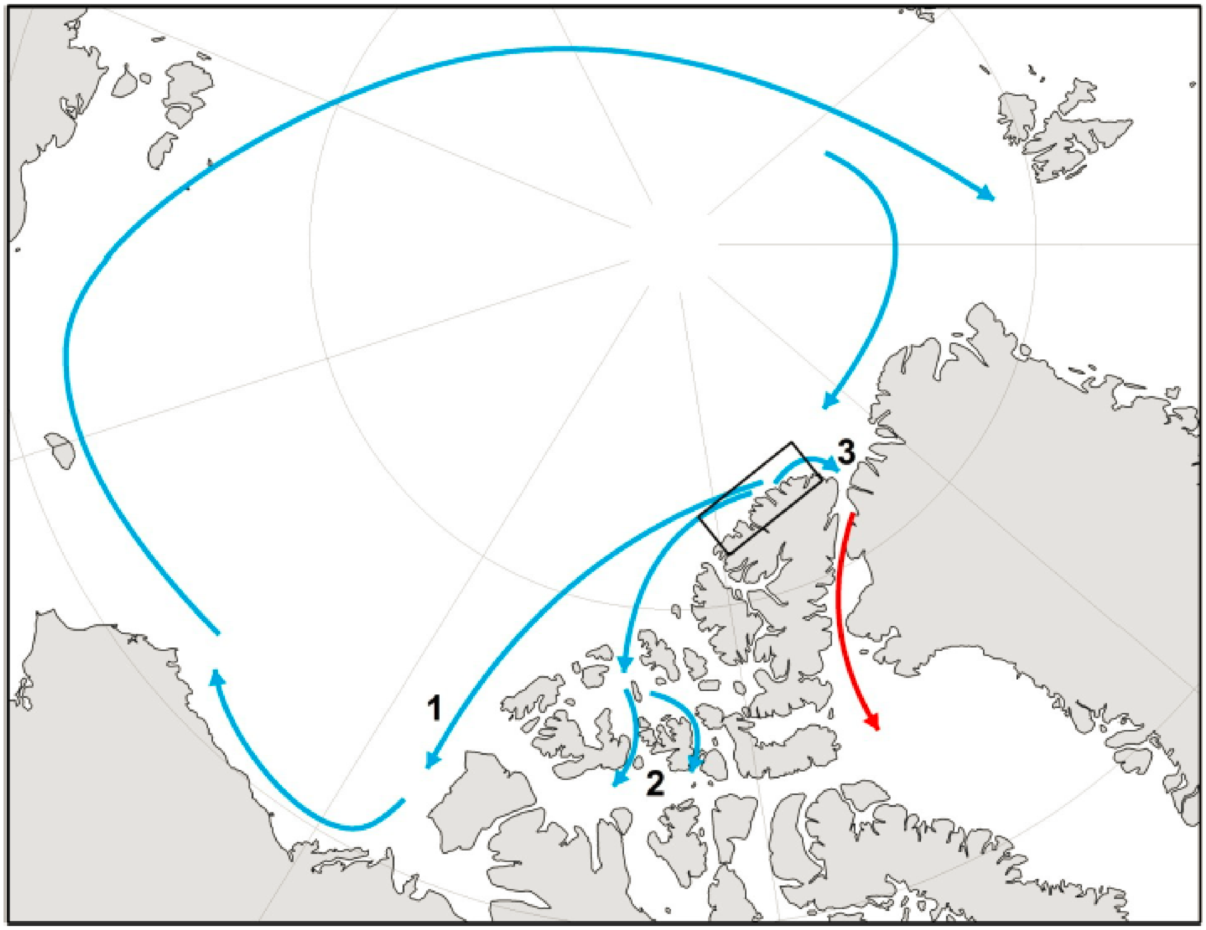
	Mackenzie	Banks	Amundsen Mouth	Amundsen
Breakup Start	No Sig. Trend	No Sig. Trend	+0.20	No Sig. Trend
Breakup End	No Sig. Trend	No Sig. Trend	No Sig. Trend	No Sig. Trend
Freeze up Start	+0.15	+0.25	+0.15	+0.12
Freeze up End	+0.13	+0.18	+0.18	+0.12
Open water duration	+0.15	+0.20	No Sig. Trend	+0.18

Sea ice motion and deformation rates (lead formation, ridging, rafting etc.) have been increasing over recent decades (Rampal et al. 2009), with some of the highest velocities reported in the Southern Beaufort Sea (Kaur et al. 2019; Lewis and Hutchings 2019). Strengthening of the Beaufort Gyre ice drifts has also increased the export of sea ice out of the southern Beaufort Sea (Kwok et al. 2013), typically along westward trajectories. Increased sea ice motion may be contributing to the declining seasonal average extent of Arctic Landfast ice, resulting from later date of formation and earlier breakup. The duration of landfast ice in the Mackenzie Delta area is declining by ~2-3 d / yr (Galley et al. 2012; Mahoney et al. 2014).

Projections for sea ice extent under the RCP8.5 scenario reveal a high probability of ice-free conditions (<30% sea ice coverage) occurring in the southern Beaufort Sea towards the end of the 2020 – 2050 time frame, with probabilities > 60% in August and September, ~ 50% in October, and ~20% in November. Up to 75% of natural variability in sea ice trends are driven by annual atmospheric variability (Olonscheck et al. 2019), and large-scale atmosphere-ocean teleconnections linked to tropical ocean anomalies (e.g., Screen and Deser 2019). Prediction uncertainty for these predictions is estimated at approximately 2 decades (e.g., Jahn 2018).

3.8 Glacial ice

Marine glacial ice forms on land through long-term processes of freshwater ice accretion in cold climates. For glacial ice shelves in the form of tidewater glacier and ice sheets, very large ice pieces break off to form icebergs or ice islands. Icebergs are generally very thick with ice drafts of tens of meters to 100 m or more (Stantec 2013). Ice islands are sheets of level glacial ice that can be several tens of meters thick with very large horizontal dimensions of 1 to 30 plus km. Once launched, these glacial ice features pose formidable hazards to marine operations until they break up and melt. Ice islands can form off northern Greenland and the northernmost Arctic Islands (Ellesmere and Axel Heiberg islands) and drift south-westward through offshore portions of the Canadian Beaufort Sea (Figure 3-61).



NOTES: Generalized drift tracks from these ice islands are indicated in blue. The most common historically has been a clockwise circulation in the Beaufort Gyre (1). However, it is also possible for drift through the Canadian Arctic Archipelago (2) to occur when sea ice cover is light. Ice islands rarely travel south via Kennedy Channel (3). Other ice islands are produced by the calving floating glacier tongues of northwestern Greenland, such as Petermann Glacier. These ice islands drift south along the coast of Baffin Island (red arrow)

SOURCE : from Mueller et al. 2013

Figure 3-61 Map of the Arctic Ocean showing the region where thick ice shelves are found along the northern coast of Ellesmere Island (black rectangle)

3.8.1 Current trends

There is a trend dating back to the early 20th century (Mueller et al. 2017), including more extensive observations available since the late 1990's, towards increased volumes of glacial ice being lost from the glaciers of northern Ellesmere Island, estimated at 38 Gigatons per year (GT/yr) from 2003-2013 (Harig and Simons 2016). This loss of glacial ice mass results in an increase in the frequency and volume of occurrences of marine glacial ice entering the Arctic Ocean (Copland et al. 2007). Mueller et al. (2013) report a loss of 552 km^2 of ice shelf extent from northern Ellesmere Island, especially in the years 2002 and 2008, and which have continued through to the present. Ice mass losses in Greenland and the Canadian Archipelago continue to accelerate over time (Harig and Simons 2016). The trend toward the increasing production of marine glacial ice reflects the present trend on Northern Ellesmere Island glaciers from 1999 to 2015 towards reductions in marine-terminating glaciers with floating ice tongues having been reduced in area by 4.9%, and 19 of these 27 ice tongues disintegrated, causing these glaciers to retreat away from the coastline (White and Copland 2018). When this retreat from the coastline occurs, further release of glacial ice would be through melting of the ice and then entering the ocean as freshwater rather than in the form of ice.

Moreover, the marine glacial ice features are exhibiting a trend toward higher velocities as they travel into and through the Beaufort Sea, due to the decreasing thickness and concentration of the sea ice associated with the reduced age of multi-year ice (see Sea Ice – Section 3.7; Barber et al. 2014). The increases in winter ice speeds have observed to double, from 2.5 to 5.0 cm/s in the Canadian Beaufort Sea over the past 35 years (Kaur et al. 2019).

3.8.2 Predictions

The loss in glacial ice is projected to continue through the 21st century with ongoing contributions to global sea level rise of 0.18 m (IPCC Scenario 8.5; Church et al. 2013). The increase in the production of marine glacial ice is also expected to continue to increase over future decades, although modeling approaches tied to climate change are not capable of simulating marine glacial ice fluxes. This increase will continue until the land-based ice retreats inland from the coastal areas. This contribution from individual tidewater glaciers and ice sheets will eventually end when the ice margin retreats onto bedrock above sea level where the bulk of the ice sheet resides. The increase in the velocity of the marine glacial ice features will continue to increase as discussed in Sea Ice – Section 3.7).

3.8.3 Uncertainties

The ongoing increase in production of marine glacial ice is uncertain. The ongoing warming of air temperatures which ultimately drives the loss glacial ice is certain to increase and to accelerate (Air Temperatures – Section 3.1). However, detailed understandings of the release of glacial ice into the ocean for each individual source glacier is highly uncertain, given the highly episodic nature of this process and the local processes involved in the calving of the glacial ice into floating marine feature (Bendsten et al. 2017). The timing of this retreat of glaciers away from the coastline along the Arctic

Ocean upstream of the Beaufort Sea is variable and uncertain, especially for the extensive glaciers off the northern coast of Greenland.

3.8.4 Limitations

Even with the increased frequency and volume of occurrences of marine glacial ice features in the Beaufort Sea, these features occur only rarely. Marine glacial ice is unlikely to be present at any given time for any given location in the Beaufort Sea (Barber et al. 2014). Nevertheless, when they are present, they can have a major effect on offshore oil and gas, shipping and other activities in the Beaufort Sea.

3.8.5 Summary

The frequency of occurrence and volume of marine glacial ice features in the Beaufort Sea, including ice islands and icebergs originating in the Canadian Arctic Archipelago and northern Greenland, has been increasing since the late 1990's. While the occurrence of these massive individual floating ice features is not common, they can have a major effect on offshore oil and gas, shipping and other activities in the Beaufort Sea. The potential effects of these features are also increasing due to the trend toward larger ice velocities of the sea ice in the Beaufort Sea, something that is already occurring. The time frame over which the current trend towards increased numbers and volumes of marine glacial ice features will continue is uncertain due to the ultimate retreat of glaciers away from the coastlines through the ongoing warming and melt of the glaciers and ice sheets in the decades ahead.

3.9 Waves

Ocean Waves in the Arctic Ocean, emerging with the decline in summer sea ice extent, are becoming an increasingly important characteristic over larger areas of the Arctic Ocean. Apart from the Atlantic sector, the Arctic Ocean has typically been sufficiently ice covered to limit the development of waves. However, over the past 40 years, summer sea ice extent has been declining at a rate of approximately 13% per decade, with a record minimum sea ice extent reported in 2012 of only 3.41 x 10^6 km^2 (Parkinson and Comiso 2013). This represents an emerging zone of the Arctic Ocean where a pre-existing wave climate is essentially non-existent. Furthermore, areas such as the Beaufort Sea and Amundsen Gulf are experiencing earlier breakup, delayed freeze-up and longer periods of open water (Galley et al. 2016); see also Section 3.7.

3.9.1 Current trends

A number of studies have addressed trends in wave properties in the Beaufort Sea, and wider Arctic Ocean. Swail et al. (2007) presented a 20-year (1985–2005) wave climate for the southern Beaufort Sea for estimating mean wind speeds and waves during the ice-free period of June–November. Estimates for 99th percentile winds and waves for September show values between 13 and 17 m/s for winds with lower values towards the east, and wave heights increasing from 0 to about 3.5 m parallel to the coast and up to 4.5 m close to the shelf edge. Liu et al. (2016) note positive trends in 99^{th} percentile winds (10 m above the surface) of +0.28m/s/decade.

Swail et al. (2007) estimated maximum 25-year return wind speed extremes of about 18–24 m/s with lower values towards the east and maximum individual wave height extremes ranging from 4 m close to the coast to 14 m close to the shelf edge.

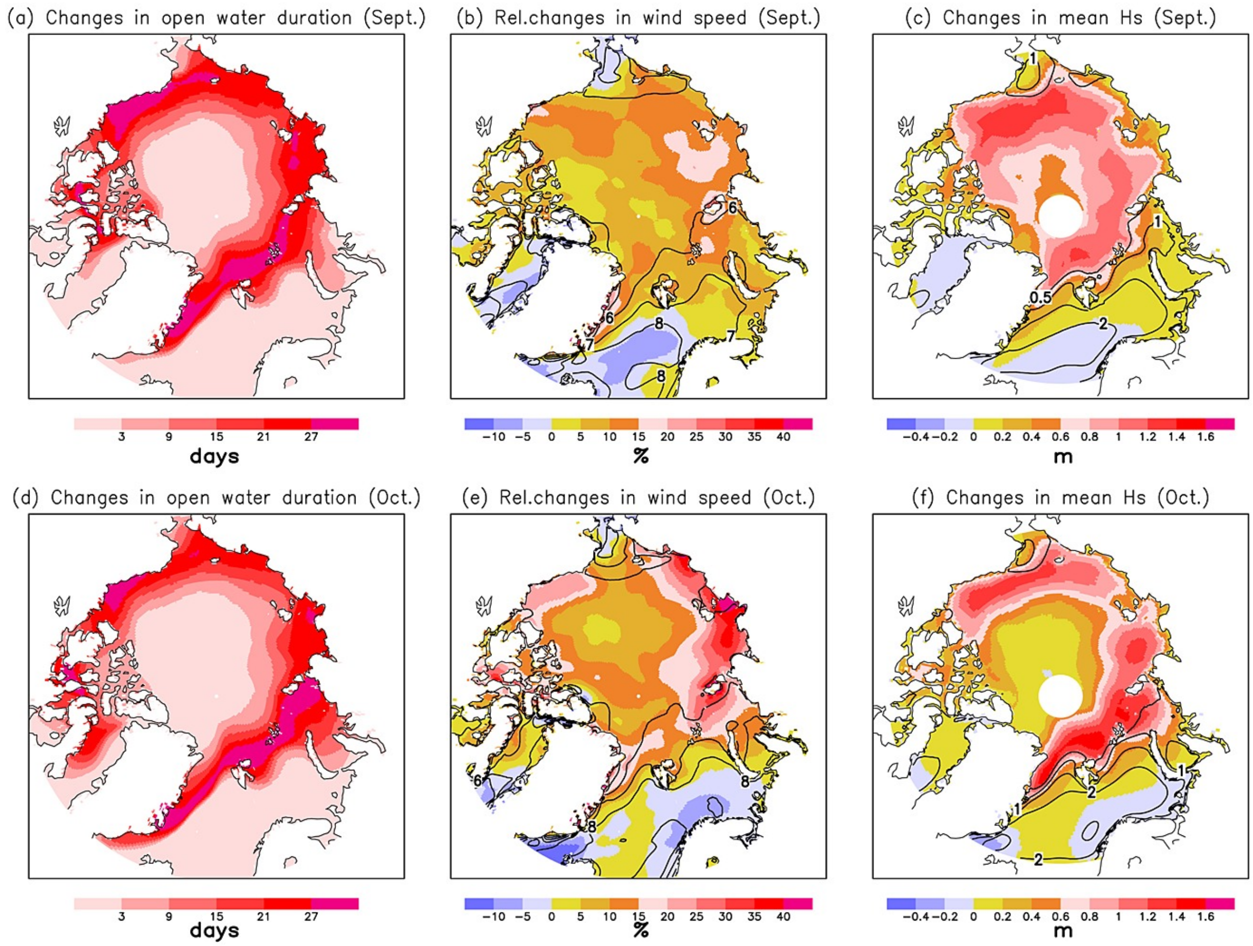
Wang et al. (2015) identified trends in waves over the 1970 – 2013 period, including some recent years of notable summer sea ice decline. Significant wave heights (H_s) have increased over the Canadian Beaufort Sea westward to the northern Chukchi Sea in September, with the Beaufort–Chukchi–Siberian Seas regional mean significant wave height increasing at a rate of 3% to 8% per decade in July – September.

Thomson et al. (2016) present wave model hindcasts from four selected years spanning recent reduced summer sea ice conditions. In particular, larger waves are found to be more common in years with a longer open water season, and peak wave periods (T_P) are longer. There is an implicit trend and evidence for increasing wave energy along the coastal areas and this signal is corroborated by satellite altimeter estimates of wave energy.

At present, waves are not fully developed during a storm under limited fetch conditions present early in the melt season, and where large volumes of ice remain present during summer months. Lintern et al. (2013), conducted a modeling exercise showing that extending the fetch as little as 100 km (thereby simulating ice retreat) led to wave heights at the coast being increased by 20 cm.

3.9.2 Predictions

Church et al. (2013) (AR5) provide projections that wave heights and the duration of the wave season will increase in the Arctic Ocean as a result of reduced sea ice extents and volumes. This is independent of changes in wind and storms and will affect rates of coastal erosion and coastal communities and exacerbate the effects of commensurate storm surges (Overeem et al. 2011; Thomson et al. 2016). Khon et al. (2014) used the third-generation wave forecast model WAVEWATCH-III (WW3) (Tolman 2009) forced by winds and SIC produced with the regional model HIRHAM (Bossing Christensen et al. 2007), under the SRES-A1B scenario (Similar to RCP6.0), to analyze possible changes to the wind–wave climate in the Arctic Ocean in the 21st century. The focus is on September when open water areas tend to be highest. The outcomes demonstrate overall growth in wave height in the Arctic, and more frequent extreme waves in different areas of the Ocean. Changes to wave climate are due to both ice retreat in summer months and a regional increase in surface winds with the role of wind change, both increases and decreases, being significant. Khon et al. (2014) indicate increases in significant wave height (H_s) around 25%–35% in the Beaufort Sea and northern CAA for 2046 – 2065, relative to 1980 – 1999 for September and October (Figure 3-62).



NOTE: Contours indicate mean climatological U_{10} and H_s for 1980–1999

SOURCE: Adapted from Khon et al. 2014

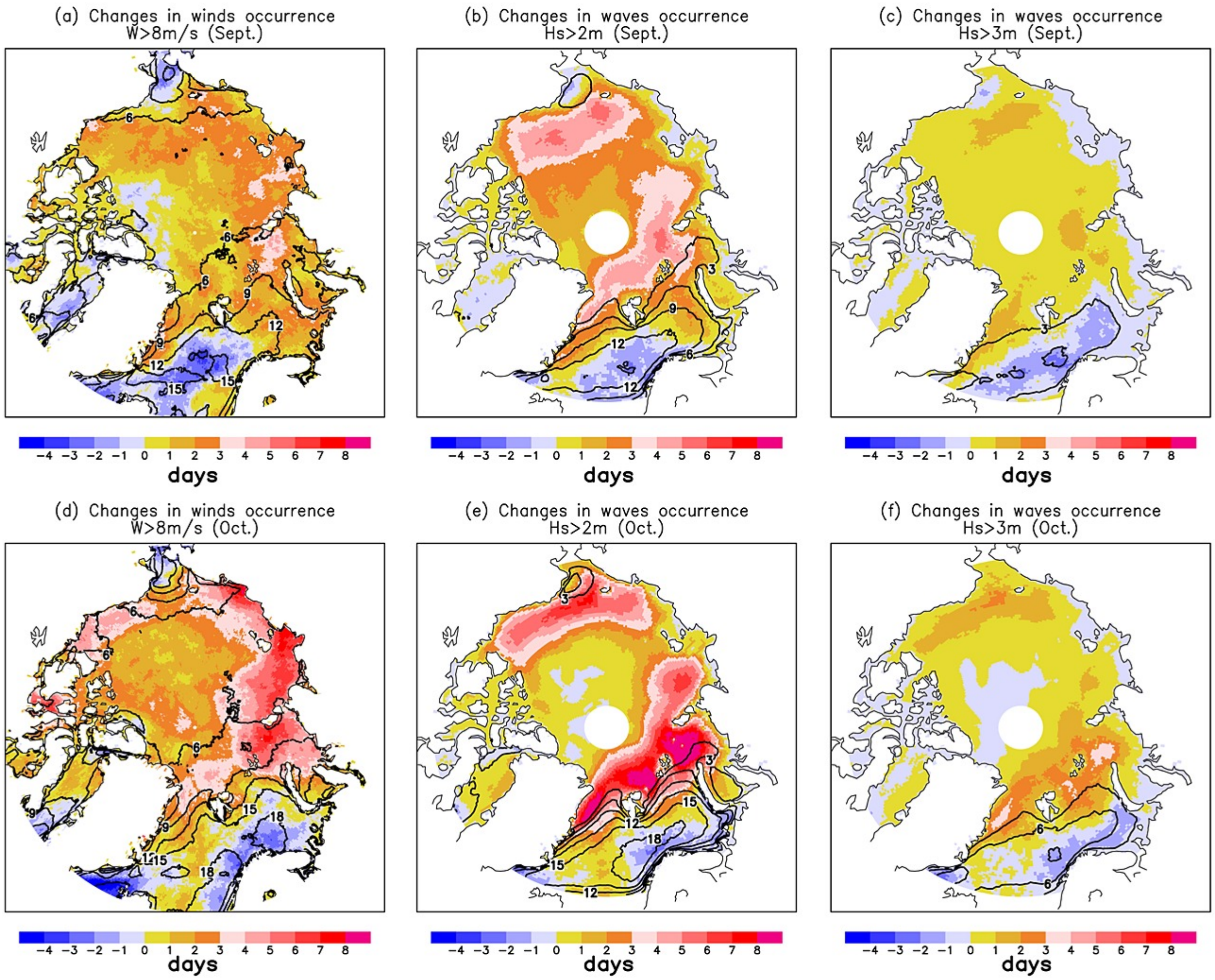
Figure 3-62 (a,d) Simulated changes in open water duration (ice concentration less than 25%), (b,e) mean wind speed at 10 m height U_{10} (normalized to mean U_{10} for reference period 1980–1999), and (c,f) significant wave height H_s for the period 2046–2065 relative to 1980–1999, for September and October

Khon et al. (2014) noted a substantial contribution of projected wind changes to the occurrence of large waves in the Beaufort Sea. The change in frequencies of days with winds >8 m/s, waves occurrence where H_s > 2m, and H_s > 3m are shown for September and October respectively in Figure 3-63.

Perrie et al. (2013) study distributions, e.g., means and 10% highest values for winds, and waves for present climate, represented as 1970–1999, and future climate, represented as 2040–2069, and the effects of climate change for the Beaufort Sea. Their simulations use Wavewatch III forced by winds from the Canadian Regional Climate Model (CRCM), for the same SRES as Khon et al. (2014). Results are similar to those in Khon et al. (2014). Changes of H_s heights in waters off the Mackenzie Delta are estimated as not exceeding 0.5 m.

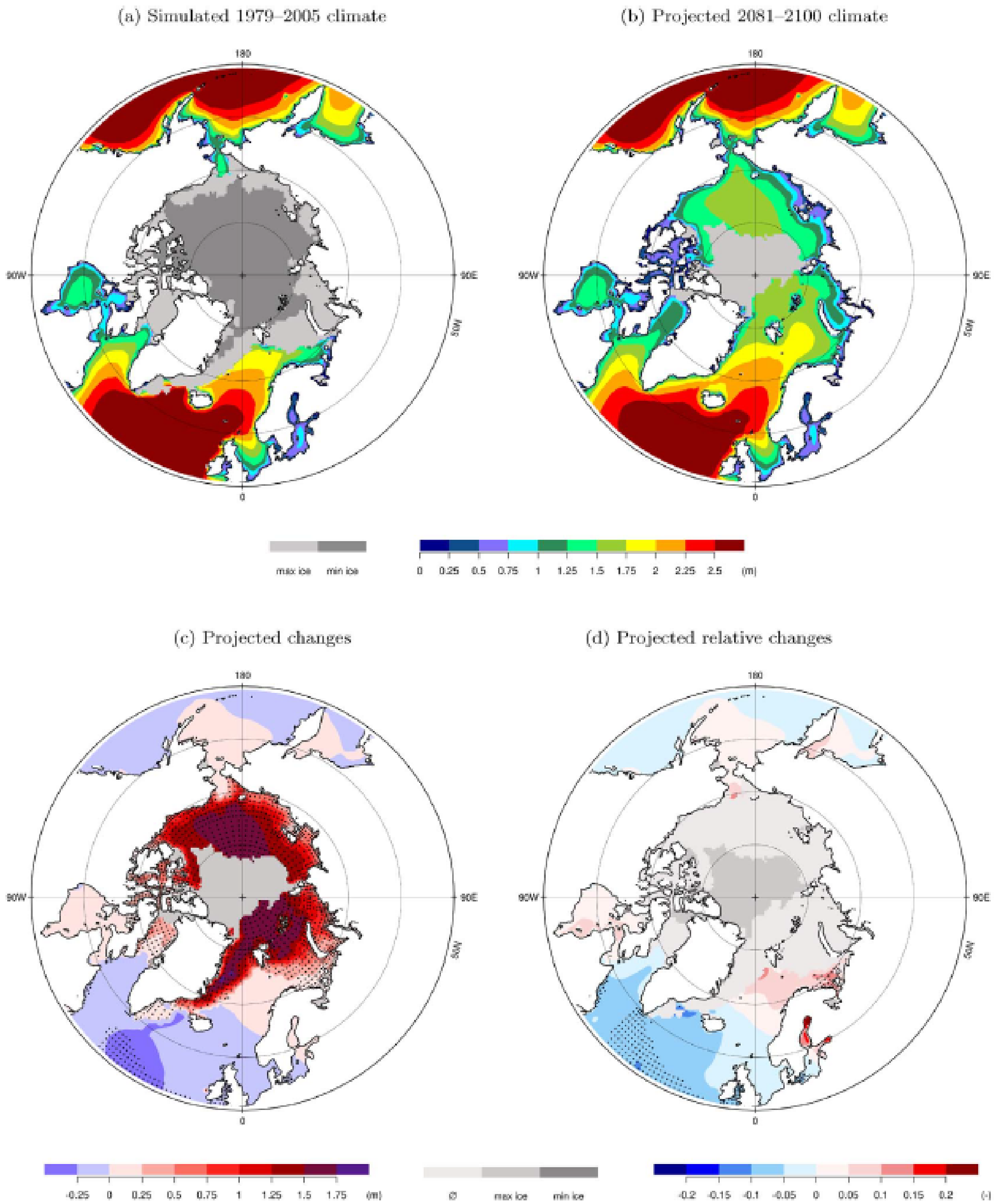
Casas-Prat et al. (2018) provides projections for an Arctic wave climatology under the RCP8.5 scenario for the 2081 – 2100 timeframe (Figure 3-64 through Figure 3-67). Projected mean September H_S in the Beaufort Sea and Amundsen Gulf are expected to range between 0.5 – 1.0 m for Amundsen Gulf, and 1.0 – 1.5m in the southern Beaufort Sea (Figure 3-64), with their maxima to range between 2.0 – 3.0 m and 2.0 – 3.5m in Amundsen Gulf and southern Beaufort Sea, respectively (Figure 3-65).

Projected mean wave periods (T_p) for September in the Beaufort Sea and Amundsen Gulf are expected to range between 4.0 – 6.0 s for Amundsen Gulf, and 6.0 – 7.0 s in the southern Beaufort Sea (Figure 3-66).



NOTE: Contours show mean values for the reference period
SOURCE: Adapted from Khon et al. 2014

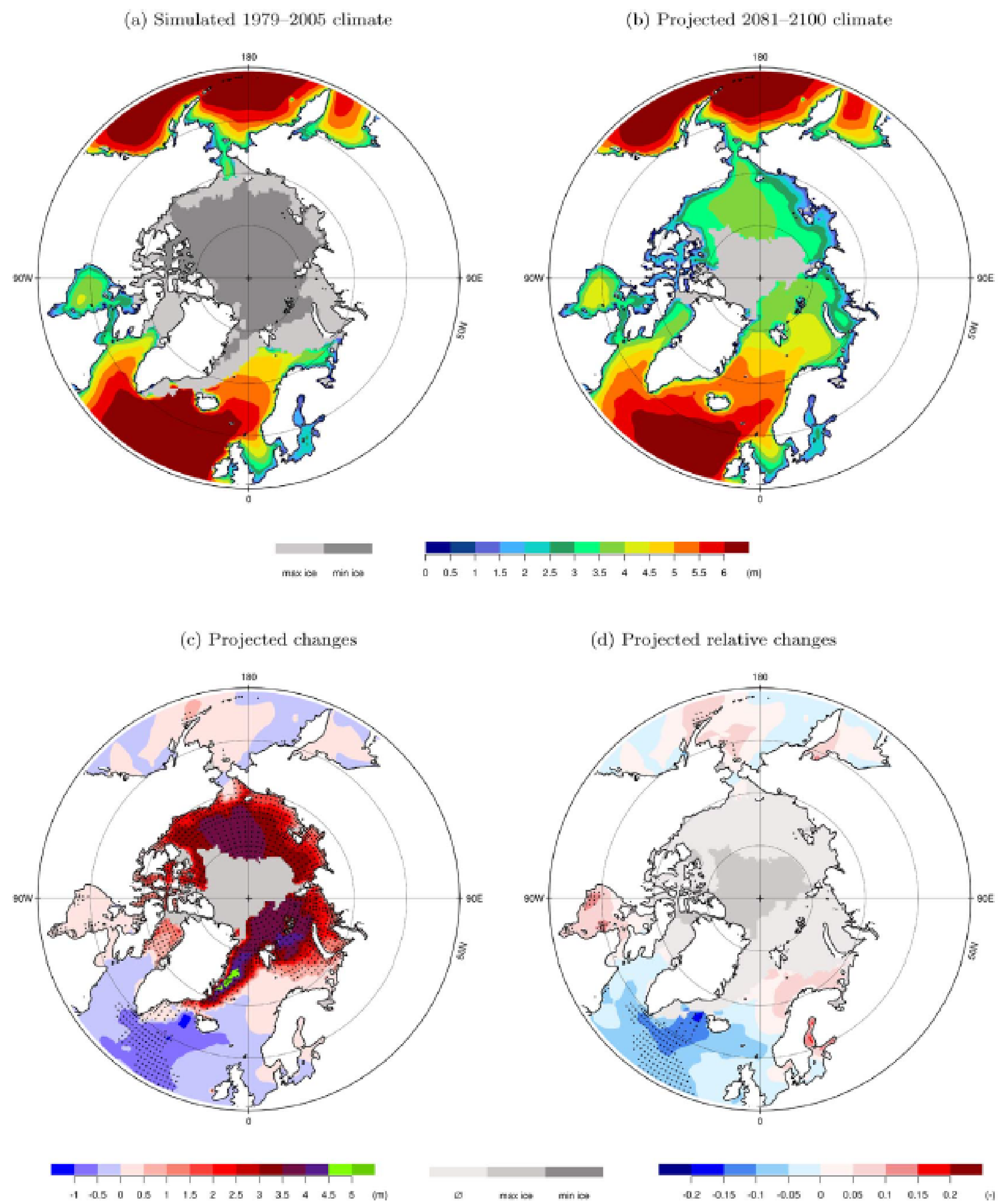
Figure 3-63 (a,d) Simulated changes in occurrence of winds exceeding 8 m/s, significant wave heights exceeding (b,e) 2 m and (c,f) 3 m for the period 2046–2065 relative to 1980–1999, for September and October



NOTE: The “min ice” indicates the areas where sea ice concentrations of above 75% was simulated by all the five models, and “max ice” by at least one model. Stippling indicates areas where projected changes are statistically significant ($p < 0.05$)

SOURCE: Adapted from Casas-Prat et al. 2018

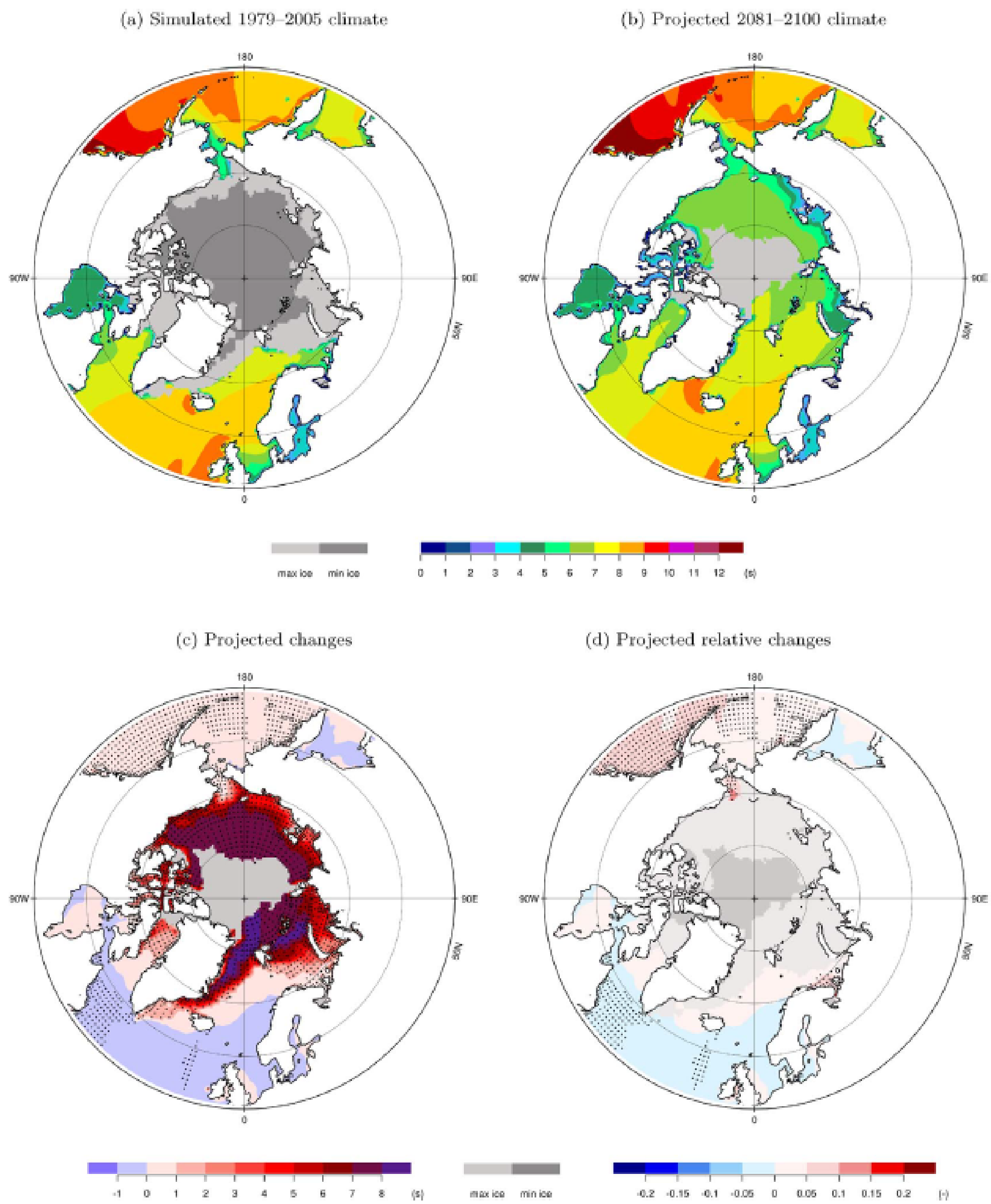
Figure 3-64 Ensemble average of the 1979 – 2005 and 1981 – 2100 climatological means of September mean H_s and of the corresponding projected changes and relative changes by 2081 – 2100



NOTE: The “min ice” indicates the areas where sea ice concentrations of above 75% was simulated by all the five models, and “max ice” by at least one model. Stippling indicates areas where projected changes are statistically significant ($p < 0.05$)

SOURCE: Adapted from Casas-Prat et al. 2018

Figure 3-65 Ensemble average of the 1979 – 2005 and 1981 – 2100 climatological means of September maximum H_s and of the corresponding projected changes and relative changes by 2081 – 2100



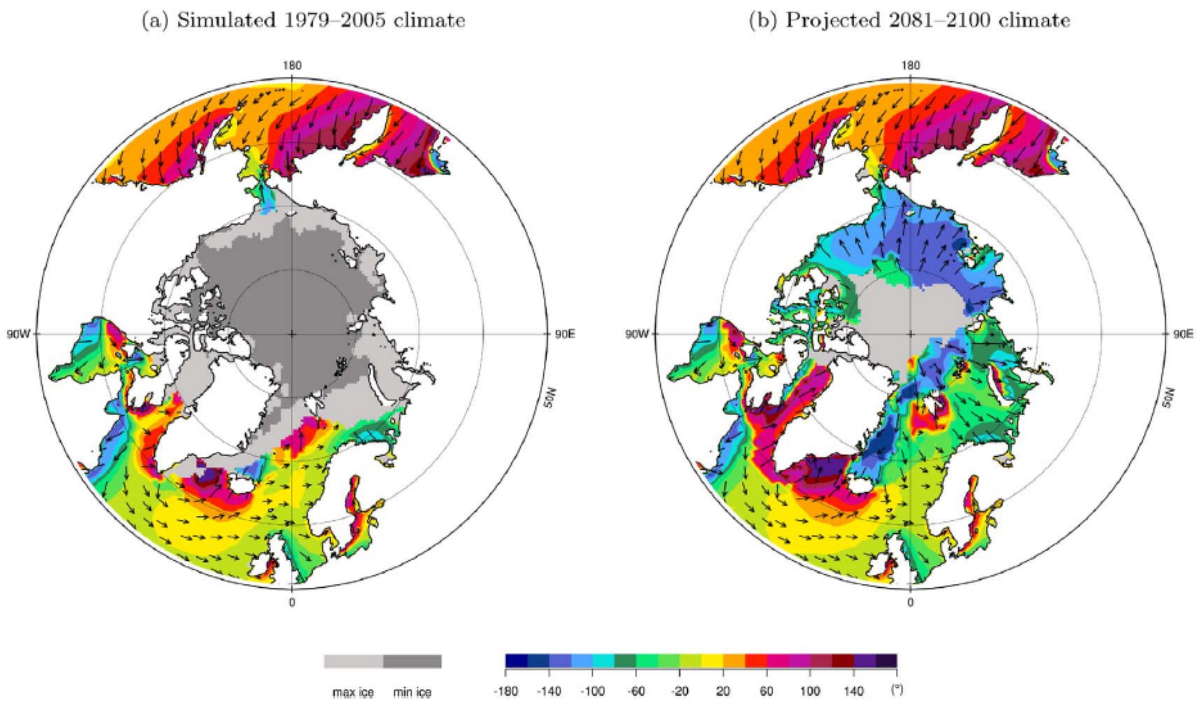
NOTE: The “min ice” indicates the areas where sea ice concentrations of above 75% was simulated by all the five models, and “max ice” by at least one model. Stippling indicates areas where projected changes are statistically significant ($p < 0.05$)

SOURCE: Adapted from Casas-Prat et al. 2018

Figure 3-66 Ensemble average of the 1979 – 2005 and 1981 – 2100 climatological means of September mean wave periods (T_p) and of the corresponding projected changes and relative changes by 2081 – 2100

Reduced sea ice cover will result in greater distances of open water for waves to travel across (fetch) and, with a southward mean wave direction for the Arctic Ocean, this will result in increased wave impacts on coastal infrastructure and communities in the Canadian Arctic (Figure 3-67).

Overall, these trends suggest that increasing wave energy could constitute a mechanism to break up remaining sea ice and accelerate ice retreat (Asplin et al. 2012; Asplin et al. 2014; Thomson and Rogers 2014; Wang et al. 2015); however, the rate of sea ice reduction could also be enhanced by wave mixing in the upper ocean, causing an added release of heat (Smith et al. 2018). The effect of large period swells (>16 s) propagating far from the ice edge into multiyear pack ice with little attenuation in the surrounding first-year ice fields was observed *in situ* in 2009 (Asplin et al. 2012), and may be occurring more frequently now and in the future with decreased summer sea ice extent.



NOTE: The “min ice” indicates the areas where sea ice concentration of above 75% was simulated by all the five models, and “max ice”, by at least one model

SOURCE: Adapted from Casas-Prat et al. 2018

Figure 3-67 Ensemble average of the 1979–2005 and 2081–2100 climatological mean of September mean θm

3.9.3 Uncertainties

Increases in wave activity and height can be expected in areas and seasons that have had ice cover in the past but will not in the future. There is high confidence that the duration of the wave season in the Canadian Arctic has increased since 1970 and will continue to do so over the 2020 – 2050 period as sea ice continues to decline as projected. Wave development will continue to be limited by sea ice impeding fetch distances, and thus, uncertainties in future sea ice extents, sea ice mobility patterns, and annual variability in break-up/freeze-up patterns, along with the chaotic nature of atmospheric dynamics will continue to introduce year-to-year uncertainty in wave climatology.

There is generally low confidence in any region-specific projections of changes in wind speeds and waves in a large part due to the uncertainty in the timing of ice retreat in the various models. Furthermore, the effects of wave–bottom interactions, triad interactions, and bottom friction processes that become important for shallow water are not well simulated in current models (e.g., Swail et al. 2007).

3.9.4 Limitations

The greatest limitation in generating projections for wave climatologies in the Arctic Ocean is that in many regions, an existing wave climatology is essentially non-existent due to the historical presence of perennial sea ice cover. Observations of the present climate are marginal, have limited spatial-temporal coverage, and cannot be extrapolated to future climates. Furthermore, wind patterns at high latitudes in the Northern Hemisphere appear to be shifting (Dobrynin et al. 2012), and the interaction of surface winds with increased fetch will continue to evolve providing a dynamic environment for wave development. The increase in wave energy may affect both the coastal zones and the remaining summer ice pack, as well as delay the autumn ice-edge advance. However, trends in the amount of wave energy impinging on the ice-edge are inconclusive, and the associated processes, especially in the autumn period of new ice formation, have yet to be well-described by in situ observations.

For a more accurate wave climate projections over the coming decades, a more detailed analysis of natural climate variability in the region is necessary (Khon et al. 2014), evidenced in part by an underestimation of ice retreat in climate models (Wang and Overland 2012). Natural cycles, such as the Atlantic Multidecadal Oscillation, may have an essential influence on relatively fast (within several decades) climate changes (Mokhov et al. 2012). An increasing number, frequency and/or intensity of storms may further enhance wave-forced sea ice retreat (Simmonds and Rudeva 2012; Zhang et al. 2013).

3.9.5 Summary

Clear trends in the annual duration of the open water season and in the extent of the seasonal sea ice minimum suggest that the sea state should be increasing, independent of changes in the wind forcing in the southern Beaufort Sea (Swail et al. 2007; Wang et al. 2015; Thomson et al. 2016). Projections under the SRES-A1B scenario (Similar to RCP6.0) by Khon et al. (2014) demonstrate an expected increase of significant wave heights (H_s) of 25%–35% in September – October in the Beaufort Sea and northern CAA for 2046 – 2065, relative to 1980 – 1999. Casas-Prat et al. (2018) provides projections for an Arctic wave climatology under the RCP8.5 scenario for the 2081 – 2100-time frame. Although beyond the scope of the time frame of this report (2020 – 2050), their results for mean and maximum H_S, T_P, and wave direction depict what we may expect of ice-free conditions in the southern Beaufort Sea in regard to wave characteristics.

There is high confidence that the duration of the wave season in the Canadian Arctic has increased since 1970 and will continue to do so over the 2020 – 2050 period. In contrast, there is low confidence in region-specific projections of wind speeds and waves due to the uncertainty in the timing of ice retreat in the various models. Improved understanding of natural variability, and increased opportunities for in situ wave studies under future low summer sea ice minimums will improve future projections of wave properties moving forward.

3.10 Water Column Structure

Information is provided on main physical and chemical water column characteristics than can derived or understand from past data and climate prediction models (see section on limitations below), including salinity, pH and alkalinity, dissolved oxygen, as well as stratification and mixed layer depth.

3.10.1 Current trends

3.10.1.1 Salinity

Salinity has been measured at about 5 m above bottom in 50 m of water at a mooring in the southern Beaufort Sea from 1999 to 2013, but no statistically significant trend has been obtained (Steiner et al. 2014).

Peralta-Ferriz and Woodgate (2015) have examined the properties of the mixed layer using hydrographic casts from 1979 to 2012. In the southern Beaufort Sea in winter (November to May) they found that salinity within the mixed layer has been decreasing at a rate of 0.04 ± 0.01 psu/yr. In the summer months (June to September), the mixed layer has been getting saltier with rates of 0.29 ± 0.05 psu/yr in the presence of sea ice, and 0.20 ± 0.02 psu/yr when ice-free. Peralta-Ferriz and Woodgate (2015) hypothesized that the salinification trend in summer is due to changes in the fate of fresh-water from the Mackenzie River. Another hypothesis may be linked to changes in the Beaufort Gyre affecting Ekman pumping and freshwater distributions within the Arctic (Proshutinsky et al. 2009).

3.10.1.2 Stratification and Mixed Layer Depth

Mixed layer depth differs by season; it is larger in winter when wind forcing and brine rejection from ice formation increase mixing. Based on hydrographic profiles from 1979 to 2012, Peralta-Ferriz and Woodgate (2015) found that during winter months (November to May), the mixed layer depth in the Southern Beaufort Sea has been decreasing by 0.20 ± 0.06 m / year. In the summer months, the mixed layer depth has been increasing at a rate of 0.33 ± 0.10 m / year in the presence of ice cover, and it has been increasing at a rate of 0.11 ± 0.03 m / year in ice-free conditions. The deepening of the mixed layer in the summers in the Southern Beaufort is attributed to reduced stratification due to the salinification of the mixed layer. Overall, Peralta-Ferriz and Woodgate (2015) note that mixed layer depths can vary over small spatial and temporal scales. They found that winter mixed layer depths tend to be deeper and more variable than summer mixed layer depths.

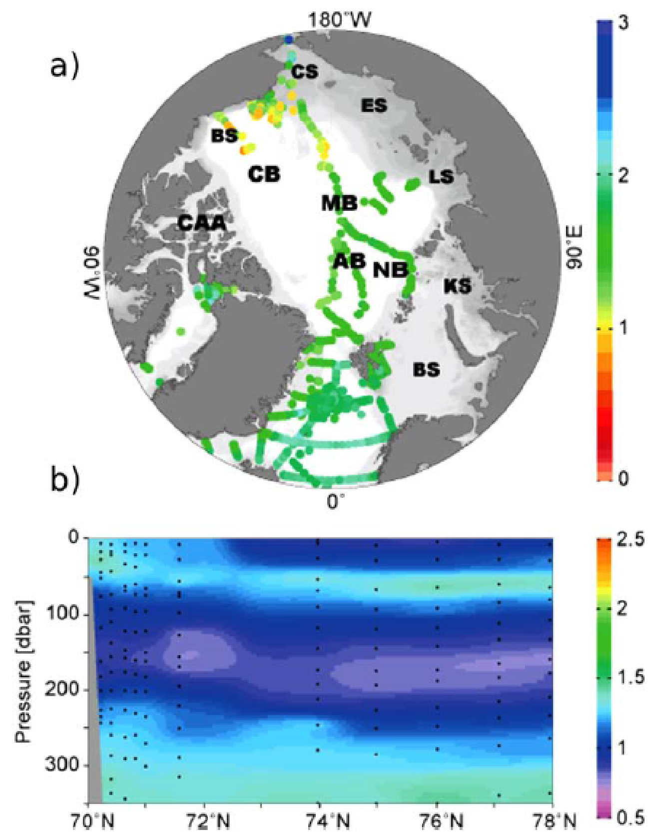
3.10.1.3 pH and Alkalinity

As human activity has increased the carbon dioxide content in the atmosphere, carbon dioxide concentrations within the surface waters of the oceans has increased. This extra carbon dioxide can form carbonic acid which can break down into its hydrogen, bicarbonate and carbonate ions. This process in-turn decreases the pH or increases the acidity. This process is called ocean acidification and also modifies the saturation state of carbonate, important for organisms to build shells ($CaCO_3$). There are several forms of carbonate, and their saturation state is quantified through a parameter known as omega (UHawaii 2019):

$$\Omega = [Ca^{2+}] \times [CO_3^{-2}] / [CaCO_3] \qquad (1)$$

Values of Ω, specifically for the aragonite form of carbonate, in excess of 4 are ideal, between 3.5 and 4 are adequate, between 3.0 and 3.5 are low, and less than 3 are extremely marginal (NOAA 2019). Aragonite has a saturation level 1.5 times that of the calcite form, making it more susceptible to undersaturation (Steiner et al. 2014). As saturation levels drop, it becomes more difficult for organisms with shells to grow and maintain their shells.

Surface saturation levels for aragonite for the 1986-2005 period indicate levels of 1-1.4 for most of the Arctic, but with some values below 1 within the Beaufort Sea (Figure 3-68; Steiner et al. 2014). Greenan et al. (2018) note that within Canada, the Arctic has the fastest rate of acidification. Processes such as increased air-sea interactions due to reduced ice cover have a role to play in this rate (Steiner et al. 2014).



SOURCE : From Steiner et al. 2014

Figure 3-68 Surface aragonite saturation levels for 1986-2005 (top). Profiles of aragonite saturation levels for August 2011 along 140 ˚W (bottom)

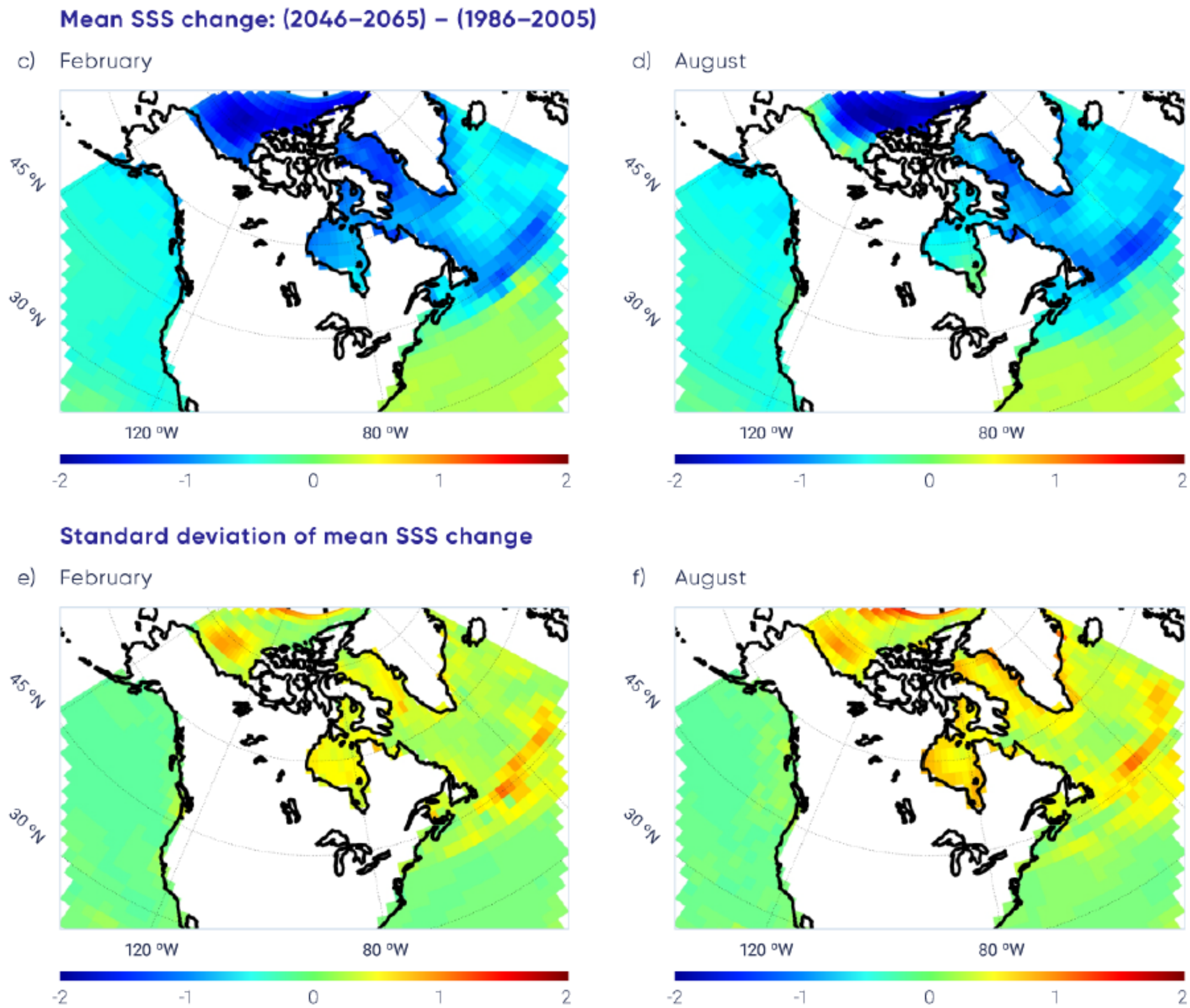
3.10.1.4 Dissolved Oxygen

With global trends of increasing surface stratification, reduced ocean ventilation and increasing temperatures have reduced the solubility of dissolved oxygen. Reduced oxygen solubility can lead to hypoxic or low oxygen content waters. On a global scale, the world’s oceans have declined in oxygen content by 2% since the 1960’s (Schmidtko et al. 2017). The loss of dissolved oxygen in the Arctic has exceeded the global mean; losses in the Arctic Ocean represent 3.1% of the global losses, but the Arctic accounts for only 1.2% of the world’s oceanic volume (Schmidtko et al. 2017).

3.10.2 Predictions

3.10.2.1 Salinity

CMIP5 mean sea surface salinity is predicted to decrease for the Arctic by up to 2 psu under RCP8.5 forcing by 2045-2065 (Figure 3-69). This freshening is expected to be driven by the melting of sea ice and increased precipitation (Greenan et al. 2018).

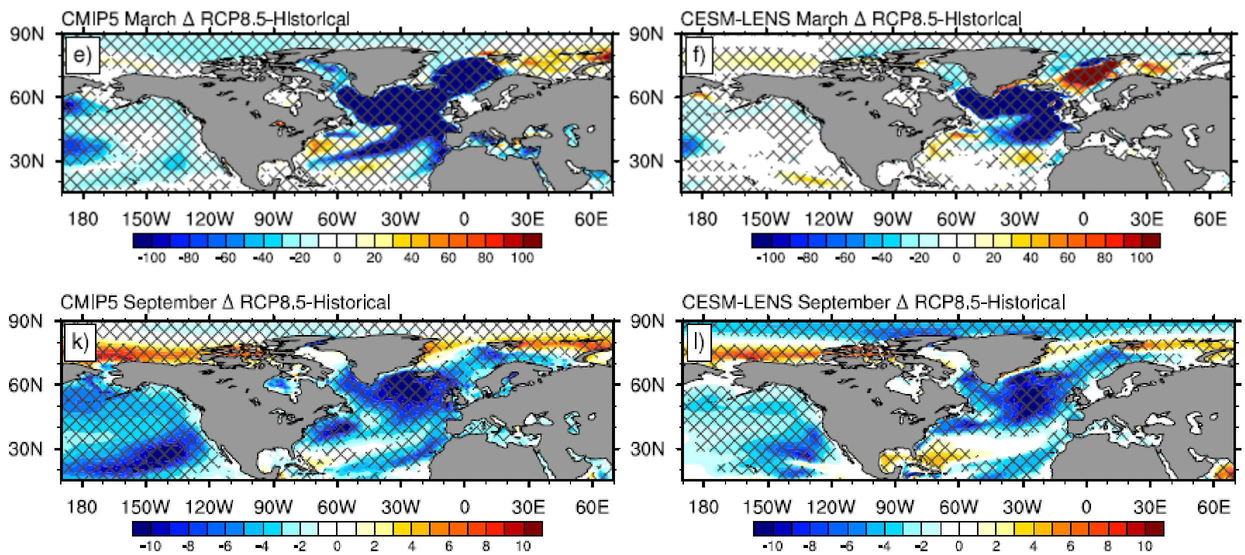


NOTE: The standard deviation in the model runs provides context to the significance of these patterns
SOURCE: Greenan et al. 2018

Figure 3-69 Sea surface salinity difference between 2045-2065 and 1986-2005 for February (top left) and for August (top-right)

3.10.2.2 Stratification and Mixed Layer Depth

Alexander et al. (2018) examine mixed layer depth (MLD) through the CESM-LENS models which predict a shoaling of 0-20 m in the southern Beaufort Sea in March by the end of the 21st century (Figure 3-70). In contrast, the CMIP5 models predict a shoaling of 0-10 m in the southern Beaufort Sea in March over the same time period (Alexander et al. 2018). Both of these results are based on over 80% of the model runs which had a significant trend at the 95% significance level. For September, both model types predict a shoaling of 3-8 m, with a similar level of significance as found in the March results.



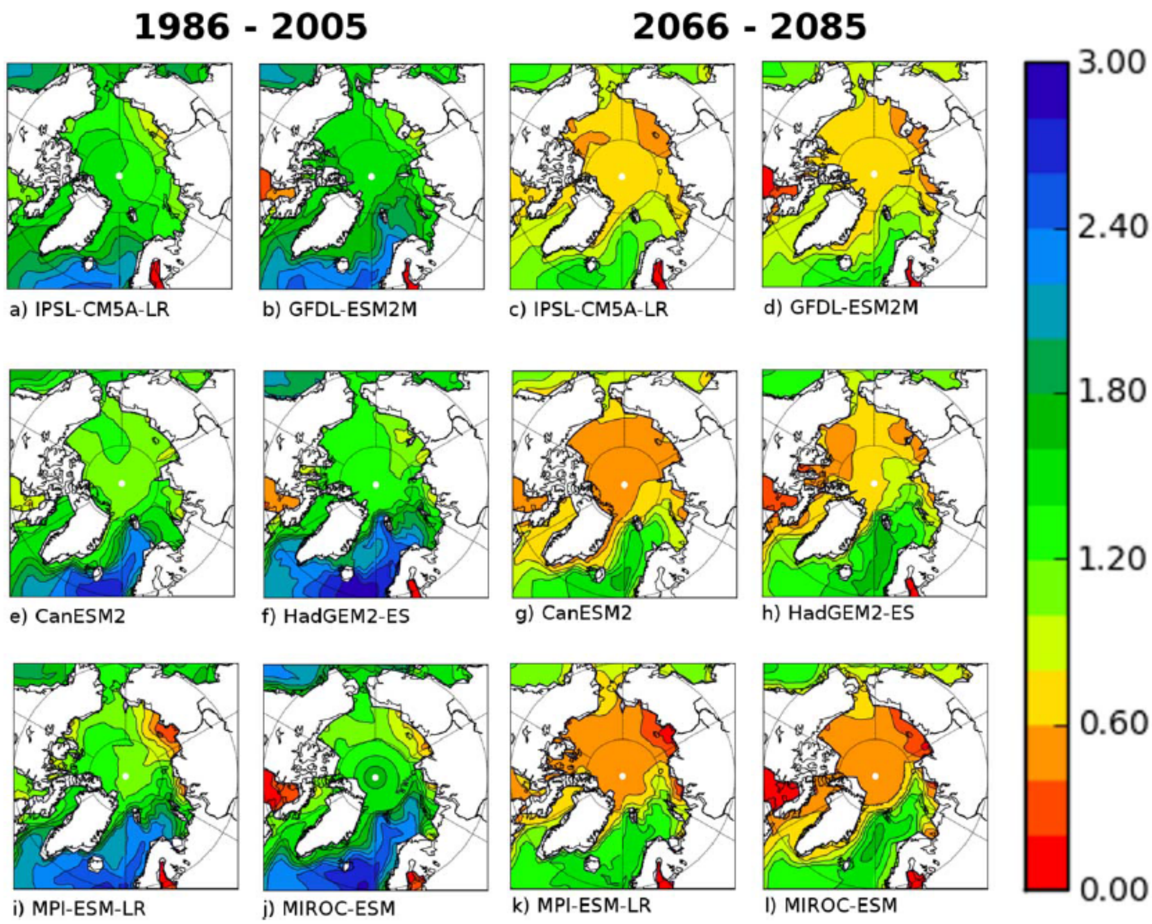
NOTE: The results in the left-hand column is based on 26 CMIP5 models and the right-hand column is based on 30 CESM-LENS ensemble runs. Cross hatches are based on 80% of the model runs indicating a trend which is significant at the 95% level.

SOURCE: From Alexander et al. 2018

Figure 3-70 Change in the mixed layer depth between 1976-2005 and 2070-2099 for March (top row) and for September (bottom row)

3.10.2.3 pH and Alkalinity

Greenan et al. (2018) predict that the Arctic will be the first place where the surface waters will become undersaturated (Ω<1). During the summer months increased water temperatures cause a seasonal minimum in saturation levels. For 68-79˚N, 124-160˚ W under RCP8.5 forcing (Steiner et al. 2014) the pH is predicted to drop from 8.1 to 7.8 by mid-century, with surface aragonite saturation levels below 1 by 2066 (Figure 3-71).



SOURCE: Steiner et al. 2014

Figure 3-71 Various model outputs of surface aragonite saturation for 1986-2005, and for 2066-2085

3.10.2.4 Dissolved Oxygen

Dissolved oxygen levels are expected to continue to drop in the surface waters of the southern Beaufort Sea by the middle of the 21st century even though the specifics vary from model to model even within the CMIP5 framework (Bopp 2013).

3.10.3 Uncertainties

3.10.3.1 Salinity

Regional characteristics and local influences such as the Mackenzie River are not well modelled by global models. A regional model exists but has not been run under RCP8.5 forcing.

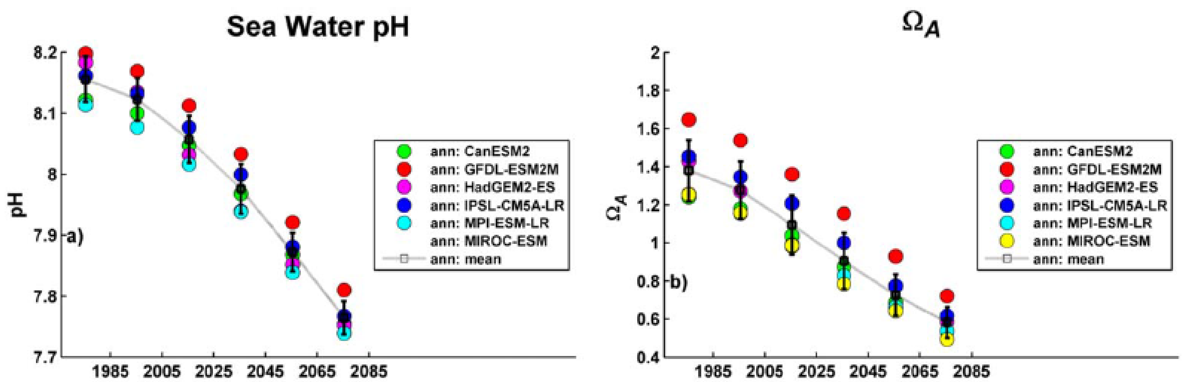
3.10.3.2 Stratification and Mixed Layer Depth

As already discussed in the context of sea surface temperatures (Section 3.6.2), the variability between models within the RCP8.5 forcing was greater than the variability due to climate (Alexander et al. 2018). Increasing winds increases mixed layer depth whereas increased freshwater inputs and reduced sea-ice extent decrease reduced mixed layer depth.

3.10.3.3 pH and Alkalinity

The loss of sea ice increases atmosphere-ocean interactions. Predicted increased freshwater input into this region from the Mackenzie river and precipitation reduces the surface concentrations of CO_2 and accelerates CO_2 uptake and the rate of acidification (Steiner et al. 2014). Yet both sea ice loss and freshwater inputs have their own uncertainties, and these affect our confidence in specific alkalinity forecasts.

Exactly when undersaturation will occur is not a simple problem to answer either. Not only are there spatial variations in the saturation level, but there are also substantial differences across the different models. As an example, Steiner et al. (2014) investigated 6 different CMIP5 models and found annual mean undersaturation at 68-79˚N, 124-160˚ W under RCP 8.5 forcing to occur anywhere between 2010 and 2049 (Figure 3-72) with Ω (aragonite) values dropping from 1.4 to 0.7.



SOURCE: Steiner et al. 2014

Figure 3-72 Sea water pH (left) and aragonite saturation levels (right) for 68-79˚N, 124-160˚ W under RCP8.5 forcing

3.10.3.4 Dissolved Oxygen

There are few model results of dissolved oxygen changes over the next 30 years specific to the western Arctic. Model results have tended to underestimate the observed rate of decrease in dissolved oxygen by a factor of about 2 (Greenan et al. 2018), and modelling of subsurface dissolved oxygen concentrations has been highly uncertain (Bopp et al. 2013).

3.10.4 Limitations

The quantification and understandings of current trends in water properties in the southern Beaufort Sea are limited by the absence of long-term data sets, especially in the fall, winter and spring under ice cover. The global models used primarily as the basis for predictions have inherent uncertainties due to the difficulty in adequately representing complex physical, chemical and biological processes, especially given the necessary limits on the spatial resolution of the model grid elements and the availability of input data sets to force the model.

3.10.5 Summary

Salinification within the mixed layer of the southern Beaufort Sea has been the exception to Arctic-wide freshening. This salinification specific to the southern Beaufort is expected to be linked to changes in the plume trajectory of the Mackenzie River or changes in the Beaufort Gyre (Peralta-Ferriz and Woodgate 2015). Barring impacts from these types of processes, both global and regional models indicate freshening of the southern Beaufort Sea in summer by 1.5 to 2 psu by the mid-21st century.

Related to the observed increase in the surface salinity in the southern Beaufort Sea, the summer mixed layer depth has been observed to be increasing. Different numerical models predict increases of up to 3-8 m in the mixed layer depth in the summers by the middle of the 21st century.

There is good agreement among the models that the Arctic will continue to see rapid acidification, including the southern Beaufort Sea. Some instances of undersaturation are already observed in parts of the southern Beaufort Sea, but undersaturation is expected to be more prevalent throughout the region sometime by mid-century.

Deoxygenation is also expected to continue, with a rate of deoxygenation within the Arctic that is higher than the global average.

3.11 Permafrost

Permafrost is ground that remains at or below 0°C for two years or longer. Permafrost is an important component of the Canadian landscape, underlying about 40% of the landmass (Figure 3-73) and extending under parts of the Canadian Arctic Ocean (Figure 3-74). The soil layer above the permafrost that thaws and freezes annually is referred to as the active layer. The entirety of the permafrost within the Inuvialuit Settlement Region is considered to be continuous permafrost, which means that more than 80% of the ground surface is underlain by permafrost.

The distribution and thickness of permafrost are a reflection of a region’s long-term climate and glacial history (Ford et al. 2016). The southern limit of continuous permafrost corresponds closely to a mean annual air temperature of –8ºC. Depths range from over 700 m beneath the northeastern portion of Richards Island and the adjacent offshore region to the north, to less than 100 m in the modern Mackenzie Delta and offshore Mackenzie Bay regions (Figure 3-74 and Figure 3-75). Along the Tuktoyaktuk Peninsula, permafrost thicknesses exceed 600 m but tend to thin to less than 100 m in a southeasterly direction (Allen et al. 1988).

In parts of the western Arctic, permafrost that formed during the last glaciation when sea level was much lower (Mackay 1972) still persists as subsea permafrost in the nearshore and shelf of the Beaufort Sea (Taylor et al. 1996). When paleoclimatic history is similar between two regions, differences in the lithology (sediment type, porosity, or faulting) or differences in local hydrology (Frederick and Buffett 2015) may explain large differences in submarine permafrost distribution. For example, whereas the submarine permafrost on the majority of the Canadian Beaufort Shelf is present out to a water depth of 100 m (Hu et al. 2013), at the Alaskan Beaufort it is only present to 20 m water depth (Brothers et al. 2012).

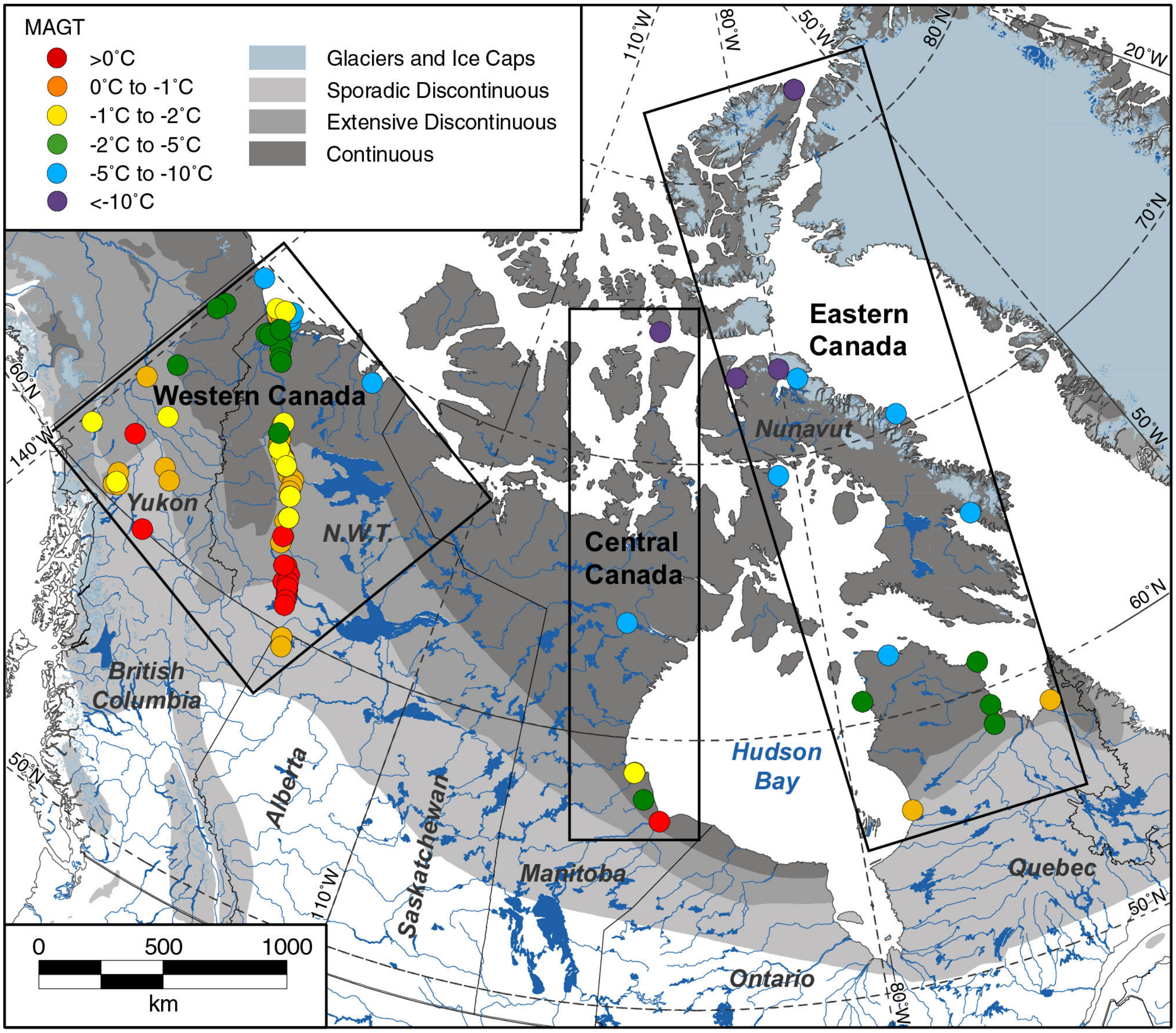
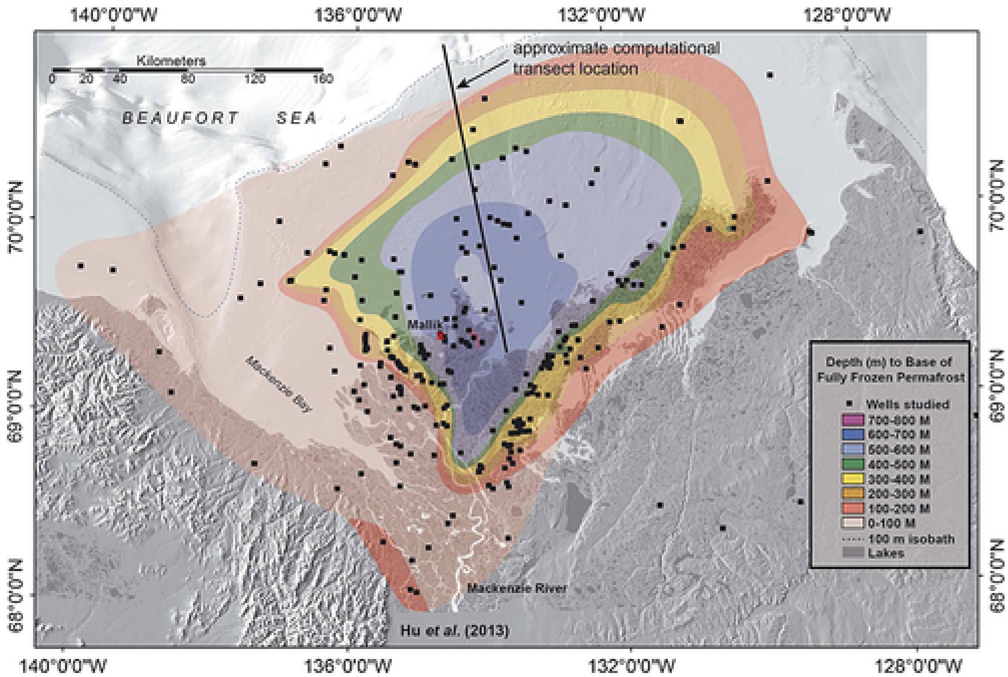
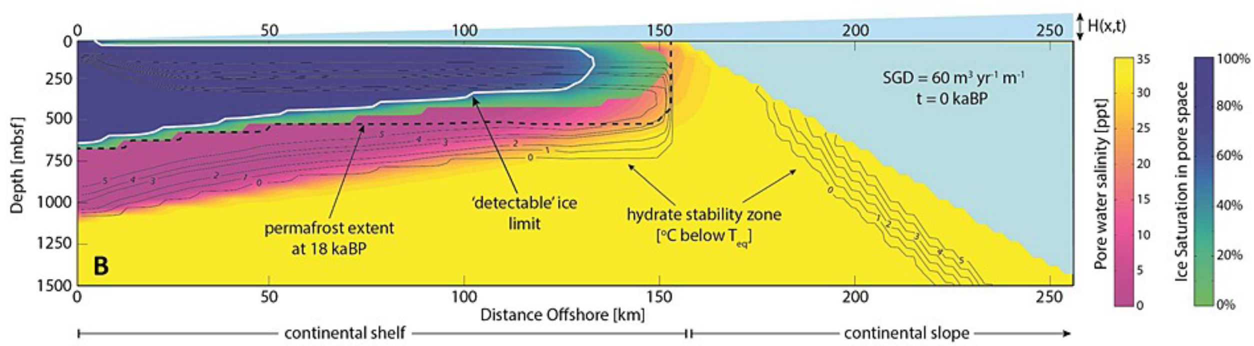


Figure 3-73 **Extent of permafrost in Northern Canada. Permafrost monitoring stations show average temperatures of the ground**



SOURCE: from Frederick and Buffet (2015), modified from Hu et al. (2013)

Figure 3-74 Map of the depth to the base of fully frozen, ice-bearing permafrost at the Canadian Beaufort Shelf



NOTE: This depiction is from a groundwater model, which represents the known depths most closely
SOURCE: from Frederick and Buffett 2015

Figure 3-75 Profile of the Beaufort shelf showing the presence of subsea permafrost

As the Arctic warms, ice-rich permafrost degradation is becoming increasingly widespread. Derksen et al. (2018) laid out the concerns of changing permafrost conditions and highlighted the thawing of ice-rich permafrost resulting in ground instability among the chief concerns. Arctic coastal communities face the additional unique challenges of coastal erosion because of processes related to thawing of the shore face (Ford et al. 2016); see Section 3.13. Also, of concern are the following:

- Permafrost conditions are linked to hydrological (e.g., drainage) and land surface processes (e.g., erosion and slope movements); ground warming and thawing can therefore affect ecosystems.
- The northern circumpolar permafrost region holds reserves of carbon (approximately 1000 petagrams [Pg] in the upper 3 m) as large as the total amount of carbon in the atmosphere (Hugelius et al. 2014; Olefeldt et al. 2016). If permafrost thaws, it could release massive amounts of greenhouse gases (carbon dioxide and methane) into the atmosphere (Romanovsky et al. 2017).
- Northern soils efficiently store mercury, which is vulnerable to release as a consequence of permafrost thaw (Schuster et al. 2018). Permafrost thawing can also release other compounds and dissolved material (e.g., Kokelj and Jorgenson 2013; Kokelj et al. 2013), including contaminants associated with waste facilities that may depend on permafrost for containment (e.g., Prowse et al. 2009; Thienpont et al. 2013).

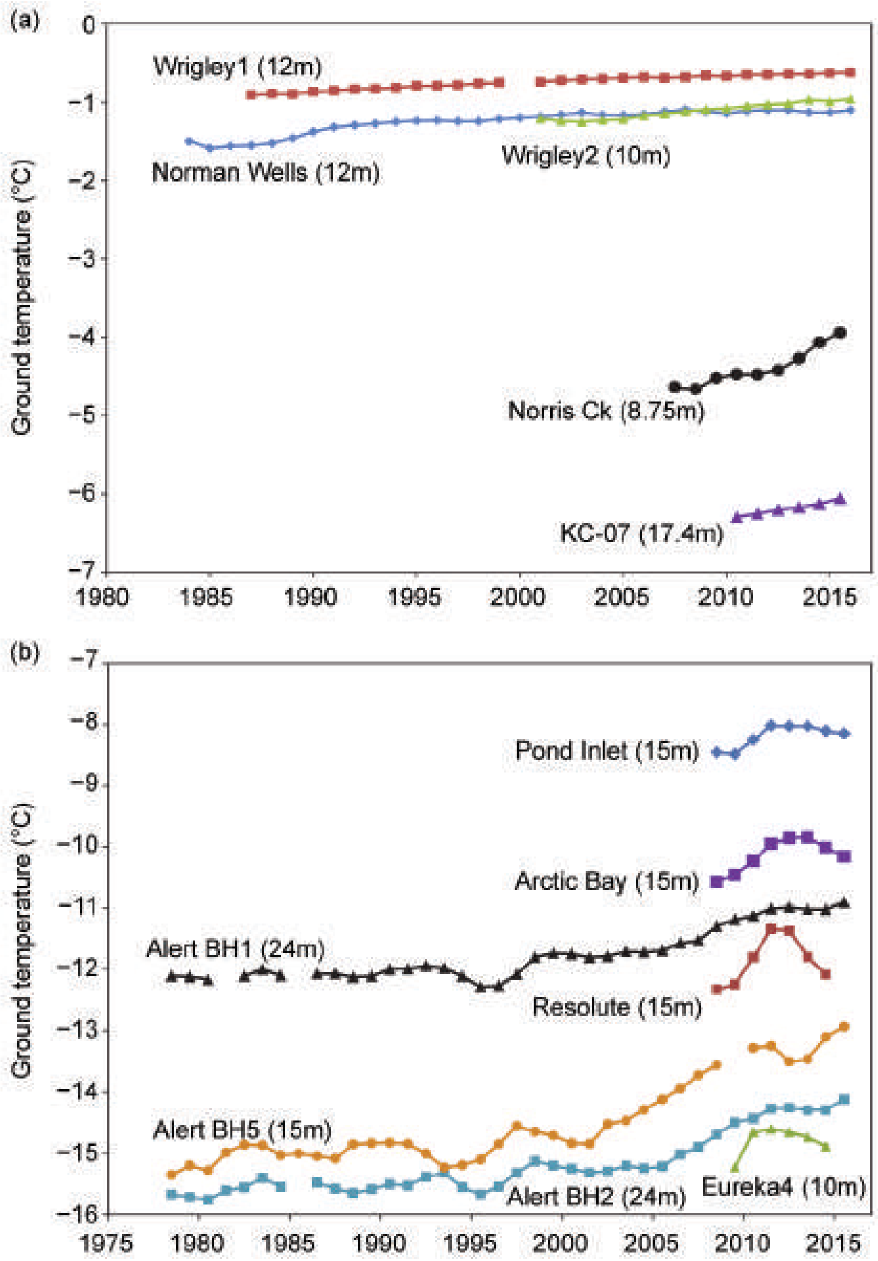
3.11.1 Current trends

3.11.1.1 Onshore Permafrost

Romanovsky et al. (2017) describe the recent trends of onshore permafrost in the Inuvialuit Settlement Region. Regional variability in permafrost temperature records, indicates more substantial permafrost warming since 2000 in higher latitudes than in the sub-Arctic. The distribution of variability is in general agreement with the pattern of average surface air temperature anomalies over this same time period.

In the discontinuous permafrost of the central Mackenzie Valley (Norman Wells, Wrigley), warming has been observed since the mid-1980s, but the rate of temperature increase has generally been lower since 2000 and less than about +0.2°C per decade. In contrast, recent increases in permafrost temperature have been greater in the northern Mackenzie River region, up to +0.9°C per decade (Figure 3-76), which is likely associated with greater increases in surface air temperature over the last decade (Smith et al. 2016).

Active Layer Thicknesses (ALT) in the Mackenzie Valley (Figure 3-77) have been measured since 1990. Records from 25 sites with thaw tubes in the Mackenzie Valley, northwestern Canada, indicate that overall there has been a general increase in ALT in this region since 2008 with a peak value occurring in 2012, about 10% greater than the 2003-2012 mean (Duchesne et al. 2014; Smith et al. 2016). Although ALTs were lower after 2012, they are on average greater than the 2003-2012 mean (Figure 3-78).



NOTE: The depths of measurement are indicated on the graph.
SOURCE: from Romanovsky et al. 2017, which is updated from Smith et al. 2016

Figure 3-76 Time series of average annual permafrost temperatures in (a) the discontinuous, warm permafrost of the central Mackenzie River Valley, Northwest Territories, Canada (Norman Wells and Wrigley), and in colder continuous permafrost in the northern Mackenzie Valley near Inuvik (Norris Ck and KC-07); (b) continuous, cold permafrost in the High Canadian Arctic (Alert, Eureka, Resolute, Arctic Bay, and Pond Inlet)

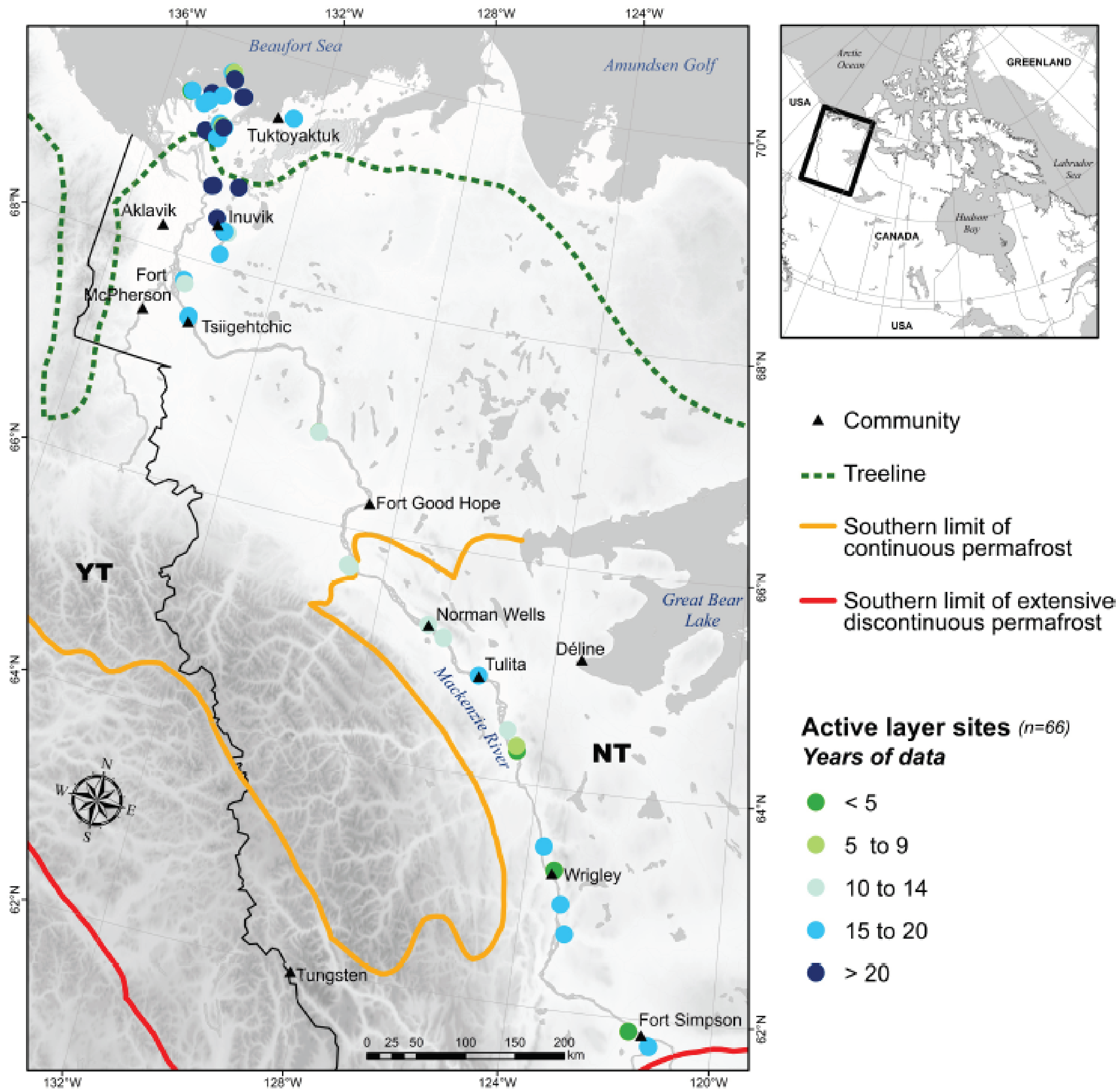
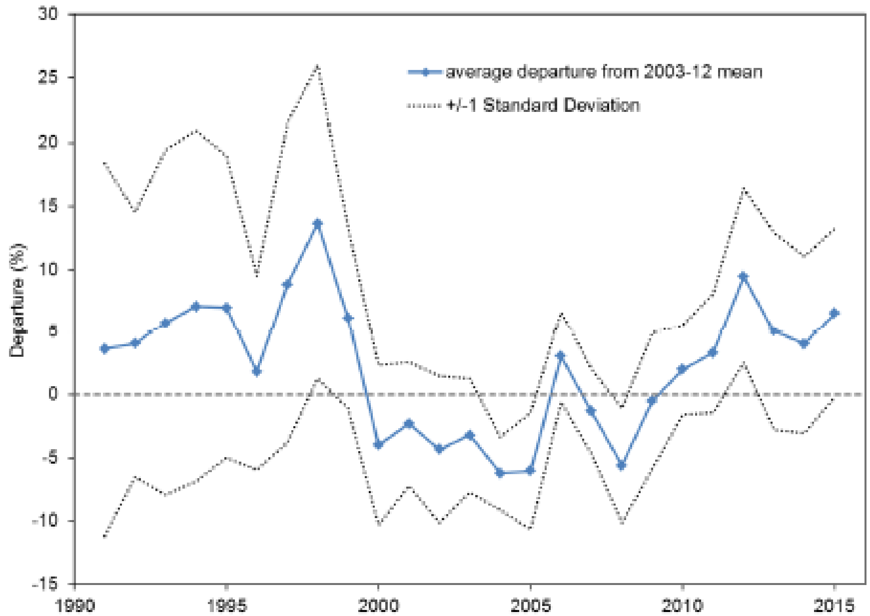


Figure 3-77 Location map of active layer monitoring sites in the Mackenzie Valley



NOTE: 2015 ALT based only on northern sites visited in 2016
SOURCE: from Smith et al. 2017

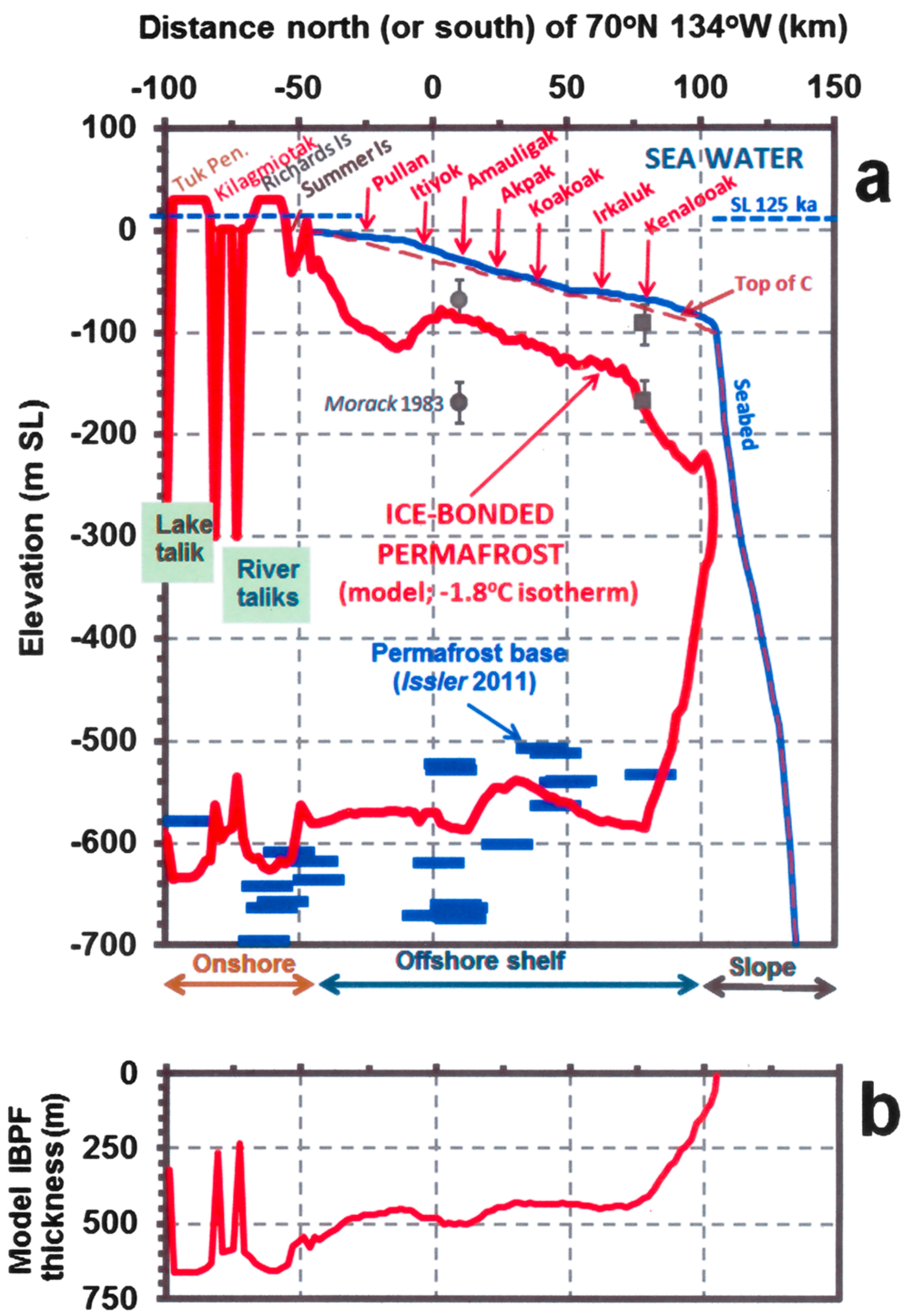
Figure 3-78 Mean ALT departures (%) from 2003-12 mean for 25 sites

A recent study within the Inuvialuit Settlement region also indicates that very cold permafrost might be degrading more rapidly than predicted (Farquharson 2019), seemingly due to the thin vegetation/soil cover in the region that allows for a more rapid top down thaw in increasingly warming summers.

Worldwide, according to the 5th assessment of the IPCC (IPCC 2014), there is high confidence that permafrost temperatures have increased in most regions of the Northern Hemisphere since the early 1980s, with reductions in thickness and areal extent in some regions. The increase in permafrost temperatures has occurred in response to increased surface temperature and changing snow cover.

3.11.1.2 Offshore Permafrost

Taylor et al. (2013) developed a model to fit the existing data on the subsea permafrost in the Beaufort Sea. The present seaward extent of the permafrost body is the ~95 m isobath where the permafrost thins out over a distance of <2 km (Figure 3-79). This outer limit of ice-bonded permafrost occurs less than 2 km before the physical shelf/slope break.

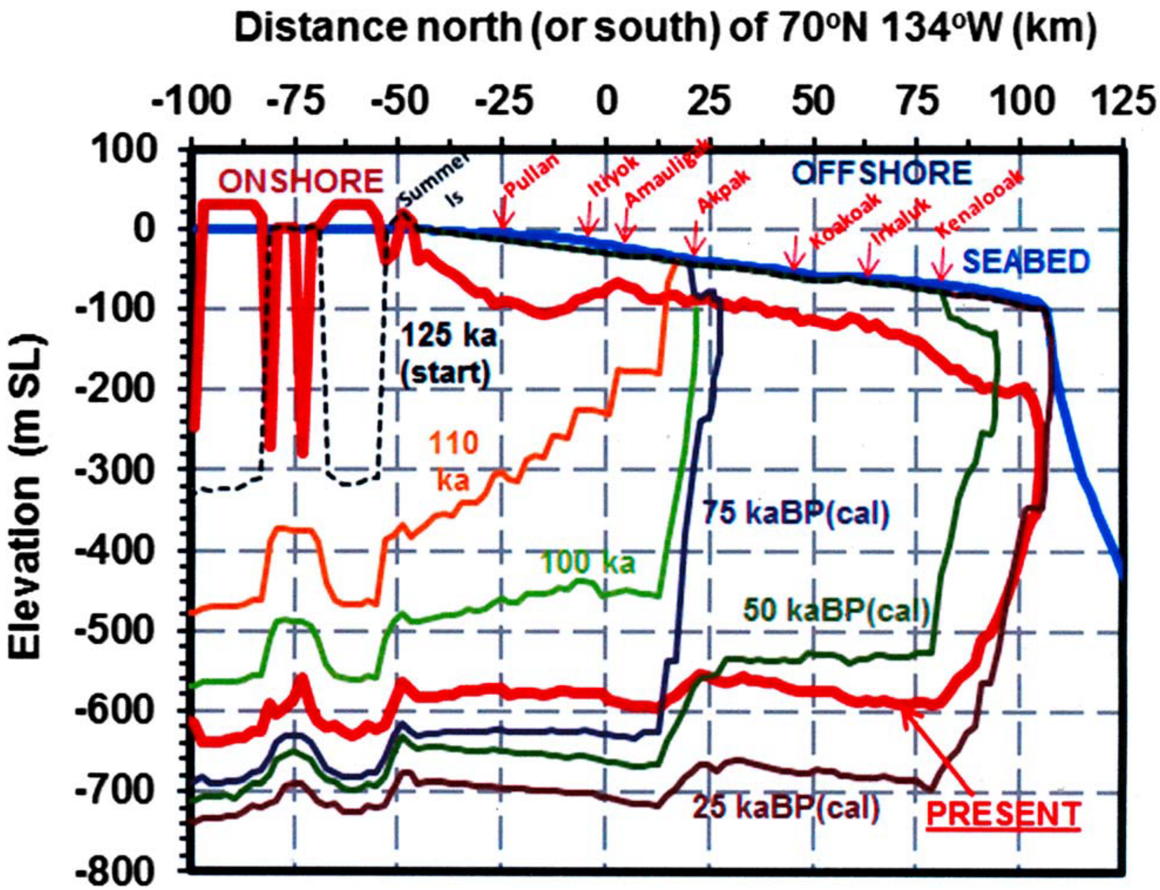


SOURCE: from Taylor et al. 2013

Figure 3-79 **(a) Permafrost model versus geophysical interpretations, outer Mackenzie Delta-Beaufort shelf and slope relative to present sea level along the transect. The heavy red line shows the model-predicted present extent of ice-bonded permafrost (IBPF). (b) Model permafrost thickness in Figure 3-76a. Vertical exaggeration is ~370×**

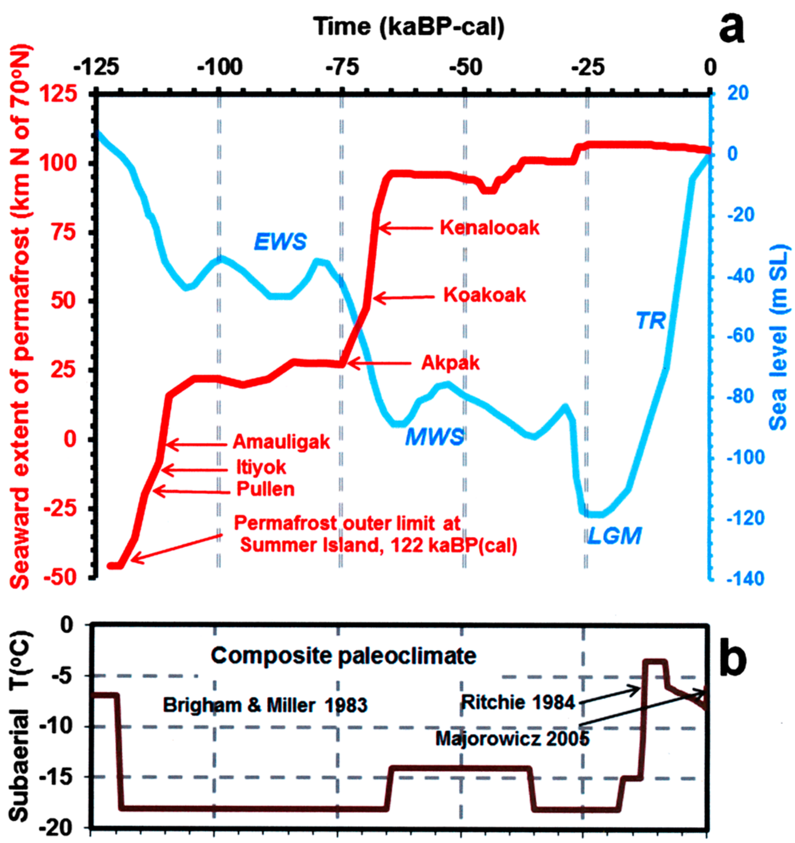
The modelled development of the subsea permafrost is shown in Figure 3-80 and Figure 3-81. During the Last Interglacial (~130,000–116,000 years BP), the permafrost body may have extended no further than the present coast; as sea level fell from the Interglacial high of ~7 m above the present sea level, permafrost advanced offshore and reached the Amauligak oil field after <15,000 years (by ~110,000 years BP). Subsea permafrost continued to advance offshore but at much reduced rates overall, correlated with two still stands in sea level change in the early and middle Wisconsinan (EWS and MWS), with a notable offshore 65 km jump within~10,000 years, in response to a ~50 m fall in sea level between the EWS (~100,000–75,000 years BP) and the MWS (~65,000–35,000 year BP); see red profile in Figure 3-81a between 75 and 50 ka .

Since the Holocene marine transgression (~ last 11,500 years) the outer limit of permafrost has retreated back towards the coast by less than 2 km (Figure 3-81a).



NOTE: 125 kaBP(cal) is the starting position for the model (i.e., the thermal equilibrium with a marine LIG)
SOURCE: from Taylor et al. 2013

Figure 3-80 Model spatial and temporal evolution of the ice bonded permafrost body (IBPF) from onshore to shelf edge, at 25 ka increments since the Last Interglaciation (LIG)

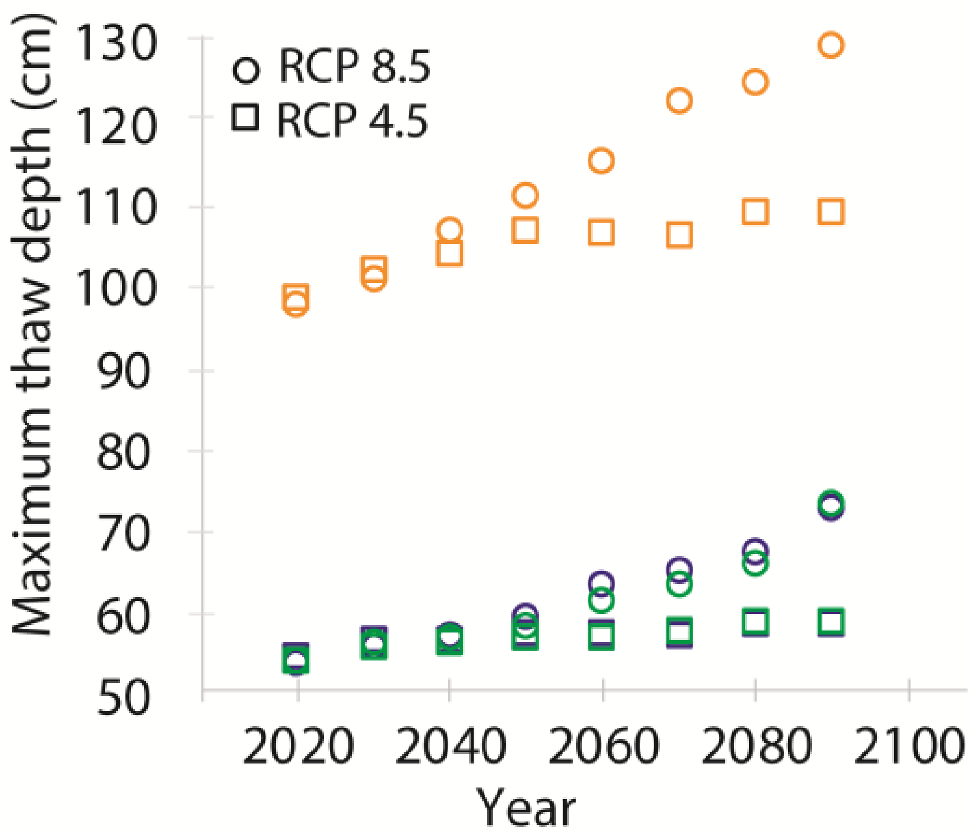


SOURCE: From Taylor et al 2013

Figure 3-81 (a) Advance of the seaward limit of ice-bonded permafrost relative to industry wells (left axis) versus composite sea level (right axis). EWS and MWS, early and middle Wisconsinan stillstands in sea level; TR, marine transgression; LGM, Latest Glacial Maximum. (b) Paleoclimate model

3.11.2 Predictions

Projections under RCP8.5 indicate a substantial amount of near-surface permafrost degradation. It is virtually certain that near-surface permafrost extent at high northern latitudes will be reduced as global mean surface temperature increases, with the area of permafrost near the surface (upper 3.5 m) projected to decrease by 37% (RCP2.6) to 81% (RCP8.5) for the multi-model average (IPCC 2014). Specifically for sites within the Inuvialuit settlement region (Figure 3-82), maximum thaw depths under RCP8.5 are projected to increase from 98 cm to 112 cm at Green Cabin, Banks Island by 2050, from 54cm to 60cm at Mould Bay, Prince Patrick Island, with smaller predicted change further north at Isachsen, Ellef Ringnes Island from 53 cm to 57 cm.



NOTE: Mould Bay (Prince Patrick Island), blue; Green Cabin (Banks Island), orange, Isachsen (Ellef Ringnes Island), green.

Figure 3-82 Projected thaw depths for study sites under RCP 4.5 and 8.5

3.11.3 Uncertainties

Dramatic warming of the climate predicted by RPC8.5 will affect permafrost temperatures and conditions from both warming air and warming seas. The uncertainties are summarized well by Derksen et al. (2018) and references therein. In most regions the conditions are not known presently in enough detail for which to estimate the changes. For instance, in some cases above, permafrost degradation is happening at rates faster than predicted, due mainly to the ground conditions not being well understood in the first place. The measurements of deep and undersea permafrost by seismic profiling and other methods already have large variation (Figure 3-79). Although a model shows that the shallow undersea permafrost is slowly receding landward, it is very much unknown how the deep permafrost will react to a changing climate. It is also uncertain how permafrost will respond to other climate related affects such as changing rainfall, new shrub growth, increasing wildfires (and vegetation changes), feedback loop between thaw induced slumping and slump induced thawing, and human clearing and construction (Derksen et al. 2018).

3.11.4 Limitations

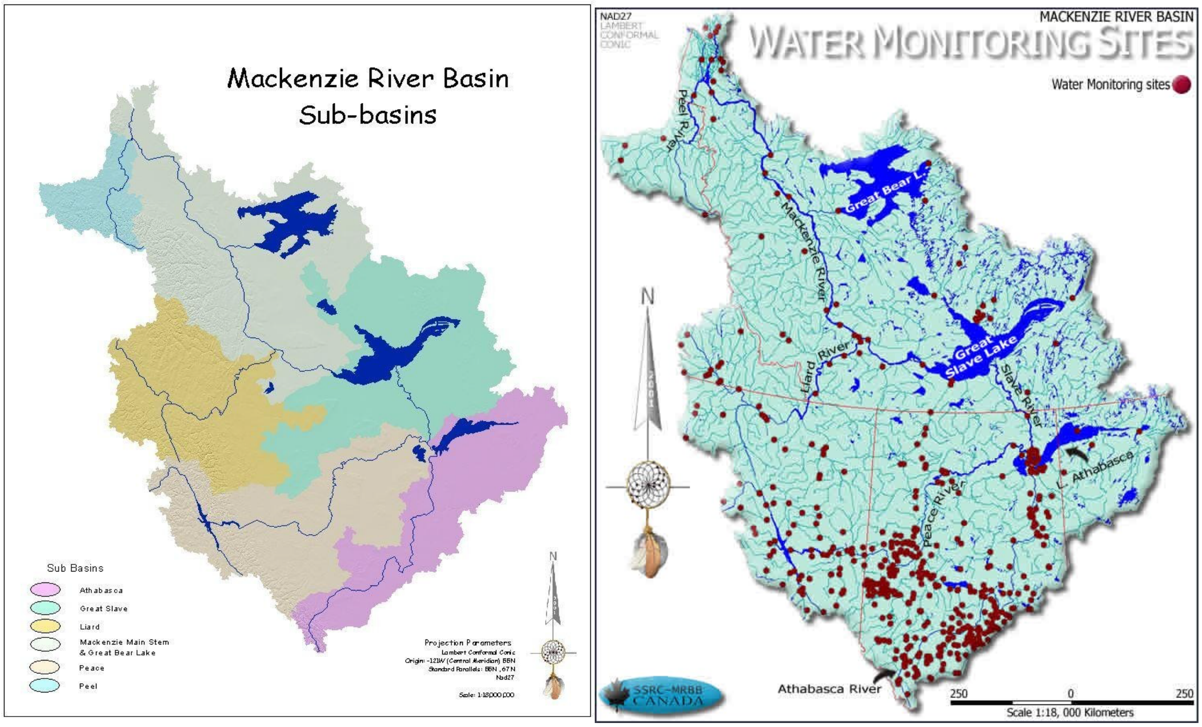
There is a great deal of natural variability in permafrost conditions throughout the region. As described above and including a recent detailed investigation of three locations (Farquharson 2019), changes in permafrost are highly dependent on soil cover and current ground ice conditions, which are unmeasured for the vast majority of the region. Due to the density of the measurements in the Mackenzie Valley, a trend of greater warming to the North can be established. In other areas no such spatial trend is possible, except that all over permafrost temperatures have been generally increasing and thaw layer thicknesses are generally increasing. Limitations exist in the scientific understanding of feedback loops as described in the Uncertainty section above.

3.11.5 Summary

The Inuvialuit settlement Region lies entirely within land and sea of continuous permafrost. In the Southern portion of the region, the Mackenzie delta, permafrost temperatures are rising at rates up to +0.9°C per decade. In the northern regions, the permafrost temperatures are rising more than 1°C per decade, and with surprising permafrost thaw due to warm summers. On the seabed, the permafrost which currently extends out over 100 km from shore is receding at a slow rate, 2 km since the Holocene marine transgression. There is high confidence that permafrost temperatures will continue to increase, with projections for decreases in maximum thaw depths under RCP8.5 between 4 and 14 cm by 2050 throughout the region.

3.12 Freshwater runoff from Makenzie River

The Mackenzie River runs 1,738 km (main stem) from southern Alberta (at the headwaters of the Athabasca River) through BC, Alberta, the Yukon and Northwest Territories. As Canada's largest river basin (draining ~20% of Canada), it encompasses many different climate zones and terrain from prairie plains to arctic areas of permafrost and represents a watershed area of 1,680,000 km^2. Annual mean discharge is 10,000 m^3s^{-1}, with maximum discharge around 22,000 m^3s^{-1}. The Mackenzie River basin includes seven major rivers, (Peace, Athabasca, Slave, Liard, Great Bear, Peel, and Mackenzie), three large lakes (Great Bear, Great Slave and Athabasca), one large estuarine delta, many freshwater deltas and 6 sub-basins (Athabasca, Peace, Great Slave, Liard, Mackenzie-Great Bear and Peel sub-basin (Figure 3-83). These lakes and sections of the river are prone to seasonal variations in water levels and occasional floods. Northern sections of the river experience surges during melt seasons and at times portions of the river may be completely frozen over. These varied conditions make the Mackenzie River basin a challenge for river basin models (Lintern and Haaf 2014). Mackenzie River flows are also known to be associated with naturally occurring internal climate variability, mainly El Niño–Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and Arctic Oscillation (AO) (St. Jacques and Sauchyn 2009).



SOURCE: Image: www.mrbb.ca

Figure 3-83 (left) Sub-basins and (b) drainage network and monitoring stations of the Mackenzie River System as of 2003

Over 2600 hydrometric (water-level and streamflow) stations are currently operated within the Mackenzie River Basin (Figure 3-83). Streamflow is the volume of water flowing past a point on a river in a unit of time (e.g., m^3s^{-1}). Most stations are in the southern part of the country; as a result, the network is often inadequate to describe water characteristics and trends in northern Canada. The Reference Hydrometric Basin Network (RHBN) is a subset of stations from the national network that are used primarily for the detection, monitoring, and assessment of climate change (ECCC 2017). These stations are characterized by near pristine or stable hydrological conditions and have been active for at least 20 years (Harvey et al. 1999). St. Jacques and Sauchyn (2009) estimate that baseflow, the portion of streamflow resulting from seepage of groundwater, contributes ~41% of the Mackenzie River discharge to the Arctic Ocean.

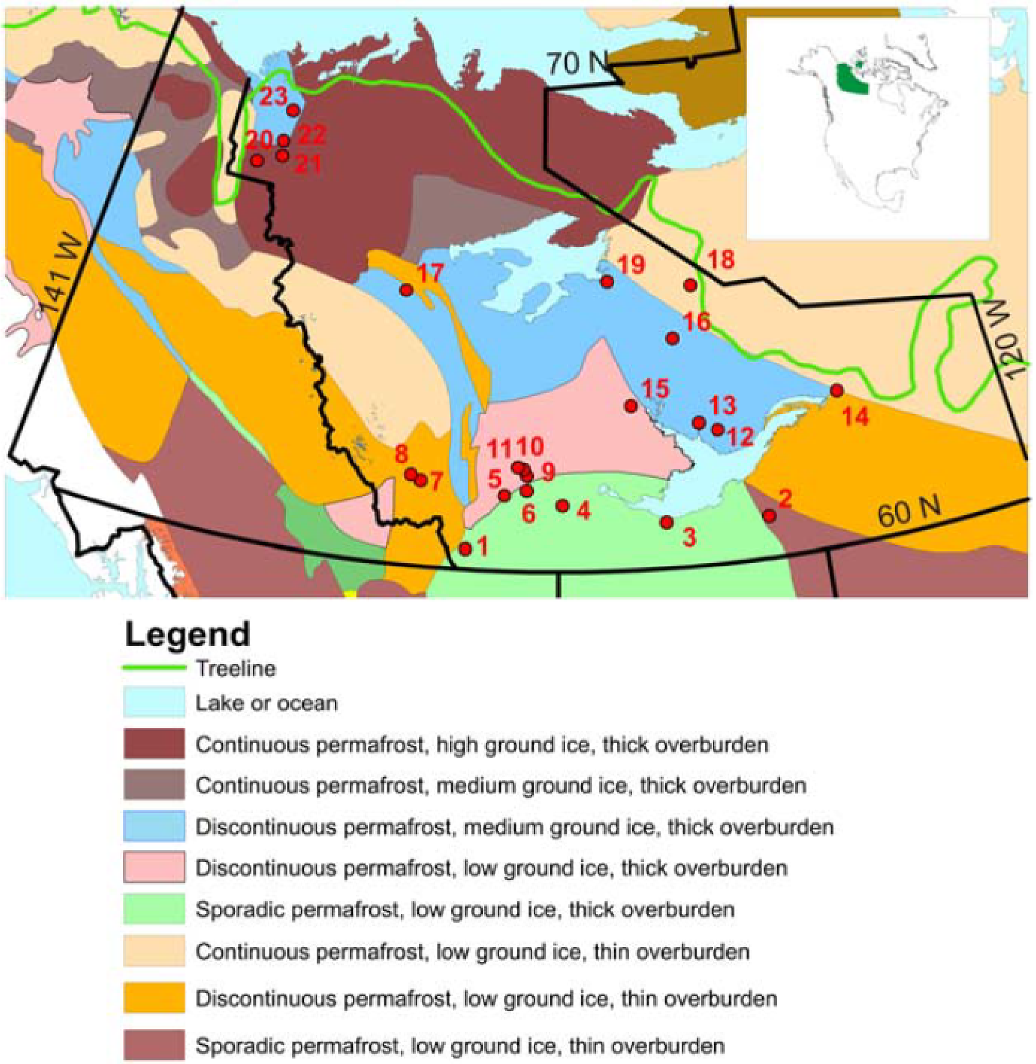
3.12.1 Current trends

In the Mackenzie Basin (British Columbia, Alberta, and Northwest Territories), the spring freshet has followed an onset trend of beginning 2.7 days earlier per decade from 1973 – 1998 (Woo and Thorne 2003). These trends are consistent with increasing spring temperatures, and the resulting earlier spring snowmelt (e.g., DeBeer et al. 2016). The seasonal timing of peak streamflow in Canada has shifted, driven by warming air temperatures (Bonsal et al. 2019). Over the past several decades, spring peak streamflow following snowmelt has trended towards earlier spring flows, along with increased winter flows, particularly for the Mackenzie River basin.

Another key driver of seasonal Mackenzie water volume is changes in the availability of baseflow. Winter base flow has increased significantly ($p < 0.05$) (0.5 – 271.6% /yr) in parts of the Mackenzie basin due to enhanced water infiltration from permafrost thawing due to climate warming. St. Jacques and Sauchyn (2009) assessed trends in winter baseflow river volumes, and their relative contribution to changes in annual river flow at 23 river gauges in the Mackenzie River Basin. Key sites are presented in Table 3-25.

Table 3-25 Changes in winter baseflow trends and relative contributions to changes in Annual River flow at selected river gauges (as shown in Figure 3-84) in the Mackenzie River Basin (adapted from St. Jacques and Sauchyn 2009).

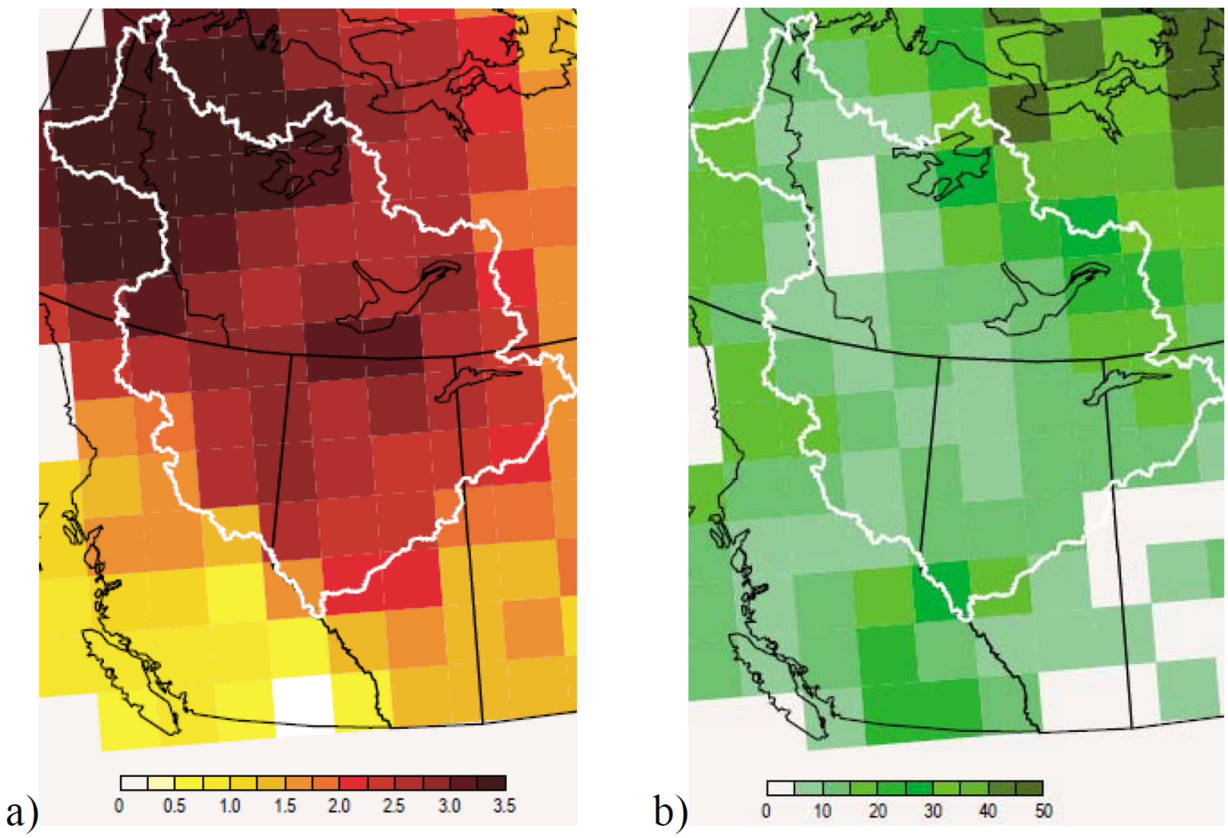
			Winter Baseflow			Annual River Flow			
Streamflow Station Name	Map ID	Period of Record	Mean (m^3/s)	Total Change over Period of Record (%)	Average Change / yr (%)	Mean (m^3/s)	Total Change over Period of Record (%)	Average Change / yr (%)	Baseflow Contribution (%)
Liard River at Ford Liard	1	1966-2007	351.4	29.5	0.7	1946.5	7.5	0.2	18.1
Liard River near the mouth	9	1973-2007	477.2	31.5	0.9	2488.6	6.7	0.2	19.2
Mackenzie River at Fort Simpson	10	1965-2007	2777.4	30.4	0.7	6864.0	7.9	0.2	40.5
Mackenzie River at Norman Wells	17	1966-2007	3404.5	21.3	0.5	8512.6	0.3	0.006	40.0
Peel River above Fort McPherson	20	1975-2007	92.3	60.9	1.9	692.0	-3.4	-0.1	13.3
Mackenzie River at Red River	21	1973-2007	3740.2	26.3	0.8	9094.2	3.5	0.1	41.1
Mackenzie River at Inuvik	23	1973-2007	25.7	157.0	4.5	137.0	15.3	0.5	18.8



SOURCE: adapted from St. Jacques and Sauchyn 2009

Figure 3-84 Map of the 23 river gauges and permafrost extent and type, ground ice content, and overburden thicknesses for the Northwest Territories

Yip et al. (2012) examined changes in the hydrologic cycle in the Mackenzie River Basin in northern Canada focusing on temperature, precipitation, runoff, evapotranspiration and freshwater storage. WATFLOOD, a distributed hydrological model, was employed with two different climate input data sets: Environment Canada gridded observed data and the European Centre for Medium-range Weather Forecasting (ECMWF) reanalysis data (ERA-40). They found a regional pattern of warming temperatures (+2.0 – 3.5°C) and increasing precipitation (+5 – 20 mm/yr) for 1950 – 1998 (Figure 3-85). For both data sets, there is a warming trend on an annual and monthly basis, except for October.

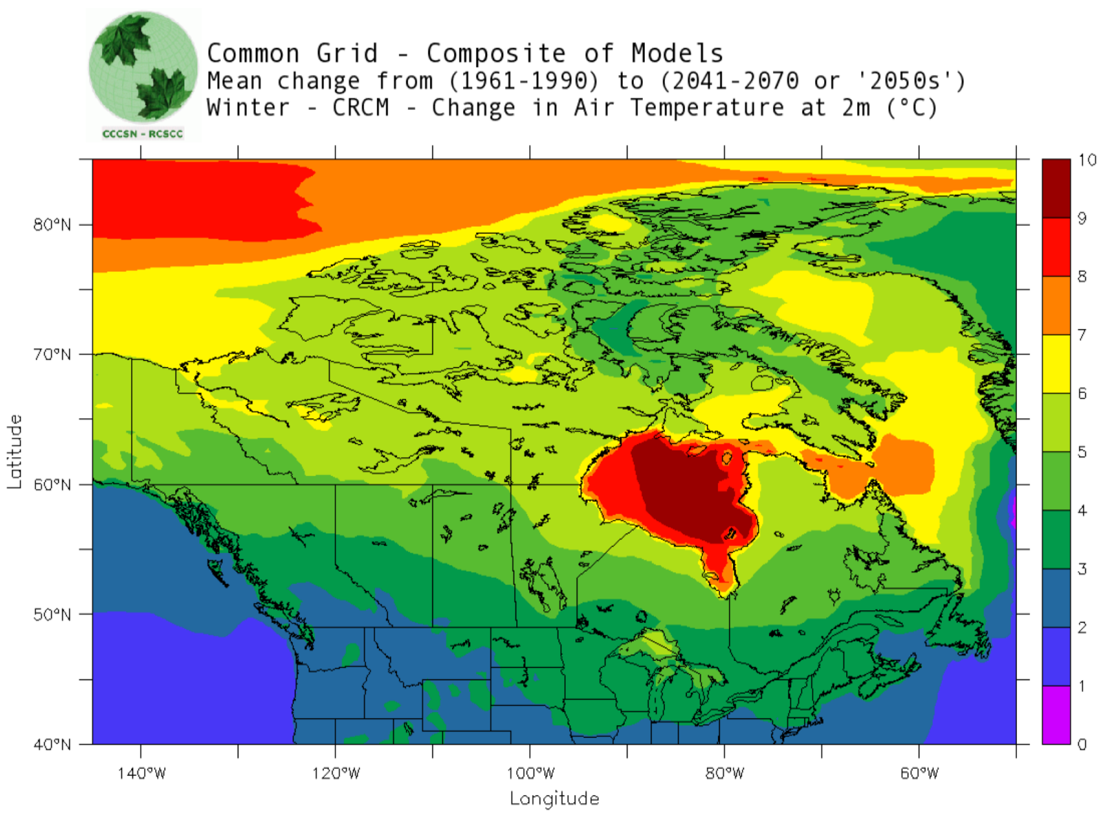


SOURCE: Adapted from Yip et al. 2012

Figure 3-85 Trends in (a) Maximum daily air temperatures (°C) in winter and (b) increase in precipitation (mm/yr)

3.12.2 Predictions

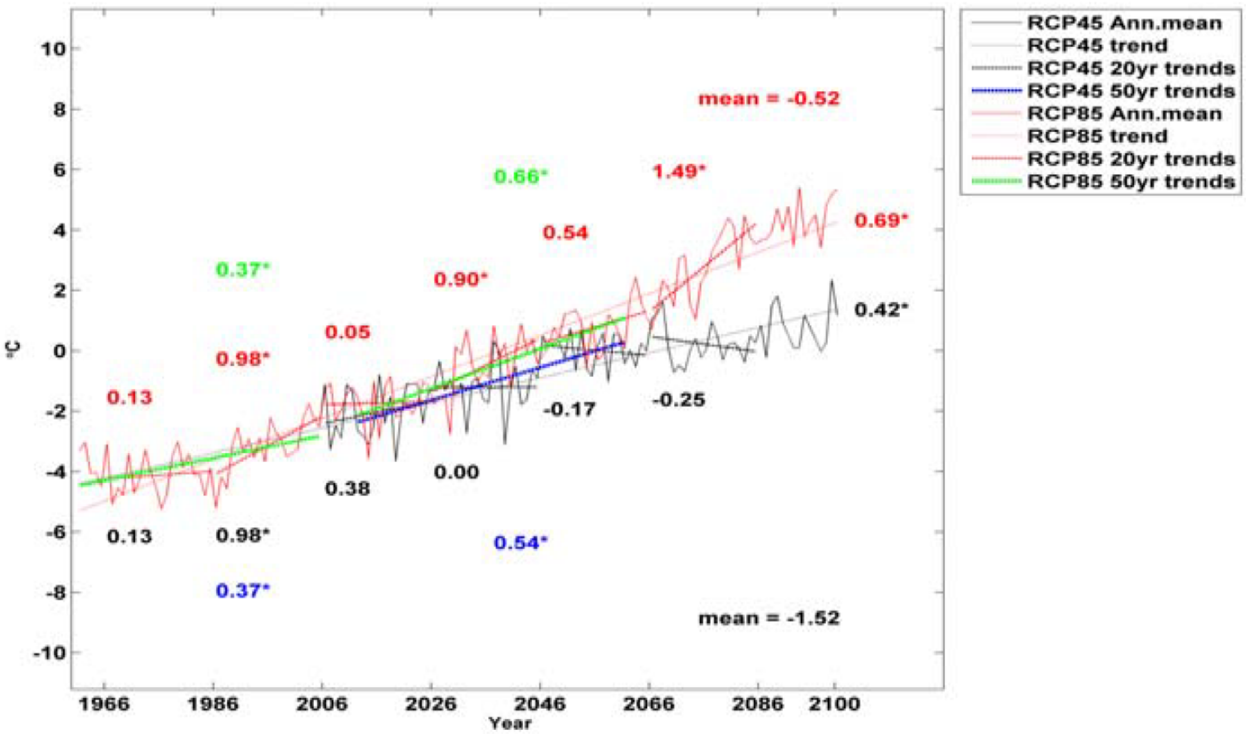
Projections to changes in seasonal air temperatures and precipitation are key to determining future water volumes and timing of peak river discharge. The Canadian Climate Change Scenarios Network (CCCSN 2009*)* has produced a mean ensemble of the IPCC AR4 (IPCC 2007) modelling assessment for Canada based on the international dataset from twenty-four modelling centres based on mean change from 1961 to 1990. To project climate change in the year 2050 (2041 - 2070) in Canada, OURANOS (a partner of Environment Canada) has presented mean model results from their two latest versions of the Canadian Regional Climate Model (CRCM 4.2.0 and 4.2.3) (CCCSN 2009*)*, noting a predicted increase in air temperatures of 0.66 °C/decade (2012 - 2061) for the RCP8.5 scenario (Figure 3-86).



NOTE: Mean model results from two versions of the OURANOS CRCM.
SOURCE: Adapted from Steiner et al. 2013

Figure 3-86 Projected change in mean winter air temperature from 1961 – 1990 to 2041 – 2070 under RCP8.5

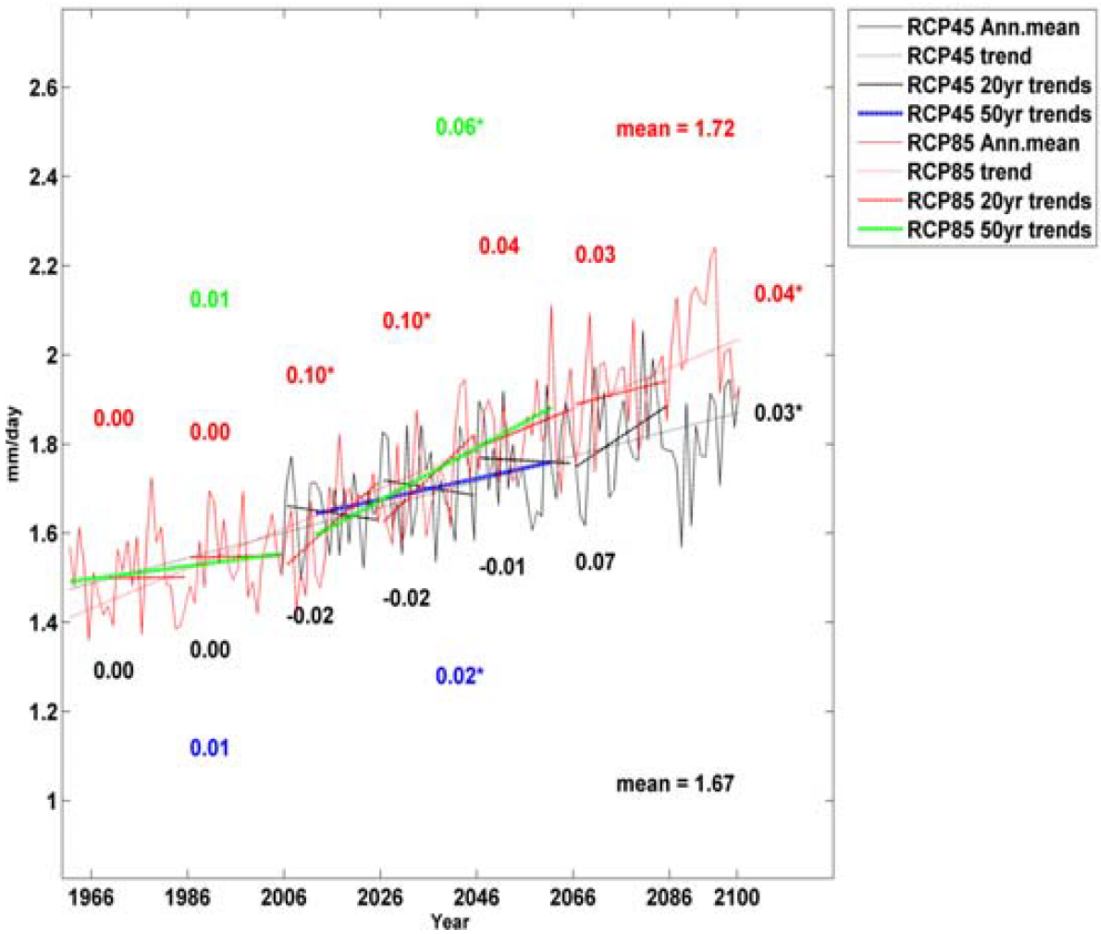
The fifty-year trend in air temperatures (2012 - 2061) is greater than the historical trend (0.37 °C/decade for 1961 - 2005). The historical and fifty-year trends are significant on the 5% level, but most of the bi-decadal trends are not (Figure 3-87).



NOTE: All trends are °C decade^{-1}. An asterix denotes significance at the 95% level ($p < 0.05$).
SOURCE: Adapted from Steiner et al. 2013

Figure 3-87 CanRCM-NAM annual mean air temperature with bidecadal trends and historical (1961 – 2005), a projected 50-year period (2012 – 2061), and a long-term trend (2061 – 2100) trend for scenarios RCP4.5 and RCP8.5, averaged over the Mackenzie River Basin (Figure 3-83)

Projections for precipitation trend upward throughout the Mackenzie River Basin. The historical trend (1961 - 2005) is 0.01 mm/day/decade. Trends increase to 0.06 mm/day/decade for RCP8.5 (2012 - 2061), but due to variability within the data, most of the trends are not significant at the 95% level *($p < 0.05$)* (Figure 3-88).

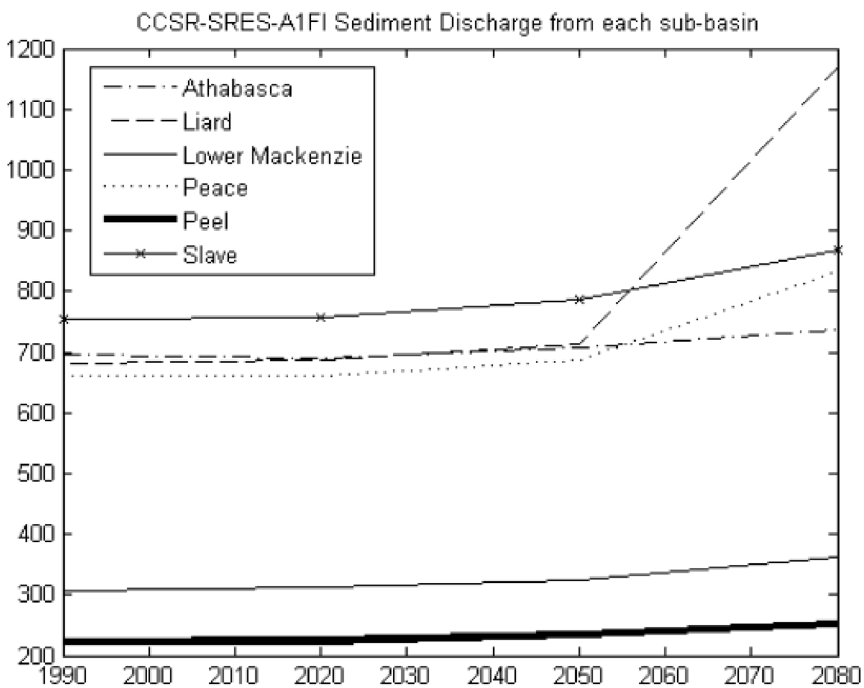


NOTE: An asterix denotes significance at the 95% level (p <0.05).
SOURCE: Adapted from Steiner et al. 2013

Figure 3-88 Same as for Figure 3-86, but for annual mean precipitation (mm/day)

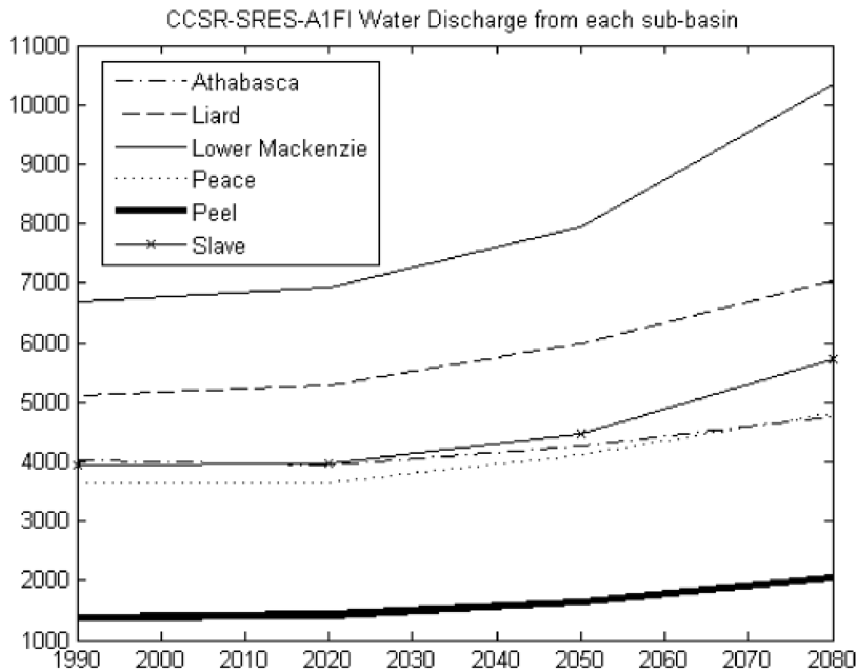
Vetter et al. (2017) expect a general increase in annual flow volumes from the Mackenzie River under warming climate scenarios, characterized by an increase in the magnitude of winter streamflow and earlier spring peak flows. They note a significant increase in 10-year return frequencies of 15-day winter and fall low flows, and one-day high flow events.

Lintern and Haaf (2014) generated river volume (Figure 3-89) and sediment discharge (Figure 3-90) for the Mackenzie River sub-basin regions following scenarios detailed in the Special Report on Emissions (Nakicenovic et al. 2000). The report identified a total of 40 scenarios; six were agreed upon by the international Modeling teams involved as the most representative (A1FI, A1T, A1B, A2, B1 and B2). Each experiment group focused on a slightly different combination of future population, economic development, energy efficiency and sources, agricultural production and pollution control trends. The CCSR-SRES-A1FI scenario is essentially equivalent to the RCP8.5 (Riahi et al. 2011).



SOURCE: adapted from Lintern and Haaf 2014

Figure 3-89 Projected sediment discharge (kg s^{-1}) volumes from all sub-basins in climate change scenario CCSR-SRES-A1FI

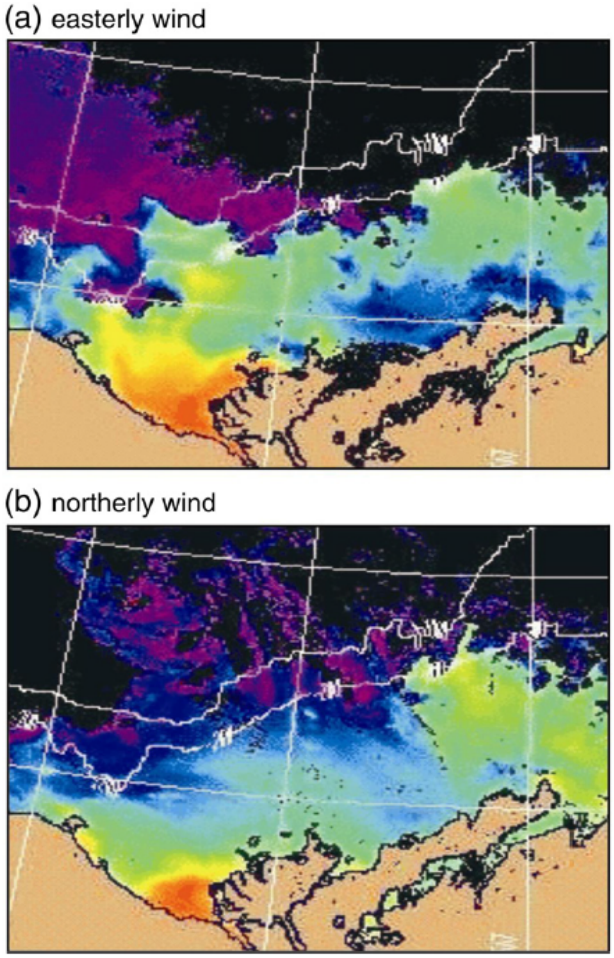


SOURCE: adapted from Lintern and Haaf 2014

Figure 3-90 Projected water discharge (m^3 s^{-1}) volumes from all sub-basins in climate change scenario CCSR-SRES-A1FI

The CCSR model is run by the Japan Centre for Climate System Research. The CCSR-SRES-A1FI climate change experiment begins with high water and sediment discharge (relative to the current climate discharges). For most sub-basins the water discharge increases most dramatically between 2050 and 2080. The exception to this trend is the Athabasca sub-basin which has a relatively steady water discharge predicted over the entire climate change timeline. Alternatively, the sediment discharge remains relatively constant over the climate change timeline for five of the six sub-basins. The anomaly in this case is the Liard, which predicts a dramatic increase of almost 60% between 2050 and 2080. This climate change scenario exhibits many of the same monthly trends seen in the previous example. Most pronounced is the earlier melt. The month of highest water discharge in both the Athabasca and Slave sub-basins is predicted as June in the base period (1961-1990) but moves to April by 2080.

The input of freshwater discharge from the Mackenzie River represents an input of heat energy into the southern Beaufort Sea. Lintern et al. (2013) performed modeling exercises on river and sediment discharge under different wind conditions. The discharge and dissipation characteristics of the river flow under easterly and northerly wind forcing is shown in Figure 3-91. Under expected higher total discharge volumes, the spatial pattern of the discharge of freshwater into the Beaufort Sea will continue to be strongly controlled by wind forcing.



SOURCE: adapted from Lintern et al. 2013

Figure 3-91 Warm water discharge from the Mackenzie River is pushed towards the coast by incoming offshore water as winds shift to northerlies

Changes in sediments, nutrients and biota entering from Arctic rivers will affect phytoplankton dynamics in Arctic coastal waters (Waleron et al. 2007), as well as the organic carbon dynamics of the Arctic Ocean. The changes in river inflow will affect the physical and chemical properties of coastal shelf ecosystems, which produce more than 80% of the total primary production in Arctic seas (Hill and Cota 2005). The AR5-ESMs simulate a decrease of -2.3 ± 1 mmol/m^3 in annual surface nitrate (NO_3) for the Beaufort Sea Regions. The Beaufort Sea region has higher NO_3 (~6 x 10^3 mmol m-^{3}) levels than the (~4 x 10^3 mmol m^{-3}) during the 1966 - 1985 bi-decade, however, the sub-basins experience a similar rate of loss, dropping faster before 2025 than after (Vancoppenolle et al. 2013).

3.12.3 Uncertainties

Uncertainty in the future projections of water volumes and discharge timing of the Mackenzie River depend on how each sub-region of the river basin will be affected by changing air temperatures (high confidence), precipitation (medium confidence), groundwater (low-confidence), and future extreme weather events (high confidence). Past studies vary in their projections for the Mackenzie River Basin sub-regions, and the basin as a whole. Manabe et al. (2004) predicted that as a result of climate warming, the annual flow of the Mackenzie River will increase by 21% by 2050 or even double that estimate if carbon dioxide continues to increase. Nohara et al. (2006) show future flow in the Mackenzie River to be 14,271 $m^3 s^{-1}$, compared to a simulated flow of 12,275 $m^3 s^{-1}$, at present, hence, an increase of 16.3%. The Mackenzie River system is unlikely to be substantially affected by changes in hydrologic processes operating within the Arctic and Sub-Arctic but rather depends on changes in water balance processes operating well outside the Arctic. Compared to other Arctic high latitude rivers, the degree temperature increase is not that high for upper Mackenzie River Basin, hence headwater warming, and snowmelt runoff are not projected for the Mackenzie Basin (Prowse et al. 2006). Schindler and Smol (2006) also predicted that in the long-term, the flow will decline because of declining snowpacks and glaciers in the headwaters of the Mackenzie River.

The effect of projected atmospheric warming on the Liard River discharge is unclear. Changes include higher flow in winter because of wetter and warmer winters, lower spring freshets because of reduction in snow accumulations, and low summer flows indicating a warmer, drier summer climate. These changes can have potential consequences on ice jamming and floods. However, it is not clear if the recent decrease in stream flow on the Liard River is a long-term climate fluctuation or an early signal of climate change (MRBB 2004). Thorne (2011) used SLURP, a hydrological model, to assess uncertainties in the Liard River discharge based on prescribed climate warming, resulting in 1 to 12 days earlier spring freshet, up to 22% decrease in summer runoff due to enhanced evaporation, and up to 48% increase in autumn flow. They find the magnitude of changes in river discharge to be highly uncertain, ranging from a 3% decrease to a 15% increase in annual runoff due to differences in GCM projections of basin-wide temperature and precipitation.

3.12.4 Limitations

Limited in situ observations in the Arctic lead to significant gaps and limitations in this assessment. Future projections for Mackenzie River discharge volumes and timings are dependent on input parameters from global and regional climate models that do not capture local details well. General tendencies for air temperature and noisy projection output for precipitation will limit the resolution and accuracy of hydrological modeling output.

3.12.5 Summary

GCMs consistently project increasing rates of pan-Arctic river discharge for the 21st century, however the projections of volumes and timings of the discharge characteristics of the Mackenzie River are highly variable, particularly for changes to baseflows which are strongly linked to local changes in permafrost and groundwater infiltration rates. RCP 8.5 scenario model projections for 2020 – 2050 suggest an increase of 16 – 20% in future flow volumes. This is linked to higher certainties surrounding rising temperatures in the river basin, particularly during winter. Projections for precipitation are highly uncertain and may account for some of the uncertainty in river flow projections. Timing of the arrival of the spring freshet will vary by sub-region, however the trend is for an earlier arrival of the spring freshet, an increase in autumn to spring discharge, and a decrease in summer flows, leading to an overall increase in annual discharge. Changes in sediments, nutrients and biota entering from Arctic rivers will affect phytoplankton dynamics in Arctic coastal waters, and organic carbon dynamics of the Arctic Ocean.

3.13 Coastal exposure and erosion

Summaries of coastal erosion in the region are available and much of the following text is borrowed from Ford et al. (2016) and Lantuit et al. (2012). In permafrost regions, coastal erosion is both a mechanical and a thermal process (Aré 1988; Wolfe et al. 1998). Thermal erosion occurs above the mean tide line when higher water levels associated with storm surge and waves thaw the permafrost. It also occurs below the mean tide line when thawed material at the water-sediment interface is removed mechanically by waves, currents or sea-ice scour, and the underlying frozen sediment is then subject to degradation.

Common mechanisms of shoreline retreat are retrogressive sliding and block failure (Figure 3-92). Retrogressive thaw slumping is commonly seen along unlithified coastal slopes and occurs when massive ground ice is exposed by wave action. The ice body thaws quickly, and the headwall retreats backward. Sediment contained within the massive ice or in the overburden accumulates at the base of the slump or forms a mud slurry that flows downslope to the beach and is easily washed away. The back-wasting of the slump headwall continues until the ice body melts completely or enough sediment accumulates at the base that the ice face becomes insulated and protected from further thaw. Continued wave action may later expose the ice once again, initiating a new cycle of retrogressive thaw-slump activity.

Block failure occurs because of the presence of ice wedges that form when the soil contracts and cracks during especially cold winters (Ford et al. 2016). The following spring, surface water trickles into the crack in the permafrost; it then freezes and expands, forming a thin vein of ice. This vein becomes a plane of weakness in the soil, so that any additional cracking tends to occur at the same location. Over time, these veins build up to form wedges of ice that can be several metres wide and high. When waves attack a bluff during storms, they erode a horizontal niche at the base. Once the niche becomes deep enough, the weight of the overlying block of sediment causes it to collapse, generally along the plane of an ice wedge (Walker 1988). The occurrence of block failure is episodic, being a function of storminess, water level and other physical factors (Hoque and Pollard 2009; Barnhart et al. 2014).

NOTE: Note that failure occurs along ice wedges, which outline the tundra polygons
SOURCE: Photos from Ford et al. 2016 and courtesy of N.J. Couture

Figure 3-92 A. Aerial photograph of a retrogressive thaw slump along the Beaufort Sea coast, YK, generated by the thawing of ice-rich sediment. B. erosion by block failure along the Beaufort Sea coast, YK.

3.13.1 Current trends

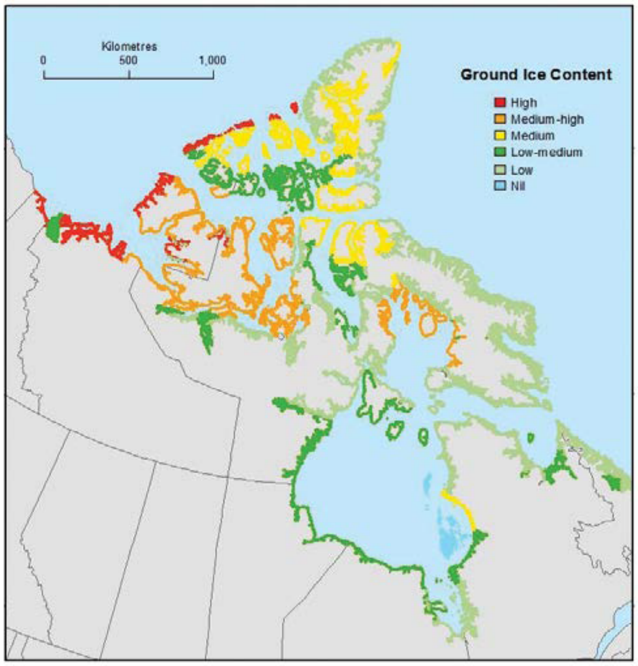
Coastal erosion processes and trends are inextricably linked to the other variables in this report. It is widely written that coastal erosion will generally increase in the Arctic due to increasing coastal wave action, commensurate with longer durations of open water and wave fetch and warming regional air and sea temperatures which thaw coastal permafrost.

Despite common concerns expressed by community residents of increased erosion rates in the western Arctic, including the Yukon and Alaska coast, a regional analysis for the southern Beaufort Sea found no statistically significant increase in the trend in areas of rapid erosion between 1972–2000 (Manson and Solomon 2007). Erosion rates of 1.0 to 2.0 m/year were reasonably consistent over those three decades. Prior to establishing erosion control measures at Tuktoyaktuk, the long-term rates of coastal retreat were on the order of 2 m/year (Solomon 2005) and reached up to 10 m of shoreline loss during a single storm in August 2000. Being the largest coastal community in the BRSEA Study Area, which is slowly relocating landward, Tuktoyaktuk is still the regional centre of much research on this topic (e.g., McClearn 2018).

Higher permafrost temperatures can intensify coastal processes, such as thawing of the shore face (Aré et al. 2008), block failure (Hoque and Pollard 2009) and retrogressive thaw slumping. Increased temperature of permafrost is also generally associated with an increase in the thickness of the active layer, which can, in turn, destabilize coastal infrastructure. Because of this, several northern communities have incorporated research on changing permafrost conditions into their coastal adaptation planning (e.g., Couture et al. 2002; Forbes et al. 2014). Indeed, since the regional analysis published in 2007, some very large and quickly degrading shorelines erosion features have been noted. For example, recent field observations on Pelly Island, NWT reported erosion rates as high as 40 m of shore being lost in 2017. Changes may be observed within a matter of days under particularly intense storms (D. Whalen, pers. comm. and CBC 2017).

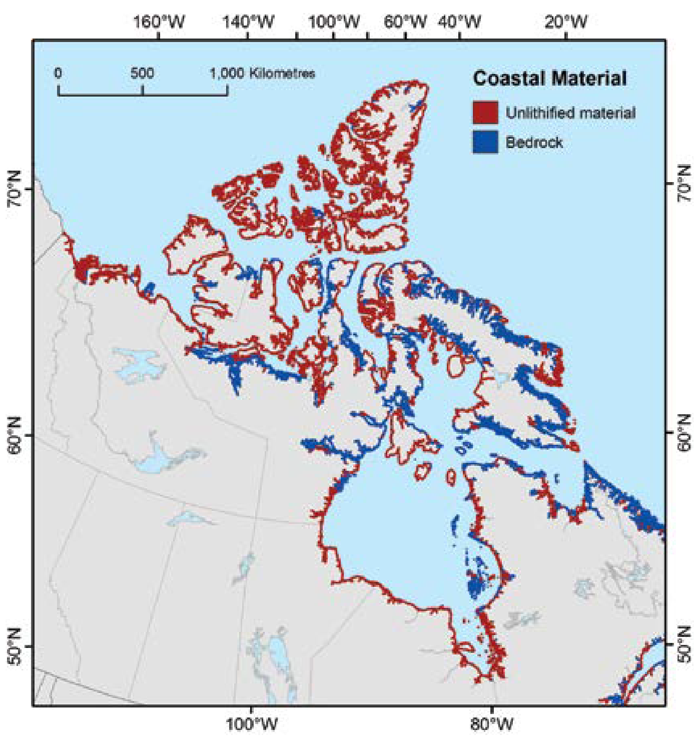
Irrgang (2019) summarizes several findings indicating that on the westernmost side of the Canadian Beaufort Sea region unlithified and ice-bonded coasts are particularly prone to coastal erosion, as is reflected in their high retreat rates. Likewise, Lantuit et al. (2012) found that rates of erosion are particularly large on unlithified coastlines. The spatial distribution of areas with these features are shown in Figure 3-93 and Figure 3-94. On a pan-Arctic scale, Lantuit (2012) indicated that the Beaufort Sea coastline as a whole is characterized by the strongest retreat, with coastal erosion rates exceeding 1.1 m per year, consistent with the regional assessment of Manson and Solomon (2007) at 1 to 2 m per year (Figure 3-95).

In the whole Arctic approach of Lantuit et al. (2012), erosion rates are positively yet poorly ($r^2 = 0.23$) correlated with ground ice content. The poor correlation appears to be explained by the presence of sea ice in some of the study areas, which fronts the shorelines and protects the ground ice rich shores from waves. The height of the shoreface being eroded is also not a good predictor for erosion rate. The very highest shores (>10m) do have lower erosion rates than shores less than 10 m, due to a larger quantity of debris which must be removed. But except for those very high cliffs, as a whole, erosion rates are not linked to backshore elevations (Héquette and Barnes 1990; Lantuit et al. 2012).



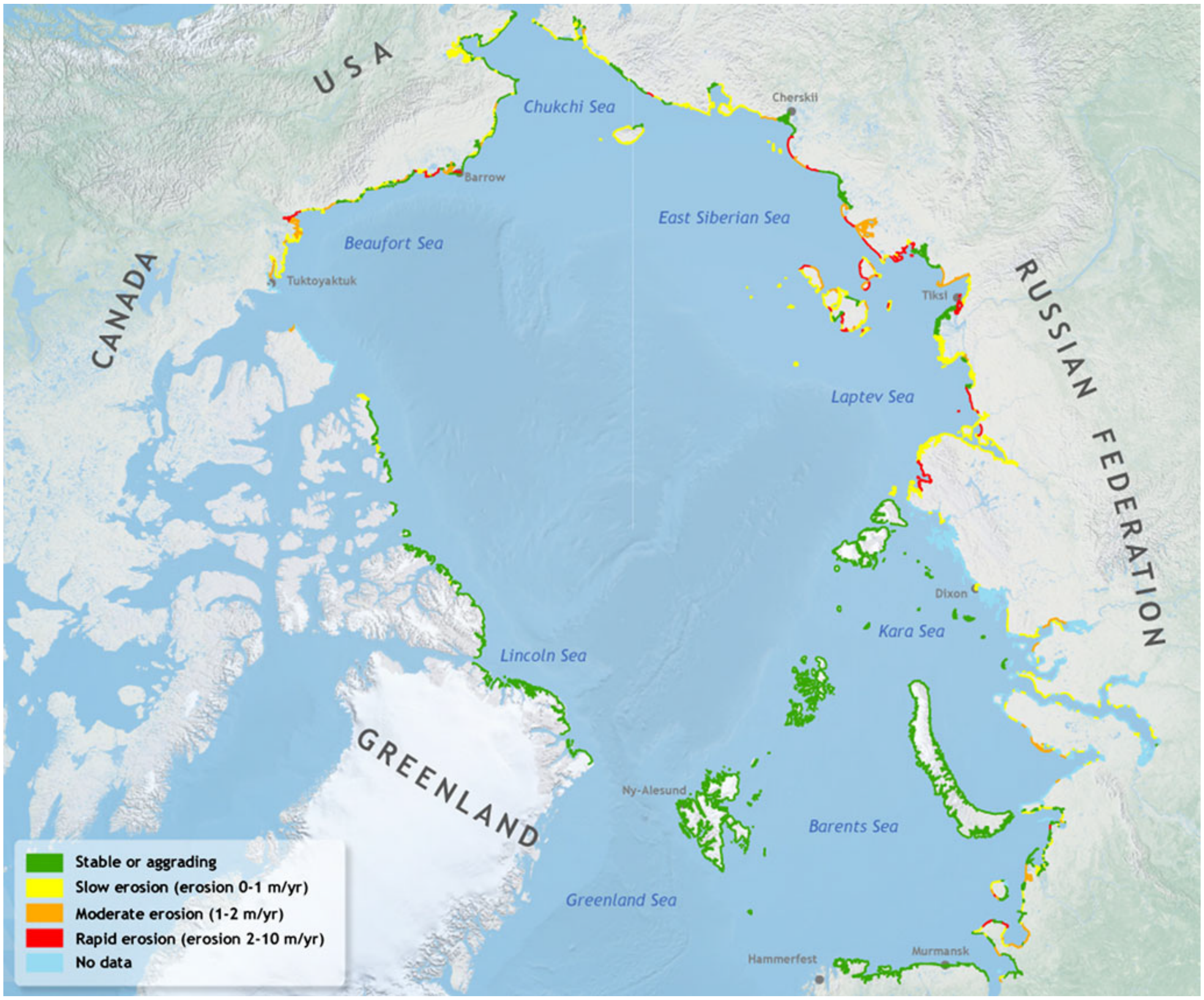
SOURCE: (Couture and Manson 2016), based on data from Natural Resources

Figure 3-93 Ground-ice volumes in the North Coast region



SOURCE: from Couture and Manson 2016

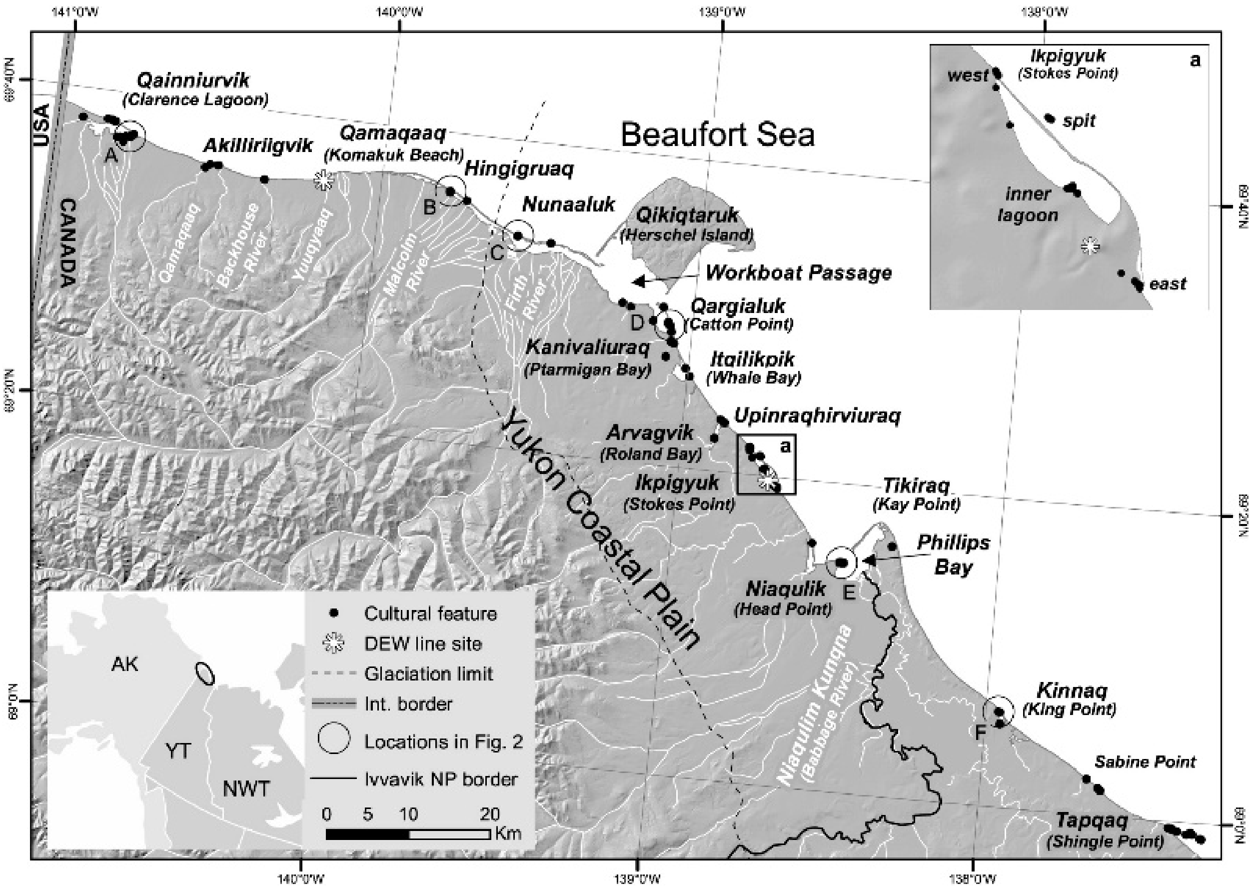
Figure 3-94 Variability of coastal material in the North Coast region



NOTE: The spatial variability in erosion rates generally observed at local scales is also a prominent regional feature.
SOURCE: Lantuit et al. 2012

Figure 3-95 Circum-Arctic map of coastal erosion rates

Two site specific predictive shoreline retreat studies exist within the BRSEA region. The first is west of the delta (Figure 3-96; Irrgang et al. 2019). The second is within that same region, but very specific to Herschel Island (Radosavljevic et al. 2015).



NOTE: Base map: 30 m Yukon digital elevation model, interpolated from the digital 1:50 000 Canadian Topographic Database (Yukon Department of Environment 2016).

SOURCE : from Irrgang et al. 2019

Figure 3-96 Study area of the Yukon coast showing the locations of cultural features and infrastructure

The first study was conducted to determine historical and future erosion from the international border with Alaska, USA, in the west to Tapqaq (Shingle Point) in the east and comprises the 10–40 km wide Yukon Coastal Plain (Irrgang et al. 2018). That study, and references therein, reported that present day coastal erosion can be as high as 9 m per year along the Yukon coast, and coastal erosion and flooding have the potential to put cultural heritage, existing infrastructure, and travel routes at high risk. Many cultural sites along the mainland coast, as well as on Qikiqtaruk (Herschel Island), have been or are about to be eroded. Investigations of the DEW line site at Qamaqaaq (Komakuk Beach) show that the landing strip has been eroding, on average, by approximately 1 m per year since the 1950s.

The second study had the objectives of assessing potential erosion and flood hazards specifically at Herschel Island, a UNESCO World Heritage candidate site. Widespread erosion currently characterizes that study area. The rate of document shoreline movement ranged from -5.5 to -2.7 m per year (mean -0.6 m per year). Mean coastal retreat decreased from -0.6 m per year to -0.5 m per year, for 1952–1970 and 1970–2000, respectively, and increased to -1.3 m per year in the period 2000–2011. Ice-rich coastal sections most exposed to wave attack exhibited the highest rates of coastal retreat.

3.13.2 Predictions

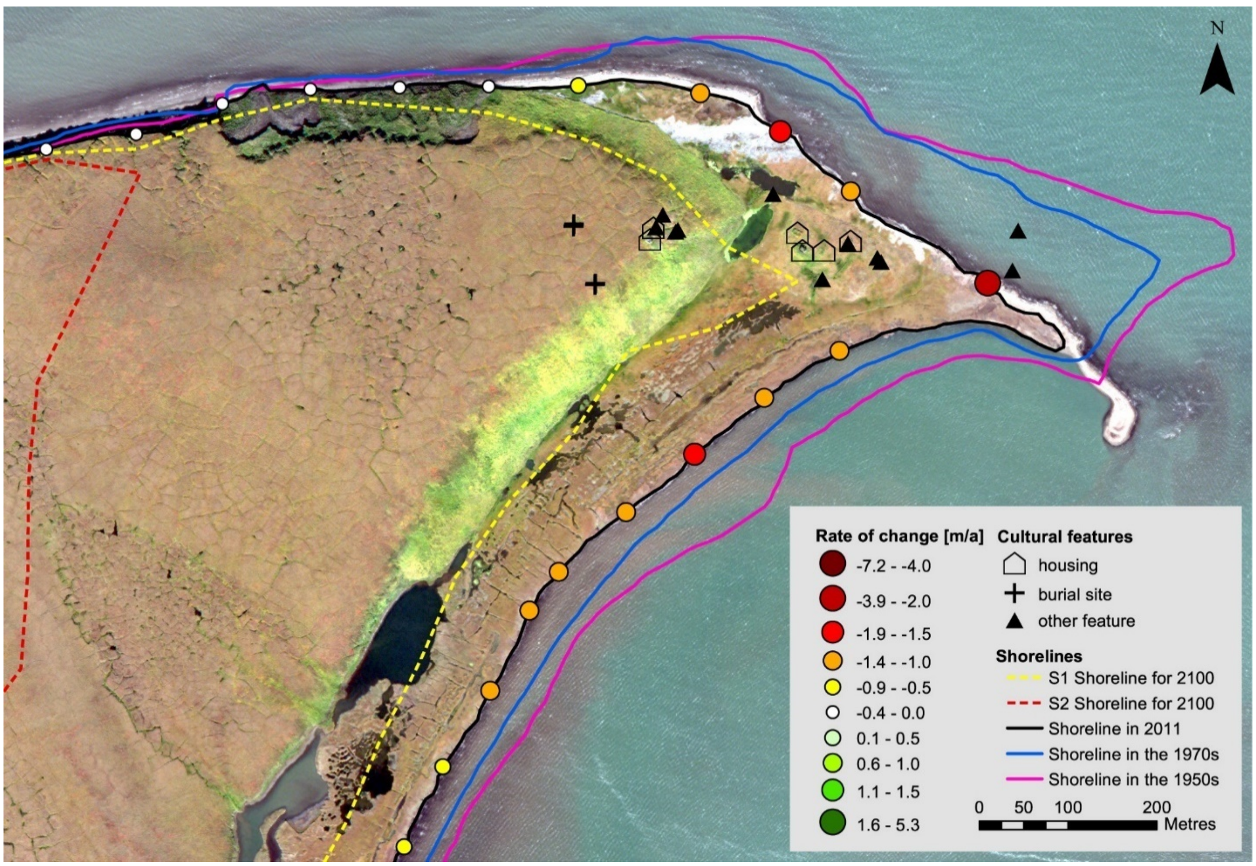
According to Lantuit et al. (2012) and Aré (1988) wave energy is the primary force affecting coastal erosion. Wave size depends on both ice-free fetch length and wind speed, and duration. Northwest of Tuktoyaktuk into the open Beaufort Sea is one of the largest and most energetic fetches in the Inuvialuit Settlement Region, and with continued expansion of the open water extent and duration larger waves, and thus increased erosion, can indeed be expected under future conditions (see also Section 3.9 on waves). The community is aware of this and is presently making plans (and has slowly started) to move inland.

Sometimes sections of coast adjacent to one another can have very different erosion rates due to their angle of exposure to waves. Irrgang (2019), for instance, found that areas sheltered or angled obliquely to the predominant north westerly storms have undergone less coastal erosion, even when immediately adjacent to areas with high erosion rates. The same can be said for areas in more northern latitudes of the region, which have decreased fetches.

As discussed in the section on permafrost (Section 3.11), temperatures and resulting decreasing coastal permafrost will influence rates of erosion in areas particularly susceptible to this type of thermal erosion. The southern portion of the Canadian Beaufort Sea is one of those areas, due to its ground ice rich coasts. Other susceptible areas include the US Beaufort Sea, the US Chukchi Sea, and the Kara Sea (Figure 3-95). In contrast to the more northern islands of the Inuvialuit Settlement Region where permafrost degradation is currently slower, the implication is that the southern coastline of the Inuvialuit Settlement Region (ISR) will be more severely affected as it is exposed to both increasing processes; higher wave energy and quicker degrading permafrost. Given the difference in heat capacity, sea surface temperature, rather than air temperature, which contribute more to erosion.

In the short term, decadal changes to sea-ice extent and duration and to storm intensity in many areas of the Arctic ocean are expected to lead to increased frequency and magnitude of extreme-water-level events and coastal erosion (Ford et al. 2016). With later freeze-up extending the open-water season into the fall storm season when higher waves may occur, the overall probability of a wave event increases. Lintern et al. (2013) conducted hydrodynamic wave modelling to assess this in the region. It was determined that simulated ice retreat of 100 km led to wave heights at the coast being increased by 20 cm. The most substantial sediment erosion occurs at the northern tips of the Mackenzie Delta and the Tuktoyaktuk Peninsula, and around the area of Herschel Island.

The future scenarios considered by Irrgang (2019) for the entire Yukon coast west of the Mackenzie Delta are for erosion rates of 0.7 and 2.2 m per year. The latter results in a future land loss of 30 ha per year and a total loss of approximately 2660 ha between 2011 and 2100, and many cultural heritage sites lost. According to the future shorelines (dotted lines) cultural sites are threatened under both erosion rate scenarios (Figure 3-97). In the first scenario (S1), nine cultural features are expected to be eroded, whereas under the second scenario (S2) all cultural features are expected to be eroded by 2100. Here though, we see the difficulty of not having a digital elevation model as part of the model. On the eastern shore of Niaqulik, the 1950s–2011 EPR is related to the erosion of a low-lying inundating area and is thus comparatively high. These high rates are used in the algorithms to project shoreline retreat to 2100. Yet, this section of coast is backed by a much higher hinterland, so while the cultural sites are undoubtedly at risk, the second scenario probably grossly overestimates the erosion of the shoreline.

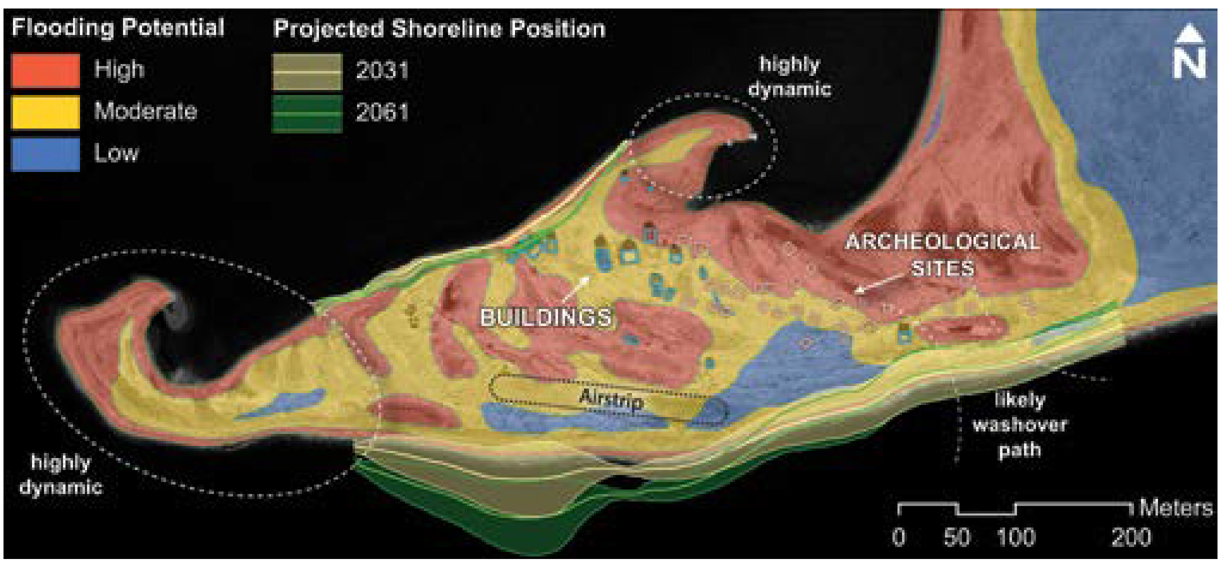


SOURCE: Base image: WorldView-2 scene from August 2011

Figure 3-97 Former settlement of Niaqulik

For the predictive study of Radosavljevic et al. (2015) at Herschel Island, the researchers used linear regression rates obtained from historical data to make projections of shoreline position at 20 and 50 years into the future (Figure 3-98). The projected shoreline positions are shown in the figure. The prediction has recently been tested by Cunliffe (2019) who used a drone to survey the "likely wash over plane" of the figure (Figure 3-99). In just the summer of 2017, the researchers observed coastal retreat of 14.5 m, more than 6 times faster than the long-term average rate of 2.2 m per year (1952–2017). Coastline retreat rates exceeded 1 m per day over a single 4-day period. This is higher than predicted by the linear regression method employed by Radosavljevic et al. (2015), and higher than the long-term average. It is not stated that erosion rates have suddenly increased, rather these findings probably highlight the episodic nature of shoreline change.

The effects of coastal erosion on oil and gas operations relate to onshore infrastructure and areas where offshore pipelines make landfall. Increased rates of erosion can lead to the de-stabilization or loss of infrastructure, or damage to pipelines. Adaptive engineering techniques may be required to protect coastal infrastructure and/or construction of more costly shoreline protection may be necessary.



NOTE: The projected shorelines and potential flooding zones are superimposed on a 2011 satellite image showing the locations of buildings and archeological sites on the spit.

SOURCE : from B. Radosavljevic et al. 2015

Figure 3-98 Coastal geohazard map of the historical settlement on Herschel Island

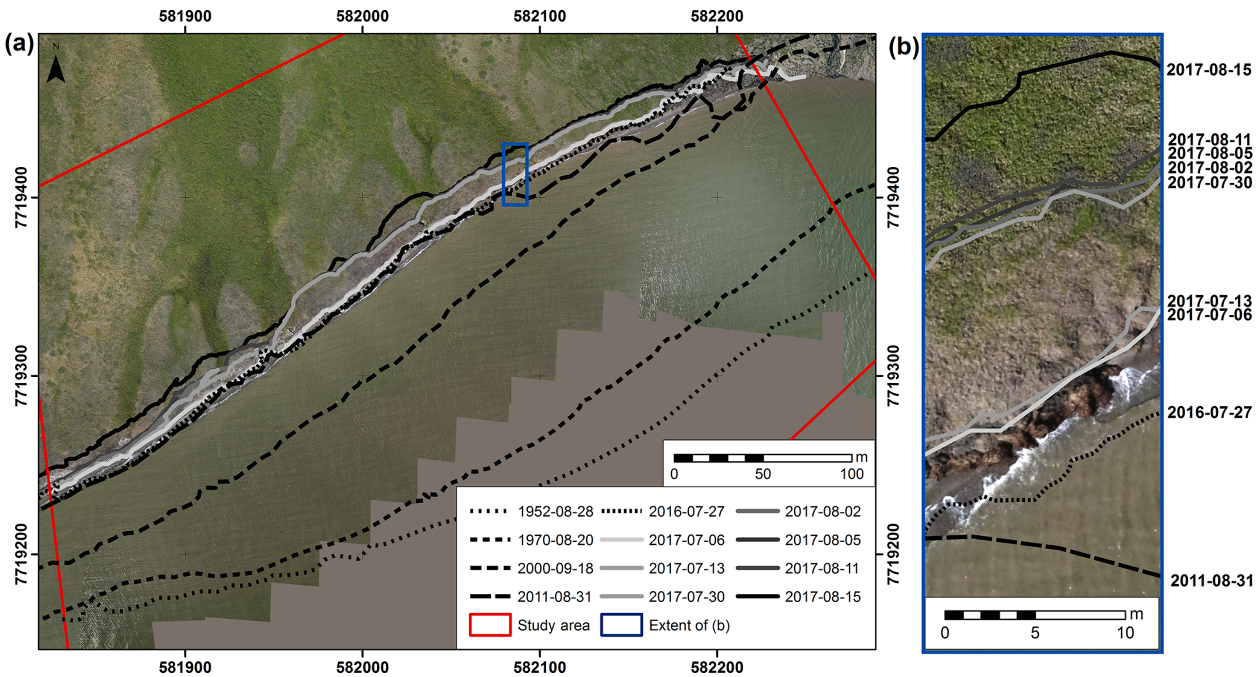


Figure 3-99 a) The location of the study region for the drone survey of Cunliffe et al., 2019. This area is just off the right hands side (east) of Figure 3-98. b) closeup of the area in the blue box of a to better show the changing coastal traces, including the very large erosive event of August 2017.

3.13.3 Uncertainties

Although processes driving coastal erosion are well understood and increased coastal erosion has been observed or is being predicted, exact rates of future erosion are hard to predict due to the episodic (e.g., storm surges) and threshold (permafrost thaw) nature of the causal events. Nevertheless, with some of the large erosion rates seen in recent years (up to 40 m in a year) it can be said that the erosion processes can be huge, are probably episodic, and are very site specific. The regional work of Irrgang (2019) indicates just how sensitive erosion rates are to wave exposure. However, the work also shows that more regionally specific data are required, including better information on elevation of the remaining land.

3.13.4 Limitations

The studies which have measured horizontal erosion of shorelines often lack digital elevation data. By self-admission, they incorrectly use current erosion rates to predict future incision, without regard to the changing inland structure of the terrain. Measurement of wave conditions is limited to only a few of the more accessible areas, and during summer months, rather than the fall months when storms are most fierce. Although they exist separately, no coastal modelling effort within the region has combined the effects of increased ice-free fetch on wave energies, and decreased ground strength due to degraded permafrost.

3.13.5 Summary

Seasonal ice within the coastal areas of the Inuvialuit Settlement Region will recede. Permafrost in the coast sediments are warming. In theory, this means that coastal erosion will increase, since it is mostly caused by storm waves, and secondarily by thawing and either slumping or block failure of coastal sediment. Some very high coastal erosion rates of up to 40 m per year have been observed. It is not clear that long term rates are in fact increasing yet, but it is clear that these large events are episodic and widespread in the region. It is expected that increases in coastal erosion will be mainly in the southern part of the region to begin with, due to the unlithified (non-bedrock) and ice rich nature of those shorelines. Further north, even in unlithified shores, the ground has a smaller percentage of ice to be affected. Due to the sparsity of infrastructure in the area, it is mainly cultural heritage sites that will be affected in the short term.

4 SUMMARY AND CONCLUSIONS

The physical environment in the BRSEA region has been undergoing substantial changes, most of which are predicted to continue over the 30-year time frame investigated for this study. We summarize the main current and projected trends in the table below (Table 4-1), and refer the reader to the individual sections for further detail and information on spatial heterogeneity.

Table 4-1 Summary of Current Trends and Future Projections of Key Physical Attributes

Physical Attribute	Metric	Unit	Current Trend	Future Projection (2020-2050)
Air temperature (means, maxima, variability)	Mean	°C	Annual mean daily temperature of –10.0°C, increasing at a rate of +0.07 °C/year over the past 30 years at Tuktoyaktuk	Expected to increase by 5.2°C by 2050
	Maxima	°C	Annual mean daily maximum temperature of –6.4°C, increasing at a rate of +0.06 °C/year over the past 30 years at Tuktoyaktuk	Expected to increase by 4.7°C by 2050
	Variability	°C	Standard Deviation of 15.3°C at Tuktoyaktuk	Expected to increase but projections on the magnitude of the variability were not available
Precipitation (rain and snow)	Rain	mm/yr	+0.92 mm/year at Tuktoyaktuk	Expected to continue to increase but no projections available as to magnitude. Combined precipitation is projected to increase by +19.2 % by 2050 at Tuktoyaktuk
	Snow	mm/yr	+0.60 mm/year at Tuktoyaktuk	Expected to continue to increase but no projections available as to magnitude. Combined precipitation is projected to increase by +19.2 % by 2050 at Tuktoyaktuk
Frost-free days	Days <0°C	days/yr	67 days/year at Tuktoyaktuk, 38 days/year at Sachs Harbour	+39 frost-free days/year by 2050 at Tuktoyaktuk +49 frost-free days/year by 2050 at Sachs Harbour
Wind (direction, speed, variability, frequency of extreme events)	Direction (mean/median)	degrees	Mean wind direction of 175° and median of 140° (ESE) at Tuktoyaktuk; ESE and WNW at Pelly Island	Limited projections available for wind direction; may be more reversals of the surface wind direction as the climate warms, sea ice thins, and the locations of the maximum Sea Level Pressure (SLP) changes
	Speed (mean/ median)	km/h	Current wind speed at Tuktoyaktuk has a mean of 11.68 km/h, and median of 11.00 km/h. Past mean trends are variable with a slight decrease of -0.12 m/s/decade in recent data	Winds speeds are projected to increase over the next 30 years by a median of 5% to a maximum of 6.5% for the Beaufort Sea region

Table 4-1 Summary of Current Trends and Future Projections of Key Physical Attributes

Physical Attribute	Metric	Unit	Current Trend	Future Projection (2020-2050)
Wind (direction, speed, variability, frequency of extreme events) (cont'd)	Variability		Variability in wind speed is equal to 11.68 ± 11.19 km/h at Tuktoyaktuk Variability in wind direction: 175 ± 105° at Tuktoyaktuk	Complex interactions between climate warming, locations of maximum SLPs, and changes to direction; example: the collapse of the Beaufort High in 2017, with change in direction of surface winds, and this may be more frequent in future
	Frequency of extreme events (>2SD)	Frequency of Change (FOC) – numbers per month	During the Open Water Season of June through October, the current mean storm frequency for the Beaufort Sea region ranges from 3.1 (June) to 4.5 (October) storms per month	Projected change in storm track density per month per unit area is -0.9 to 0.9 for the Beaufort Sea region for the 2080s, but were not identified for the 2050s
Sea level rise (including frequency and severity of storm surges)	Mean sea level rise (at Tuktoyaktuk, NWT)	mm yr-	+1.9 ± (2.0)	+300mm ± 200mm mean increase by 2050
	Frequency of Storm Surges >1.5m at Tuktoyaktuk	Exceedance Probability (0 – 1.0)	0.39	Increased likelihood
	Frequency of Storm Surges >2m at Tuktoyaktuk	Exceedance Probability (0 – 1.0)	0.04	Increased likelihood
Ocean temperature and heat content (including inferences on bottom temperature)	Near-Bottom Temperatures	˚C	None	Expected to increase marginally, but this is very uncertain
	Summer Mixed Layer Temperature	˚C	-0.03 ˚C/year	Uncertain as this recent trend likely due to changes in the freshwater distribution.
	Summer Sea Surface Temperature (SST)	˚C	>0.05 ˚C /yr in the Southern Beaufort -0.03 ˚C /yr south of Banks Island	Mean SST of 3-4 ˚C 50%-70% of SST observations in excess of the 1976-2005 maxima.

Table 4-1 Summary of Current Trends and Future Projections of Key Physical Attributes

Physical Attribute	Metric	Unit	Current Trend	Future Projection (2020-2050)
Sea ice (extent, thickness, type, timing, including landfast ice)	Ice Thickness	m	Decreasing as multi-year ice transitions to first year ice; Largest reductions are in deep offshore waters of Canada Basin; reduction rate only 0.1 m/decade on slope and shelf	If current trend continues, ice thickness reduction of 0.3 m by 2050 from present values on continental slope and shelf, with larger reductions in the much deeper water of the Canada Basin
	Timing of Ice Freeze-up	weeks	Large inter-annual variability, statistically later by 0.15 weeks/yr in most areas; change larger at 0.2 weeks/year off Banks Island	Current trend expected to continue, 2050 freeze-up in coastal areas may be delayed by 4.5 weeks from present conditions
	Timing of Break-up	weeks	Large inter-annual variability, with no significant trend in most areas, except Amundsen Mouth at 0.2 weeks/yr	Possibility of earlier break-up, but magnitude is uncertain.
	Open Water Duration	weeks	Increasing by 0.15 – 0.20 weeks/yr except no significant trend in Amundsen	Current trend expected to continue; increased open water duration of 4.5 to 6 weeks from present conditions; 50 to >60% chance of ice-free conditions in late summer and early fall by 2050
	Ice Motion	cm/s	Winter mean ice speeds on shelf have increased from 2 to 5 cm/s in last 35 years	Expected to continue to increase but no projections available as to magnitude
	Landfast Ice Duration	days	Reductions of 2-3 days/yr, varying according to sub-region	Expected to continue to increase at or near present levels resulting in reductions of 60-90 days from present conditions
Glacial ice (ice islands and Icebergs)	Numbers of Marine Glacial Ice features	Numbers	Increasing due to ablation of glacial ice in the Canadian Arctic Archipelago and northern Greenland	No projections are available but increases expected to continue through to 2050

Table 4-1 Summary of Current Trends and Future Projections of Key Physical Attributes

Physical Attribute	Metric	Unit	Current Trend	Future Projection (2020-2050)
Waves (height, direction, speed, variability, frequency of extreme events)	Duration of the Open Water Wave Season	days	Increasing due to increased duration of open water	Highly certain that increases would continue through to 2050 and beyond
	Mean Significant Wave Height (H_S)	M	Increasing by 3 – 8% from 1970-2013	Increases of 0.5 – 1.5 m in years 2046-2065 relative to 1980-1999.
	Mean Direction	Degrees clockwise from North	Increased occurrence of easterly winds and waves relative to westerly winds and waves	No projections available for 2050 period, but models for later periods suggest north-easterly waves (45 degrees) would be dominant
	Peak Period (T_P)	S	Increasing as winds and waves increase	Projected to increase to 6-7 s by 2081-2100
Currents and water column structure (physical and chemical)	Near-Bottom Salinity	Practical Salinity Unit (PSU)	None	Uncertain
	Summer Mixed Layer Salinity	PSU	-0.04 PSU/yr	Uncertain – salinification of up to 1.5 PSU in the regional model, freshening of < 1 PSU in the global model.
	Summer Mixed Layer Depth	M	0.11 m/yr (when ice-free)	Increases by 3-8 m
	pH and Alkalinity	pH/ Saturation Level	Fastest rate of acidification in Canada	Increased acidity and under saturation (<1) of carbonate expected
	Dissolved Oxygen	T_{mol}	-73 T_{mol}/decade (mean vertically integrated value)	Continued decrease, but the models have had poor skill with this parameter.
Permafrost conditions	Extent of permafrost	Degrees North	Continuous permafrost in Mackenzie Valley 67.5 degrees N, advancing at average of 3 km N per year Subsea permafrost northern extent decreasing -2 km N over the past 10000 years	Predictions for RPC8.5 indicate faster northern encroachment of discontinuous permafrost, possibly up to 9 km per year average, which would mean to the Beaufort coast before 2050. Subsea permafrost northern extent moving shoreward < 0.1 km by 2050.

Table 4-1 Summary of Current Trends and Future Projections of Key Physical Attributes

Physical Attribute	Metric	Unit	Current Trend	Future Projection (2020-2050)
Permafrost conditions (cont'd)	Permafrost temperature	ºC	Variable, generally increasing at 0.9 ºC per decade in south and faster in north	Increasing trend expected. As permafrost temperatures approach 0ºC, permafrost is no longer viable.
	Active layer thickness (m)	M	Variable	For few RPC 8.5 projections available present day = 0.54 m, 2050 = 0.6 m, 2080 = 0.73 m
Freshwater runoff from Mackenzie River (timing, volume and water quality)	Mean discharge	m^3/sec	10,000	11,800 ± 1600 (10-20% increase over baseline)
	Maximum discharge	m^3/sec	22,000	25960 ± 2000 (10-20% increase over baseline)
	Sediment discharge	kg/sec	1715	1870 (<10% increase over baseline)
	Freshet Timing	days / decade	+2.7	7 – 28 days earlier
	Month of maximum river volumes	Month	June	May (by 2050)
	Water quality (NO_3)	mmol/m^3	N/A	−2.3 ± 1
Coastal exposure and erosion	Erosion	m/year	1-2 m per year average in Mackenzie Delta area, up to 40 m/year reported in extreme cases (e.g., Pelly Island) Average 1.2 m/year on Herschel Island. Up to 9 m per year along Yukon Coast	Coastal exposure and erosion were not variables considered in the RPC8.5 climate models; as a result, there are no projections for coastal exposure from those sources. However, at current average rates coastal retreat would be 30-60 m by 2050 at susceptible locations and hundred of metres or more at particularly exposed locations.

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APPENDIX D

Detailed Assessment of Potential Environmental Effects to the Biophysical and Human Environment

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D.1 Introduction

D.1.1 Background

This Appendix is the detailed assessment of environmental effects that might occur as a result of human activities and industrial operations in the BRSEA Study Area[1]. Environmental effects include both potential adverse effects and benefits for a VC. In assessing potential environmental effects on the biophysical and human environment, Traditional and Local Knowledge (TLK) and western science were used as equal knowledge systems to support valid, verified and reliable observations about environmental conditions, trends, potential outcomes and mitigation.

The detailed assessment in this Appendix is the basis for the summary of environmental effects in Chapter 8 and supports discussion of findings, gaps and needs for future management, research and monitoring in Chapter 9. Chapter 8 is intended to provide a summary of the predicted environmental effects for each of the physical, biological and human VCs for the BRSEA that could result from human activities associated with the Status Quo, differing intensities of offshore oil and gas development (Scenarios 2 through 4) and a large oil release event (Scenario 5). Chapter 8 describes (1) how environmental effects may differ as a result of development intensity and (2) types of environmental effects that are likely to arise from specific groups of activities in marine areas and coastal zones. It also summarizes potential environmental effects of a large oil release. Cumulative effects and effects on climate change are discussed at a high level.

This Appendix provides detailed descriptions and justifications for the assessment of environmental effects for each VC relative to:

- scoping, including identification of indicators, spatial and temporal boundaries, and characterization terms for potential residual effects
- pathways through which adverse effects or positive benefits may occur
- potential residual environmental effects on the VC (i.e., adverse effects and benefits), based on TLK (where available for a VC), western science and past environmental assessments, including adverse effects and benefits associated with each of the five scenarios
- approaches to management and mitigation of effects for each VC, including reduction of adverse effects and improvements in positive benefits
- characterization of residual environmental effects for the VC for each scenario
- cumulative effects associated with the Status Quo Scenario, as well as the Status Quo Scenario in combination with each of the three oil and gas scenarios separately
- potential effects of climate change on the VC and potential effects pathways, residual effects and cumulative effects on each VC for that scenario

[1] References for TLK and cited literature are located in Chapter 10.

- information and data gaps that should be addressed to better understand potential adverse effects and benefits on the VC
- recommendations for monitoring and follow-up

The assessment in this Appendix is organized around three major components and associated VCs for these components in the following order:

- Physical Environment
- Biological Environment
- Human Environment

Potential adverse effects and benefits are described and assessed for each VC. Adverse effects are typically associated with impacts to the physical and biological environment and some aspects of the human environment (e.g., strains on infrastructure, public health concerns, changes in traditional use, and cultural vitality). Benefits largely occur through positive changes in the local and regional economy, increased employment and wage income, associated benefits to the region's demographics; some aspects of traditional harvesting and cultural vitality; development of new infrastructure, and improvements in public health and services.

D.1.2 Use of Traditional Knowledge in the Effects Assessment

TLK was used in the assessment of potential effects as a knowledge system equal to western science to aid in the understanding of effect pathways, the characterization of effects, approaches to mitigate and manage adverse effects, and methods to monitor changes through follow-up programs such as Environmental Effects Monitoring (EEM) programs. TLK also was used to describe the spatial and temporal scope of effects based on observations and direct experience with industrial activities and other infrastructure developments spanning decades (e.g., oil and gas development began in the ISR during the late 1950s).

When used together, TLK and western science provided strong insight on past and potential future environmental effects on the Inuvialuit and biophysical environment within the BRSEA Study Area. Accordingly, these two knowledge systems are cited together throughout this chapter to support and justify the assessment of environmental effects.

For the physical environment, TLK was especially useful in describing effects associated with different human activities, industrial uses and oil and gas development; for example:

- how vessel movements and ice breaking can affect ice conditions during the Fall Transition and the Spring Transition seasons, including the formation of leads and open areas, ice stability, and refreezing of the ice following disturbances
- identifying areas susceptible to coastal modification and erosion
- predicting effects of emissions or discharges from industrial activities on air and water quality
- describing impacts of sea states, wind, ice, precipitation and fog on the conduct of certain development activities (e.g., vessel movements, aircraft operations, overwintering of equipment)

For the biological environment, TLK was used to identify and characterize effects of oil and gas activities and other human activities on marine biota, including:

- behavioural responses of marine and anadromous fish, seals, walrus, whales, polar bear, caribou and other wildlife to human disturbances, including vessel traffic, aircraft overflights, presence and operation of offshore platforms
- use of habitat by different species or wildlife groups, including changes in seasonal use of habitat, local and regional movements, and seasonal migrations
- shifts in the local or regional abundance of marine species
- reductions or losses of some species or the introduction of new species
- changes in animal health and mortality as a result of exposure to discharges or oil spills

For the human environment, TLK provides information on how human and industrial activities can affect traditional uses, cultural vitality, and socio-economic conditions; for example:

- interference with use of sites by the Inuvialuit for traditional harvesting, seasonal or permanent camps, and/or cultural purposes
- changes in the timing and use of travel routes between Inuvialuit communities and traditional uses sites (and between traditional use sites) as a direct result of human activities (e.g., ice breaking and effects on travel and fish harvesting)
- changes in the location of traditional harvesting areas, timing of the harvest or the harvesting methods as a result of anticipated or actual industrial uses or human activities and associated effects on harvested species
- effects of employment and the wage economy on the ability of Inuvialuit to participate in traditional harvesting and cultural activities, as well as longer-term effects on inter-generational transmission of language, culture and other traditional practices to young people
- effects of these changes on food security and the economic health of Inuvialuit communities
- identification of conservation areas (including protected areas) and management or exclusion of certain industrial and human activities within these areas, including guidelines on appropriate activities and practices (e.g., the creation of the Beluga Whale Management Zones to reduce interference of vessels and aircraft with use of the Mackenzie River estuary by beluga whales and associated harvesting activities of the Inuvialuit)

Inuvialuit TLK also provided an understanding on how climate change has combined and may combine with effects of human and industrial activities to modify traditional uses and cultural vitality. TLK was used to identify and corroborate mitigation measures to reduce adverse effects and promote beneficial effects to the biophysical or human environment, as well as approaches to monitor the extent of effects and the effectiveness of mitigation measures through follow-up programs.

Additional information on the use of TLK in the preparation of the Data Synthesis and Assessment Report is provided in Chapter 5. Additional information on the sources of TLK are provided in Appendix B.

D.1.3 Scope of the Assessment and Limitations

The assessment of potential adverse effects and benefits on the VCs for the five scenarios is based on hypothetical examples of different types and combinations of human and industrial activities and infrastructure and the potential effects of specific activities and infrastructure in these hypothetical scenarios on the VCs.

As discussed earlier (Section 3.1), the scenarios were deliberately developed to each include different types of infrastructure, human and industrial activities and geographic locations (within the BRSEA Study Area). ***The scenarios are not predictions of actual future projects or proposed projects; rather, they are intended to provide a framework to explore and evaluate plausible development futures within the BRSEA Study Area***, with the intention of supporting the IRC and CIRNAC in developing future policy, legislation, regulations, management processes and information needs for the BRSEA Study Area (Section 3.1).

To facilitate the consideration of these plausible futures, the hypothetical scenarios are qualitative in detail, space and time. While some quantification of volumes and intensities of activities is provided, these are general in nature. As discussed below, the scenarios are not spatially- or temporally-explicit.

Activities and infrastructure in each scenario could occur in several locations within the BRSEA Study Area; the scenarios are not based on a specific footprint in a specific location. To provide wide geographic coverage in the assessment, the scenarios covered a range of locations relative to the coastline of the ISR, with different water depths and locations relative to the continental shelf and slope; specifically:

- ***Scenario 1 Status Quo*** includes a number of activities that are already occurring in the BRSEA Study Area (e.g., use of snowmobiles and small motorized vessels, local aircraft movements and larger aircraft overflights, community resupply by large vessels, current cruise tourism vessels, and transits by large vessels) or might occur in the future in nearshore areas (e.g., (e.g., offshore GBS wind turbines) and moderate to very deep water over the continental shelf and slope and Arctic basin (increased international shipping and cruise tourism vessels).
- ***Scenario 2 Export of Natural Gas and Condensate*** considers development ad operation of a GBS platform for export of natural gas within 15-20 km offshore, a subsea pipeline from shore to the GBS platform, and year-round movement of LNG carriers to and from the west (e.g., past the Alaskan Beaufort Sea).
- ***Scenario 3 Oil Development in Mid-Water*** considers development of a subsea oil field and oil production from an offshore platform in a location on the continental shelf ~80 km offshore with year-round movements of oil tankers to and from the west.

- ***Scenario 4 Oil Development in Deep Water*** considers seismic exploration followed by development of a deep-water oil field, subsea pipeline infrastructure and an offshore platform for oil production and storage that is located on the continental slope ~100 km or greater offshore. Oil tankers would move year-round to and from the west, as well as to and from the east during the Open water season.
- ***Scenario 5 A Large Oil Release Event*** considered potential consequences of a hypothetical surface oil release within the plume of the Mackenzie River (i.e., nearshore), as well as a hypothetical surface or subsea release outside the plume (i.e., moderate to very deep water over the continental shelf and slope).

The scenarios were assumed to occur over a thirty-year period from 2020-2050. While the likely seasonal timing and potential duration of specific activities and infrastructure development are described for each scenario (e.g., timing and sequence of specific activities, installation of infrastructure), the timing of events is generalized (in contrast, timing of activities would be better defined for a project-specific assessment). Temporal aspects are explored according to generalized ice- and ice-free seasons (i.e., Spring Transition, Open Water, Fall Transition and Ice seasons) rather then calendar months.

Given the lack of spatial and temporal details, and the general descriptions of the intensities and volume of specific activities and processes, the strategic environmental assessment of potential and residual environmental effects on VCs focuses on identification and descriptions of effect pathways and general characterization of potential and residual effects. The assessment is not intended to be quantitative, nor would such an assessment be appropriate given the scope of the Data Synthesis and Assessment Report or the intent of the BRSEA (see second paragraph this section).

Cumulative effects that might occur as a result of different human and industrial activities in Scenarios 1 through 4 are also discussed and, where possible, qualified using the effects characterization terms. For Scenario 1 (Status Quo), only activities within that scenario were considered in the cumulative effects assessment. For the three oil and gas development scenarios (Scenarios 2 through 4), the assessment of cumulative effects includes effects of activities within the specific development scenario, in combination with the activities in Scenario 1 since it was assumed that ongoing human and other non-oil and gas activities would be occurring at the same time as the specific hydrocarbon development in the scenario. The assessment did not include cumulative effects of multiple simultaneous development scenarios (e.g., cumulative effects of Scenario 2 and 4); such an analysis was beyond the financial and temporal scope of this report. As described earlier in this report, cumulative effects of a large oil release event (Scenario 5) were not assessed because an accidental release it is not a routine activity (see Section 4.1.7 for additional detail)

Once the residual effects of routine activities and cumulative effects on a VC had been determined, the effect that climate change (as described in Sections 3.5, 4.1, and Chapter 6) might have on the VC and on the potential residual effects on that VC under each scenario were described, taking into account how climate change might influence or change the VC, as well as how effect pathways and the characteristics of potential environmental and residual effects on a VC might change.

D.2 Physical Environment

D.2.1 Atmospheric Environment

D.2.1.1 Scoping

D.2.1.1.1 IDENTIFICATION OF INDICATORS

The assessment of potential effects on Atmospheric Environment focuses on four main indicators: air quality, greenhouse gases, in-air noise, and light. These indicators have been included in the assessment for the following reasons:

- emissions to the atmosphere may present a pathway for humans and biota to be exposed to air contaminants
- releases of greenhouse gases (GHGs) and their accumulation in the atmosphere influence global climate and may affect emission reduction targets for GHGs that have been set (e.g., federal standards; some provincial standards, GNWT) or that might be developed (e.g., Yukon or Nunavut)
- there are provisions regarding maximum quantities for air contaminants, greenhouse gases and noise levels under the federal regulation
- there are Health Canada guidelines for air quality and in-air noise and the potential related environmental effects on community health
- artificial lighting is critical to the safe and efficient operation of specific activities in a community or at a facility and can cause sensory disturbance to marine wildlife.

D.2.1.1.2 SPATIAL BOUNDARIES

The effects on Air Quality and Greenhouse Gases are directly related to the release of air contaminants and GHGs to the atmosphere associated with the combustion of fossil fuels (mainly diesel fuel, gasoline, flaring of produced gas. The effects occur near to or from activities on marine supply vessels, icebreakers, or offshore structures, loading facilities and production facilities. Air contaminants that are released disperse and concentrations decrease with distance, generally reaching ambient onshore limits ~ 0.5 – 1.5 km from the source of emissions and dispersing to background levels within 30-40 km from the source of emission (Stantec 2013b).

For the assessment of air quality, the spatial boundary is formed by the area containing the main sources of emissions and the distances associated with the dispersion of exhaust gases related to those sources.[2] The activities that are sources of emissions for each scenario are described in Chapter 5. Some sources are stationary (e.g., GBS or FPSO) and are referred to as point sources. Others are related to

[2] Some of the spatial boundaries for the physical environment are based on specific zones of influence around a specific source. In contrast, spatial boundaries for biological VCs tend to be more general in nature due to variation in abundance and seasonal distributions relative to activities and project components that do not have specific spatial locations or temporal boundaries.

transportation, such as marine vessels, or helicopters, and are referred to as mobile sources. As such, the spatial boundaries for air quality include the 30-40 km radius of large point sources and a zone on each side of the shipping lane(s) of approximately 2.5 km, to conservatively capture the potential effects of the emissions of air contaminants on air quality (Stantec 2013b).

For the assessment of GHGs, the spatial boundaries are global (i.e., the area under the global atmosphere), as the release of GHGs contributes to the global quantities of GHGs being released, and thus contributes globally to climate change. The potential effects may be felt globally; however, it is unlikely that the effects from specific activities in the BRSEA Study Area would be measurable or noticeable at a global scale. Furthermore, it is accepted that the contribution of an individual development project's emissions to climate change cannot be measured (CEA Agency 2003). The influence of GHGs on climate change, and related federal policy guidance are discussed more in Section D.2.2.

The change in sound pressure level of in-air noise for most sources decreases rapidly with distance from the source. The noise level typically decreases to background levels within approximately 2-5 km from the source (Keith 2005). Many of the sources of noise are associated with activities related to marine vessels (e.g., commercial shipping, cruise ships, re-supply), helicopters and low flying aircraft and are, therefore, mobile. The spatial boundaries for in-air noise were defined as a 10 x 10 km area around the main stationary noise sources and a 2 km zone on each side of the shipping lane(s) to capture the potential effects of in-air noise from marine vessels. (Keith 2005).

Light levels associated with marine shipping and marine oil and gas activities typically decrease with distance from the source and attenuate to background within ~ 2 km from the source. Vertically oriented or reflected light can also add to skyglow in the region, which is manifested by a 'washing out" of the night sky or a decrease in a person's ability to see stars or other celestial bodies. The spatial boundary for lighting was defined as 2 km in all directions from the light sources, and the entire ISR for skyglow.

D.2.1.1.3 Temporal Boundaries

The temporal limit of the assessment is from 2020 to 2050. Although the effects of GHGs on climate change would continue past 2050, only effects during the 2020-2050 period are considered in the assessment.

D.2.1.1.4 Assessment of Potential Effects

A qualitative characterization of potential residual effects on Atmospheric Environment (air quality, greenhouse gases, in-air noise, and light) for each scenario is based on the characterization of terms as defined in Table D-1.

Table D-1 Characterization of Residual Environmental Effects on Atmospheric Environment for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Positive**—a decrease in the quantities of air contaminants or GHGs released to the atmosphere, a decrease in noise emitted to the atmosphere, and a decrease in obtrusive lighting or lighting that causes sky glow **Adverse**—an increase in the quantities of air contaminants or GHGs released to the atmosphere, an increase in noise emitted to the atmosphere, and an increase in obtrusive lighting or lighting that increases skyglow **Neutral**—no net change in the quantities of air contaminants or GHGs released to the atmosphere, in noise emitted or in obtrusive lighting or lighting that causes skyglow
Magnitude	The amount of change in measurable parameters in the Atmospheric Environment relative to existing conditions	**Negligible**—no measurable change in emissions, noise or lighting **Low**—a measurable change but it likely to be considerably less than regulated ambient values **Moderate**—measurable change likely to be close to but less than regulated ambient values **High**—measurable change that is likely to exceed regulated ambient values
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the local area **Regional**—residual effects extend into the regional area **Extra-regional**—residual effects extend beyond the regional area
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Negligible**—Single event of release, emission, noise, light causing skyglow **Low**—Multiple irregular event (no set schedule) **Medium**—Multiple regular event—continuous release of air contaminants, noise, lighting **Continuous**—residual effect occurs continuously
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to events where effects on air quality, noise, lighting occur that last up to an hour, or 24 hours; this depends on regulated ambient values **Medium-term**—residual effect extends past hourly or 24-hour events **Long-term**—residual effect extends past 24-hour events, or through a season (e.g., the Ice Season) **Permanent**—concentrations of air contaminants or GHGs, noise levels, or lighting levels unlikely to recover to existing conditions
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.2.1.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

Air contaminants or GHG emissions are primarily related to the combustion of petroleum fuels, and have the potential to degrade air quality and contribute cumulatively to GHGs in the atmosphere. Human activities, stationary or mobile, also produce in-air noise or increase artificial light that can be a nuisance or disturbance for people and/or wildlife.

Potential impacts and associated environmental effects on the Atmospheric Environment are summarized in Table D-2. Although activities and associated impacts are similar across the scenarios, the potential effects of each scenario are discussed independently to reflect variations in timing, spatial extent, or geographic location(s) that are associated with scenario.

POTENTIAL EFFECTS OF AIR CONTAMINANTS AND GREENHOUSE GAS EMISSIONS

Activities associated with each Scenario would release air contaminants and GHGs to the atmosphere and may cause potential effects to air quality, whereby ambient air quality standards at onshore receptor locations could be exceeded.

Although the quantities of GHG gases from oil and gas development and other industrial activities in the BRSEA Study Area are unlikely to be noticeable at a global scale, these releases would contribute cumulatively to those present in the atmosphere now and would contribute to climate change. The emission rates from these activities would vary with the types, extent and duration of activities, and the petroleum fuel and other hydrocarbons consumed in each activity. Activities that would generate emissions include:

- marine vessels associated with commercial shipping, cruise ship tourism and ship-based re-supply to coastal communities
- regional boat and snowmobile traffic
- bathymetric and seismic surveys
- drilling of wells (e.g., exploration, delineation, production) and movement of drill ships
- various activities for field development and production including subsea installations, towing and operation of offshore platform, and transits by, and operation of gravity-based structures (GBS) and floating and production storage and offloading vessels (FPSO)
- marine vessels for re-supply of offshore projects (e.g., annual sea lifts, regular resupply from supply bases)
- helicopters and low flying aircraft
- transits by tankers into and out of the region

The quantities of fuel required for each of the activities are not fully known and site-specific emission data are not available for the oil and gas activities as described in the Scenarios. However, there is some information available for the total historical emissions from the region (e.g., National Pollutant Release Inventory (NPRI) and the National Inventory Reports for GHGs). Information from similar past projects off the coast of Newfoundland and Labrador suggests that a large fraction of petroleum is consumed in the generation of electrical power to drive the equipment on the drilling and production facilities.

Table D-2 Summary of Potential Impacts and Effects on Atmospheric Environment

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Air Contaminant and GHG Emissions	• vessel transits • seismic surveys (2D, 3D, 4D) • drilling • operational and maintenance activities for vessels, production platform, and wells • helicopters, low flying aircraft, and snowmobiles	• combustion of petroleum fuels leading to air contaminants and GHGs being released to the atmosphere	• increases in air contaminant concentrations leading to degradation in air quality and an additional contribution of GHGs to the atmosphere.	• concentrations of air contaminants, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), particulate matter of 2.5 microns (µm) in diameter or less ($PM_{2.5}$), particulate matter of 10 (µm) in diameter or less (PM_{10}), volatile organic compounds (VOCs), (µg/m^3); • GHG emission rates CO_2, CH_4 (methane), and N_2O (nitrous oxide) (e.g., tonnes CO_2e/year)
In-air Noise	• vessel transits (engine, propeller, and ice-breaking activities) • seismic surveys (2D, 3D, 4D) • drilling • operational and maintenance activities for vessels, production platform, and wells • helicopters, low flying aircraft, and snowmobiles	• combustion activities and associated engine noise, leading to noise emissions to the atmosphere	• increases in sound pressure levels increasing annoyance or increasing likelihood of human sleep disturbance and sensory disturbance of biological VCs	• daytime/nighttime Sound Pressure Level (dBA)
Artificial Light	• lighting used on nearshore infrastructure (wind energy turbines, marine infrastructure), offshore platforms and vessels	• artificial lighting emissions from security/navigation	• loss of cultural/aesthetic value (sky glow); human sleep disturbance (light spill), and sensory disturbance of biological VCs	• light levels trespass (lux); glare (candela or cd); sky glow (mag/arcsec^2)

Table D-2 Summary of Potential Impacts and Effects on Atmospheric Environment

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Oil Spill	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• evaporation and combustion of petroleum fuels leading to air contaminants and GHGs emitted into the atmosphere	• increases in air contaminant concentrations leading to degradation of air quality and an additional contribution of GHGs to atmosphere.	• concentrations of air contaminants, NO_2, SO_2, CO, $PM_{2.5}$, PM_{10}, VOCs, (e.g., $\mu g/m^3$) • GHG emission rates CO_2, CH_4, and N_2O. (e.g., tonnes CO_2e/year)

As noted in Section 2.12.1, the routine activities described in the Status Quo and the three oil and gas development scenarios would result in the release of various air contaminants of concern including:

- sulphur dioxide (SO_2)
- nitrogen oxides (NO_X)
- carbon monoxide (CO)
- particulate matter with different particle sizes (10 micron or PM_{10}, and 2.5 micron or $PM_{2.5}$)
- volatile organic compounds (VOCs)

Routine activities would also result in the release of greenhouse gases (GHGs) including:

- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)

The emission rates are commonly expressed as tonnes per year (t/y) and concentrations are commonly expressed as micrograms per cubic metre ($\mu g/m^3$) or parts per billion (ppb). For greenhouse gases, each gas is combined with the global warming potential (GWP) to estimate the total units of carbon dioxide equivalent or CO_2e.

For oil and gas activities, the air contaminant and greenhouse gas emissions would be generated via the following activities:

- power generation is typically supplied by turbine generators, burning either diesel fuel or fuel gas. The primary emissions from the combustion of diesel or produced gas include those noted above,
- typical emissions from the operation of marine vessel and helicopter engines include those noted above

For some oil and gas development scenarios (e.g., Scenarios 3 and 4), a flare system is an essential component of the pressure relief and safety system for a wellhead. Emissions during flaring include the air contaminants and GHGs noted above. In addition, a small amount of fuel gas would be continuously used for flare pilots during the operation of the well head platform; however, the associated air and GHG emissions would be minimal compared to other operational sources.

Blowdown events are expected to be rare (blowdowns involve venting of gas accumulated in equipment, process facilities, oil production wells, etc.). If they occur, the emissions from the blowdown events are expected to similar to those described for flaring, be short in duration, and disperse rapidly with distance from the source, to well below ambient air quality standards at onshore receptor locations.

Activities in Scenario 1 include renewable energy (one offshore wind platform), and the establishment of Conservation and Protected areas. The quantities of fuel or other energy needed for those activities is expected to be very small compared to other activities noted above. Therefore, the associated air and GHG emissions would be minimal compared to other operational sources, and effects are expected to be negligible.

Regarding climate and greenhouse gases, the 2016 Pan-Canadian (Canada, Territories, Provinces) Framework committed to reduce GHG emissions by 30 percent below 2005 levels by 2030 as part of the Paris Agreement. In June 2017, the House of Commons reconfirmed Canada's commitment to the Paris Agreement.

Earlier in 2019 the GNWT released the 2030 Climate Change Strategic Framework and the 2030 Climate Change Strategic Framework Action Plan. Goal #1 is to "Transition to a strong, healthy economy that uses less fossil fuel, thereby reducing greenhouse gas emissions by 30% below 2005 levels by 2030." (GNWT 2019b)

As a result, the GHG implications of offshore oil and gas development in the region should be considered on a project-specific basis taking into account carbon leakage and the potential for Beaufort petroleum products to displace higher GHG energy sources both domestically and internationally.

Closely related to these decisions, recent draft guidance from the federal government has become available for the strategic assessment of climate change that applies to federal impact assessments. The draft guidance explains how to consider GHG emissions of a designated project in light of addressing public policy beyond the scope of a single project (Government of Canada 2019b). The focus of this draft guidance is on the quantification of GHG emissions and upstream emissions, best available technologies, and climate change resilience. The requirement is to establish whether a designated project would hinder or contribute to meeting Canada's commitments to reduce GHG emissions by 30% below 2005 levels by 2030, and to help to achieve a low carbon economy by 2050.

This assessment considers this guidance by comparing approximate GHG emissions from each scenario to the federal targets, and the current regional targets (e.g., GNWT). Since this is a strategic assessment (and not for a specific project), the upstream emissions and best available technologies are not assessed here.

For those activities with more substantial fuel consumption, as described above, the releases of air contaminants and GHGs have the potential to cause local effects on sensitive receptors and contribute to climate change. These are considered further in the detailed assessment.

Potential Effects of In-Air Noise

In the offshore marine environment, natural sounds are generated by winds, waves, precipitation, sea ice movement, and wildlife. Strong north winds are relatively common in the BRSEA Study Area so noise from wind gusts is also common.

During community consultation, concerns about the potential for anthropogenic noise effects on the marine ecosystem were identified. (OCCP 2016: 40). Effects may be caused by noise transmitted through the air or underwater. For this assessment, the potential effects of in-air or airborne noise sources are considered for ongoing human activities in the local communities, offshore wind, shipping and from the offshore oil and gas activities. Underwater noise is considered for seabirds and marine mammals (Sections D.3.3 and D.3.5).

Anthropogenic activities that currently generate noise in the region are mainly related to marine traffic snowmobiles, motorboats, low flying aircraft, non-industrial machinery, and rifle-fire (AMAP 2017). Human created noise levels are expected to change as the Open Water Season becomes longer, thus enabling more marine traffic to travel through the region.

In-air noise generated by oil and gas activities includes:

- power generation and other activities onboard the GBS and FPSO
- marine vessel traffic during oil and gas life cycle phases
- aerial support (i.e., helicopters) used to support crew transfer to and from seismic vessels, drilling platforms and production platforms
- ice breaking
- maintenance activities

Although the noise associated with the activities under the different scenarios is likely to dissipate quickly with distance (about 2-5 km), they could result in local effects on sensitive receptors.

Potential Effects of Artificial Lighting

Artificial light supports safety and navigation requirements at night for residential and commercial activities, as well as for travel associated with hunting, fishing or trapping (e.g., snowmobiles, motorboats). Lighting is also needed for activities such as regional marine vessel traffic, commercial shipping, cruise ships, and low-level aircraft, including helicopters. Light emissions associated with offshore oil and gas activities include:

- operation of offshore structures, power generation facilities and production vessels
- vessels for drilling, resupply, ice breaking, and transport of oil and gas out of the region
- operation of helicopters and other low flying aircraft
- flaring
- maintenance activities (i.e., welding)

The nature of exploration and production activities demands that operations occur 24 hours per day, seven days per week, which means that lighting is required during dark periods for safety reasons. These safety-oriented lighting fixtures are designed to radiate light in all directions, which can contribute to light trespass, glare, or sky glow in the case of upward directed light. This includes interior and exterior lighting along walkways, stairways, ladders, towers, and process units on offshore platforms and vessels. Additional lighting is also installed near critical process equipment such as valve trains, pumps, and vessels. As an example, the operation of an offshore structure could have up to 200 luminaires, each with 150 watts of electrical power. Lighting may also be used on nearshore infrastructure (wind energy turbines, marine infrastructure) to illuminate the work areas, pathways, stairs, helicopter landing areas and vessel docking areas. Although lighting may be used throughout the day and year-round, artificial lighting impacts are only anticipated from mid-August to the end of April (outside the polar summer).

The flares can also be a source of lighting. The strength of the light would depend on the quantities and rates of petroleum product flared.

Similar to noise, glare and trespass from artificial lighting will quickly decrease with distance from the source. These impacts are not likely to extend past 5 km and are expected to be localized (Narisada and Schreuder 2004). Beyond 2 - 3 km, changes in skyglow are likely to be local and extend to the horizon near the source. These impacts could cause local effects on sensitive receptors and are considered in the assessment.

D.2.1.2 Scenario 1: Status Quo

D.2.1.2.1 Potential Effects of Routine Activities

Description of Effect Pathways

The release of air contaminants, GHGs, noise, and light from marine vessel traffic (commercial shipping, cruise ships, re-supply to the communities in the ISR, regional boat traffic), low flying aircraft, snowmobiles, and wind energy turbines have the potential to cause adverse effects in the atmosphere within the BRSEA Study Area. In general, marine vessel traffic is expected to increase during 2020 to 2050 as ice cover decreases in the north, but traffic volumes are expected to be small. Most of the increased vessel traffic would be due to increasing commercial shipping, cruise ships, military, and coast guard sailings. Air contaminant, GHG, noise, and light emissions would generally be proportional to the amount of marine vessel traffic occurring. While improving fuel standards for vessels may help reduce air contaminant emissions (Azzara and Rutherford 2015), GHG emissions are likely to increase. Emissions from low flying aircraft and snowmobiles are expected to be negligible.

Description of Range of Potential Effects

Air contaminant emissions would occur from combustion activities associated with marine vessel traffic. For marine vessel traffic, levels and types of air contaminant emissions also depend on the vessel type, size and activity (e.g., e.g., piloting into harbour, at port, or sailing on open water). The air contaminant emissions are typically highest during piloting and sailing; however, the duration of potential exposure from these emissions is on the order of a few hours or less.

The ambient concentrations of air contaminants from marine vessel traffic are highest closest to the source and dissipate as they move away from the source. Since these emission sources are moving, they affect a particular area for a short period of time as the vessels pass through to their destination.

The GHG emissions would increase in proportion to the quantities of petroleum fuels burned. As various activities in the Status Quo scenario that require fuel combustion increase, emissions contributing to the existing concentration of GHGs in the atmosphere would also increase.

Noise emissions would occur from the operation of marine vessels, and during loading/unloading or material handling at marine terminals, and the occasional foghorn calling. Wind turbines also emit noise during operation. Noise emissions are highest at the source and dissipate with distance away from the source. While the magnitude of noise emissions depends very much on the activity, most noise emissions from transportation and wind power activities are expected to be below the ambient background levels beyond about 2 kilometres.

Marine vessels and other transportation activities would increase ambient light levels in the area through safety and navigation requirements. Wind turbines also have safety lighting for navigation and aircraft safety. Glare and light trespass are typically negligible within 5 kilometres of the source. Sky glow effects may be present near the horizon close to the source but are not expected to change sky brightness for most of the night sky.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Climate change is expected to lead to an increase in vessel traffic as ice coverage decreases in the BRSEA Study Area and, through more petroleum fuel being burned in the ISR, have a relatively small indirect effect on air contaminants, GHGs, noise, and light emissions.

D.2.1.2.2 MITIGATION AND MANAGEMENT

The following mitigation measures can help reduce air contaminant, GHG, noise, and light emissions from marine vessel and other transportation activities:

- consult with Canadian Coast Guard to discuss limiting ship traffic during periods of ice cover (November to June). These consultations should include the Community Conservation Plan Working Group, the Hunters and Trappers Committee, and the Inuvialuit Game Council." (OCCP 2016: 42)
- follow stringent fuel standards to reduce air and GHG emissions from vessels
- reduce idling or unnecessary engine operation to reduce air and noise emissions
- recommend vessel routes that increase the distances between vessel and receptors to reduce exposure to air, noise, and light emissions
- prioritize lighting used for navigation and safety to reduce light emissions

Additional details are provided in Appendix F.

D.2.1.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Increases in air contaminant, GHG, noise, and light emissions are expected with increases in vessel traffic and other transportation activities in the BRSEA Study Area. However, these increases are mostly associated with vessel traffic and would be transient as vessels sail by or pilot into and out of dock. Air contaminant concentrations have been found to increase only slightly in Arctic communities due to marine vessel traffic (Aliabadi et al. 2014). Greenhouse gas emissions would increase but their contribution to global GHG emissions would be negligible. Noise emissions would be transient and would likely be above background levels only during piloting into dock. Light emissions are expected to be of low magnitude, restricted largely to safety and navigation, be short in duration and occur largely outside of the Open Water Season.

While effects on the atmospheric environment are expected to be adverse, potential effects are predicted to be negligible and limited to areas adjacent to the activities. Potential effects are expected to be multiple irregular events of short-term duration and reversible in nature. Given that increases in marine vessel traffic are tied to changes in sea ice coverage, the prediction and characterization of residual effects is made with high confidence.

CUMULATIVE EFFECTS

Given the low residual effects on the atmospheric environment associated with Scenario 1 and the dispersed nature of most activities, it is unlikely that cumulative effects from concurrent activities in the region would result in cumulative effects on air quality, acoustics, or light. The cumulative GHG emissions would also be negligible compared to national or global emissions, but the release of even small quantities would work against Canada's ability to meet their commitments through the Paris Accord.

D.2.1.3 Scenario 2: Export of Natural Gas and Condensates

D.2.1.3.1 POTENTIAL EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAYS

Increases in air contaminants, GHGs, noise, and light emissions would occur from installation and operation of a gravity-based structure (GBS) for loading/unloading, pipeline construction, LNG carrier traffic, helicopter activity transporting people and goods to the platform, increased ice-breaking and support vessel activity. Emissions associated with the installation of the pipelines and equipment are anticipated to be higher during the Open Water Season and emissions from operations are expected to occur year-round. Decommissioning is not anticipated to add new effects pathways. The majority of emissions are expected to be generated by marine vessel activity and the GBS. Other transportation activities are expected to be of short duration with emissions that are very localized to the source.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Atmospheric emissions from vessels associated with natural gas export facility would be similar to those described for vessels in Scenario 1 and largely occur 15-20 km offshore. This would include year-round activity by LNG carriers, vessels for maintenance (e.g., ice breakers), helicopters and GBS supply. Increases in air contaminant and GHG emissions would occur through fuel combustion activities and some pumping activities to bring the natural gas to the export terminal. While air contaminant and GHG emissions are expected to increase due to increasing marine vessel and aircraft activities, the air contaminant emissions are expected to be localized to the sources of emissions. Marine vessel and most aircraft traffic are expected on a weekly basis throughout most of the year; as a result, the air contaminant and GHG emissions would be relatively infrequent and low in magnitude.

Increased noise emissions would occur from marine vessel and aircraft traffic similar to Scenario 1. Noise effects would be localized to the source of emissions. Marine vessel traffic for most vessel types and most aircraft are expected to occur on a weekly basis, and be infrequent.

Light emissions would occur through navigation and safety equipment for the GBS and vessel operations. Light emissions would be highest closest to the source. Effects are expected to be similar to Scenario 1; that is, negligible beyond 5 kilometres of the GBS and marine vessels.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

As the climate changes, the Open Water Season is expected to get longer, as noted in Chapter 3. While reduced ice cover may allow more frequent marine vessel traffic (e.g., ship re-supply of the natural gas GBS), it also could require less icebreaking activity. These changes are expected to be small, thus the effects of climate change on the potential effects characterized in this scenario are expected to be negligible.

D.2.1.3.2 MITIGATION AND MANAGEMENT

In additional to applicable mitigation provided in Scenario 1, mitigation for Scenario 2 would include the use of efficient technologies and processes for the installation and operation of the GBS and pipeline(s).

D.2.1.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Based on emissions from similar export facilities and the anticipated throughput of LNG per year in Scenario 2, the LNG export facility would be a relatively large source of air contaminants, GHG and noise emissions in the BRSEA Study Area. For example, GHG emissions related to LNG export activities scaled to the LNG throughput of Scenario 2 are shown in Table D-3, and compared to GHG emissions in the northern jurisdictions in 2017. The GHG emissions from hypothetical export activities as described for Scenario 2 would be equivalent to approximately half of total annual emissions from the Yukon (as reported in 2015) or about 10% of annual emissions from the Northwest Territories. Despite this potential regional increase in GHG emissions, the contribution to national and global GHG emissions would be negligible. Air contaminant emissions from LNG export-related activities are not expected to lead to exceedances of applicable air quality standards beyond 0.5-1.5 km and would disperse to below background concentrations within approximately 10 km.

Table D-3 Comparison of GHG Emissions in Yukon, Northwest Territories, and Canada to Potential GHG Emissions from LNG Export Activities

Estimated Annual Emissions from LNG Export Activities (t CO2e)[1]	Annual GHG Emissions in Yukon in 2017 (t CO2e)	Annual GHG Emissions in Northwest Territories in 2017 (t CO2e)	Annual GHG Emissions in Canada in 2017 (t CO2e)	% Increase in GHG Emissions in Yukon	% Increase in GHG Emissions in Northwest Territories	% Increase in GHG Emissions in Canada
121,000	234,140	1,412,890	757,759,757	51.7	8.6	0.02

NOTE:
[1] Government of Canada 2017.

Noise emissions would also occur during loading activities. The distance between the GBS and coastal receptors is expected to mitigate exposure to noise during project operations, although some noise from this facility and vessel traffic associated with the export terminal may, on occasion, reach the coast.

Light emissions associated with the GBS would be limited to navigational and safety lighting. Artificial nighttime light levels for marine terminals are normally below applicable guideline levels for light spill beyond 500 m and are barely perceptible to people at a distance of about 5 km.

While effects on the atmospheric environment are expected to be adverse, potential effects are predicted to be negligible and limited to areas adjacent to the activities. The prediction and characterization of residual effects is made with medium confidence due to the availability of information on emissions and residual effects for similar projects.

CUMULATIVE EFFECTS

Given the low residual effects on atmospheric environment associated with Scenario 2, it is unlikely that concurrent activities associated with Status Quo activities outlined in Scenario 1 would result in substantial cumulative effects for air quality, GHGs, acoustics, or light. Most activities for Scenario 1 and Scenario 2 are similar and are expected to occur on a weekly or bi-weekly basis, which is relatively infrequent when compared to applicable guidelines and exposure criteria for air contaminants, noise, and light. The exposure levels are localized near the sources and are expected to dissipate well below applicable guidelines or standards for air quality, noise, and light. While GHG emissions from a single project are negligible compared to global emissions, they do contribute to global emissions, which are responsible for causing accelerated climate change. The anticipated increase in GHG emissions from Scenarios 1 and 2 may also affect Canada’s ability to meet the Paris Agreement emission reduction targets; however, these emissions are anticipated to be less than 0.1% of national emissions.

D.2.1.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.2.1.4.1 POTENTIAL EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAYS

Scenario 3 includes year-round air, noise and light emissions due to activities associated with the development, operation and decommissioning of a GBS for oil production located approximately 80 km offshore. This includes operation of a wareship next to the GBS, year-round marine vessel traffic consisting of supply vessels, tankers, and ice-breakers, and other transportation activities such as helicopter flights. There also would be some emissions during installation and decommissioning.

Air contaminant and GHG emissions would occur year-round through fuel combustion and flaring during drilling and production. Noise and light emissions would also occur during production and processing on board the GBS.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Air contaminant emissions would increase relative to Scenario 2 due to production activities on board the GBS, including diesel generators for powering various drilling and production facilities on board the GBS and wareship, and some flaring. Marine vessel traffic is expected to be similar to Scenario 2 so emissions from marine traffic are expected to be similar in duration and magnitude to Scenario 2. While the total air contaminant and GHG emissions from the both the GBS and marine traffic activities for Scenario 3 could be 50% higher than Scenario 2, they are expected to occur much farther out to sea (~80 km) and, therefore, are very likely to dissipate to below background concentration levels well before reaching the shoreline.

The potential effects of airborne noise from Scenario 3 are expected to be low because of the distance (i.e., 80 km) to sensitive receptors on or over the water (or ice). Studies of similar GBS structures in the BRSEA Study Area have measured SPLs of 62 dBA at 300 m from the facility; however, the SPLs diminished to typical background SPLs beyond one kilometre (Blackwell and Greene 2005). The marine vessel traffic (e.g., tankers, ice breakers, supply ships) is expected to be similar in frequency and magnitude to Scenario 2 and, therefore, is expected to lead to similar noise emissions, only farther out at sea for the majority of the transits.

Light emissions would occur to fulfill navigation and safety requirements for the GBS, wareship, icebreakers and tanker vessel operations, similar to Scenario 2. While lights would be noticeable close to the vessels, wareship and GBS, it is expected that a similar decrease in light levels anticipated for Scenario 2 would occur in Scenario 3. In addition, the GBS, wareship and marine vessel traffic would be much farther out at sea and are not expected to be noticeable along the coast.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

As the climate changes, the Open Water Season is expected to get longer, as noted in Chapter 3. This is likely to increase marine vessel traffic related to local ship re-supply of the wareship and GBS (e.g., 1 additional trip per year), and slightly less icebreaking activity. These changes are expected to be small, and thus the effects of climate change on the potential effects characterized in this scenario are expected to be negligible.

D.2.1.4.2 MITIGATION AND MANAGEMENT

In additional to applicable mitigation provided in Scenario 1, mitigation for Scenario 3 would include the use of efficient technologies and processes for the installation and operation of the oil production GBS and operation of the wareship.

D.2.1.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Noise, air contaminant and GHG emissions are mostly associated with power generation on board the GBS for oil production, with some additional emissions from the wareship, marine vessel traffic, use of icebreakers, fugitive emissions from leaks, and flaring. While emissions are higher than Scenario 2, the majority of the activities leading to increased emissions are far offshore. Effects on air quality, sound, and light from activities on the GBS and wareship are therefore expected to be very low. Effects from marine vessel traffic are expected to be low and infrequent, similar to the effects identified in Scenarios 1 and 2.

The GHG emissions are expected to be higher than for Scenario 2 (Table D-4) but would still represent a negligible change in national GHG emissions. Nonetheless, they present an increase in GHG emissions in the Yukon (82.9% increase over current levels) and a smaller increase in the NWT (13.7%). These changes, while small, may affect Canada's ability to meet it's commitments contained in the Paris Agreement.

Table D-4 Comparison of GHG Emissions in Yukon, Northwest Territories and Canada to Potential GHG Emissions from LNG Export Activities

Estimated Annual Emissions from LNG Export Activities (t CO2e)[1]	Annual GHG Emissions in Yukon in 2017 (t CO2e)	Annual GHG Emissions in Northwest Territories in 2017 (t CO2e)	Annual GHG Emissions in Canada in 2017 (t CO2e)	% Increase in GHG Emissions in Yukon	% Increase in GHG Emissions in Northwest Territories	% Increase in GHG Emissions in Canada
194,000	234,140	1,412,890	757,759,757	82.9	13.7	0.03
NOTE: [1] Government of Canada 2017.						

Light emissions associated with the GBS for oil production and the wareship would be largely associated with navigational and safety lighting. Light emissions from marine vessels and other activities would be similar in magnitude compared to Scenario 2. Light levels are expected to remain near baseline levels within about a kilometre of the GBS and wareship, and less for other emissions from marine vessel activities.

While effects on the atmospheric environment are expected to be adverse and year-round, potential effects are predicted to be negligible to low, and limited to areas adjacent to the activities. The prediction and characterization of residual effects is made with medium confidence due to availability of emissions and residual effects information for similar projects.

CUMULATIVE EFFECTS

Given the low residual effects on the atmospheric environment associated with Scenario 3, it is unlikely that Scenario 1 and Scenario 3 activities would result in noticeable cumulative effects on air quality, acoustics, or light. Marine vessel activities for Scenario 1 and 3 are similar and are expected to occur on a weekly or bi-weekly basis, which is relatively infrequent, and are not expected to cause exceedances of applicable guidelines or exposure criteria for air contaminants, noise, and light. Emissions from the GBS structure are not expected to overlap substantially with emissions from marine vessel traffic. The exposure levels are localized near the sources and are expected to dissipate well below applicable guidelines or criteria related to air quality, noise, and light.

While GHG emissions from a single project are negligible compared to global emissions, they do contribute to global emissions which are responsible for causing climate change. These emissions may also affect Canada's ability to meet the Paris Agreement emission reduction targets, although these emissions would be small (< 0.1%) of national emissions.

D.2.1.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.2.1.5.1 POTENTIAL EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAYS

The effects pathways for Scenario 4 are expected to be similar to Scenario 3. The production technology changes from a GBS to an FPSO, and would include more air contaminant, GHG, and noise emissions than Scenario 3 due to higher oil production rates and slightly higher marine vessel traffic. The FPSO and wareship are located further out to sea (i.e., 100 km or more) than the GBS in Scenario 3 (80 km offshore). Due to the low frequency of marine vessel and other transportation activities, there is not anticipated to be a large change in the maximum predicted exposure to these emissions. Light and in-air noise emissions are expected to be similar to Scenario 3.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Air contaminant and GHG emissions from the FPSO, wareship and drill ships are mostly associated with diesel generators for powering various drilling and production facilities, with some additional emissions from marine vessel traffic and other transportation activities. Air contaminant and GHG emissions from the FPSO are expected to increase relative to emissions from the GBS in Scenarios 2 and 3 in proportion to the increase in production of about 20-30%.

Noise emissions would mostly be associated with power generation, icebreaking and other marine traffic. Navigation and safety equipment for the FPSO, wareship, tankers, and other marine vessels would generate light emissions. Noise and light emissions are expected to be slightly increased relative to Scenario 3 due to the larger footprint of the oil development and slightly higher volumes of marine vessel traffic.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

As the climate changes, the Open Water Season is expected to get longer, as noted in Chapter 3. This is likely to increase the marine vessel traffic related to exploration or delineation drilling, and ship re-supply of the FPSO, wareship or drill ships (e.g., 1 additional trip per year), and slightly less icebreaking activity. These changes are expected to be small, and thus there are no substantive climate change-related changes to the potential effects characterized in this scenario.

D.2.1.5.2 MITIGATION AND MANAGEMENT

In additional to applicable mitigation provided in Scenario 1, mitigation for Scenario 4 would include the use of efficient technologies and processes for the installation and operation of the oil production FPSO.

D.2.1.5.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Air contaminant and noise emissions are mostly associated with power generation on board the FPSO and wareship, and the drill ships for oil production. Marine vessel operation, fugitive emissions from leaks, and flaring are other potential sources of air contaminants and noise. While emissions would be expected to be higher for Scenario 4 than the other scenarios, the majority of activities are 100 km or more offshore, and so the effects on air quality and noise from the offshore oil facility are expected to be local to the FPSO, wareship and related activities, and low for coastal receptors.

The GHG emissions from oil production are expected to be about 290,000 tonnes per year, about 20-30% higher than those relative to Scenario 3, in proportion to the increase in oil production (Table D-5). These would represent an increase from current emission levels of 123.9% in the Yukon and 20.5% in NWT. While these are large for the Yukon and less so for the NWT, the GHG emissions for a development such as described in Scenario 4 would be <0.1% of the national emission levels. These changes, while small, may affect Canada's ability to meet the commitments contained in the Paris Agreement.

Table D-5 Comparison of GHG Emissions in Yukon, Northwest Territories and Canada to Potential GHG Emissions from LNG Export

Estimated Annual Emissions from LNG Export Activities (t CO2e)[1]	Annual GHG Emissions in Yukon in 2017 (t CO2e)	Annual GHG Emissions in Northwest Territories in 2017 (t CO2e)	Annual GHG Emissions in Canada in 2017 (t CO2e)	% Increase in GHG Emissions in Yukon	% Increase in GHG Emissions in Northwest Territories	% Increase in GHG Emissions in Canada
290,000	234,140	1,412,890	757,759,757	123.9	20.5	0.04
NOTE: [1] Government of Canada 2017.						

Light emissions associated with the FPSO for oil production would be limited to navigational and safety lighting. Light trespass from light emissions are typically negligible within 5 kilometres of the FPSO and even closer for marine vessels.

While effects on the atmospheric environment are expected to be adverse and year-round, potential effects are predicted to be negligible and limited to areas adjacent to the activities. The prediction and characterization of residual effects is made with medium confidence due to the availability of emissions and residual effects information for similar projects.

CUMULATIVE EFFECTS

Given the low residual effects on atmospheric environment associated with Scenario 1 and Scenario 4, it is unlikely that concurrent activities in the region would result in substantive cumulative effects on air quality, acoustics, or light.

Many of the marine vessel activities for Scenario 1 and 4 are similar and are expected to occur on a weekly or bi-weekly basis, which is relatively infrequent, and are not expected to cause exceedances of applicable guidelines or exposure criteria for air contaminants, noise, and light. Emissions from the FPSO structure and wareship are not expected to overlap substantially with emissions from marine vessel traffic. The exposure levels are localized near the sources and are expected to dissipate well below applicable guidelines or criteria related to air quality, noise, and light.

While GHG emissions from a single project are negligible compared to global emissions, they do contribute to global emissions which are responsible for causing climate change. These emissions may also affect Canada's ability to meet the Paris Agreement emission reduction targets, though the GHG emissions are expected to be a small fraction (< 0.1%) of Canada's total emissions.

D.2.1.6 Scenario 5: Large Oil Release Event

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on air quality from such an event would differ slightly from what is described below for surface or subsea releases.

D.2.1.6.1 ASSESSMENT OF EFFECTS

DESCRIPTION OF EFFECT PATHWAY

An oil spill would lead to air contaminant and GHG emissions through the evaporation of petroleum compounds and activities associated with spill response (e.g., controlled burning). Additional noise and lighting emissions would also occur from marine vessel activity during response and cleanup.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The primary pathway for the generation of air contaminants during an oil spill is through evaporation of volatile organic compounds (VOCs) present in the pool of spreading oil and combustion emissions from the marine vessels and associated activities that are needed to respond to the spill. Air contaminant and GHG emissions would be generated from fuel combustion by the vessels and air traffic responding to the spill. Air contaminants may also be released during cleanup activities such as controlled burns.

The rate of evaporation from the spilled oil to the atmosphere would depend on the size of the spill and the spreading velocity, as well as the temperatures of the oil, the air above the spill, and the ocean water. The largest evaporation is likely to occur near during the Open Water Season because this is the warmest season and the rate of spreading is likely to be the greatest. During the Open Water Season, the surface water temperature may reach 10-11°C and evaporation would increase leading to higher ambient concentrations of VOCs in the atmosphere. These higher concentrations would occur near the spill area and decrease with downwind distance from the spill.

The winds during the Open Water and Fall Transition seasons are stronger and would help disperse air contaminants. It is noted that stronger, warmer winds can also drive higher wave heights and produce an increase in the vaporization rate of VOCs as well as dispersion into the water column. The former could lead to higher ambient concentrations in the atmosphere, while the latter would help to reduce ambient concentrations in the air. As noted, in Section 2.13.5, as much as 30% of the volume of spilled oil can be lost within a few days to a week by evaporation and natural dispersion, even in cold environments. A well-managed response and cleanup also would help to reduce the volume of oil available to evaporate into the atmosphere, although in-situ burning of released oil would add certain contaminants of concern (see below). With the exception of oil in ice, atmospheric effects of large oil release events (and higher concentrations of contaminants) are expected to be short term (i.e., days to weeks) and in the immediate area of the oil on the surface during the late Spring Transition, Open Water and early Fall Transition seasons. Oil in ice might be contained for the ice period and would be released during ice melt. Effects on the atmospheric environment would be delayed but would be similar to effects described for a release during the Open Water Season.

Part of the spill response may involve a controlled burn of the spilled oil. Some air contaminants and GHGs would be released in the event of controlled burning during clean up. Controlled burns are short term events where the spilled oil is boomed or herded into a small area and ignited. The emissions are largely combustion gases and smoke made up of partially burned hydrocarbons. The events are generally planned to take advantage of weather conditions including wind direction, lower wind speeds and lower sea states, which would reduce exposures of humans and biota to these emissions.

Noise and light emissions are also expected to occur from marine vessel traffic involved in containing and cleaning up the oil spill.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Climate change may have a small effect on the propagation of the oil spill in the water and a small increase in evaporation through an increase in water temperature. Projections of higher average winds suggest a greater likelihood of higher winds in future in the region. Higher winds may lead to an increase in evaporation due to higher entrainment in the air. Higher winds may also generate higher waves which, in turn, leads to more mixing and dispersion in the water column, resulting in lower VOC emissions in the atmosphere. However, these the effects on atmospheric environment are not expected to be substantially different from those described above.

D.2.1.6.2 MITIGATION AND MANAGEMENT

The International Marine Organization has published documents that outline best practices for managing an oil spill in the Arctic. These documents include the Polar Code, published in 2016, and the IMO I623E In-Situ Burning Guidelines, published in 2017. The safety and environmental requirements for polar vessels are described, and the methods for safely conducting controlled burning are provided (IMO 2017b). These guides should be used to reduce effects on the atmospheric environment.

D.2.1.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Spills during the Open Water and transition seasons are expected to lead to the highest amounts of volatile organic compounds (VOCs) being released into the atmosphere. The highest concentrations of VOCs along the coast are likely to occur from a spill in the Mackenzie River plume where the spill/release would be more likely to reach the coast. The concentrations of VOCs are likely to be highest where the hydrocarbons are initially exposed to the air (i.e., at locations nearest the spill).

There may be occasions where the concentrations of the VOCs are above the ambient air quality standards at locations near the source. Over time, the emission rate would decrease as the VOCs are depleted from the liquid hydrocarbon. Further, the VOCs would disperse and decrease in concentration as they move downwind. In addition, spill responses typically involve the exclusion of people from the immediate area of the spill (for human safety). Human activities and wildlife exclusion measures can reduce the number of wildlife in the immediate vicinity to a release.

During a large oil release event in the Spring or Fall Transition or Ice seasons, the liquid hydrocarbon would likely not be in contact with the atmosphere as frequently as during the Open Water Season. Therefore, spills during the Spring or Fall Transition or Ice seasons are expected to lead to smaller quantities of VOC emissions to the atmosphere.

Additional air contaminant, GHG, noise, and light emissions would be generated by the additional marine vessels and equipment needed for the oil spill response. The marine vessel activities related to clean up are expected to be roughly the same regardless of the timing of the spill, except in the case of a small spill or tanker spill where the response is likely to be relatively straight-forward requiring less effort than a bigger spill. Emissions during cleanup are expected to be small compared to emissions from normal operation of an offshore oil production facility, since facility combustion activities during normal operation are much larger than support vessel emissions. Further, emissions during cleanup are expected to occur over a shorter time period.

Controlled burns are expected to be short term events, often measured in hours to days. The emissions are largely combustion gases and smoke made up of partially burned hydrocarbons. When possible, burns are conducted only when winds and sea states are favourable (i.e., blowing away from sensitive areas or receptors); as a result, exposures to emissions from burning are reduced. There is a small potential for unplanned exposure due to abrupt changes in wind direction; however, the nature of the activity is such that the burn (area) can be reduced by adjusting the booms, if needed.

The ambient concentrations of VOCs at coastal receptors are expected to be higher for spills within the Mackenzie River plume than for spills outside the plume, partly because of the shorter distance and partly because of the warmer surface temperature of the water. These VOC concentrations may on occasion be above onshore ambient air quality standards for coastal receptors when the spill occurs near shore.

For spills outside the Mackenzie River plume and for spills during other seasons, the VOC concentrations are expected to be lower, and not exceeding onshore ambient air quality standards at coastal receptors. The cleanup activities are not expected to cause long-term effects associated with noise or light.

D.2.1.7 Summary of Residual Effects

A summary of the effects of industrial and human activities on the Atmospheric Environment for Scenarios 1 through 4 is provided in Table D-6 below. A summary of effects from an oil spill as indicated in Scenario 5 is provided in Table D-7.

Table D-6 Potential Residual Effects of Scenarios 1 – 4 on Atmospheric Environment

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Ice	• Low air contaminant, noise, light, and GHG emissions, mostly from ice breaking activities. Emissions localized to source.	• Increased air contaminant, noise, light, and GHG emissions from marine vessel activity, including shipping, cruise ships, and ice breaking. Emissions localized to sources (<5 km).	• Further increase in air contaminant, noise, light, and GHG emissions from various marine vessel activities and GBS production activities. Emissions localized to sources (<5 km).	• Still higher air contaminant, noise, light, and GHG emissions from various marine vessel activities and FPSO production activities. Emissions localized to sources and mitigated by emissions being farther out to sea (< 5 km)
Spring Transition	• Higher air contaminant, noise, light, and GHG emissions from marine vessels and other transportation activities. Effects local to sources.	• Slightly higher emissions than Ice Season due to cumulative emissions from Scenario 1. Noticeable effects still expected to be localized to most sources (< 5 km).	• Slightly higher emissions than Ice Season due to cumulative emissions from Scenario 1. Noticeable effects still expected to be localized to most sources (< 5 km).	• Slightly higher emissions than Ice Season due to cumulative emissions from Scenario 1. Noticeable effects still expected to be localized to most sources (< 5 km). • Effects to coastal receptors still low due to distance from coast.
Open Water	• Higher air contaminant, noise, light, and GHG emissions from marine vessel and other transportation activities. Effects local to sources.	• Slightly higher emissions than Ice Season due to cumulative emissions from Scenario 1. Noticeable effects still expected to be localized to within 5 km of most sources.	• Slightly higher emissions than Ice Season due to cumulative emissions from Scenario 1. Noticeable effects still expected to be localized to within 5 km of most sources.	• Slightly higher emissions than Ice Season due to cumulative emissions from Scenario 1. Effects to coastal receptors still low due to distance from coast. (< 5 km).

Table D-6 Potential Residual Effects of Scenarios 1 – 4 on Atmospheric Environment

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Fall Transition	• Higher air contaminant, noise, light, and GHG emissions from marine vessel and other transportation activities. Effects local to sources.	• Slightly higher emissions than Ice Season due to cumulative emissions from Scenario 1. Noticeable effects still expected to be localized to within 5 km of most sources.	• Slightly higher emissions than Ice Season due to cumulative emissions from Scenario 1. Noticeable effects still expected to be localized to within 5 km of most sources.	• Slightly higher emissions than Ice Season due to cumulative emissions from Scenario 1. Effects to coastal receptors still low due to distance from coast (< 5 km)
Legend				
• Least effect – No to minor effect on Atmospheric Environment				
• Moderate effect – Moderate effect on Atmospheric Environment				
• High effect – High effect on Atmospheric Environment				
• Greatest effect – Greatest effect on Atmospheric Environment				

Table D-7 Potential Effects of a Large Oil Release Event (Scenario 5) for Atmospheric Environment

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• VOC concentrations likely low near the coast as ice would slow evaporation • Some additional air contaminant, noise, light, and GHG emissions from cleanup effort, but localized to near the source.	• VOCs localized to spill area and not expected to reach coast. Low air contaminant, noise, light and GHG emissions from clean up activities.	• Localized, short term release of VOCs. • Localized increase in emissions (other air contaminants, noise, light) from marine vessel traffic used for clean-up efforts
Spring Transition	• Higher potential VOC concentrations along shoreline, but likely below applicable standards. • Emissions from marine vessel activities during cleanup likely higher than Ice Season but localized.	• VOCs and other emissions associated with clean up expected to be slightly higher but localized to areas far offshore.	• Slightly larger spill possible. • Localized, short term release of VOCs • Localized increase in emissions from marine vessel traffic used for clean-up efforts
Open Water	• Highest VOC concentrations expected. • Distance from spill to shoreline would likely keep concentrations below standards. • Emissions from marine vessel activities during cleanup likely higher than other seasons but localized.	• VOCs not expected to reach shore. Emissions associated with clean up expected to be slightly higher than Spring Transition but localized and at low concentrations.	• Larger spill possible. • Localized, Short term release of VOCs. • Localized increase in emissions from marine vessel traffic used for clean-up efforts
Fall Transition	• VOC emissions slightly higher than Spring Transition due to warmer ocean surface temperature • Other emissions from cleanup activities similar to Spring Transition	• VOC emissions slightly higher than Spring Transition due to warmer ocean surface temperature • Other emissions from cleanup activities similar to Spring Transition	• VOC emissions slightly higher than Spring Transition due to warmer ocean surface temperature • Other emissions from cleanup activities similar to Spring Transition
Longer-term/ Multi-year	• Emissions from marine vessel activities during cleanup expected. • Emissions would be localized to clean up activities • Potential for low to medium VOCs along the coast.	• Emissions from marine vessel activities during cleanup expected. • Emissions would be localized to clean up activities • Potential for low VOCs along the coast.	• Emissions from marine vessel activities during cleanup expected. • Emissions would be localized to clean up activities • Potential for low VOCs along the coast.

Table D-7 Potential Effects of a Large Oil Release Event (Scenario 5) for Atmospheric Environment

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Legend			
• Least effect – No to minor effect on Atmospheric Environment			
• Moderate effect – Moderate effect on Atmospheric Environment			
• High effect – High effect on Atmospheric Environment			
• Greatest effect – Greatest effect on Atmospheric Environment			

D.2.1.8 Gaps and Recommendations

While some information has been collected for air quality, GHG, noise, and light within the BRSEA Study Area, much is still unknown about each of these indicators, particularly in the arctic marine environment. Additional ambient monitoring in coastal communities and at sea would help to better understand and characterize the existing conditions.

The regulatory regime in Canada with respect to climate change and management of GHGs is also changing. These changes would need to be considered during future impact assessments. More emphasis is being placed on quantifying GHG emissions and understanding impacts to infrastructure from changing climate. The present requirement is to establish and demonstrate the ability of a given project to help meet Canada’s commitments to reduce GHG emissions by 30% below 2005 levels by 2030 and help achieve a low carbon economy by 2050 (ECCC 2016a). Additional information and guidance may be available in the future to assess the potential environmental effects of a particular project on climate change directly. Since the effects on climate change and weather from examined activities are not measurable, the assessment involves preparing an order-of-magnitude estimate of GHG emissions and considering the magnitude, intensity, and duration in terms of contribution to regional, territorial, provincial, national and global emission totals, and ability to meet regulatory targets, where they exist.

One area of some uncertainty is the potential for carbon leakage. The GHG implications of a specific offshore oil and gas development would need to be considered on a project-specific basis taking into account carbon leakage and the potential for Beaufort petroleum products to displace higher GHG energy sources both domestically and internationally. While this displacement is possible, (natural gas and other light hydrocarbons could displace the use of coal from another jurisdiction), it is difficult to establish in the near term. As governments develop policies and regulations to slow or eliminate the use of higher GHG energy sources (such as coal), the differences in the quantities of GHGs released to the atmosphere overall could be estimated with some certainty.

Another source of uncertainty is the potential for feedback mechanisms and changes in the offshore that are associated with climate change. There is some understanding of feedback on land. One example is that as the land warms, it can generate / release methane gas, a potent greenhouse gas and, in turn, this can generate more warming. Less is known about feedback in the marine environment. One aspect that is fairly well-known, mechanistically, is the albedo effect. This refers to the phenomena where the ice melts and the surface gets darker and this results in more heat being absorbed, thus heating up the water and air in the area more quickly. Other aspects such as the production of ground level ozone, and effects on dispersion and deposition of air contaminants from the South in the Arctic are not well known.

Future work would likely be required to better understand the impacts of climate change on potential LNG or oil developments in arctic environments and how proponents plan to mitigate those impacts.

D.2.1.9 Follow-up and Monitoring

A better understanding of the current air quality, noise, and lighting conditions throughout the BRSEA Study Area would help to better understand the range of potential effects for the atmospheric environment. As noted above, there is very little data available on ambient air quality, ambient in-air noise or lighting in the marine environment of the BRSEA Study Area. Measurements at various locations in the marine environment would help to refine assumptions that were used in this assessment because of a lack of available research or data.

D.2.2 Climate and Weather

While the potential GHG emissions from a single oil and gas activity may not be large enough to influence climate or the weather, the release of GHGs from the many sources around the planet is directly linked to climate change (IPCC 2014b). It is recognized that it is difficult to assess the potential environmental effects of a project on climate change directly. At the same time, there is scientific consensus in respect of global emissions of GHG and consequent changes to global climate as generally representing a cumulative environmental effect.

The purpose of this section of the assessment is to (i) summarize information based on TLK and western science on how weather and climate have been changing the physical environment in the BRSEA Study Areas; and (ii) to discuss how these changes are considered in the Data Synthesis and Assessment Report.

D.2.2.1 Changes in Weather and Climate

The main trends and future projections for climate and weather are summarized in Table 6-2; observations of past changes and future prediction are provided for (see Chapter 6 and Appendix C for details):

- air temperature (means, maxima, variability)
- precipitation (rain and snow)
- frost-free days
- wind (direction, speed, variability, frequency of extreme events)
- wind (direction, speed, variability, frequency of extreme events)
- sea level rise (including frequency and severity of storm surges)
- ocean temperature and heat content (including inferences on bottom temperature)
- sea ice (extent, thickness, type, timing, including landfast ice)
- sea ice (extent, thickness, type, timing, including landfast ice)
- glacial ice (ice islands and Icebergs)
- waves (height, direction, speed, variability, frequency of extreme events)
- currents and water column structure (physical and chemical)

- permafrost conditions
- freshwater runoff from Mackenzie River (timing, volume and water quality)
- coastal exposure and erosion

TLK holders from coastal Inuvialuit communities have provided a wealth of observations on changing weather and climate, sea ice and ocean conditions over the past four decades. The TLK for weather and climate and changes described in Table 6-2 describe similar trends and patterns.

Changes in weather, water, and ice were identified by TLK holders including warmer temperatures in recent years, earlier break up of ice and later freeze up of ice. It was also noted that rain and thunderstorms were becoming more common, currents have changed, and shore water levels are higher and appear to be eroding some of the bank (IMG Golder and Golder Associates 2011c:21).

TLK holders from the Hamlet of Tuktoyaktuk have observed substantial changes in weather patterns and ice conditions over the last few decades. They stated that these changes would have an effect on how industry may conduct their activities, including:

- more open water in the winter
- rougher ice
- delayed snowfall and freeze up
- greater numbers of icebergs
- larger and rougher pressure ridges
- sinking permafrost
- warmer winter temperatures
- increased coastal erosion
- strong summer storms
- shorter winter seasons" (KAVIK-AXYS Inc. 2004b:18-34).

Many TLK holders report similar changes in general weather patterns, including periods of more rain and wind. "Prevailing winds previously blew from the northwest, but now are more forceful and blow from the east. High water levels make it difficult to distinguish where the banks of rivers are located. Strong winds are causing arid conditions in the Delta, and fewer blizzards have been observed in winter." (IMG Golder and Golder Associates 2011a:18).

TLK holders have also observed change in seasonal temperatures. For example "there have been warmer temperatures in recent years, more rain, and more thunderstorms. Fishing nets need to be checked more often due to the warmer temperatures and the softening of the fish. There is more rubble ice now and this makes it tougher to hunt. Travel is not as safe" (IMG Golder and Golder Associates 2014). Another TLK holder noted that it was much colder in the 1960s and that large pieces of multi-year ice would run ashore all summer (IMG Golder and Golder Associates 2014:7). Other TLK holders noted that "The warmer weather affects the seals and the polar bears. The winds and currents put pressure on the ice, and it piles up and makes it more difficult to travel. The temperatures don't get down to -60°C anymore." (Inuvialuit Knowledge of Nanuq by D Slavik 2010:9)

TLK holders also have documented that wind speeds and direction are changing; specifically: “stronger northwest winds are another observed change” and referred to the northwest wind as a "bad wind" because it can reach up to 110 kilometres per hour (km/h) and last from two to three days." Other TLK holders said that the south winds that normally occur in January are now occurring in April and seem to be arriving later each year” (IMG Golder and Golder Associates 2011b:13).

Local knowledge experts indicated that low tides forecast east winds and high tides forecast strong west winds in the summer and potential rain, one TLK holder said that Ulukhaktok once had a consistent east wind for almost a month. It was further noted that, 30 years ago, the winds were strong and then died down until about 5 years ago when the wind speeds increased again. (IMG Golder and Golder Associates 2011d: 15).

TLK holders also have noted changes in the sea ice. Freeze up, which usually occurred in October, now occurs in November. As well, earlier snowfalls insulate new ice and delay freeze up. Also, warmer weather means that breakup comes sooner - as early as May. “People have had to change their travel patterns because of an increase in rain, which sits on top of sea ice and 'rots' it, rendering the ice potentially unsafe for travel” (IMG Golder and Golder Associates 2011f:17-18).

TLK holders said they are seeing less ice now than in the past. One TLK holder said: "We start to have open water problems probably about mid-’80s, I guess…. When we started to have problems with the open water or ice conditions not freezing anymore, [it was] not every year for a while. Now it’s every year. It doesn’t freeze anymore out there…. It’s a weather problem. So much wind, not cold enough, so much mild weather, winter like this. Some places used to be [more than] sixty below. [Now] weather are almost going to zero degrees. Yellowknife, it’s supposed to be over minus sixty this time of year. Yesterday, it was only minus six. I couldn’t believe it. Right here a long time ago, when the weather get real cold, when you’re travelling, you can’t see the person travelling behind you, about probably 25 yards. Smoke in between us, right there, from the cold weather. From your breathing and dogs breathing, when you’re travelling, so much smoke coming out of the dogs on the trail [that] you can’t see your partner travelling behind you or in front of you, 25 yards to 50 yards. Now, we don’t get that kind of weather no more; and it used to be good weather, no wind for a long time. Sometimes 32 weeks, no wind. Right now, the windy days, bad weather days, way more than the good weather. It’s very different today. That’s why we don’t have ice anymore out here." (Joint Secretariat 2015:162-163).

Another TLK holder said "It’s climate change, I’m pretty sure, making everything change here. And it’s hard for polar bears to survive in the winter because the ice is so thick, and the seals, I’m pretty sure we’re losing millions and millions of seals because of the thickness of the ice. And I’m pretty sure they’re having a hard time keeping those breathing holes open all year round, like right from October until the ice goes…. because of ice piling up. And climate change, I’m pretty sure makes it difficult for seals to keep their breathing holes open all year — six, seven months. That’s the one big change in the ice that I see today, even though I haven’t had a chance to go out there yet this year. But I would see with my two eyes that things are way different from the day I was born." (Joint Secretariat 2015:194).

Some TLK holders expressed concern regarding the drilling platforms and ice conditions. One TLK holder said the “ocean open[s] up more and more” with “more cracks” and that “this happens earlier in the spring (March and April) than it once did.” One TLK holder cautioned that the “west wind is what make[s] the ice thinner.” Another TLK holder also said that, in the winter “sometimes there’s open water” when “leads open up," which are usually caused by "high winds." He noticed these leads around King and Kay Points. One TLK holder explained that "pressure ridges, current and wind create the open areas." (KAVIK-AXYS Inc. 2004c:4-9)

D.2.2.1.1 IMPLICATION OF CHANGES IN WEATHER AND CLIMATE TO THE BRSEA

Earlier guidance from the CEA Agency (2003; now the IAA) identified that "the environmental assessment process cannot consider the bulk of GHG emitted from already existing developments. Furthermore, unlike most project-related environmental effects, the contribution of an individual project to climate change cannot be measured". As noted in the previous section, recent guidance from the Government of Canada (2019b) provides direction on how climate change should be considered in an impact assessment, including guidance on the quantification of GHG emissions, best available technologies, and climate change resilience, and how a project's GHG emissions should be assessed.

For a strategic assessment such as the BRSEA, the assessment needs to consider how GHG emissions from a development, in combination with other emission sources, would affect Canada's ability to meet these targets (i.e., essentially a development's contribution to cumulative environmental effects of GHGs). To do this, an order-of-magnitude estimate of GHG emissions is required for each development scenario, taking into account the magnitude, intensity, and duration of these emissions in terms of contributions to regional, territorial, national and global emission totals, and ability to meet regulatory targets, where they exist. These comparisons are provided in Section D.2.1.

D.2.3 Oceanography

D.2.3.1 Scoping

D.2.3.1.1 IDENTIFICATION OF INDICATORS

Regional oceanographic processes in the ISR are dominated by a high-pressure weather system resulting in clockwise winds that drive surface water currents and sea ice motion (Proshutinsky and Johnson 1997), known as the Beaufort Gyre. Shifts in the location of this high-pressure weather system or the presence of low-pressure weather systems can cause the reversal of the Beaufort Gyre, causing counter clockwise rotation of the surface currents (McLaren et al. 1987), especially in the summer months. The direction of these systems results in upwelling and downwelling conditions that affect the physical and biological dynamics on the Beaufort Sea shelf. This system and its ocean currents are temperature and wind driven and, therefore, are not influenced by human activities related to any of the five scenarios that are part of this assessment.

The assessment of oceanography in this section is focused on water quality, an important indicator of habitat quality for marine organisms, which could be influenced by activities under the different scenarios. Water quality has direct effects on the health of marine lower trophic levels, fish, seabirds, and marine mammals, as well as harvested species and health of the Inuvialuit. Water quality characteristics of concern include salinity, temperature, stratification and mixed layer depth, pH and alkalinity, dissolved oxygen, turbidity (suspended sediments), and contaminants.

D.2.3.1.2 *SPATIAL BOUNDARIES*

The spatial boundary for the effects assessment of the five scenarios on oceanography and water quality includes the entire BRSEA Study Area.

D.2.3.1.3 *TEMPORAL BOUNDARIES*

The assessment of potential effects on oceanography and water quality encompasses a 30-year period between 2020–2050.

D.2.3.1.4 *ASSESSMENT OF POTENTIAL EFFECTS*

The magnitude and geographic extent of effects on marine water quality is assessed first. For effects that are not negligible, the direction, frequency and duration of the effects are assessed, along with the ecological and socio-economic context. The characterization terms used in assessing effects on oceanography are defined in Table D-8.

Table D-8 Characterization of Residual Environmental Effects on Oceanography for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect on the VC	**Positive**—a net improvement in water quality **Adverse**—a reduction in water quality **Neutral**—no net change in the water quality
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no measurable change in water quality **Low**—a measurable change in the water quality, that is within the range of natural variability **Moderate**—a measurable trend in water quality outside the range of natural variability **High**—a measurable trend in water quality that affects fauna, flora and people
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the local area around the activity **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area) **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area)
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity **Continuous**—residual effect occurs continuously for the duration of the activity

Table D-8 Characterization of Residual Environmental Effects on Oceanography for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to one phase (e.g., seismic survey, exploration drilling) or season **Medium-term**—residual effect extends through multiple seasons or years (e.g., production phase) **Long-term**—residual effect extends beyond the life of the project (e.g., beyond closure) **Permanent**—measurable parameter unlikely to recover to existing conditions
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.2.3.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

Activities that could affect water quality include seabed disturbance, ice disturbance, vessel activity, routine discharges from vessels and platforms, and a hypothetical large oil release.

The passage of ships can be expected to mix the upper ocean and increase the mixed layer depth locally, especially in the Open Water Season when the mixed layer depth is shallow. This impact may only be on the order of hundreds of metres in width and last up to a few hours. Given the episodic nature and the relatively small area involved, effects of vessel activity on ocean mixing is considered negligible and is not considered further.

Ice-breaking activities could influence thermal structure of the upper ocean. Such an interaction could occur in the Spring and Fall Transition seasons and Ice Season. In the transition seasons, ships would agitate the water column causing warmer or cooler water (respective of season) from depth to be brought to the surface. This water may cause a negligible increase in the heat flux as it is cooled (or warmed) by the atmosphere and influence surface ocean habitat for plankton and fish. In the Ice Season, heat fluxes would be much larger than in the transition seasons, but they would also be over a short period of time as new leads formed by passing vessels would quickly refreeze. Given the small overall footprint of this effect and its short-term nature, effects on heat exchange are expected to be negligible in magnitude and are therefore not considered further.

Seabed disturbances may result from marine construction activities on the seafloor including preparation (e.g., suction dredging) of the foundation for the LNG and condensate pipelines, the GBS loading platform or GBS production facility, subsea manifolds, subsea pipeline bundles, and anchoring systems for wareships and FPSOs. Such activities may result in an increase in suspended sediments, altering local habitat quality. Effects are expected to be episodic, short-term, localized, reversible and of negligible to low magnitude.

Development activities include routine discharges of cooling water generated on vessels and drilling platforms, grey water from vessels and platforms (treated sewage and food waste) and water-based drilling muds, sand and drill cuttings[3] (DeBlois et al. 2014a). Such discharges could affect the local temperature of surrounding waters, lead to local increases in salinity due to brine discharge, local decreases in salinity due to grey water discharge (Brandsma et al. 1992), and increases in suspended sediment. Cooling water would be discharged into the ocean during vessel operations. During seismic and shipping activities, the vessels would be in motion and the quantities of cooling water being discharged would be negligible. Effects would be further reduced by advection and diffusion. Cooling water would also be discharged from heat exchangers used in production processes. This activity would be a long-term near-continuous activity during production and would create thermal plumes. However, advection and diffusion would keep the effects localized, negligible to low in magnitude and reversible.

Brine discharge would increase salinity locally and be most common during production when desalination processes would be required. Grey water discharge would decrease the salinity locally and would have the most influence during production activities. Both activities would be near-continuous. Advection and diffusion of discharged brine would create a steep saline gradient from the discharge point and keep the effects localized (DeBlois et al. 2014a). Compared to natural seasonal changes in salinity due to sea-ice formation and melting, the magnitude of effect from brine discharge is expected to be negligible to low in magnitude. If there are effects, they would be reversible.

For Scenario 5 only, PAH concentrations in the water column are an important water quality effect that would arise from oil released in a subsea oil well blow-out or due to vertical mixing of spilled oil within the water column.

The relationship between human activities, interactions, impacts and potential effects are summarized in Table D-9.

[3] There is zero discharge of synthetic and oil-based muds and hazardous waste at sea; these wastes are contained, and shipped to land based treatment or disposal facilities. Bilge and ballast water from vessels are also not typically discharged.

Table D-9 Summary of Potential Impacts and Effects on Oceanography

Potential Impact[4]	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Seabed Disturbance	• subsea well, manifold, and pipeline installations and repairs	• marine construction activities on the seafloor result in suspended sediments which affect water quality and have potential effects on benthic communities and fish	• low to negligible effect on suspended sediment concentrations given small area of the activities and short duration	• suspended sediment concentration
Ice Disturbance	• icebreakers transiting through sea ice (ice management, support, transport)	• increase in heat exchange with atmosphere, most notably in the Ice Season	• during the Ice Season, when the impact is largest, the leads would quickly refreeze. • overall effects on thermal properties due to generated leads is expected to be negligible in magnitude • **further assessment of this impact is not warranted.**	• NA
Vessel Activity	• vessel use during the Open Water Season (commercial, personal use, tourism, sea lift, military, research, harvesting)	• local increases in the mixed layer depth	• mixing along ship paths is over an area that is on the order of 100 m across and the hundreds of km in length– a very small area compared to the ISR • changes would last for short periods of time, hours at most • changes are expected to be negligible in magnitude • **further assessment of this impact is not warranted.**	• NA

4 Potential impacts of Air Contaminants and GHG Emissions, Noise (in air and underwater), Artificial Light, and Vessel Collision are not considered for Oceanography as there are no direct impact from these activities and processes on this VC. However, changes in Oceanography that affect biota and human uses are discussed in the Summary of Potential Impacts and Effects for those VCs.

Table D-9 Summary of Potential Impacts and Effects on Oceanography

Potential Impact[4]	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Routine Discharges	• grey water and cooling water generated on vessels and drilling platforms (and water reuse) • treated sewage and food waste • water-based drilling muds, sand and drill cuttings	Changes to water quality including: • local heating of ocean waters • local increases in salinity due to brine discharge • local decreases in salinity due to grey water • local increase in suspended particles	• advection and diffusion of sea water would keep these effects localized • beyond the local discharge sites, thermal changes are expected to be negligible to low in magnitude locally • effects on local salinity are expected to be near-continuous and long-term as they would persist through most of the project, • the magnitude of the changes on heat exchange and salinity would be small, even at the discharge site. • decrease in local water quality as a result of increased suspended particles	• spatial extent of thermal and salinity plumes • total suspended sediments
Oil Spill	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• water quality (e.g., PAH concentrations)	• PAH within the water column may get taken up by zooplankton, benthic animals, fish or whales	• PAH concentrations

Since the potential effects of Scenarios 1 through 4 on water quality are considered to be negligible to low, and there is a great deal of commonality between these scenarios, they are summarized in one sub-section below.

D.2.3.2 Scenarios 1-4: Routine Activities

D.2.3.2.1 POTENTIAL EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAYS

Routine discharges from vessels and fixed platforms are common to the four scenarios. In Scenario 1, these discharges are limited to vessel-based discharges where in Scenarios 2 to 4, the discharges can also occur from fixed platforms, wareships, and other vessels. The discharges in Scenarios 3 and 4 also include drilling muds and cuttings from drill ships and the fixed platform in Scenario 3.

The preparation of the seabed for infrastructure (e.g., suction dredging) and installation of infrastructure are the primary pathways for marine construction activities to potentially result in the re-suspension of sediments into the water column. Activities in Scenarios 1 to 4 that could result these types of effects include preparation of the seabed for and installation of the GBS for wind energy turbines in Scenario 1; the dual subsea pipelines and the GBS loading platform in Scenario 2, the GBS platform in Scenario 3; and the manifolds and pipeline bundles in Scenario 4. Anchoring of the wareship in Scenarios 3 and 4 and the FPSO in Scenario 4 also could resuspend sediment. Spudding of deepwater wells (e.g., suction dredging of the glory holes) in Scenario 4 would also resuspend sediment.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

In Scenarios 1-4, vessel activities are expected to increase over the next 30 years within the region. Increases would result from increased commercial shipping, cruise ship tourism, ship-based resupply of communities, scientific research and military vessels and exercises which would result in increasing level of potential vessel-based routine discharges. In Scenarios 2, 3 and 4, additional vessel activities include support vessels and tankers, as well as fixed platform activities and wareships resulting in potential routine discharges on a year-round basis.

The effects of routine discharges would be largest during the Open Water Season when vessel activities increase, especially in Scenario 1, but to a lesser extent in Scenarios 2, 3 and 4.

The effects of routine discharges on water quality is generally expected to be very localized and restricted to the immediate vicinity of the vessel and/or platform location. Mitigation measures, including adherence to waste treatment and disposal guidelines (Section 2.5) and zero discharge for synthetic and oil-based muds and hazardous waste, can greatly reduce effects on water quality.

For seabed disturbance, elevated suspended sediment concentrations could occur from sea-floor marine construction activities (e.g., installation of pipelines, the GBS, and manifolds), anchoring of the FPSO and wareships, and initial spudding of wells (Scenario 4). The effects of these activities would be highly localized, of short duration (generally days up to a few weeks for Scenario 2) and negligible.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

As climate change increases the length of the Open Water Season, the length of time over which ships might be present and for routine discharges to occur would increase. Scenarios 2-4 would be year-round operations, with some increase expected for supply vessels if open water conditions are extended due to climate change.

D.2.3.2.2 MITIGATION AND MANAGEMENT

Mitigation and management measures to protect sea water from increased sediment suspension would be employed during the preparation of the seabed for wind energy turbines in Scenario 1, the offshore portions of the LNG and condensate pipelines in Scenario 2; the GBS platforms in Scenarios 2 and 3; the installation of manifolds in Scenario 4; and the initial spudding of deepwater wells in Scenario 4 (note that the drilling of wells in Scenario 3 would be from inside the GBS). Modelling results and timing windows could be used to reduce the potential for sediments to affect a region of importance to local biota at a specific time and monitoring during the work could confirm that work is stopped when sediment levels exceed an established threshold.

Effects of discharges on water quality can be effectively reduced by adhering to waste treatment and disposal guidelines (Section 2.5). This includes:

- treatment of grey water, sewage and food wastes before disposal
- use of water-based muds
- treatment of water-based muds and associated wastes (e.g., sand and cuttings), produced water, and deck drainage to meet minimum thresholds for oil content
- zero discharge for synthetic and oil-based muds and hazardous waste

Modelling of the transport and fate of the temporarily suspended sediment can be completed during project planning which can then be used to plan construction timing to avoid interactions with biological VCs.

D.2.3.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

As described, effects on water quality can be effectively reduced by adhering to waste treatment and disposal guidelines (Section 2.5), including a zero-discharge policy for synthetic and oil-based muds and associated wastes.

Modelling of sediment transport can be used during planning and design of projects and their operations to reduce the effect of suspended sediments during the preparation of the seabed for pipelines, GBS platforms, or subsea manifolds, anchoring of the FPSO and wareship, and initial spudding of deepwater wells (Scenario 4). Such changes in project design and operations can help reduce residual effects on water quality and associated effects to biological communities. Monitoring suspended sediment concentrations during operations and applying corrective actions if thresholds are approached can also help reduce effects on water quality to negligible levels.

CUMULATIVE EFFECTS

Given adherence to waste management standards and practice as described in Table 2-5, the primary cumulative effect of potential concern would be suspended sediment concentrations from seabed preparation and installation of structures, anchoring of wareships and the FPSO, and spudding of wells (Section D.2.3.2.1).

Since suspended sediments would fall out of suspension over distance and time, few cumulative effects on water quality are expected given the dispersed nature of infrastructure in the Status Quo and the three oil and gas development scenarios. The location of the seabed preparation for and installation of the dual pipelines and the GBS loading facility in Scenario 2 might be in proximity to (or distant from) infrastructure installations of the GBS for wind energy turbines in Scenario 1. In contrast, effects on water quality from Scenario 3 (e.g., GBS seabed preparation and installation and wareship anchoring) and Scenario 4 (FPSO and wareship anchoring and seabed preparation for manifolds, pipeline bundles and deepwater drilling) would each be spatially separated from similar effects in Scenario 1. As noted, waste handling would follow the standards and guidelines in Table 2-5; as a result, effects on water quality are predicted to be highly localized around the platforms or vessels. Cumulative effects of discharges from vessels in Scenario 1 are not expected to overlap to a large extent with similar discharges predicted effects from vessels and platforms in Scenarios 2, 3 or 4.

Given the above, cumulative effects on water quality would be minor or negligible; however, monitoring of sensitive areas during concurrent operations (if they occur) should be undertaken to assess potential effects on water quality and implement appropriate operational and management actions. Concerns about cumulative effects of suspended sediment concentrations can be further allayed by staggering the operations in space and time.

D.2.3.3 Scenario 5: Large Oil Release Event

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on oceanography from such an event could differ slightly from what is described below for surface or subsea releases.

D.2.3.3.1 ASSESSMENT OF EFFECTS

DESCRIPTION OF EFFECT PATHWAY

A large release of oil would affect water quality which, in turn, would affect other VCs such as lower trophic levels, fish, seabirds and marine mammals, as well as traditional use and cultural vitality.

Following a large oil release event on the sea surface, there would be an initial spreading of the surface oil followed by horizontal dispersion and advection by currents and wind (Transportation Research Board and National Research Council 2003). Depending on the actual constituents in the spill, dissolution occurs to some degree. This is particularly important for the aromatic hydrocarbons which tend to be quite soluble (Transportation Research Board and National Research Council 2003). During a surface spill, water quality at the surface would be most affected.

Waves, especially breaking waves, can break apart oil at the surface into droplets and mix it into the near-surface water column (ITOPF 2011). The water quality can be adversely affected to the greatest depths during the Open Water Season and into the early Fall Transition Season due to the predominance of waves.

Emulsification may also happen depending on the constituents in the spill and the level of agitation introduced by the sea state. If emulsification does occur, it may increase the oil viscosity by several orders of magnitude (Transportation Research Board and National Research Council 2003) reducing its ability to disperse and tending to localize effects on water quality. In the Mackenzie River plume, where sediment concentrations are elevated, sorption of oil droplets to sediments may cause oil to settle out of the water column (ITOPF 2011). This reduces oil concentrations at the near surface, which improves the water quality at surface, but it causes water quality to deteriorate at the seabed. Water quality can also be affected over a wider depth range when oil is mixed to depth by Langmuir circulation (shallow, slow, counter-rotating vortices at the ocean's surface aligned with the wind) (McWilliams and Sullivan 2001).

Following ice formation, oil may be taken up by the ice through the emptying brine channels (Transportation Research Board and National Research Council 2003). Oil that adheres to the ice is less likely to disperse or become an emulsion. While the local water quality at the oil water interface can be affected, this can also make clean-up efforts easier since the oil is localized. Oil that is not cleaned-up, and remains on the underside of the ice sheets, would be encapsulated into newly formed sea ice, and would travel with the ice overwinter. As the ice melts during the Spring Transition or Open Water Season, the oil would be released back into the water. This pathway can affect water quality over the medium term (i.e., months to years).

In the case of a blowout or subsurface release, a jet of oil and possibly gas exits into the water column. The jet is slowed by the resistance of the sea water and becomes a slurry of oil droplets and possibly bubbles that rise to the surface. Larger droplets and bubbles rise faster and entrain the smaller droplets and bubbles. Sub-surface currents can cause the oil to spread at depth causing the surface expression to be widespread. A subsurface release can affect a large volume of water since the oil moves vertically and horizontally through the water column. In the presence of large currents, the dispersion of the oil is enhanced and the nature of the release is no longer plume-like; instead, oil droplets are separated far enough apart to rise individually to the surface (Transportation Research Board and National Research Council 2003). The smallest droplets rise at the slowest rates and would likely have the greatest effect on the mid-water column water quality.

In deep water releases, the entrainment of sea water into the plume can reduce the density so that the plume no longer rises. As the plume continues to disperse horizontally at depth (e.g., mushrooming), the heaviest constituents may settle out, affecting water quality in the water column to the seabed. The settling out of the heaviest constituents then allows the plume to resume rising and affects the water quality higher up in the water column. This process is known as peeling (Transportation Research Board and National Research Council 2003). If the net density is not reduced sufficiently, the plume remains at depth, otherwise it can continue until it reaches the surface, potentially at a large distance from the subsurface release.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Subsurface releases would affect water quality through released PAHs. Interactions between oil and sea water that occur closer to the release point would not have had as much opportunity to be dissolved and mixed with the seawater. Further up the water column away from the release point, the oil would have had more opportunity to dissolve into the water column or break into individual oil droplets (dispersion). Oil may also be deposited on the seabed through interactions with sediments (oil-mineral aggregations) or oil contained in fecal pellets. On reaching the seabed surface, the oil-mineral aggregations and other forms can be spread across a wide area.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Climate change is expected to result in warmer ocean temperatures in the Transition and Open Water seasons, Warmer sea surface temperatures may increase rates of oil spill spreading and weathering, and lead to changes in the magnitude of effects on water quality.

D.2.3.3.2 MITIGATION AND MANAGEMENT

Techniques to mitigate and manage a release of oil into the ocean is provided in Sections 2.13 and 3.10.5.3.

D.2.3.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

No mechanical recovery system of surface oil is perfect, nor are surface burns. Following these remedial steps, oil would still be present at the surface and in the water column and would negatively affect water quality. Similarly, as the sea state increases, oil recovery operations and containment systems become less effective and water quality is adversely affected. The presence of sea-ice also introduces extra challenges as oil can become trapped under, in and around the ice (Dickins 2011). This oil can then be released back into the water column to adversely affect water quality in the following Open Water Season. Use of dispersants reduces surface concentrations of oil, improving water quality at the surface, but allows oil to mix into the water column and disperse, negatively affecting the water quality at depth. The chemical properties of the dispersants themselves may further affect water quality (Chapman et al. 2007). Adsorption of oil to sediments also takes oil away from the surface, with some potential to fall out of suspension (depending on the specific gravity of the aggregation). This pathway also improves surface water quality, but negatively affects water quality through the water column in the short term, and at the seabed in the long-term. Storms may resuspend oily sediment deposits into the water column, allowing them to be redeposited later elsewhere on the seabed. Over time, these resuspension events can reduce the magnitude of water quality issues but increase the geographic extent of the water quality issues.

The sub-sea release outside of the Mackenzie River plume is considered to have the greatest effect as oil would initially be released into the ocean near the sea-floor, then would rise as an oil plume in the water column and gradually disperse. Unless the oil plume reaches a level where it has entrained so much seawater that it is neutrally buoyant and unable to rise further, the plume would reach the surface and form a slick. The two surface spills would not affect as large a volume of water. However, processes such as emulsification, dispersion and dissolution would affect water quality within the upper water column. Effects would be largest during the Open Water Season due to more extensive spreading and entrainment into the water column.

D.2.3.4 Summary of Effects

Effects of Scenarios 1 through 4 on water quality are summarized in Table D-10.

Effects of Scenario 5 on water quality, due to the released oil, are summarized in Table D-11.

D.2.3.5 Gaps and Recommendations

The Mackenzie River is the dominant source of suspended sediments in the region. Satellite imagery provides a historical record of the surface extent of the sediment plume when there is daylight and clear conditions. To understand acceptable levels of suspended sediment concentrations during activities that may increase suspend sediment concentrations, an understanding of the natural background suspended sediment concentrations is required. Data on sediment is also of value in understanding possible adsorption of oil by sediment to form oil-mineral aggregates and the movement and deposition of oil-mineral aggregates. Some datasets are available in the literature, but overall this dataset is sparse and would likely need supplementation, depending on the exact location of activities.

D.2.3.6 Follow-up and Monitoring

To understand the effect of a large oil release event on water quality and organisms that depend on water quality, baseline data are required on water quality and sediment quality. Monitoring of PAHs in sediments, seawater and biota following a spill, in the context of the baseline studies, can assist in deciding when it is safe to resume harvesting activities (Sammarco et al. 2013).

Table D-10 Potential Residual Effects of Scenarios 1 – 4 on Oceanography.

Season	Scenarios 1, 2, 3, and 4
Ice	• Routine discharges – Water quality effects mitigated through adherence to waste management standards and guidelines (Table 2-5) (e.g., treatment of grey water and sewage, use of water-based muds, treatment of water-based muds and associated wastes, produced water, and deck drainage to meet minimum thresholds for oil content, zero discharge for synthetic and oil-based muds and hazardous waste).
Spring Transition	• Routine discharges – Water quality effects mitigated through adherence to waste management standards and guidelines (Table 2-5) (e.g., treatment of grey water and sewage, use of water-based muds, treatment of water-based muds and associated wastes, produced water, and deck drainage to meet minimum thresholds for oil content, zero discharge for synthetic and oil-based muds and hazardous waste).
Open Water	• Routine discharges – Water quality effects mitigated through adherence to waste management standards and guidelines (Table 2-5) (e.g., treatment of grey water and sewage, use of water-based muds, treatment of water-based muds and associated wastes, produced water, and deck drainage to meet minimum thresholds for oil content, zero discharge for synthetic and oil-based muds and hazardous waste). • One-time effects on water quality due to introduction of suspended sediments from seabed preparation and installation of structures, anchoring of wareships and the FPSO, and spudding of wells. Effects can be reduced by using numerical modeling to plan operations and on-site monitoring during operations.
Fall Transition	• Routine discharges – Water quality effects mitigated through adherence to waste management standards and guidelines (Table 2-5) (e.g., treatment of grey water and sewage, use of water-based muds, treatment of water-based muds and associated wastes, produced water, and deck drainage to meet minimum thresholds for oil content, zero discharge for synthetic and oil-based muds and hazardous waste).

Legend
• Least effect – No to minor effect on oceanography and the VCs it supports
• Moderate effect -- Moderate effect on oceanography and the VCs it supports
• High effect – Major effect on oceanography and the VCs it supports
• Greatest effect – Severe effect on oceanography and the VCs it supports

Table D-11 Potential Effects of a Large Oil Release Event (Scenario 5) for Oceanography

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• Oil trapped in leads and beneath the ice can result in minor adverse effects to the water quality at the ice/water interface until oil becomes encapsulated in new forming ice	• Oil trapped in leads and beneath the ice can result in minor adverse effects to the water quality at the ice/water interface until oil becomes encapsulated in new forming ice • Oil spreads at depth and is more likely to be emulsified or broken into fine oil droplets (longer residence times and longer term effects on water quality)	• Oil trapped in leads and beneath the ice can result in minor adverse effects to the water quality at the ice/water interface until oil becomes encapsulated in new forming ice
Spring Transition	• Oil trapped in leads and beneath the ice can cause large adverse effects to the water quality at the ice/water interface as the ice melts and oil is released • Greater potential for waves can result in mixing and lead to adverse effects on water quality deeper in the water column • Sorption with sediments within the plume would enhances precipitation of oil and can affect water quality down to the seabed	• Oil trapped in leads and beneath the ice can cause large adverse effects to the water quality at the ice/water interface as the ice melts and oil is released • Greater potential for waves can result in mixing and lead to adverse effects on water quality deeper in the water column • Oil spreads at depth and is more likely to be emulsified or broken into fine oil droplets (longer residence times and longer term effects on water quality)	• Oil trapped in leads and beneath the ice can cause large adverse effects to the water quality at the ice/water interface as the ice melts and oil is released • Greater potential for waves can result in mixing and lead to adverse effects on water quality deeper in the water column
Open Water	• Oil at the surface adversely affects near-surface water quality • Sorption with sediments within the plume enhances precipitation of oil and can affect water quality down to the seabed.	• Oil at the surface adversely affects near-surface water quality • Waves can result in mixing and lead to adverse effects on water quality deeper in the water column • Oil spreads at depth and is more likely to be emulsified or broken into fine oil droplets (longer residence times and longer term effects on water quality)	• Oil at the surface adversely affects near-surface water quality • Waves can result in mixing and lead to adverse effects on water quality deeper in the water column

Table D-11 Potential Effects of a Large Oil Release Event (Scenario 5) for Oceanography

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Fall Transition	• Oil at the surface adversely affects near-surface water quality • Waves can result in mixing and lead to adverse effects on water quality deeper in the water column • Sorption with sediments within the plume enhances precipitation of oil and can affect water quality down to the seabed.	• Oil at the surface adversely affects near-surface water quality • Waves can result in mixing and lead to adverse effects on water quality deeper in the water column • Oil spreads at depth and is more likely to be emulsified or broken into fine oil droplets (longer residence times and longer term effects on water quality)	• Oil at the surface adversely affects near-surface water quality • Waves can result in mixing and lead to adverse effects on water quality deeper in the water column
Longer-term/ Multi-year	• Oil that is not cleaned up before freeze-up can become entrapped in the sea ice and adversely affect water quality the following Open Water Season • Most residual oil removed by ongoing spill response, cleanup, weathering and biodegradation.	• Oil that is not cleaned up before freeze-up can become entrapped in the sea ice and adversely affect water quality the following Open Water Season • Most residual oil removed by ongoing spill response, cleanup, weathering and biodegradation.	• Oil that is not cleaned up before freeze-up can become entrapped in the sea ice and adversely affect water quality the following Open Water Season • Most residual oil removed by ongoing spill response, cleanup, weathering and biodegradation.

Legend
• Least effect – No to minor effect on oceanography and the VCs it supports
• Moderate effect – Moderate effect on oceanography and the VCs it supports
• High effect – Major effect on oceanography and the VCs it supports
• Greatest effect – Severe effect on oceanography and the VCs it supports

D.2.4 Sea Ice

D.2.4.1 Scoping

D.2.4.1.1 IDENTIFICATION OF INDICATORS

The assessment of potential effects on sea ice focuses on the potential effects on sea ice cover within the BRSEA Study Area; at a regional scale (near-shore and offshore), as well as near Inuvialuit communities. The parameters assessed for sea ice are landfast ice, sea ice leads, pressure ridges, floe sizes, freeze-up timing, contaminants in sea ice, and ice motion. These parameters were chosen on the basis of their importance as habitat for marine mammals (landfast ice, ice leads, pressure ridges, floe sizes, contaminants in sea ice), as a hunting and traveling platforms for people (landfast ice, freeze-up timing, ice motion), and their effect on the timing of animal and Inuvialuit use of the sea ice (freeze-up timing).

D.2.4.1.2 SPATIAL BOUNDARIES

The spatial boundaries of sea ice coverage are dependent on season and typically cover 100% of the BRSEA Study Area during the Ice Season (i.e., all marine waters within the ISR). Although Inuvialuit use of the sea ice for hunting and transportation is typically in proximity to coastal areas and coastal communities (i.e., most use is within 10 km of shore) (Section 3.6), sea ice is a key habitat feature for marine mammals throughout the ISR. Changes to seasonal sea ice cover would alter habitat throughout the BRSEA Study Area and, while the specific of these changes are uncertain, they must be assessed in concert with potential present and future impacts from industrial activities, such as resource development and shipping.

D.2.4.1.3 TEMPORAL BOUNDARIES

The assessment of potential effects on sea ice encompasses a 30-year period between 2020– 2050.

D.2.4.1.4 ASSESSMENT OF POTENTIAL EFFECTS

The assessment of potential effects on sea ice cover from industrial activities considers direct and residual effects from nearshore and offshore activities. Qualitative characterization of potential residual effects associated with each scenario is based on the characterization terms defined in Table D-12.

Table D-12 Characterization of Residual Environmental Effects on Sea Ice for the Time Period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect on the VC	**Positive**—a net benefit to the sea ice as habitat, suitability for use by humans and biota and predictability of sea ice conditions **Adverse**—a reduction in the sea ice habitat quality, suitability for use by humans and biota and predictability of sea ice conditions **Neutral**—no net change in the sea ice as habitat or reliability for use by humans and biota and predictability of sea ice conditions
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no measurable change **Low**—a measurable change but would not affect the sea ice as habitat or transportation surface **Moderate**—a measurable change with potential to affect the sea ice as habitat or transportation surface **High**—measurable change with relative certainty of affecting the sea ice as habitat or transportation surface
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the immediate (i.e., local) area around the activity **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area) **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area)
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity **Continuous**—residual effect occurs continuously for the duration of the activity
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to one phase (e.g., seismic survey, exploration drilling) or season **Medium-term**—residual effect extends through multiple seasons or years (e.g., production phase) **Long-term**—residual effect extends beyond the life of the project (e.g., beyond closure) **Permanent**—measurable parameter unlikely to recover to existing conditions
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period as the effect after completion of activities and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed area**—is currently undisturbed or not adversely affected by human activity **Disturbed area**—has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.2.4.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

Issues and concerns with human activities and impacts on sea ice habitat result from industrial construction, icebreaking, and shipping operations during the Ice Season and the Spring and Fall Transition seasons. A summary of potential effects of habitat alteration resulting from routine activities is provided below. A summary of potential effects of an oil spill on sea ice is provided in Section D.2.4.6. Potential effects during the Open Water Season are not discussed, except where incursions of old or multi-year ice may occur at an offshore development site.

The relationship between human activities, interactions, impacts and potential effects are summarized in Table D-13.

POTENTIAL EFFECTS OF DISTURBANCE ON SEA ICE

Routine icebreaking activities: The sea ice provides habitat for marine mammals throughout the year, but the Spring and Fall Transition seasons are particularly critical feeding times for polar bears. During the winter, bears tend to den in areas with substantial pressure ridges in coastal areas near Banks Island and along the mainland of the NWT and Yukon (see Section D.2.6 for more details).

Icebreaking activities have the potential to create short-term disturbances of sea ice in coastal areas and may affect landfast ice where present. The effects on landfast ice would vary by season. During the Fall Transition and Ice seasons (October – April), the broken ice and open water ship tracks of icebreakers are not expected to remain open for long; however, they do temporarily create artificial sea ice leads that rapidly refreeze. This would be at irregular intervals, and very specific to the footprint of the activity. Ship wakes effectively introduce temporary artificial features that could behave like sea ice leads under wind forcing, thereby promoting dynamic thickening of sea ice (pressure ridges) where vessels transit and strong winds blow perpendicular to the vessel track.

During the Spring Transition Season to Open Water Season (May – July), icebreaking activities would likely avoid the thick nearshore landfast ice; however, there may be necessary intrusions into landfast ice that could have adverse effects on the local landfast ice edge. In areas of mobile sea ice, icebreaking may locally reduce ice floe sizes during the Spring Transition Season, however this is not expected to have an adverse effect on the sea ice. Routine ice breaking may introduce small, finite quantities of airborne or other contamination (e.g., discharges, paint chips from ship hulls) that may introduce very small concentrations of contaminants into the sea ice; however, this effect would be limited to the icebreaking footprint and is expected to have a negligible effect on total sea ice contaminant levels. Black carbon deposition from industrial activities may affect the sea ice at local – regional scales. There are no known effects of routine icebreaking activities on freeze-up timing, winter sea ice lead formation, or ice motion. Effects of icebreaking on sea ice and associated effects on marine mammals and polar bear are discussed in Sections D.3.5 and D.3.6.

Table D-13 Summary of Potential Impacts and Effects on Sea Ice

Potential Impact[5]	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Seabed Disturbance	• subsea well manifold, and pipeline installations and repairs	• possible localized thermodynamics effects on sea ice formation.	• highly localized likely negligible effects on rates of seasonal sea ice growth. • **further assessment of this impact is not warranted.**	• NA
Ice Disturbance	• icebreakers transiting through sea ice (ice management, support, transport) • presence of structures on/in sea ice or open water (drillships, platforms, wind energy turbines).	• direct breaking of the landfast ice surface along linear transits, occurring as single or multiple irregular occurrences • footprint-specific vessel damage to pressure ridges • artificial creation of sea ice leads, which would refreeze rapidly during the Ice Season, but potentially linger during the Spring Transition Season • local reduction of ice floe sizes in the Spring Transition Season	• moderate short-term effects on sea ice in the icebreaking footprint • introduces a rough, rubbled surface that may temporarily affect the reliability or safety of the sea ice surface for snowmobile travel • limited potential for trapping of marine mammals in wind-forced sea ice leads during the Spring Transition Season.	• remote sensing of vessel tracks and assessment of surface roughness
Vessel Wake	• vessel use during Open Water Season (commercial, personal use, tourism, sea lift, military, research, harvesting).	• No interaction	• NA	• NA

5 Potential impacts of Air Contaminants and GHG Emissions, Noise (in air and underwater), and Artificial Light are not considered for Sea as there are no direct impacts from these activities and processes on this VC. However, changes in Sea Ice that affect biota and human uses are discussed in the Summary of Potential Impacts and Effects for those VCs.

Table D-13 Summary of Potential Impacts and Effects on Sea Ice

Potential Impact[5]	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Routine Discharges	• air emissions • bilge and ballast water • drilling muds and lubricating fluids • drill cuttings and disposal • sewage and food waste • cooling water and deck drainage	• potential for limited amounts of unmanaged discharges to become mixed into the snow-covered sea ice cover	• effects on sea ice physical indicators are negligible • **further assessment of this impact is not warranted.**	• NA
Oil Spill	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from a subsurface location (well head, pipeline)	• potential for oil to migrate upward into brine channels with forming sea ice, thereby entraining contaminants into ice floes, cavities, and pressure ridges. • oil-in-ice and residue from *in situ* burning would affect sea ice contaminants • use of dispersants permits naturally occurring hydrocarbon-degrading microorganisms to biodegrade the oil, leaving a small proportion of recalcitrant residue that would affect sea ice contaminant levels. • oil interaction with sea ice may induce some melting, but depends on the oil pour point temperature, ambient air temperature, and type of oil spilled.	• high effect expected on sea ice contaminant levels from and oil spill. • *In Situ* burning is expected to have a high effect on black carbon deposition over a local-regional scale • *In Situ* burning would affect sea ice thermodynamics while oil is burning • effects on other sea ice indicators are expected to be negligible.	• monitor movement of oil in brine channels using physical sampling methods (ice cores) or on-ice sensors

The installation of a subsea pipeline and/or other underwater infrastructure may introduce an indirect thermodynamic effect to the water column, which may propagate to the surface in nearshore or shallow continental shelf sites, possibly affecting the rate of sea ice growth (freeze-up timing). However, it is unlikely this effect would be measurable for sea ice as it would be negligible in magnitude and limited to a small local area near the activity. A manifold installed at an offshore site (400 – 1000 m beneath the sea surface) would have no effect on the sea ice above as any thermodynamic influence would be fully absorbed by the lower layers of the overlying water column.

There is potential for sea ice leads to be formed in the lee of an offshore platform, which may locally increase the availability of open water habitat. Although short-term for exploratory drilling activities, this effect would be a medium-term effect for a full build-out of a nearshore or offshore resource development operation (e.g., a GBS or FPSO). Effects of icebreaking and lead formation on biota are discussed later in this Appendix (Section D.3.5.1.5).

Icebreaking from shipping activities, particularly near coastal communities and, especially within the land fast ice zone, may have potential effects on sea ice stability, structure, and predictability, and indirectly influence the people that depend on ice. A vessel may break a linear path through landfast level first-year ice types, leaving behind a wake of broken ice that would quickly refreeze into a rough, rubbled ice track. This can pose a hazard to snowmobile travel and potentially sever traditional hunting routes for periods of time during the Ice Season. In the Spring Transition Season, icebreaking within the landfast ice zone may alter the extent of seasonal landfast ice, at least temporarily, or potentially induce local concerns within Inuvialuit communities about early break-up and decay of the landfast ice edge. This effect would be considered an irreversible single event, but the overall effect would be early local break-up of landfast ice and limited to the season in which it occurred.

Repeated vessel operations at weekly intervals may create multiple refrozen ship wakes, of varying strength, roughness, and thickness over a wide area creating wider-reaching effects on Inuvialuit transportation on the ice and marine mammal habitat. Ship-wakes in wind-forced mobile sea ice, although present, are not considered to be of major concern due to ongoing natural sea ice dynamic processes. Effects of repeated icebreaking would be short-term and limited to the footprint of the activity (in this case, a linear track). Repeated icebreaking during the Spring Transition Season could also affect local ice floe sizes along the transit pathway since larger ice floes would not refreeze together following icebreaking. Footprint-specific impacts on ice floe sizes would be limited to the Spring Transition Season; such changes would have a limited effect on traditional hunting and transportation activities as the use of ice by Inuvialuit would be declining as the season advances. This has been especially so in recent years with increased open water and unpredictability of the sea ice surface, particularly around Ulukhaktok, Sachs Harbour, and Tuktoyaktuk (Joint Secretariat 2015:44).

Airborne contaminants, particularly black carbon deposition may reduce the albedo of the snow-covered sea ice surface and enhance snowmelt and sea ice loss during the summer months. However, <1% of high-latitude total black carbon deposition is expected to be from Arctic shipping sources, due to the long-distance transport of much larger relative contribution of black carbon from non-shipping sources at lower latitudes (Browse et al. 2013).

The effects of icebreaking in the mobile ice zone are not assessed further, since sea ice dynamic processes leading to the creation of leads and pressure ridges, coupled with climate change, have a much-larger relative effect on the suitability and reliability of the mobile sea ice surface for Inuvialuit travel. Ice floe edges and areas of open leads that were once predictable are no longer occurring in the same places from one year to the next or cannot be reached due to excessive rubble ice from natural physical forcing of the sea ice cover. Hunters from Tuktoyaktuk have noted these changes since approximately 2000 (Joint Secretariat 2015:162-163).

D.2.4.2 Scenario 1: Status Quo

D.2.4.2.1 Potential Impacts and Effects of Routine Activities

Description of Effect Pathways

Disturbance of the sea ice would occur from icebreaking vessel transits associated with research, military, commercial, or industrial activities; however, such icebreaking would likely only be required intermittently in the late Spring Transition and early Fall Transition seasons. When icebreaking does occur, it directly affects ice floes and potentially landfast ice cover, along the vessel's route. Activities or infrastructure that operate year-round (e.g., renewable energy, low level aircraft, snowmobiles) have negligible effects on the sea ice and are not notable pathways for effects on the sea ice.

Description of Range of Potential Effects

Icebreaking activities associated with industrial and shipping activities are limited in scope and duration and are not expected to occur within landfast ice cover near coastal Inuvialuit communities at present, unless deemed necessary for sealift access. Such activities could directly affect the reliability and integrity of the sea ice surface as a transportation medium. This effect would be limited to the mid-late Spring and late Fall Transition seasons. Such activities would leave an unstable field of rubble ice that may not refreeze and would represent a hazard to snowmobile operators and pedestrian harvesters. It is assumed that icebreaking in nearshore areas would only occur in proximity to coastal logistical bases and harbours and would be employed primarily to maintain a ship track in and out of the harbour. These activities would primarily be restricted to the late-Fall Transition and mid-late Spring Transition seasons.

Effects of Climate Change on Potential Effects

The combined changes in sea ice extent, dynamic processes, and timing of sea ice formation and breakup are key effects of climate change that would directly affect ongoing industrial and socioeconomic activities throughout the ISR. There is potential for climate change to delay the onset of sea ice formation (timing of freeze-up), which may encourage longer operating seasons for Status Quo activities. Furthermore, climate change may lead to delayed refreezing of vessel tracks following icebreaking, especially if air temperatures are delayed in becoming very cold (e.g., <-10°C). Sea ice mobility is expected to continue to increase throughout the Ice Season, thereby potentially enhancing sea ice dynamic processes (i.e., sea ice lead formation, pressure ridges); although no trend has been identified at present for sea ice lead formation (Lewis and Hutchings 2019). It is presently unknown how climate change might affect the extent and duration of landfast ice cover in the Canadian Arctic; however, it is likely that in the future there would be less sea ice for shorter portions of the year.

D.2.4.2.2 MITIGATION AND MANAGEMENT

General mitigation measures and standard operational procedures to reduce effects on sea ice cover should be employed. Existing and common travel routes should be used by vessels and icebreakers where possible to reduce the footprint of ice disturbance areas. Icebreaking within landfast ice should be avoided, where possible, to mitigate effects on marine mammals and Inuvialuit community activities. Measures specific to sea ice as habitat for individual species can be found in other sections (see Appendix F).

D.2.4.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Residual effects from single-event icebreaking activities in undisturbed areas from vessel transits are expected to be limited to the presence of a rough, linear path of rubble and broken ice, (i.e., limited to the footprint of the vessel's transited route) and be a low magnitude effect. The effects of icebreaking would diminish over time (i.e., short-term effects) as the sea ice refreezes and becomes overlain with drifted snowfall (i.e., the effect is naturally reversable). Should icebreaking occur during the Spring Transition season, new sea ice may not form again and may eventually break up and melt during the late Spring Transition and the Open Water seasons. Sea ice floe sizes may be locally affected by icebreaking activities; however, this is not expected to be a concern.

CUMULATIVE EFFECTS

There are no notable cumulative effects from icebreaking on the sea ice surface for Scenario 1 given that most vessel activity would occur during the Spring Transition, Open Water and Fall Transition seasons, and is expected to be dispersed throughout the BRSEA Study Area. In addition, expected changes to the sea ice climatology from climate change are expected to be much larger.

D.2.4.3 Scenario 2: Export of Natural Gas and Condensates

D.2.4.3.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAYS

Installation of the GBS and loading facility would be done during the Open Water Season and would avoid interaction with sea ice until the Fall Transition Season.

During the Ice Season and the Spring and Fall Transition seasons, changes in ice (e.g., ice deformation and buildup) are expected in the vicinity of the GBS and the associated loading facility for the LNG carriers and condensate tankers. This would result in alteration of the sea ice surface and ice floe size distributions within a limited radius around the platform. Ice management activities around the GBS and loading facility could also change sea ice conditions. Icebreaking activities from weekly transits by LNG carriers and condensate tankers may affect ice stability, structure and predictability for use by traditional harvesters and others; however, these tracks would be a considerable distance offshore (e.g., >15 km) and are not expected to interfere substantially with local Inuvialuit transportation and hunting activities. The duration of these effects is expected to be limited during the Ice Season, where the surface would quickly refreeze and become snow-covered due to new and blowing snow. This effect would be more pronounced during the Spring Transition Season where disturbed landfast sea ice cover may not refreeze, and the vessel tracks could be a hazard or barrier to travel.

Description of Range of Potential Effects

Icebreaking and management activities around the GBS, and icebreaking by the LNG carriers and condensate tankers would result in localized effects to sea ice for short (Ice Season) to moderate (mid-late Spring and late Fall Transition seasons) durations. Ice breaking in landfast and nearshore ice near coastal Inuvialuit communities during the mid-late Spring and late Fall Transition seasons could directly affect the reliability and integrity of the sea ice surface as a transportation medium. The disturbed landfast sea ice cover may not refreeze during the Spring Transition Season, and the vessel track would thus represent a hazard, or barrier to travel. We have assumed icebreaking in nearshore areas would only occur in proximity to coastal service and supply bases and would be used primarily to maintain a ship track in and out of the harbour. These activities are primarily restricted to the late-Fall Transition and mid-late Spring Transition seasons.

Effects of Climate Change on Potential Effects

The effects of climate change described for Scenario 1 are also applicable for Scenario 2.

D.2.4.3.2 Mitigation and Management

Mitigations described for Scenario 1 are also applicable for Scenario 2.

D.2.4.3.3 Effects Characterization

Residual Effects

Sea ice properties may be affected in the local vicinity of the GBS in an otherwise undisturbed area (i.e., a low to moderate magnitude effect). When sea ice remains mobile, ice build-up around the structure may create artificial areas of ice deformation (pressure ridges) on the windward side, and areas of reduced ice floe sizes and artificial sea ice lead openings on the leeward side. These effects would be short-term in duration, and reversible.

Low magnitude residual effects from multiple-regular icebreaking activities from the LNG carriers, condensate tankers and other vessel transits are expected to be limited to the presence of multiple rough, linear paths of rubble and broken ice, (i.e., limited to the footprint of the vessel's transited route). During the Ice Season, the effects of icebreaking would diminish over time (i.e., short-term effects) and be reversible as the sea ice refreezes and becomes overlain with drifted snowfall; however, this may be limited in duration if the same vessel track is used for subsequent transits. Maintenance of an icebreaking corridor through areas of land fast ice during the early Spring and late Fall Transition seasons, would leave an unstable field of rubble ice that may not refreeze and would represent a hazard to snowmobile operators and pedestrian harvesters.

Changes in sea ice habitat as a result of icebreaking and the presence of industrial development associated with Scenario 2 are predicted to be localized and short to long-term in duration (i.e., single vessel passage versus multiple passages). The effects would be minimal in magnitude, except for moderate effects arising from icebreaking activities in land fast ice during the Spring Transition Season. Habitat alterations from the presence of artificial sea ice leads is anticipated to potentially occur locally in sea ice leads created by vessel traffic and in the lee of the offshore structure; however, these are expected to of short duration (i.e., days to weeks). The prediction of residual effects on sea ice from human and industrial activities is made with low certainty given the type, speed and extent of recent changes in sea ice associated climate change.

Potential effects on Inuvialuit use of sea ice associated with Scenario 2 are considered in Section D.4.4.3.

CUMULATIVE EFFECTS

The predicted impacts of ongoing climate change are expected to affect the timing, seasonal predictability, structure, and stability of sea ice cover. Activities under this development scenario may seasonally add to this with decreased ice cover duration, extent and predictability due to the multiple-regular icebreaking activities occurring for marine traffic to and from the GBS and localized residual effects from the GBS itself. The cumulative effects of activities described in Scenario 2, combined with those described in Scenario 1 would have an overall greater net impact on the sea ice by affecting the sea ice cover (potentially nearshore ice cover as well) with regular icebreaking activities. Expected changes to sea ice climatology may reduce the overall duration of the icebreaking season necessary to service the GBS. There is a high degree of uncertainty as to whether climate change would affect the extent of landfast sea ice.; This factor would determine how the GBS interacts with sea ice, should ice remain mobile in the nearshore for long periods of time in the future.

D.2.4.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.2.4.4.1 ASSESSMENT OF EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAYS

Installation of the GBS and wareship would be done during the Open Water Season and would avoid interaction with sea ice until the Fall Transition Season.

During the Ice Season and the Spring and Fall Transition seasons, ice deformation and buildup from the GBS and wareship and ice management around the platform would result in alteration of the sea ice surface and ice floe size distributions within a limited radius around the GBS and wareship.

Icebreaking activities associated with a westward tanker transit every 5 days (700km return trip) and ice management activities within a 2 km circular radius around the GBS may affect sea ice floe size distributions and change the scale of local sea ice dynamic processes as broken ice floes refreeze and collide with each other. Ice floes may raft, or create small pressure ridges, particularly in the lee of the offshore structure; however, this effect is expected to be highly localized. Since this development is approximately 80 km offshore, changes in sea ice would have limited or no effect on sea ice as a reliable travel medium for Inuvialuit travel and harvesting activities.

Local Inuvialuit transportation and harvesting activities may be affected by multiple-regular occurrences of linear vessel tracks through nearshore and land fast ice (e.g., access to supply and service bases in coastal areas), especially during the late Spring and early Fall Transition seasons. No breaking of landfast ice is expected during the Ice Season. Breaking of land fast ice and nearshore ice during the Spring and Fall Transition seasons is likely to result in sea ice cover that may not refreeze. The broken ice in the vessel track would represent a hazard, or barrier to travel by local people.

Description of Range of Potential Effects

Icebreaking in nearshore areas is likely to occur in proximity to coastal service and supply bases and would be used primarily to maintain a ship track in and out of the harbours during the mid-late Spring Transition and late-Fall Transition seasons. Icebreaking activities, particularly within landfast ice cover near coastal Inuvialuit communities during these two seasons could directly affect the reliability and integrity of the sea ice. In turn, this could affect the sea ice surface as a transportation medium for Inuvialuit harvesters (e.g., spring hunting for species such as geese; caribou hunting during the fall freeze up season). Effects to the sea ice surface may be more pronounced during the Spring Transition Season where disturbed landfast sea ice cover may not refreeze.

Little or no effect on sea ice is expected during the peak of the Ice Season (January to March) as icebreaking is not likely to be undertaken during that season. If such icebreaking did occur, the surface would likely refreeze or be dynamically closed by wind-forcing and become snow-covered due to new and blowing snow. Should ice conditions deteriorate in the future to the point where sea ice remains persistently mobile in the region throughout the winter, then natural disruptions to the offshore ice cover would likely exceed those caused by icebreaking. Landfast ice would be reduced in extent, and increasingly vulnerable to the effects of icebreaking at the end of the Ice Season into the Spring Transition Season.

The range of potential effects on ice floe sizes, artificial sea ice leads, and sea ice dynamics near the GBS and wareship would be limited to the local area where regular ice management activities are taking place (i.e., 2 km circular transits).

Effects of Climate Change on Potential Effects

The effects of climate change described for Scenario 1 are also applicable for Scenario 3.

D.2.4.4.2 Mitigation and Management

Mitigation measures described for Scenario 1 are also applicable for Scenario 3.

D.2.4.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Sea ice may experience low-moderate magnitude residual effects in the local vicinity of the GBS associated with Scenario 3. When sea ice remains mobile, ice build-up around the structure may create artificial areas of ice deformation (pressure ridges) on the windward side, and areas of reduced ice floe sizes and artificial sea ice lead openings on the leeward side. These effects are predicted to be localized and short-term in duration (medium-term over the life of the GBS), and reversable. The overall effects from ice breaking would be low in magnitude, with the exception of moderate effects arising from potential icebreaking activities in land fast ice during the mid-late Spring and late Fall Transition seasons, and in the immediate vicinity of the GBS. There may be some low-magnitude adverse effects on the integrity of the sea ice surface as a transportation medium for local travel where icebreaking activities take place; however, these effects are expected to be confined to the footprint of the activity, are short-lived in duration, and are considered naturally reversable

Low magnitude residual effects from multiple-regular icebreaking activities from vessel transits through mobile sea ice are expected to be limited to the presence of multiple rough, linear paths of rubble and broken ice, (i.e., limited to the footprint of the vessel's transited route). The effects of icebreaking would diminish quickly over time (i.e., short-term effects) as the sea ice moves, refreezes and becomes overlain with drifted snowfall; however, this may be limited in duration if the same vessel track is used for subsequent transits. During the mid-late Spring and late Fall Transition Season, icebreaking within land fast ice cover would leave an unstable field of rubble ice that may not refreeze and would represent a hazard to snowmobile operators and pedestrian harvesters. The prediction of residual effects on sea ice from human and industrial activities is made with low certainty given the type, speed and extent of recent changes in sea ice associated climate change.

Potential effects on Inuvialuit use of sea ice associated with Scenario 4 are considered in Section D.4.4.4.

CUMULATIVE EFFECTS

The cumulative effects of activities described in Scenario 3, combined with those described in Scenario 1 would have an overall greater net impact on the sea ice than Scenario 2 by affecting the sea ice cover (potentially landfast cover as well) with regular icebreaking activities. However, the expected changes to the sea ice climatology associated with climate change may reduce the overall duration of the icebreaking season necessary to service the GBS. There is a high degree of uncertainty as to whether climate change would affect the extent of landfast sea ice; and this factor would determine how the GBS interacts with the sea ice, should it remain mobile in the nearshore for longer periods of time in the future.

D.2.4.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.2.4.5.1 Assessment of Effects of Routine Activities

Description of Effect Pathways

A dynamically positioned drillship would operate on-site during the Open Water Season, and into the early part of the Fall Transition Season. The movement of these ships at the end of the drilling season would have a limited impact on first-year sea ice and is not expected to cause adverse effects to habitat or traditional transportation or harvesting activities in the immediate area.

Changes in ice habitat (e.g., ice deformation and buildup) from the FPSO and wareship, as well as ice breaking around the platform during the Ice Season and the Spring and Fall Transition seasons would result in alteration of the sea ice surface within a limited radius around the FPSO and wareship. Floe sizes are expected to be affected in the local vicinity from ice management and icebreaker activities.

Icebreaking activities arising from weekly ship transit activities, including a westward tanker transit every 5 days following a 700 km return trip, and ice management activities within a 2 km circular radius around the GBS may affect sea ice floe size distributions and change the scale of local sea ice dynamic processes as broken ice floes refreeze and collide with each other. The eastward tanker transit (one per month during the Open Water Season) may require some icebreaker support in some years when ice remains in the Northwest Passage or Amundsen-Queen Maude Gulf.

Description of the Range of Potential Effects

The range of potential effects on ice floe sizes, artificial sea ice leads, and sea ice dynamics near the FPSO and wareship would be limited to the local area where regular ice management activities are taking place (i.e., 2 km circular transits). Icebreaking activities in support of tanker traffic would occur over long linear routes; however, given the distance offshore for most shipping (i.e., >100 km), these activities are would have limited potential to interact or conflict with Inuvialuit use of the sea ice, with the exception being where ship transits occur close to coastal areas (e.g., vessel transits from coastal supply and service based during the mid-late Spring and late Fall Transition seasons).

Icebreaking in nearshore areas would only occur in proximity to coastal service and supply bases and would be used primarily to maintain a ship track in and out of the harbour. These activities are expected to occur primarily during the late-Fall Transition and mid-late Spring Transition seasons. Icebreaking activities, particularly within landfast ice cover near coastal Inuvialuit communities could directly affect the reliability and integrity of the sea ice surface as a transportation medium during the mid-late Spring and late Fall Transition seasons. During these seasons, disturbed landfast sea ice cover may not refreeze, and the vessel track would represent a hazard, or barrier to travel.

Effects of Climate Change on Potential Effects.

The effects of climate change described for Scenario 1 are also applicable for Scenario 4.

D.2.4.5.2 MITIGATION AND MANAGEMENT

Mitigation measures described for Scenario 1 are also applicable for Scenario 4.

D.2.4.5.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Changes in sea ice as a result of icebreaking and the presence of offshore infrastructure associated with Scenario 4 are predicted to be localized and short or medium-term in duration. The effects would be negligible to low in magnitude, except for moderate effects arising from potential icebreaking activities in land fast ice during the mid-late Spring and late Fall Transition seasons. Sea ice leads are anticipated to potentially be created with the passage of vessel traffic, and in the lee of the offshore facilities; however, these are expected to be short-lived in duration. Potential effects on Inuvialuit use of sea ice associated with Scenario 4 are considered in Section D.4.4.5.

CUMULATIVE EFFECTS

The cumulative effects of activities described in Scenario 4, combined with those described in Scenario 1 would have an overall greater net impact on the sea ice by affecting the sea ice cover (potentially landfast cover as well) with regular icebreaking activities. In addition, the expected changes to the sea ice climatology associated with climate change may reduce the overall duration of the icebreaking season necessary to service the FPSO and wareship, as well as tanker and supply ship routes. There is a high degree of uncertainty as to whether climate change would affect the extent of landfast sea ice; and this factor would determine how the FPSO interacts with the sea ice, should it remain highly mobile for longer periods of time during the Ice Season in the future.

D.2.4.6 Scenario 5: Large Oil Release Event

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on sea ice from such an event would differ slightly from what is described below for surface or subsea releases.

D.2.4.6.1 ASSESSMENT OF EFFECTS OF AND OIL SPILL

DESCRIPTION OF EFFECT PATHWAY

Three potential large oil release events are assessed to determine their potential effect on sea ice indicators. These scenarios are: 1) a platform or tanker spill within the Mackenzie River plume (surface release of oil), 2) from a platform outside of the Mackenzie River plume (subsea release of oil), or 3) a tanker incident (surface release of oil) outside the Mackenzie River plume. The primary effect pathway of an oil spill in sea ice is into brine channels during sea ice freeze-up, under-sea oil seeping up through fissures that may be covered by snow, absorption of oil into snow-covered sea ice surfaces, and pooling of oil in spring meltpond water (Dickins 2011). Oil spilled directly onto the sea ice surface is not expected to spread far laterally; however, it would infiltrate the sea ice into cracks and through the brine channel matrix. Oil spills from subsea incidents would need to travel vertically through the water column to reach the underside of sea ice.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Oil spills would interact differently with sea ice, depending on the source of the oil (subsea versus surface), and the time of year (i.e., well-developed sea ice surface versus early ice freeze-up).These processes have the potential to introduce contaminants to the sea ice through the brine channels and into cracks and cavities over a wide area of sea ice cover.

Oil spills resulting from a subsea incident may result in some components of the crude oil not reaching the ice surface due to emulsification, dispersion, dissolution and spreading by under-ice currents from the ocean. A lower concentration of oil is expected to reach a larger area of the sea ice in this case. Given the difficulty of responding to an under-ice oil spill event, it is likely that this oil may accumulate under the ice cover for several days or weeks, depending on the severity of the event. As new ice forms, the oil under the ice would be encapsulated in the ice and would likely remain in the ice until the ice melt the following year.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Changes in the extent and duration of sea ice (and the extent and duration of open water) as a result of climate change would affect the trajectory and behaviour of a large oil release. Furthermore, changes to the annual discharge characteristics of the Mackenzie River may alter the nature of the Mackenzie River plume and the extent to which freshwater input contributes to sea ice growth near the river delta and the dispersion of oil.

D.2.4.6.2 MITIGATION AND MANAGEMENT

Techniques to mitigate and manage a release of oil into the ocean is provided in Sections 2.13 and 3.10.5.3.

Widespread mitigation activities within sea ice, particularly *in situ* burning, may introduce lateral melting where oil has pooled into cracks and cavities. The growth of these lateral cavities may trap 10-35% of the crude oil inside the ice, where it cannot be burned or be mechanically collected until the ice melts (Farahani et al. 2015, 2017).

D.2.4.6.3 *EFFECTS CHARACTERIZATION*

RESIDUAL EFFECTS

In the event of a large oil release in the Fall Transition or Ice seasons, quantities of oil may become trapped in brine channels and cavities for the remainder of the Ice Season and may be transported beyond the BRSEA Study Area through natural sea ice motion. This represents an adverse effect that may be low to high in magnitude in that sea ice contaminants are trapped within the sea ice and spread over a large area. Sea ice cover that melts out completely in the following summer would release the trapped oil to the water column, where spill response and recovery measures and natural biodegradation would help reduce oil in the environment. Sea ice floes that do not melt out entirely the following season would likely drain out most of the oil with natural brine channel drainage; however, low concentrations of contaminants would likely remain in the sea ice. This would represent a medium-term effect as contaminants would be present in second-year ice cover.

The presence of the dark, sooty by-product of burning oil-in-ice would collectively decrease the albedo of the sea ice, particularly as the melt season advances. This would be an adverse effect in addition to oil trapped in the brine channels, and within cavities induced by lateral melting from in situ burning of oil. These materials would decrease the surface albedo of sea ice by a low-moderate amount and increased solar heating during the melt season. This may have a net adverse effect on local-scale thermodynamic processes in sea ice melt rates. If oil is present over a local extent under the sea ice, and the oil-in-ice is permitted to move / spread / disperse within the pack ice, this could scale up the effect to a regional-scale.

D.2.4.7 *Summary of Effects*

Effects on sea ice associated with activities in Scenario 1 to 4 are summarized in Table D-14. Effects of a large oil release event on sea ice are summarized in Table D-15.

D.2.4.8 *Gaps and Recommendations*

Lateral melting and growth of cavities in ice floes from *in situ* burning represents a potential complication for spill response measures in sea ice and should be reviewed further to determine acceptable thresholds of spill size and infiltration into the ice surface to permit effective mitigation by *in situ* burning.

D.2.4.9 *Follow-up and Monitoring*

For future projects similar to the three oil and gas development scenarios described here, develop a baseline for sea ice to better assess effects; two types of monitoring are recommended:

- monitoring of sea ice contaminants in areas immediately surrounding active industrial projects
- evaluation of how repeated icebreaking vessel tracks can affect ice roughness and integrity; this could be done using remote sensing methods (e.g., lidar, synthetic aperture radar, etc.)

Table D-14 Potential Residual Effects of Scenarios 1 – 4 on Sea Ice

Season	Scenario 1: Status Quo	Scenario 2 Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Ice	• No to negligible effects in this season	• Tanker transits, and ice breaking within 2 km of GBS may locally affect landfast ice cover and sea ice habitat • Nearshore ice breaking (while unlikely) may affect Inuvialuit transportation and harvesting	• Presence of the GBS and wareship, ice management within 2 km of GBS and wareship, and tanker transits may locally affect sea ice habitat • Nearshore ice breaking (while unlikely) may affect Inuvialuit transportation and harvesting	• Presence of the FPSO and wareship, ice management within 2 km of FPSO and wareship, and tanker transits may locally affect sea ice habitat • Nearshore ice breaking (while unlikely) may affect Inuvialuit transportation and harvesting
Spring Transition	• Limited, short-term adverse effects to Inuvialuit transportation and harvesting activities as a result of icebreaking. No or minor regional effects.	• Weekly ship tracks may affect sea ice habitat, sea ice leads, Inuvialuit transportation and harvesting activities. Possible effect on landfast ice breakup.	• Weekly ship tracks may affect sea ice habitat, sea ice leads, and nearshore Inuvialuit transportation and harvesting activities. • Nearshore ice breaking may affect Inuvialuit transportation and harvesting	• Ice floe sizes may be affected in areas of ice management and tanker transits. • Nearshore ice breaking may affect Inuvialuit transportation and harvesting
Open Water	• No notable local or regional effects.	• No notable local or regional effects.	• No notable local or regional effects.	• No notable local or regional effects.

Table D-14 Potential Residual Effects of Scenarios 1 – 4 on Sea Ice

Season	Scenario 1: Status Quo	Scenario 2 Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Fall Transition	• Moderate effects to local sea ice development due to vessel track rubble fields	• Limited effects to local sea ice development due to vessel track rubble fields • Nearshore ice breaking may affect Inuvialuit transportation and harvesting	• Limited effects to local sea ice development due to vessel track rubble fields • Nearshore ice breaking may affect Inuvialuit transportation and harvesting	• Limited effects to local sea ice development due to vessel track rubble fields • Nearshore ice breaking may affect Inuvialuit transportation and harvesting

Legend
• Least effect – No to minor effect on sea ice physics, habitat, or integrity of sea ice as a transportation medium
• Moderate effect -- Moderate effect on sea ice physics, habitat, or integrity of sea ice as a transportation medium
• High effect -- Major effect on sea ice physics, habitat, or integrity of sea ice as a transportation medium
• Greatest effect – Severe effect on sea ice physics, habitat, or integrity of sea ice as a transportation medium

Table D-15 Potential Effects of a Large Oil Release Event (Scenario 5) for Sea Ice

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• Limited spatial extent of the plume would confine oil spills to a small area, and limit dispersion of sea ice contaminants.	• Limited spreading potential • Oil-based sea ice contaminants would drift with the pack ice • Lateral melting and by-products of in situ burning may act as further contaminants, and lower the local / regional albedo of the sea ice surface	• Limited spreading potential • Oil-based sea ice contaminants would drift with the pack ice • Lateral melting and by-products of in situ burning may act as further contaminants, and lower the local / regional albedo of the sea ice surface
Spring Transition	• Cleanup of under-ice oil would be difficult, and some oil may linger to the open-water season. • Contaminants in meltpond water may eventually drain through to the water column below. • Brine channel drainage would remove most oil, but residual contaminants would linger.	• Cleanup of under-ice oil would be difficult, and some oil may linger to the open-water season. • Contaminants in meltpond water may eventually drain through to the water column below. • Brine channel drainage would remove most oil, but residual contaminants would linger.	• Cleanup of under-ice oil would be difficult, and some oil may linger to the open-water season. • Contaminants in meltpond water may eventually drain through to the water column below. • Brine channel drainage would remove most oil, but residual contaminants would linger.
Open Water	• NA, no ice	• NA, no ice	• NA, no ice
Fall Transition	• Residual oil remaining at the surface or within the water column may be drawn into sea ice brine channels upon freeze-up, thereby affecting sea ice contaminants. • Cleanup would be more difficult than other seasons due to mixing within turbulent seas and young ice types.	• Residual oil remaining at the surface or within the water column may be drawn into sea ice brine channels upon freeze-up, thereby affecting sea ice contaminants. • Cleanup would be more difficult than other seasons due to mixing within turbulent seas and young ice types.	• Residual oil remaining at the surface or within the water column may be drawn into sea ice brine channels upon freeze-up, thereby affecting sea ice contaminants. • Cleanup would be more difficult than other seasons due to mixing within turbulent seas and young ice types.

Table D-15 Potential Effects of a Large Oil Release Event (Scenario 5) for Sea Ice

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Longer-term/ Multi-year	• Most residual oil removed by an ongoing spill response and natural microbial breakdown of hydrocarbons.	• Most residual oil removed by ongoing spill response and cleanup natural microbial breakdown of hydrocarbons.	• Most residual oil removed by ongoing spill response and cleanup natural microbial breakdown of hydrocarbons.
Legend			
• Least effect – No to minor effect on sea ice physics, habitat, or integrity as a transportation medium			
• Moderate effect -- Moderate effect on sea ice physics, habitat, or integrity as a transportation medium			
• High effect -- Major effect on sea ice physics, habitat, or integrity as a transportation medium			
• Greatest effect – Severe effect on sea ice physics, habitat, or integrity as a transportation medium			

D.2.5 Coastal Dynamics and Sea Floor Geology

D.2.5.1 Scoping

D.2.5.1.1 Identification of Indicators

The selection of indicators for the coastal dynamics and sea floor geology VC considers the importance of different processes and conditions in the coastal area and along the seafloor and their implications on the biological and human environment. The chosen indicators are coastal stability and seafloor permafrost conditions.

TLK holders have identified coastal erosion as being of concern to the communities of Aklavik, Inuvik, Tuktoyaktuk and Sachs Harbour while seafloor permafrost is not mentioned. Coastal erosion was identified in many of the TLK studies: Aklavik (IMG Golder and Golder Associates 2011a; ACCP 2016), Inuvik (ICCP 2016) and Tuktoyaktuk (KAVIK-AXYS Inc. 2004b; TCCP 2016). Concerns about beaches disappearing due to slumping of seashore banks, resulting in impediments to travel were reported by the people of Sachs Harbour (IMG Golder and Golder Associates 2011c).

D.2.5.1.2 Spatial Boundaries

Coastal stability is considered for the area immediately seaward of the coastline over the entire coastline of the ISR where development and human activities impinge on the coastlines. Permafrost conditions are considered for areas where permafrost is present immediately below the sea floor, from the coastline to the outer shelf at water depths of approximately 95 m (i.e., the offshore limit of subsea permafrost).

D.2.5.1.3 Temporal Boundaries

The temporal boundary for the assessment of coastal dynamics is the 30-year period between 2020-2050.

D.2.5.1.4 Assessment of Potential Effects

The assessment of potential effects considers:

- the degree to which coastal stability may be affected
- the extent of the seafloor in which the permafrost may be degraded due to the heat transfer from development facilities or structures.

The magnitude and geographic extent of effects of scenario-based activities on coastal stability and seafloor permafrost conditions is assessed first. For effects that are not considered negligible, the direction, frequency and durations of the effects are assessed.

A qualitative characterization of potential residual effects on coastal dynamics and seafloor geology associated with each scenario is based on the characterization terms defined in Table D-16.

Table D-16 Characterization of Residual Environmental Effects on Coastal Stability and Seafloor Permafrost Conditions for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Positive**—a seaward extension of the coastline or an increase in the extent of seafloor permafrost **Adverse**—a shoreward retreat of the coastline or a reduction in the extent of seafloor permafrost **Neutral**—no net change in the location of the coastline or no net change in the extent of seafloor permafrost
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no measurable change in the coastline position or extent of subsea permafrost **Low**—a measurable change that does not affect the overall coastline stability or overall seafloor permafrost condition. **Moderate**—a measurable change with potential to affect overall coastline stability and seafloor permafrost condition. **High**—a measurable change that affects overall coastline stability and seafloor permafrost condition.
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the local area **Regional**—residual effects extend into the BRSEA Study Area **Extra-regional**—residual effects extend beyond the BRSEA Study Area
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity **Continuous**—residual effect occurs continuously for the duration of the activity
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to one phase (e.g., seismic survey, exploration drilling) or season **Medium-term**—residual effect extends through multiple seasons or years **Long-term**—residual effect extends over the life of the project (e.g., beyond closure) **Permanent**—measurable parameter unlikely to recover to existing conditions
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.2.5.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

The issues and concerns with coastal stability are linked to the level of activities for vessel movements in shallow coastal waters, especially within and close to the approaches to coastal supply and service bases (e.g., Tuktoyaktuk Harbour). Vessel movements can result in disturbances to the coastline through vessel induced flows, in particular: propeller wash onto the seabed and the generation of wake-wash waves (Didenkulova et al. 2011; Macfarlane et al. 2019; Huntington et al. 2015a; Hughes et al. 2007). These effects would only be realized if the vessel was operated within a few kilometres of the coastline. Effects could occur through the erosion of bottom sediments in the very shallow coastal waters from vessel-derived currents that can transport sediments away, resulting in erosion of the coastline. When vessel generated waves reach the coastline, they can induce erosion and resuspension of bottom sediments from the shoreline, which are then transported away, resulting in coastal erosion (Table D-17).

Dredging in harbours, harbour entrances and approaches to harbours could also result in changes to coastal current and associated changes in coastal stability and permafrost.

Routine activities that could affect permafrost conditions include site preparation and development for facilities or structures such as supports or bases for offshore wind energy turbines, subsea pipelines, or GBS platforms that are in contact with the sea floor where there is permafrost immediately beneath the sea floor. These facilities could include drilling in permafrost and subsequent production of higher temperature hydrocarbons, which may result in the melting of the ice content in the permafrost and potential destabilization of the well-bore (Blasco et al. 2013). Site preparation for many facilities could involve suction dredging to provide a level and stable surface for installation of structures (e.g., the GBS platforms, manifolds) and pipelines, as well as site preparation for drilling. An effect could occur if the facilities or structures that are in contact with the seafloor need to be operated at temperatures that are warmer than natural ocean temperatures near the seafloor. These higher ambient temperatures could result in melting and degradation to the permafrost layer immediately below the seabed. However, this effect, is predicted to be of negligible magnitude due to the small areas affected relative to the extent of seafloor in the BRSEA Study Area and is not assessed further. However, mitigation measures, as discussed below, should be included in projects.

Of note, subsea cryogenic pipelines for LNG are operated at temperatures substantially below freezing (e.g., ~-150C to -160C). While insulated pipe is used for these pipelines, they can create frost bulbs or heaves around the pipeline as a result of freezing substrates in the immediate area of the pipeline (DeGeer and Nessim 2008; Brown et al. 2009).

Table D-17 Summary of Potential Impacts and Effects on Coastal Dynamics and Sea Floor Geology

Potential Impact[6]	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Seabed Disturbance	• pipelines carrying natural gas and condensates to offshore loading facility • dredging in harbours and harbour entrances • GBS structure on seafloor	• development structures in contact with the seabed in which heat transfers to the seabed • dredging increases water depths and also releases sediments which can be transported and deposited at the coastline • drilling in permafrost or production of higher temperature hydrocarbons in wells may result in melting of permafrost ice and destabilization of well-bore	• temperatures above ambient conditions may reduce subsea permafrost in the vicinity of the seabed structures • cryogenic pipelines may create a localized frost bulb • the magnitude of effects is limited to the immediate vicinity of the footprint of the pipeline route and GBS structure and is expected to be negligible to low. The magnitude would be quantified when detailed geotechnical engineering studies are conducted • dredging alters the coastline either directly or through deposition of sediments from nearby dredging	• loss of areal extent of subsea permafrost due to anomalous temperatures in pipelines or the GBS structure • loss or increase in coastline extent due to dredging

[6] Potential impacts of Air Contaminants and GHG Emissions, Noise (in air and underwater), Artificial Light, Ice/Open Water Disturbance, Routine Discharges and Vessel Collision are not considered for Coastal Dynamics and Seafloor Permafrost as there are no direct impacts from these activities and processes on this VC. However, changes in Coastal Dynamics and Seafloor Permafrost that affect biota and human uses are discussed in the Summary of Potential Impacts and Effects for those VCs.

Table D-17 Summary of Potential Impacts and Effects on Coastal Dynamics and Sea Floor Geology

Potential Impact[6]	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Vessel Wake	• local vessels • commercial, tourism, sea lift, military, research, harvesting • ship-based resupply for offshore oil and gas developments	• wake effects in the form of vessel-generated currents and wake-wash waves from vessels operating in proximity to the coastline	• vessel induced flows can move sediment away from the coast and lead to coastal erosion. Effects are expected to be highly localized with individual events dispersed over a wide area • overall, this effect is expected to be negligible to low in magnitude and local • further assessment of this effect is not warranted	• NA
Oil Spill	• oil released from surface and sub-surface sources (tanker and related transfer spills; well head blowout) resulting in vessel-based beach cleanup operations	• vessel wake effects in proximity to the coastline • mechanical cleanup of shoreline	• increased vessel induced flows can move sediment away from the coast and lead to coastal erosion • mechanical cleanup of oiled shoreline can alter the stability of the soil and lead to coastal erosion • overall, these effects are expected to be negligible to moderate in magnitude and could extend beyond local • further assessment of this effect is not warranted	• potential loss of coastline

D.2.5.2 Scenarios 1-4: Status Quo and Routine Hydrocarbon Developments

D.2.5.2.1 POTENTIAL EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAYS

The location and frequency of vessel activities during the Open Water Season is the primary pathway for an effect on coastal stability. Vessel activities may extend from the latter portion of the Spring Transition Season through the Open Water Season to the mid- or even late Fall Transition Season, although the level of activities is much reduced during later transition periods.

In Scenario 1, the potential development of bases for offshore wind energy turbines could result in resuspension and movement of suspended sediments during site preparation (e.g., suction dredging) and the construction of the base of the turbines. They could also affect subsea permafrost in the immediate vicinity of the structure.

In Scenarios 2 and 3, the preparation of the seabed and construction of subsea pipelines, and site preparation and use installation of GBS platforms could result in effects on subsea permafrost. In Scenario 4, subsea infrastructure and seabed disturbances are in deep water approximately 100 km or more offshore; as a result, subsea structures such as manifolds, pipeline bundles and disturbance from anchoring would be beyond the outermost seaward limit of subsea permafrost. In Scenario 5, oil effects on coastlines and spill response activities and associated disturbance on the coastline and nearshore could result in effects on coastline stability and permafrost.

Dredging of harbours, harbour entrances and shipping channels also can directly affect coastal stability through suspension and transport of sediment by currents. The effects of dredging on permafrost in nearshore areas is likely very small, other than localized direct effects of permafrost that is removed due to this activity.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

In Scenarios 1-4, vessel activities are expected to increase over the next 30 years within the region. In Scenario 1, the increases are associated with additional ship transits for commercial shipping, cruise ship tourism, ship based resupply of communities, scientific research and military vessels and exercises. Some of these increased vessel activities would be in proximity to the coastline and in harbours, where the vessel activities may cause localized coastal erosion and effects on coastline stability. In Scenarios 2, 3 and 4, vessel activities would occur year-round in offshore areas (e.g., ice-breaking, ice management, carrier and tanker movements, supply ships). In nearshore areas, vessel movements would be focused in areas close to harbour entries for coastal service and supply bases (e.g., Tuktoyaktuk, Summers Harbour), with transits occurring during the late Spring Transition, Open Water and Fall Transition seasons.

The effects would be largest during the Open Water Season when there is no or little sea ice to reduce the vessel speeds or the resulting wake-wash waves. The effects would vary according to the amount of increased vessel activities within a few kilometres or less of the coastline and the number of vessels entering harbours, such as Tuktoyaktuk. The effects would also depend on vessel speed; of note, effects can be greatly reduced with implementation of lower vessel speed restrictions. Given that effects are limited to vessel movements close to the coastline, very large vessels such as deep draft cruise ships and large military, scientific research and other commercial vessels are not likely to have an effect because there are navigational restrictions in shallow coastal waters. However, if these large ships use smaller transit vessels to move people or freight into coastal harbours, these smaller vessels may have some effect on coastal stability.

The effects of offshore wind energy turbines in Scenario 1 are expected to be negligible, after mitigation, especially if the wind turbine locations are a few kilometers from the coastline

In Scenarios 1 through 4, dredging activities may occur in proximity to the coastline to maintain shipping lanes, harbour entrances and harbour basins for the service and supply bases (e.g., Tuktoyaktuk, Summers Harbour); such dredging may have an effect on coastal stability. The effects could add or detract from coastline stability according to the transport and fate of the sediments released from dredging but, in any event, would affect very small areas compared to the total length of the coastline in the BRSEA Study Area. The effects of dredging on subsea permafrost would be limited to the direct removal of the subsea permafrost itself which would be a very small volume and affect a small area of the seabed.

Effects of Climate Change on Potential Effects

Climate change and natural processes are already resulting in coastal erosion along all parts of the coastline of the BRSEA Study Area, at low to high erosion rates, which varies according to local and regional geological, permafrost and oceanographic conditions (as discussed in Sections 3.4 and 7.2.4).

For most coastlines, the effects of increased vessel movements over the next 30 years is expected to be negligible compared to the dramatic changes that are expected to occur from climate change. Potential scenario activity-related effects are expected to add to these effects. However, the portion of the coastline in which effects may occur is small relative to the total length of the coastline in the BRSEA Study Area. In contrast, climate change effects are expected to affect the full length of the coastlines within the BRSEA Study Area.

Climate change is also resulting in reduction of the permafrost below the seafloor due to increased water temperatures of near-bottom waters as the duration of the Open Water Season increases. The longer Open Water Season is resulting in more heating of the water column due to solar radiation, along with increases in air temperatures.

Water temperatures are also rising due to warm water inputs to the Beaufort Sea. Of note. water from the Pacific Ocean that is entering the BRSEA Study Area from the Chukchi Sea is already relatively warm and fresh (Section 7.2.3.1). With climate change, there is a concern that further warming of water in Chukchi Sea from its current temperature of 11 C to 13 C could affect water temperatures in the Beaufort Sea (Timmermans et al. 2018). This warming could also affect subsea permafrost.

D.2.5.2.2 MITIGATION AND MANAGEMENT

General mitigation measures and standard marine vessel operation procedures can be used to reduce the effect of vessel movements on coastal erosion. These mitigation measures include:

- adherence to reduced vessel operating speeds in harbours and the approaches to harbours
- use of vessel routes that keep vessels away from coastlines that are particularly vulnerable to coastal erosion due to moderate to high levels of erosion associated with natural and climate change processes
- for offshore wind energy turbines, analysis/modelling of potential effects of resuspension and transport of sediments may be warranted, especially in areas in proximity to the coastline. Monitoring of suspended sediments transport might also be considered to confirm effects.
- the potential effect of heating of the seafloor from subsea pipelines can be mitigated through the geotechnical engineering design for the pipeline, in combination with the operation of the shore-based processing plant which determines the temperature of the LNG and condensate which is transported through the pipeline. The geotechnical engineering of the design and operation of the full facility can be used to reduce the effects of the operation of the pipeline on the natural permafrost immediately below the seafloor.
- similar geotechnical design and operating measures can be considered for offshore structures such as GBS platforms, including the engineering design mitigation measures used to reduce the potential for destabilization around well-bores extending below GBS platforms
- dredging programs should include modeling and, if necessary, project monitoring during construction, to predict changes in sediment transport and coastal stability

D.2.5.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Although vessel activities associated with Scenario 1 are expected to increase in frequency and seasonal extent over the next 30 years, the effects on coastal stability are largely confined to the Open Water Season. The effects from different types of vessel use would be adverse, low magnitude over a local geographic extent at an unknown frequency, perhaps low to moderate, over very short durations of hours or less for each vessel transit. With mitigation and management, the residual effects on coastline stability are expected to be negligible to low on regional geographic scales.

In Scenarios 2 through 4, vessel movements would occur year-round, including ice breaking, ice management, carrier and tanker movements, and supply vessels. However, these vessel movements, except for twice yearly re-supply transits, would be far from shore and would not affect coastal erosion.

Climate change in the form of lengthening of the open water shipping season and, thereby, the numbers of vessel movement events each year, could increase the residual effects.

The effects of resuspended sediments and transport of these sediments toward the coastline from offshore wind energy turbines is expected to be negligible after mitigation. The GBS footprint is much larger than the footprint of a wind turbine, and would be located far from the coastline, so effects on coastal stability from GBS platforms are not expected.

Dredging effects on coastal stability and subsea permafrost are expected to be highly localized (i.e., small areas near harbours or bases) and are expected to be negligible to low relative to natural processes along the length of the coastline within the BRSEA Study Area. The effects of dredging on subsea permafrost are also expected to be very small. Effects of dredging on coastal stability and subsea permafrost are predicted to be negligible to low.

In Scenario 2, the residual effects of subsea pipelines on the subsea permafrost conditions would occur over a small total area (i.e., 15-20 ha; width of < 0.01 km over a length of 15-20 km). With suitable engineering design applied to mitigating the temperature differences and resulting heat or cold flux into the seafloor, the residual effects would be negligible on regional geographic scales.

CUMULATIVE EFFECTS

Since the residual effects of Scenarios 1 to 4 on coastal stability and subsea permafrost are localized and of low magnitude relative to the BRSEA Study Area, it is expected that cumulative effects from concurrent events would be similar to residual effects (i.e., localized and low magnitude).

The largest effect on coastline stability would be associated with climate change and natural processes, resulting in low to high adverse effects, depending on the composition of the coastline and exposure to waves, storm surges and weather. For example, coastline erosion along the Tuktoyaktuk Peninsula, prior to erosion control measures, was retreating at a rate of 2m/yr (Walker 1988). By comparison, the cumulative effects due to human activities are expected to be much smaller, although these human effects would exacerbate the total adverse effect.

The largest effect on subsea permafrost conditions is due to climate and natural processes, resulting in low to high adverse effects, varying by geographic location. By comparison, the cumulative effects due to human activities in Scenarios 1 to 4 are expected to be smaller, although these human effects would exacerbate the total adverse effect.

D.2.5.3 Scenario 5: Large Oil Release Event

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on coastal stability and subsea permafrost from such an event would differ slightly from what is described below for surface or subsea releases.

Description of Effect Pathways

Increased vessel movements would be expected during oil spill containment and response in coastal areas and along shorelines. Small vessels are often used to provide logistical support for clean-up personnel and equipment being brought in for the response operations. These vessels may be transiting between a harbour or other landing site to pick-up or drop-off personnel and supplies.

There is no discernable effect of an oil spill on the subsea permafrost conditions. In Scenario 4, the deepwater oil well blowout, there could be some effect of the subsea blowout on the local seafloor but in these water depths of several hundred metres, subsea permafrost is not present.

Description of Range of Potential Effects

The geographical range in which potential effects may occur is very large depending on: the season in which the oil spill occurs, the season in which spill response operations may occur; the location of the oil spill relative to the Mackenzie River plume; the type and location of the release (a surface spill from a tanker, other type of vessel or passenger ship, or from a GBS) or at the seafloor (i.e., a subsea well blow-out; and the effectiveness of the oil spill response measures. A detailed discussion of marine oil spills, spill response planning and response measures are provided in Section 2.13 and Section 3.10.

Substantial increases in coastal vessel traffic and shoreline clean-up related activities could lead to effects on coastline stability as described above. Coastal effects are predicted to be highest for a surface spill within the Mackenzie plume, particularly during the Open Water Season.

Note that clean-up of spills conducted in deeper waters, such as in the vicinity of the LNG loading facility (Scenario 2), the GBS oil production facility (Scenario 3) and the deepwater FPSO facility (Scenario 4) are expected to have less effect on coastal stability, as a large portion of the oil is predicted to remain offshore. If oil is transported by currents and winds from an offshore location in deeper waters to the shoreline (e.g., along the Yukon Slope) increased vessel activities and shoreline spill response measures could affect coastal stability.

Effects of Climate Change on Potential Effects

The effect of climate change on the potential effects of an oil spill on coastal stability are via the increasing duration of the Open Water Season (which is already occurring) when coastal effects are most likely. As the duration of the Open Water Season increases, the chances that an oil spill would encounter the coastline increases, which would increase the likelihood of vessel -based operations in support of the clean-up of this oil.

D.2.5.3.1 Mitigation and Management

Spill response planning would take into account coastal areas where shoreline erosion and loss of permafrost is occurring; these areas are summarized in the update to the Beaufort Regional Coastal Sensitivity Atlas (Environment Canada 2014). Measures could be used to reduce effects on shoreline operations on coastal stability (e.g., use of low-pressure vehicles and human support). Additional details are provided in Appendix F.

D.2.5.3.2 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

The residual effects of oil spills on coastal stability would largely be confined to the Open Water, the late Spring and early Fall Transition seasons. These effects would be adverse, but highly variable in magnitude and spatial extent depending on the amount and type of oil to be cleaned up and the location of the oil release relative to the coastline and sensitive sites. The magnitude of the effects on coastal stability could range from negligible to moderate with the effects confined to a local or small regional portion of the coastline. The frequency of occurrence of coastal stability effects is commensurate with the frequency of occurrence of a large oil spill., which is a low probability event.

D.2.5.4 Summary of Residual Effects

Effects on coastal stability and subsea permafrost associated with activities in Scenario 1 to 4 are summarized in Table D-18. Effects of a large oil release event on coastal stability and subsea permafrost are summarized in Table D-19.

D.2.5.5 Gaps and Recommendations

Additional information is required to better understand the anticipated rate of future coastal erosion along the mainland coast of the ISR over the next 30 years and to what degree the erosion rate would change from past and present and rates as documented in Section 7.2.4. This information should be used to update key planning documents such as Community Plans and the Beaufort Coastal Sensitivity Atlas (Environment Canada 2014).

Information is also required on the rate of future permafrost degradation immediately below the seafloor over the next 30 years.

D.2.5.6 Follow-up and Monitoring

Studies of the estimated rate of future coastal erosion along the mainland coast of the ISR over the next 30 years should be undertaken using western science and TLK approaches.

Monitoring of seafloor permafrost should be undertaken if infrastructure is proposed in the offshore; this should include monitoring of permafrost temperatures and extent prior to site preparation, after site preparation and following installation of the structure.

Table D-18 Potential Residual Effects of Scenarios 1 – 4 on Coastal Dynamics and Sea Floor Geology

Season	Scenario 1: Status Quo	Scenario 2 Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Ice	• No coastal stability effects • No seafloor permafrost effects	• No coastal stability effects • Negligible reduction of seafloor permafrost on regional geographic scales (limited to pipeline corridor)	• No coastal stability effects • Negligible reduction of seafloor permafrost on local geographic scales	• No coastal stability effects • No seafloor permafrost effects
Spring Transition	• No coastal stability effects • No seafloor permafrost effects	• No coastal stability effects • Negligible reduction of seafloor permafrost on regional geographic scales (limited to pipeline corridor)	• No coastal stability effects, • Negligible reduction of seafloor permafrost on local geographic scales	• No coastal stability effects • No seafloor permafrost effects
Open Water	• Increased vessel movements in shallow water have negligible to low effects on regional geographic scales • No seafloor permafrost effects • Bottom preparation for wind turbine bases	• Increased vessel movements have negligible effects on regional geographic scales • Dredging of harbour and bottom preparation for infrastructure • Negligible reduction of seafloor permafrost on regional geographic scales (limited to pipeline corridor)	• Increased vessel movements have negligible effects on coastal stability at regional geographic scales • Dredging of harbour and bottom preparation for infrastructure • Negligible reduction of seafloor permafrost on local geographic scales.	• Increased vessel movements have negligible effects on regional geographic scales • Dredging of harbour • No seafloor permafrost effects

Table D-18 Potential Residual Effects of Scenarios 1 – 4 on Coastal Dynamics and Sea Floor Geology

Season	Scenario 1: Status Quo	Scenario 2 Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Fall Transition	• No coastal stability effects • No seafloor permafrost effects	• No coastal stability effects • Negligible reduction of seafloor permafrost on regional geographic scales (limited to pipeline corridor)	• No coastal stability effects • Negligible reduction of seafloor permafrost on local geographic scales.	• No coastal stability effects • No seafloor permafrost effects
Legend				
• Least effect – No or minor regional effects				
• Low to Moderate effect – N/A				
• High effect – N/A				
• Greatest effect – N/A				

Table D-19 Potential Effects of a Large Oil Release Event (Scenario 5) for Coastal Dynamics and Sea Floor Geology

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• No effect on coastal stability • No permafrost effects	• No effect on coastal stability • No permafrost effects	• No effect on coastal stability • No permafrost effects
Spring Transition	• Use of vessel based support for coastal clean-up is possible but the effect is expected to be low or negligible. • No permafrost effects	• Use of vessel based support for coastal clean-up is possible, but considered unlikely; clean-up areas would likely be located along coastlines outside of the Mackenzie River plume. Effects on coastal dynamics would be low, localized, likely spatially dispersed and of generally short to moderate duration. • No permafrost effects	• Use of vessel based support for coastal clean-up is possible, but considered unlikely; clean-up areas would likely be located along coastlines outside of the Mackenzie River plume. Effects on coastal dynamics would be low, localized, likely spatially dispersed and of short- to long-duration. • No permafrost effect
Open Water	• If a large oil release event occurred and oil reached the coastline, high levels of vessel based support would be required possibly for a long duration. Effects on coastal dynamics would be localized, likely spatially dispersed and of short- to long-duration. • No permafrost effects	• Use of vessel based support for coastal clean-up is possible, but considered unlikely; clean-up areas would likely be located along coastlines outside of the Mackenzie River plume. Effects on coastal dynamics would be localized, likely spatially dispersed and of short- to long-duration. • Locations would be far-removed from the Mackenzie River plume, resulting in very unlikely occurrences permafrost effects • No permafrost effects	• Use of vessel based support for coastal clean-up is possible, but considered unlikely; clean-up areas would likely be located along coastlines outside of the Mackenzie River plume. Effects on coastal dynamics would be localized, likely spatially dispersed and of short- to long-duration. • No permafrost effects

Table D-19 Potential Effects of a Large Oil Release Event (Scenario 5) for Coastal Dynamics and Sea Floor Geology

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Fall Transition	• Use of vessel based support for coastal clean-up is possible. • Use of vessel based support for coastal clean-up is possible but the effect is expected to be low or negligible • No permafrost effects	• Use of vessel based support for coastal clean-up is possible but limited in extent due to difficult working conditions; • Clean-up areas would be confined to coastlines outside of the Mackenzie River plume. • No permafrost effects	• Use of vessel based support for coastal clean-up is possible; clean-up areas would be confined to coastlines outside of the Mackenzie River plume but limited in extent due to difficult working conditions • No permafrost effects
Legend			
• Least effect – No to minor effect on Coastal Stability			
• Low to Moderate effect – Moderate effect on Coastal Stability			
• High effect – Major effect on Coastal Stability			
• Greatest effect – Severe effect on Coastal Stability			

D.2.6 Coastal Habitat

D.2.6.1 Scoping

D.2.6.1.1 Identification of Indicators

Coastal habitats in the BRSEA Study Area includes the coastal beaches, mud flats, and river deltas along the ocean, including protected coastal areas (see Section 7.2.6). Onshore habitat (i.e., terrestrial and freshwater habitats) that are above the highest high water mark are outside of the BRSEA Study Area and are not considered in the scope of this report.

D.2.6.1.2 Spatial Boundaries

The spatial boundary used for the assessment of the coastal habitat VC is defined as the area between the highest high water mark and the coastal nearshore environment (defined as water depths of 20 m or less and offshore distances of 10 km or less, whichever is smaller).

D.2.6.1.3 Temporal Boundaries

The temporal boundary for coastal habitat is the 30-year period between 2020-2050.

D.2.6.1.4 Assessment of Potential Effects

The assessment of potential effects on coastal habitat considers residual effects on the coastal beaches, mud flats, and river deltas along the ocean. Qualitative characterization of potential residual effects associated with each scenario is based on the characterization terms defined in Table D-20.

Table D-20 Characterization of Residual Environmental Effects on Coastal Habitat for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Positive**—an increase in the quality or quantity of habitat **Adverse**—a decrease in the quality or quantity of habitat **Neutral**—no net change in the quality or quantity or habitat
Magnitude	The amount of change in measurable parameters on VC relative to existing conditions	**Negligible**—no measurable change in the quality or quantity of habitat **Low**—a measurable change in the quality or quantity of habitat, but within the limits of what would be expected due to natural variation **Moderate**—a measurable change in the quality or quantity of habitat, that exceeds the limits of what would be expected due to natural variation **High**—a measurable change in the quality or quantity of habitat, that exceeds the limits of what would be expected due to natural variation and results in cascade effects to flora and fauna or human indicators that depend on it.

Table D-20 Characterization of Residual Environmental Effects on Coastal Habitat for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the local area around the activity **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area) **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area)
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity **Continuous**—residual effect occurs continuously for the duration of the activity
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to one phase (e.g., seismic survey, exploration drilling) or season **Medium-term**—residual effect extends through multiple seasons or years (e.g., production phase) **Long-term**—residual effect extends beyond the life of the project (e.g., beyond closure) **Permanent**—measurable parameter unlikely to recover to existing conditions
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.2.6.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

The primary issues and concerns associated with effects to coastal habitat include direct habitat disturbance from vessel wake and dredging, direct removal of habitat through placement of new nearshore infrastructure (e.g., subsea pipelines, GBS), or contamination of habitat resulting from an oil spill. A summary of potential effects on coastal and nearshore habitat under consideration for this analysis is provided below. A summary of potential effects of an oil spill is provided in Section D.2.6.6.

Offshore activities (e.g., offshore vessel activity, seismic surveys, drillships and platforms) in Scenarios 2 to 4 would have almost no interaction with coastal habitat (with the exception of ship transits to and from coastal service and supply bases) and therefore few residual effects. These activities and associated effects are not considered further.

Effects on coastal habitat would be most prevalent during the Open Water Season when construction is most likely to occur, when more vessels are present that can generate wake-based erosion, and in the unlikely event of a large oil release, if oil is driven by waves and currents onto beaches. During the Ice Season and the early Spring Transition and late Fall Transition seasons, sea ice is expected to protect coastal habitat from erosion because it limits vessel traffic. It also would help constrain the spread of oil in water and transport onto shorelines in the event of a spill.

POTENTIAL EFFECTS OF VESSEL WAKE

Potential effects to coastal habitats could occur from vessel wakes causing erosion (Didenkulova et al. 2011; Macfarlane et al. 2019; Huntington et al. 2015a; Hughes et al. 2007) (Section D.2.5). Vessels create wakes, which are pressure waves caused by the disturbed water mass. These pressure waves travel to the shoreline and can cause direct erosion of coastal environment. The power of the wave erosion varies by vessel size, speed, distance from shore, and vulnerability of the shore habitat.

POTENTIAL EFFECTS OF SEABED DISTURBANCE

Activities such as modification or maintenance of harbour entries and channel, as well as wharfs, pilings, retaining walls and other port infrastructure would require modification of the seabed and shoreline and thus affect coastal and nearshore habitat. Directional drilling of pipelines, dredging of the pipeline trenches and nearshore laying of pipelines, or placement of nearshore wind energy turbines could result in direct disturbance or removal of coastal habitat. Placement of fill or installation of shoreline retaining structures could disturb habitat and result in localized effects on the nearshore ecosystems.

The relationship between human activities, interactions, impacts and potential effects on coastal habitat are summarized in Table D-21.

Table D-21 Summary of Potential Impacts and Effects on Coastal Habitat

Potential Impact[7]	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Seabed Disturbance	• nearshore activities in harbours and in association with subsea pipelines and nearshore wind energy turbines	• infrastructure development converting coastal habitat to industrial or community use	• removal of or change in quality or quantity of habitat	• loss of aerial extent of habitat (acres)
Ice Disturbance	• maintenance of ship channels and harbour entrance during Spring and Fall Transition seasons	• minimal or no interactions with coastal habitat	• NA	• NA
Vessel Wake	• vessel use during Open Water Season (commercial, personal use, tourism, sea lift, military, research, harvesting)	• erosion or disturbance to shoreline habitat and seabed	• change in quality or quantity of habitat	• loss of aerial extent of habitat (acres)
Oil Spill	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from a subsurface location (well head, pipeline)	• direct physical alteration of shoreline habitat • fouling of physical and biological habitat feature	• change in quality of habitat • change in biological community structure and diversity • change in overall resilience of habitat	• aerial extent of habitat altered or lost (acres) • change in habitat productivity

[7] Potential impacts of Air Contaminants and GHG Emissions, Noise (in air and underwater), Artificial Light, Routine Discharges and Vessel Collision are not considered for Coastal Habitat as there are no direct impacts from these activities and processes on this VC. However, changes in Coastal Habitat that affect biota and human uses are discussed in the Summary of Potential Impacts and Effects for those VCs.

D.2.6.2 Scenario 1: Status Quo

D.2.6.2.1 POTENTIAL EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Nearshore vessel activity (commercial, tourism, sea lift, military, research, harvesting, personal use) could directly affect habitat by creating wakes which can disturb coastal habitat. Effects are likely to extend from the late Spring Transition, through Open Water, and into the early Fall Transition seasons.

Construction operation and maintenance of facilities (e.g., harbours, offshore wind energy turbines) can affect coastal environments by converting natural habitat into modified habitat, or indirectly by disrupting coastal processes that influence habitat (e.g., sediment dispersion along coastlines, altering shoreline slope, hardening shorelines).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Nearshore vessel activity typically has limited effects, due to sea traffic dispersed over large areas. Effects would be concentrated around areas of nearshore boat traffic such as harbours and docks or narrow passes. These areas can receive enough traffic to cause an increase in erosion, over and above normal weather generated forces. Effects may range from changes in shoreline habitat, to loss of shoreline habitat.

Construction and development of infrastructure can have large localized effects. Infrastructure can directly change the nearshore habitat through dredging, fill, or placement of structures. If habitat is common and ubiquitous, effects can be limited. If habitat is specialized, or valued by a particular biological component, it can have large effects. It is be expected that environmental conditions for project approvals would not permit the latter or impose certain conditions on the approval.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

With increasing extent and duration of the length of the Open Water Season (Laidre et al. 2015) and thinner ice, there may be increased wind driven wave erosion along the shoreline. Loss of permafrost is anticipated to increase due to coastal slumping and mass loss (see Section 7.2.5). Loss of sea ice would allow larger waves to accelerate coastal erosion, resulting in effects to coastal habitats. Habitat may also be lost through sea level changes. Loss of habitat could result in increased pressure on ecosystems.

D.2.6.2.2 MITIGATION AND MANAGEMENT

General mitigation measures and standard operational procedures associated with the protection of coastal habitat have been shown to be effective in mitigating potential effects on VCs. These include:

- restrictions of ship speeds: Reduce speeds to less than 10 knots in proximity to coastal habitat to reduce wake (Fonseca and Malhotra 2012)
- conservation buffers: Identify important coastal habitat, and establish conservation buffers to guide development planning efforts

D.2.6.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Although effects to coastal habitat in Scenario 1 are expected to increase in frequency and seasonal extent over the next 30 years, effects to coastal habitat from vessel wakes and coastal development are anticipated to be negligible.

Although residual effects of Scenario 1 are expected to be minimal (given current habitat conditions), the rapid shift in habitat that may result from climate change could amplify effects and exert substantially more pressure on habitats to a point where effects resulting from human activities could be also be amplified.

CUMULATIVE EFFECTS

Nearshore vessel activities may result in localized changes to coastal habitat, but effects would largely be transitory to short-term (e.g., duration of the passage of a vessel) and localized to the areas of these vessel activities. These effects would be minor compared to the changes to coastal habitat caused by natural processes and climate change. Changes in coastal habitat associated with construction, operation and maintenance of infrastructure and harbours also would be localized but effects would persist over the long-term (i.e., until the structure is removed, and the coastline restored). Since the overall spatial extent is very small and sites would be dispersed, no cumulative effects are anticipated for coastal habitat under Scenario 1.

The impacts from climate change are predicted to amplify or cause more substantial effects on coastal habitats. The cumulative losses of coastal habitat from these processes is predicted to be large. These changes will occur regardless of the impact of human activities described in the scenarios.

D.2.6.3 Scenario 2: Export of Natural Gas and Condensates

D.2.6.3.1 ASSESSMENT OF EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

The effect pathways are the same as Scenario 1 (e.g., use of nearshore vessels and seabed disturbance by infrastructure and maintenance activities) as a result of the pipeline crossing of the coastline and the nearshore construction activities, including dredging for the pipelines extending out to the LNG loading facility.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The range of potential effects are the same as Scenario 1 but effects are expected to be more intense over the duration of the construction activities. There would be an increase in the frequency of vessel transits in and out of shore-based service and supply bases. This may cause increased effects from wake erosion on shorelines surrounding the shore infrastructure and greater effects on coastal habitat.

As directional drilling would be used to install the pipelines out to about 1km from shore, little or no disturbance of coastal habitat is expected from installation of the two pipelines. It is assumed that the entry point for the pipeline would be located back from the existing shoreline. Some disturbance of the seabed would occur during laying of pipe on the seabed beyond the exit point from the directionally drilled portions due to dredging of the trenches that the pipeline would be located within.

EFFECTS OF CLIMATE CHANGE IN POTENTIAL EFFECTS

The effects of climate change on Scenario 2 are anticipated to be similar to those described for Scenario 1.

D.2.6.3.2 MITIGATION AND MANAGEMENT

Mitigation measures and standard operational procedures to limit the effects to coastal habitat are the same as included under Scenario 1. As noted above, use of directional drilling technology to install the nearshore portions of the dual pipelines will reduce or avoid disturbances to coastal habitat.

D.2.6.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Effects to coastal habitat in Scenario 2 are expected to increase in frequency and seasonal extent over the next 30 years. There would be an additional adverse effect from increased infrastructure development and vessel traffic; but effects are anticipated to be localized over the short to long-term. Vessel wake erosion is anticipated to be minimal and mitigated with speed limits. Seabed disturbance is also anticipated to be limited to the areas where coastal infrastructure is constructed. Environmental protection plans and other mitigation measures (e.g., silt curtains) can be used to reduce effects on coastal habitat (see also Appendix F).

CUMULATIVE EFFECTS

Similar to Scenario 1, no or minimal cumulative effects are anticipated for Coastal Habitat. The effects of Scenario 2 combined with Scenario 1, are anticipated to remain low, with a local footprint. Additionally, most activities in Scenario 1 are in Open Water Season, which would have limited overlap with Coastal Habitat. The impacts from climate change are similar to those described for Scenario 1.

D.2.6.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.2.6.4.1 ASSESSMENT OF EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

The effects to coastal habitat under Scenario 3 are less than those for Scenario 2 since construction is offshore of the coastal habitat zone. The only expected interaction with coastal habitat would be from the resupply vessel movements each year during construction and operation.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The effects are much reduced from those of Scenario 2. Increases in local vessel activity for resupply can increase wake erosion and accelerate erosion of coastal habitat. In contrast to Scenario 2, the disturbance to the of coastal or nearshore seabed is negligible.

EFFECTS OF CLIMATE CHANGE IN POTENTIAL EFFECTS

The effects of climate change on Scenario 3 are similar to those described for Scenario 1.

D.2.6.4.2 MITIGATION AND MANAGEMENT

Mitigation measures are similar to Scenario 1 and 2.

D.2.6.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Effects to coastal habitat in Scenario 3 are expected to be similar to Scenario 1. There would be an additional adverse effect from increased vessel traffic. These effects are anticipated to be localized and mitigated with vessel speed limits and habitat buffers. No residual effects are anticipated from seabed disturbance.

CUMULATIVE EFFECTS

Similar to Scenario 1, no or minimal cumulative effects due to vessel activities are anticipated for Coastal Habitat. Scenario 3 activities are largely offshore with limited effects to the coasts. The primary source of effects would be transits by vessels in and out of coastal service and supply bases. With mitigation, vessel- based erosion is anticipated to a negligible effect. The impacts from climate change are similar to those described for Scenario 1.

D.2.6.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

The potential effects, effects of climate change, mitigation measures, and cumulative effects for Scenario 4 on coastal habitat are anticipated to be the same as those described for Scenario 3. Discussions of each of these topics are not repeated here.

D.2.6.6 Scenario 5: Large Oil Release Event

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on coastal habitat from such an event would differ slightly from what is described below for surface or subsea releases.

D.2.6.6.1 ASSESSMENT OF EFFECTS

DESCRIPTION OF EFFECT PATHWAY

The primary effect to coastal habitat is the introduction of oil onto coastal and seabed substrate, flora and fauna. Oil can be washed ashore and coat coastal habitats or PAHs can be taken up by benthos via flocculation (Section D.2.3.3). Oil spill clean-up activities on the coastline can result in coastal erosion and degradation as described in Section D.2.5. Both processes can directly degrade coastal habitats, and lead to effects on the broader biological environment (Section D.3).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Accidental releases would introduce oil into the environment and transport of oil to coastal areas is likely to result in oiling of shorelines and nearshore habitats. Oil would be distributed throughout the water column as a result of dispersion, dissolution and emulsification, and can be distributed on the coastline by wave action. Weathering and sunlight would begin to evaporate lighter portions and degrade heavy oil chains in the long term. Sediments may become entrained with oil; wave action can form oil-substrate aggregations and push oil into the substrate. Response actions and associated movement of people and equipment could further disturb the shoreline. Small releases would likely create a localized effect that may be managed and contained.

Drift rates of oil are highly dependent on localized current, wind, and weather patterns. The effects of a moderate release of oil on coastal habitat would be highly dependent on the season and location of the spill. Larger oil releases could substantially inhibit the structure and function of coastal habitats.

Very large oil releases can have large effects on coastal habitat. The most severe effects are likely to be associated with a surface spill in the Open Water Season within the Mackenzie River plume. There is anticipated to be rapid spreading and dispersion of oil, with large nearshore effects down current/wind from the spill. Shoreline oiling is likely to be widespread, with greater effects if the spill continues to take place over the long term.

Lower effects are anticipated from sub-sea releases and tanker incidents outside the plume since much of the oil are expected to remain offshore and be transported westward offshore (Section 3.10.5). These are also anticipated to have spread rapidly and lead to free drifting oil. A major portion of the released oil is expected to evaporate, disperse, or dissolve into the water column (~ 30%) (Section 2.13.5). The Mackenzie River plume is anticipated to provide some protection to coastal habitat by keeping the majority of the spilled oil offshore (Section 3.10.3). Effects would be directed down current, which may include coastal environments to the east or west of the Mackenzie River, depending on weather conditions.

The least effect on coastal habitat is anticipated during the Ice Season. Sea ice is anticipated to limit the spreading of spilled oil. Surface oil is anticipated to be trapped in the ice and have limited migration. This is anticipated to keep large quantities of oil from moving to the coastal habitats. In addition, during the Ice Season, the Mackenzie River plume continues to exert some pressure in the shallow under ice currents, further helping to keep most of the released oil offshore.

Moderate effects are anticipated during the Fall Transition Season. Spills are likely to move with the forming ice in the localized direction of wind and currents. While the ice is anticipated to limit spreading of released oil, oil would still be able to travel to coastal environments until solid freeze up occurs.

During the Spring Transition Season, oil in ice would be released into the water through brine and meltwater channels and the gradual melting of the ice. Oil released into nearshore water would be a threat to coastal habitats (as described for the Open Water Season).

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Climate change is not anticipated to change the potential effects of oil spill on coastal habitat.

D.2.6.6.2 MITIGATION AND MANAGEMENT

Spill response planning and methods are described in Section 2.13 with additional information in Section 3.10.5.3.

D.2.6.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Residual effects of oil spills on the coastal habitat are anticipated to be regional and long term in duration. The magnitude of effects varies depending on release size, type of oil, the season and location of the spill, and site-specific ocean and weather conditions. A large oil spill that directly contacts shorelines and associated coastal habitats is likely to result in adverse and severe effects on coastal habitats and the biota and people that use these habitats. Effects on habitat structure and function are predicted to be long-term, depending on the effectiveness of the spill response. Potential effects of oil releases on specific groups of biota are discussed in more detail in Section D.2. Potential effects on human uses and aspects are discussed in Section D.3.

D.2.6.7 Summary of Potential Residual Effects

Potential residual effects of Scenarios 1 through 4 on coastal habitat are summarized in Table D-22. Potential residual effects of a large oil release event on coastal habitat is summarized in Table D-23.

D.2.6.8 Gaps and Recommendations

Gaps and recommendations listed under Section D.2.5.5 also address information needs for effects of activities on coastal habitats. In addition, knowledge on the type, extent and characteristics of coastal and nearshore habitats in the proximity to oil and gas activity would be beneficial to establish a more robust baseline prior to project development.

D.2.6.9 Follow-up and Monitoring

Recommendations for follow-up monitoring listed under Section D.2.5.6 also address monitoring needs for effects of activities on coastal habitats. In addition, the Beaufort Regional Coastal Sensitivity Atlas (Environment Canada 2014), should be updated on a regular basis to reflect ongoing changes in coastal and nearshore habitat quality associated with climate change and natural processes.

Table D-22 Potential Residual Effects of Scenarios 1 – 4 on Coastal Habitat

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4 Oil Development in Deep Water
Ice	• Negligible effects from vessel wakes and seabed disturbance.	• Negligible effects from vessel wakes and seabed disturbance	• Negligible effects from vessel wakes and seabed disturbance	• Negligible effects from vessel wakes and seabed disturbance
Spring Transition	• Negligible effects from vessel wakes and seabed disturbance	• Low effects from pipeline installation and maintenance and wake erosion from nearshore vessel activity	• Negligible effects from vessel wakes and seabed disturbance	• Negligible effects from vessel wakes and seabed disturbance
Open Water	• Negligible effects from vessel wakes and seabed disturbance	• Medium effects from pipeline installation and maintenance and wake erosion from nearshore vessel activity	• Negligible effects from vessel wakes and seabed disturbance	• Negligible effects from vessel wakes and seabed disturbance
Fall Transition	• Negligible effects from vessel wakes and seabed disturbance	• Low effects from pipeline installation and maintenance and wake erosion from nearshore vessel activity	• Negligible effects from vessel wakes and seabed disturbance	• Negligible effects from vessel wakes and seabed disturbance
Legend				
• Least effect – No to minor effect on habitat				
• Moderate effect – Moderate effect on habitat				
• High effect – Major effect on habitat				
• Greatest effect – Severe effect on habitat				

Table D-23 Potential Effects of a Large Oil Release Event (Scenario 5) for Coastal Habitat

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• Limited spreading with negligible anticipated effect on coastal habitat	• Limited spreading with negligible anticipated effect on coastal habitat	• Limited spreading with negligible anticipated effect on coastal habitat
Spring Transition	• Limited spreading with mobile drifting ice fields and potential to reach coastal habitat	• Limited spreading with mobile drifting ice fields offshore with anticipated negligible effect on coastal habitat	• Limited spreading with mobile drifting ice fields offshore with anticipated negligible effect on coastal habitat
Open Water	• Rapid spreading and dispersion in coastal zone with anticipated severe effects on coastal habitat • Widespread shoreline oiling	• Rapid spreading and dispersion • Uncontained, free drifting, widespread distribution	• Rapid spreading and dispersion • Uncontained, free drifting, widespread distribution
Fall Transition	• Limited spreading with mobile drifting ice fields and potential to reach coastal habitat	• Limited spreading with mobile drifting ice fields offshore with anticipated negligible effect on coastal habitat	• Limited spreading with mobile drifting ice fields offshore with anticipated negligible effect on coastal habitat
Longer-term/ Multi-year	• Widespread shoreline oiling can result in severe long-term effects on structure and function of coastal habitat	• Offshore location of spill should result in limited effects on coastal habitats in long-term	• Offshore location of spill should result in limited effects on coastal habitats in long-term
Legend			
• Least effect – No to minor effect on habitat			
• Moderate effect – Moderate effect on habitat			
• High effect – Major effect on habitat			
• Greatest effect – Severe effect on habitat			

D.3 Biological Environment

D.3.1 Marine Lower Trophic Levels

D.3.1.1 Scoping

D.3.1.1.1 IDENTIFICATION OF INDICATORS[8]

Marine lower trophic level indicator groups include phytoplankton, zooplankton, and benthic macrofauna. Phytoplankton live in the upper levels of the water column and under ice; zooplankton live throughout the water column; and macrofauna on the sea floor make up the majority of the marine biomass in the Arctic, particularly on the shelf and shelf edge.

These groups were selected based on ecological or cultural importance, or linkages to other VCs:

- ecological importance (e.g., nutrient cycling and energy transfer, food-web dynamics, or ecosystem services such as carbon sequestration)
- cultural importance (e.g., species or groups of species that are traditionally harvested)
- linkages to other VCs (e.g., via food-web dynamics. For example, zooplankton are important food sources for other VCs such as bowhead whales, various seabirds, and some marine fish)

Although bacteria were not chosen as indicators as detailed in Section 7.3, it is recognized that they could play an important role during the biological breakdown of oil spills, even in this Arctic environment (e.g., Gerdes et al. 2005; Garneau et al. 2016; Vergeynst et al. 2018). More research on this topic is needed in the Arctic.

D.3.1.1.2 SPATIAL BOUNDARIES

The selected indicator groups for lower trophic levels are present throughout the BRSEA Study Area. Consequently, the spatial boundary for this VC is defined as the marine waters of the ISR (Figure 1-1). This spatial boundary encompasses potential present and future impacts associated with human activities.

D.3.1.1.3 TEMPORAL BOUNDARIES

The assessment of potential effects on lower trophic level indicators encompasses a 30-year period between 2020–2050.

[8] For some VCs, the assessors identified a suite specific human uses, species or processes or groups of human uses, species or processes to better characterize the response of a VC to human and industrial activities and climate change. These indicators are used to assess potential risks and benefits to a VC, as well as describe mitigation and management measures, monitoring and follow-up needs, and important data gaps.

D.3.1.1.4 ASSESSMENT OF POTENTIAL EFFECTS

The assessment of potential effects on lower trophic level indicators considers residual effects on the indicator groups effects across the entire BRSEA Study Area (Figure 1-1), and not on individual species or localized species assemblages. Qualitative characterization of potential residual effects on indicators associated with each scenario is based on the characterization terms defined in Table D-24.

Table D-24 Characterization of Residual Environmental Effects on Lower Marine Trophic Levels for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect on the VC	**Positive**—a net benefit to the health, mortality, habitat or behaviour of the indicator group that could result in a positive change in status or resiliency. **Adverse**—a reduction or influence on the health, mortality, habitat or behaviour of indicator group that could result in a change in status or resiliency. **Neutral**—no net change in the health, mortality, habitat or behaviour of the indicator group.
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no meaningful change in health, mortality, habitat or behaviour of the indicator group. **Low**—a small level change in the health, mortality, habitat or behaviour of the indicator group but would not affect long-term sustainability. **Moderate**—a medium level change in the health, mortality, habitat or behaviour, with potential to affect long-term sustainability. **High**—a large change in the health, mortality, habitat or behaviour with relative certainty of affecting long-term sustainability.
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity. **Local**—residual effects extend into the local area around the activity. **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area). **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area).
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once. **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity. **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity. **Continuous**—residual effect occurs continuously for the duration of the activity.

Table D-24 Characterization of Residual Environmental Effects on Lower Marine Trophic Levels for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to one phase or season (e.g., seismic survey, exploration drilling). **Medium-term**—residual effect extends through multiple seasons or years (e.g., production phase). **Long-term**—residual effect extends beyond the life of the project (e.g., beyond closure). **Permanent**—measurable parameter unlikely to recover to existing conditions.
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation. **Irreversible**—the effect is unlikely to be reversed.
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity. **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring.

D.3.1.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

Potential effects on marine lower trophic levels are expected to be primarily associated with habitat disturbance resulting from ice-breaking and ice management, artificial light, drilling of wells, other subsea infrastructure, and discharges into the water column (e.g., treated drilling muds, sand cuttings, treated deck drainage, treated gray water). Potential effects of habitat alteration resulting from routine activities on marine lower trophic levels are discussed below. Potential effects of an oil spill on marine lower trophic levels are discussed in Section D.3.1.6.

The relationship between human activities, interactions and potential effects on marine lower trophic levels are summarized in Table D-25. Although activities and associated effects are similar across the Status Quo and the three oil and gas development scenarios, potential effects of each scenario on marine lower trophic levels are discussed independently to identify specific interactions that may result from variations in timing, spatial extent, or geographic location that is assumed for each scenario. Plankton is anticipated to be most vulnerable to potential effects during the spring and summer bloom as the ice is retreating (Section 7.2.2) when productivity is at its highest and residual effects on plankton could result in greater cascading effects to the benthos and higher trophic levels.

Research suggests that underwater noise generated by seismic sound source arrays is sufficiently intense to kill zooplankton occurring within 2 m of the source and could result in sub-lethal injuries within 5 m (Østby et al. 2003 cited in Boertmann and Mosbech 2011). More recent research suggests that seismic surveys could result in up to a 3-fold decrease in zooplankton abundance within a 1.2 km radius from the sound source (McCauley et al. 2017).

Because most invertebrates do not have the ability to hear sound or have internal air spaces, they may be relatively resilient to noise disturbances (Keevin and Hempen 1997; Christian et al. 2003). However, deformities and delayed scallop larvae development were documented during experimental playback of seismic recordings (de Soto et al. 2013). Adult scallops also could be vulnerable to underwater noise as suggested by a massive mortality event observed in Australia several months after seismic activities in the area (Przeslawski et al. 2017). A study by Morris et al. (2018) recently rejected the hypothesis that seismic sound arrays were adversely affecting commercial snow crab (*Chionoecetes opilio*) catch per unit effort (CPUE).

Localized mortality of zooplankton near a seismic sound source is unlikely to affect population viability or zooplankton abundance and distribution over the larger geographic scale of the BRSEA Study Area. Although underwater noise may affect some invertebrate species, residual effects to zooplankton and benthic invertebrates are expected to be negligible and potential effects of noise on marine lower trophic levels is not discussed further.

Ice disturbances (i.e., ice breaking activities) are not expected to directly affect benthic macrofauna but might interact with phytoplankton and zooplankton. Possible effect pathways include habitat alteration or changes in prey availability. The breaking up ice sheets would allow more light to penetrate the ocean stimulating localized phytoplankton growth (Cobb et al. 2008; Horvat et al. 2017). Sympagic (sea ice) algae might also benefit in this way or from increased edge effects (Falk-Petersen et al. 2000). However, given the relatively small area that would be affected by ice breaking (e.g., the swath of water travelled by ice-capable vessels) or other human activities (e.g., offshore platforms) compared to the larger BRSEA Study Area and the arctic ecosystem, meaningful direct, indirect, or cascading effects are not expected (Pinnegar et al. 2000; Shurin et al. 2002). Given the spatial scope of potential effects, ice disturbance on lower marine trophic levels is not discussed further.

Artificial Light

Artificial light has the potential to directly affect phytoplankton and zooplankton by attracting them to the artificially lit area. Although surface light is not likely to reach the seabed and have a direct effect on benthic macrofauna, the attraction of plankton to a localized area can attract higher trophic levels (e.g., fish) and result in a habitat enhancement over a larger scale. It is anticipated that underwater lights would rarely be used. Consequently, only surface-based light sources are discussed in relation to plankton.

Many phytoplankton and zooplankton make diel vertical migrations towards and away from light (Martynova and Gordeeva 2010). This contributes to one of the largest biomass migrations on earth (Giometto et al. 2015). However, little research has been done to systematically characterize the effects of artificial light on marine zooplankton (Martynova and Gordeeva 2010). Some studies have shown that artificial light sources elicit different responses from different plankton depending on the species of plankton, time of day, ontogeny (the interaction of an individual with its environment), and other variables such food-condition (i.e., hungry or fed) (Eggersdorfer and Haden 1991; Martynova and Gordeeva 2010; Giometto et al. 2015). Different responses to light are likely adaptive depending on the environment. For example, a specific response may serve to reduce predation rates, improve access to food, limit UV damage, or improve survival during different life history stages (Eggersdorfer and Haden 1991; Giometto et al. 2015).

Seabed Disturbance

Seabed disturbances have the potential to affect benthic macrofauna but are not expected to interact with phytoplankton or zooplankton. Activities that directly affect the sea bed (e.g., drilling, pipelines, anchors) might alter the physical structure of the seabed or change water quality parameters (i.e., by introducing contaminants or increasing turbidity).

Physical disturbances have the potential to bury sessile or slow-moving invertebrates or temporarily increase turbidity, potentially resuspending existing contaminants. While most potential contaminants used near the seafloor have low bioavailability, PAHs, cadmium, or barite would be a concern if accidently released (Melton et al. 2000; Neff 2007; Nuneku and Ayobahan 2014). These chemicals would likely remain in the sediment for decades (Dunton et al. 2012; Trefry et al. 2014), potentially bioaccumulating or moving through the food web.

Routine Discharges

Routine discharges (Table 2-5) have the potential to affect marine lower trophic levels. Surface discharges of treated grey water could interact with phytoplankton and zooplankton, while drilling muds released near the seafloor (e.g., during spudding of a well) could interact with benthic macrofauna. Potential effects on this VC would depend on the volume, concentration, and nature of the material discharged. Routine discharges may include (Table 2-5):

- bilge and ballast water
- treated sewage and food waste discharges
- grey water generated on vessels and drilling platforms
- cooling water
- discharge of water-based drilling muds, drill cuttings and sand

Strict guidelines exist in Canada for monitoring of environmental effects from routine discharges from exploration drilling and offshore platforms (e.g., Government of Canada 1985). Although there are often near-field effects, there seems to be little evidence of severe, far reaching, or lasting effects on the benthic flora or fauna (e.g., DeBlois et al. 2014b; Jerez Vegueria et al. 2002; Whiteway et al. 2014).

Bilge and ballast water have the potential to introduce invasive species if released within the BRSEA Study Area. However, as discussed in Section 2.5, *Canada's Ballast Water Regulations* require vessels that travel outside Canada's Exclusive Economic Zone (EEZ) to exchange their ballast water and flush tanks that contain residual sediment and ballast water with saltwater before entering Canadian waters. These regulations align with Canada's responsibilities under the *International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004.* By exchanging ballast in deeper water outside the EEZ, the potential to introduce non-native species to Canada's coastline is substantially reduced. Potential residual effects resulting from bilge and ballast water are anticipated to be negligible and are not discussed further.

Sewage and food waste discharge must meet waste treatment and disposal guidelines (Table 2-5). Residual effects of this type of discharge on lower trophic levels are expected to be negligible and are not discussed further.

Grey water discharge could alter marine habitats by changing water quality parameters such nutrient loading, contaminant levels, or increasing turbidity values. Potential contaminants released include hydrocarbons, metals, or PAHs; however, because these waste streams must be treated to levels of 15 mg/L or less before discharge, concentrations of hydrocarbons and PAHs are low. Routine discharges might also be warmer than ambient water, potentially affecting temperature-sensitive larvae of lower marine trophic level indicator groups.

Liquid and solid discharges may be ingested or absorbed by benthic flora and fauna and accumulate harmful constituents over time (Boesch and Rabalais 2003; Olsgard and Gray 1995). Bioaccumulation of some contaminants (e.g., heavy metals) may lead to cascading effects through the arctic food web, which is primarily dependent on benthic biomass (e.g., Bluhm and Gradinger 2008; Piepenburg 2005).

Drill muds and cuttings that are disposed on the seafloor form mounds that can be up to 1–2 m deep at the core of the disposal site, dissipating to 1 cm within 1 ha surrounding the core (BOEM 2015). Disposal of materials can smother or injure sessile benthic macrofauna and modify habitat within that footprint. The disposal of drilling solids is regulated in Canada and only water-based muds are permissible for discharge at sea without treatment (Section 2.5).

A summary of potential impacts and effects on marine lower trophic levels is provided in Table D-25.

Table D-25 Summary of Potential Impacts and Effects on Marine Lower Trophic Levels

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Noise (in-air and underwater)	• vessel transits (engine, propeller, and ice-breaking activities) • seismic surveys (2D, 3D, 4D) • drilling • operational and maintenance activities to vessels, production platform, and wells • helicopters, low flying aircraft, and snowmobiles	• no interaction anticipated because most invertebrates cannot sense sound and do not have internal, pressure-sensitive air spaces	• residual effects are anticipated to be negligible, and potential interaction pathway is limited • **further assessment of this impact is not warranted**	• NA
Artificial Light	• lighting used on nearshore infrastructure (wind turbines, marine infrastructure), offshore platforms and vessels	• phytoplankton and zooplankton might react to light • artificial light not likely to reach benthic macrofauna	• change in behaviour (e.g., attraction or repulsion to light stimulus) • change in mortality (e.g., predation risk might change due to changes in behaviour) • change in habitat (e.g., reduced suitability where artificial light is sensed)	• distribution or species composition of plankton assemblages
Seabed Disturbance	• subsea well, manifold, and pipeline installations and repairs	• disturbances not expected to affect plankton • benthic macrofauna might be displaced, attracted, or smothered by disturbances	• change in behaviour (e.g., attraction or repulsion to disturbances) • change in health (e.g., as a result of decreased foraging efficiency) • change in mortality (e.g., benthic macrofauna might be smothered or injured) • change in habitat (e.g., reduced suitability where disturbances occur)	• distribution or species composition of benthic invertebrate communities • estimate area and/or quality of habitat disturbed • see Section 2.5 for water quality mitigation measures

Table D-25 Summary of Potential Impacts and Effects on Marine Lower Trophic Levels

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Ice Disturbance	• icebreakers transiting through sea ice (ice management, support, transport) • presence of structures on/in sea ice or open water (drillships, platforms, wind turbines)	• breaking ice may increase light penetration in water resulting in higher phytoplankton productivity	• increased light availability to phytoplankton resulting in increased local productivity • increased local abundance of higher trophic levels (attracted to area of higher productivity) • **effects are expected to be local and of negligible magnitude. Further assessment of this impact is not warranted**	• NA
Routine Discharges	• air emissions • bilge and ballast water • drilling muds and lubricating fluids • drill cuttings and disposal • sewage and food waste • cooling water and deck drainage	• routine discharge could reduce water quality and affect phytoplankton, zooplankton and benthic communities • grey water discharge could provide localized nutrient source that results in habitat enhancement	• change in behaviour (e.g., attraction or repulsion to effluent) • change in health (e.g., via contaminant levels) • change in mortality (e.g., zooplankton and benthos) • change in habitat (e.g., thermal plume, water and sediment toxicity)	• levels of selected contaminants in representative species • distribution or species composition of benthic invertebrate communities • estimate area and/or quality of habitat disturbed • see Section 2.5 for water quality mitigation measures
Oil Spill	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released at surface from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• an oil spill is expected to have direct (e.g., physical contact with oil) or indirect (e.g., ingestion and possible bioaccumulation) effects on the VC. Ecosystem-wide consequences are possible but would depend on the severity of the spill	• change in behaviour (e.g., embryonic or neurological damage) • change in health (e.g., via altered foraging efficiency or injury) • change in mortality (e.g., contact or ingestion) • change in habitat (e.g., reduced suitability in oil-fouled areas)	• distribution or species composition of benthic invertebrate communities • levels of selected contaminants in representative species • estimate area and/or quality of habitat disturbed • see Section 2.5 for water quality mitigation measures

D.3.1.2 Scenario 1: Status Quo

D.3.1.2.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Potential effect pathways include habitat alteration resulting from seabed disturbance (gravity-based offshore wind turbines and associated seabed infrastructure) or routine discharges (primarily associated with grey water from vessels). Sources of artificial light and noise associated with Scenario 1 are limited (e.g., to transiting vessels) and are not expected to have a measurable effect on this VC.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Potential effects include changes in mortality risk, health, habitat or behaviour. Small numbers of benthic macrofauna might be displaced or smothered by seabed disturbances associated with the construction of seabed infrastructure (e.g., gravity-based offshore wind turbine). As described above, discharges from vessels are regulated by Canadian laws and regulations and are not expected to have a measurable effect on marine lower trophic levels.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

The longer duration of the Open Water Season could facilitate an increase in vessel activity in the region and could increase the potential for interaction and potential effects on marine organisms (Laidre et al. 2015). In addition, physical stressors on marine species (e.g., altered ocean temperature, reduced extent and quality of sea ice, increased ocean acidification) is shifting species assemblages and distributions and may reduce the general resiliency of individual species and communities. On the other hand, there remains uncertainty on how lower trophic levels would respond to changing environmental conditions in the Arctic, ranging from increases in primary production due to a longer open water season and a new or stronger fall bloom (e.g., Tremblay et al. 2012 to a collapse of phytoplankton stocks due to increased occurrence of fungal parasites (Frenken et al. 2016). Consequently, climate change may affect species associated with each of the indicator groups, but the severity of potential effects of human activities on these groups is not expected to change substantially over the 30-year assessment period.

D.3.1.2.2 MITIGATION AND MANAGEMENT

General mitigation measures and standard operational procedures associated the protection of the marine environment (Table 2-2) and waste treatment (Table 2-5) should be employed. Relevant mitigation measures and management plans to specifically reduce residual effects on lower marine trophic level indicators include:

- regional monitoring and enforcement of ballast water management
- local monitoring and enforcement of grey water discharge (see Section 2.5 for water quality mitigations measures)
- regional long-term monitoring of plankton and benthic species abundance and distribution

A summary of applicable mitigations and planning measures is provided in Appendix F.

D.3.1.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Potential residual adverse effects of seabed disturbances and routine discharges on lower marine trophic level indicators are expected to be low magnitude, limited to the immediate footprint of the activity, and occur as multiple irregular events on a medium-term time frame. Potential effects are expected to be reversible.

Changes in physical and chemical ocean conditions as a result of climate change could alter species composition, biomass and productivity in the Arctic over time (e.g., Bluhm and Gradinger 2008). However, climate change is not expected to alter the predicted effects of Scenario 1 on marine lower trophic levels over the 30-year assessment period.

CUMULATIVE EFFECTS

Given the low magnitude and limited spatial extent of residual effects on marine lower trophic levels associated with Scenario 1, it is unlikely that concurrent activities in the region would result in adverse regional cumulative effects. The prediction of no cumulative effects is made with low certainty as it is not well understood how severe the effects of climate change on lower trophic levels would be over the 30-year assessment period

D.3.1.3 Scenario 2: Export of Natural Gas and Condensates

D.3.1.3.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

Activities associated with Scenario 2 that may interact with marine lower trophic levels and result in potential effects are similar to those described for Scenario 1. Pathways include habitat alteration resulting from seabed disturbance (offshore GBS platform and subsea pipelines) or routine discharges (primarily associated with grey water discharge from vessels and the GBS). The GBS would be a source of artificial light that may have potential effects on plankton in the local area.

D.3.1.3.2 MITIGATION AND MANAGEMENT

Mitigation and management measures to reduce potential effects of Scenario 2 activities on lower marine trophic level indicators would be similar to those described for Scenario 1.

D.3.1.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Potential residual adverse effects of seabed disturbances, routine discharges and artificial light on lower marine trophic level indicators are expected to be low magnitude, limited to the immediate footprint of the activity, and occur as continuous events on a medium-term time frame. Potential effects are expected to be reversible. Climate change is not expected to alter the predicted effects of Scenario 2 on marine lower trophic levels over the 30-year assessment period.

CUMULATIVE EFFECTS

While Scenario 2 represents an increase in the intensity of effects (e.g., frequency, duration, geographical extent) compared to Scenario 1, residual effects are expected to remain localized and low in magnitude. The influence of climate change on the prediction of cumulative effects is similar to what was described for Scenario 1.

D.3.1.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.3.1.4.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Effect pathways for Scenario 3 include habitat alteration resulting from seabed disturbance (offshore GBS platform) and routine discharges (primarily associated with tankers, supply vessels and the GBS). The GBS would be a source of artificial light that could have potential effects on plankton directly adjacent to the platform.

While Scenario 3 includes subsea drilling, wells would be directionally drilled from within the GBS, which would limit the seabed footprint associated with drilling to the footprint of the GBS. Water-based drill muds and cuttings and produced water would be discharged to the marine environment or reinjected into wells.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The range of potential effects resulting from vessels and routine discharges are similar to what is described for Scenario 1 and Scenario 2. Given the regular frequency of vessels associated with the offloading facility and ongoing operations on the GBS, effects associated with routine discharges would be continuous. Drill muds and cuttings that are discharged to the seabed could alter habitat, smother sessile benthic invertebrates, and potentially cause injury or mortality in the immediate vicinity of the GBS.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Climate change is not expected to alter the predicted effects of Scenario 3 on marine lower trophic levels over the 30-year assessment period.

D.3.1.4.2 MITIGATION AND MANAGEMENT

Mitigation and management measures to reduce potential effects of Scenario 3 activities on lower marine trophic level indicators are identical to those described for Scenario 1 and 2. In addition, baseline conditions of benthic habitat and species health in the local area of the drilling platform should be established prior to the start of construction. Long-term monitoring should then be undertaken to monitor potential effects of drilling activity and operations on marine benthic habitat.

D.3.1.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Potential residual adverse effects of seabed disturbances, routine discharges and artificial light on lower marine trophic level indicators are expected to be low magnitude, limited to the GBS footprint and near-field areas, and occur continuously over the life of the development. Potential effects are expected to be reversible once the GBS is removed. The influence of climate change on the prediction of effects is similar to what was described for Scenario 1.

CUMULATIVE EFFECTS

While Scenario 3 represents an increase in the intensity of effects (e.g., frequency, duration, geographical extent) compared to Scenarios 1 and 2, the frequency, duration, and geographical extent of potential residual effects of Scenario 3 activities on marine lower trophic levels are expected to be similar to those described for Scenario 2. Given that residual effects on marine lower trophic levels from Scenarios 1 and 3 are expected to remain localized and low in magnitude, it is unlikely that concurrent activities in the region would result in adverse regional cumulative effects.

D.3.1.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.3.1.5.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

The pathways, range and influence of climate change on potential effects of activities associated with Scenario 4 (e.g., installation and presence of FPSO and wareships, subsea infrastructure, drilling, shipping) are anticipated to be similar to what was described for Scenario 3. The total footprint of benthic habitat that may be disturbed or altered by Scenario 4 drilling activities would be larger given the requirement for up to six sub-sea manifolds (with a 2 ha footprint per manifold), associated pipe bundles and risers, and anchors associated with the turret mooring.

D.3.1.5.2 MITIGATION AND MANAGEMENT

Mitigation and management measures to reduce potential effects of Scenario 4 activities on lower marine trophic level indicators are identical to those described for Scenarios 1 - 3.

D.3.1.5.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Given the frequency of vessel activity required for operations support and transport of oil, and the larger geographic extent of benthic habitat disturbance, potential residual adverse effects from seabed disturbances on lower marine trophic level indicators are expected to be low magnitude. Residual effects would be localized around the activity and is not likely to have a measurable effect on the lower marine trophic level in the local or regional area. Residual effects would be limited to the immediate footprint of the activity and occur continuously on a medium-term time frame. Potential effects are anticipated to be reversible.

CUMULATIVE EFFECTS

Given that residual effects on marine lower trophic levels from Scenarios 1 and 4 are expected to remain localized and low in magnitude, it is unlikely that concurrent activities in the region would result in adverse regional cumulative effects. The influence of climate change on the prediction of cumulative effects is similar to what was described for Scenario 1.

D.3.1.6 Scenario 5: Large Oil Release Event

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on lower marine trophic levels from such an event may differ slightly from what is described below for surface or subsea releases.

D.3.1.6.1 POTENTIAL IMPACTS AND EFFECTS OF A LARGE OIL RELEASE

DESCRIPTION OF EFFECT PATHWAY

Oil entering the environment can affect plankton and benthic communities via multiple pathways including:

- mortality through direct contact or ingestion of oil-fouled prey
- change in health through direct contact or ingestion of oil-fouled prey
- change in behaviour through direct contact or ingestion of oil-fouled prey
- habitat degradation in oil-fouled areas, including decreased light penetration and associated potential effects on growth of primary producers and subsequent effects to zooplankton and benthos.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The greatest effects of an oil spill on plankton would be during periods of ice-associated or open water phytoplankton blooms in spring and summer/fall, or as a result of a subsea release under longer-term, multi-year ice where the oil becomes trapped under thick ice and is difficult to remove. Impacts would be particularly important around regions of high productivity such as ice edges and other biological hotspots. Changes to the timing or magnitude of the ice-associated or open water blooms could cascade through the marine ecosystem as they are key in transferring energy to zooplankton and the benthos (e.g., Kedra et al. 2015). Given the importance of lipid rich zooplankton in arctic food webs, loss of these plankton resources, even for a single season, would affect higher trophic level organisms. Because oil from a subsea spill would rise to the surface (and continue to contaminate the surface and water column, with limited contamination of the seafloor), potential direct effects to benthic macrofauna are expected to be less compared to those for plankton. However, indirect effects to benthic macrofauna, via food web dynamics, remain a concern.

Potential effects of oil on plankton range from fluctuating intensity of photosynthesis in phytoplankton, to physiological response, change in growth and reproduction rates, mortality, deformity, or reduced egg and larval survival in zooplankton (Tang et al. 2019). As petroleum levels dissipate, the rapid population regeneration cycle of plankton is expected to repopulate the affected region with few long term (i.e., multi-year) effects to plankton (Committee on Oil in the Sea: Inputs Fates and Effects et al. 2003; Minerals Management Service 2003; National Research Council 1985).

A spill within the Mackenzie River plume during the Open Water Season would pose the greatest threat to benthic macrofauna since the oil may reach the shoreline and could alter inter- and sub-tidal habitat. Oil could also smother benthic organisms resulting in acute and chronic effects on health or mortality. Ingestion of oil can be lethal or result in chronic exposure and uptake and can be passed up the food chain to higher trophic levels (Starr et al. 1981; Teal and Howarth 1984). As contaminants can persist, buried in intertidal or shallow subtidal sediments, for decades (Ballachey et al. 2007; Short et al. 2004; Short et al. 2006) and may be resuspended into the water column following disturbance or erosion, potential effects on marine lower trophic levels could persist over the long term (see Section D.2.6.6 for more information on potential effects of an oil spill on coastal habitats).

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Physical stressors on marine species (e.g., reduced extent and quality of sea ice, altered ocean temperature, ocean acidification, shifting species assemblages and distributions), may reduce the general resiliency of individual species and communities. Therefore, it is likely that climate change would exacerbate potential effects from an oil spill on marine lower tropic level indicators by contributing additional stressors. The effects of climate change on marine lower tropic level would depend on individual species life history traits (that might improve or reduce the ability to rebound from an effect) and overall community resilience (e.g., food web complexity or functional redundancy) to withstand the combined stressors.

D.3.1.6.2 MITIGATION AND MANAGEMENT

Oil spill response planning and measures are discussed in Sections 2.13 and 3.10.5.3. Additional details are provided in Appendix F.

D.3.1.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Potential residual adverse effects from a hypothetical oil spill on the lower marine trophic level are expected to be moderate to high magnitude, regional to extra-regional (given the potential spread of an oil slick along the coastline) and occur as a single event over a long-term to permanent time frame. Most potential effects would be reversible (e.g., photosynthesis rates and plankton abundance and species composition), while others may be irreversible (e.g., damaged or altered shoreline habitats; see Section D.2.6.6 for more information on potential effects of an oil spill on coastal habitats).

D.3.1.7 Summary of Residual Effects

Potential residual effects of Scenarios 1 – 4 and a large oil release event on marine lower trophic levels are summarized in Table D-26 and Table D-27.

D.3.1.8 Gaps and Recommendations

Although it is generally believed that underwater noise has little effect on invertebrates (Andriguetto-Filho et al. 2005; Day et al. 2016), potential effects have been noted (Hawkins et al. 2015) and warrant further research to understand how human activities (i.e., seismic, vessel noise, dredging, drilling) could affect plankton and benthic macroinvertebrates. Of note, proponents for future projects would be expected to provide project-specific information on potential effects of underwater noise.

Bacteria could play an important role during the biological breakdown of oil spills, even in the Arctic environment. More research on this topic is needed in the Arctic.

Assessment of the timing and location of phytoplankton blooms is needed. It is expected that phytoplankton blooms are occurring earlier, and possibly under sea-ice. Therefore, for phytoplankton, the ice covered/transition period could become more critical than the open water period. A spill when ice is present could affect both the ice algae and phytoplankton spring bloom with subsequent effects on zooplankton, fish and the benthic community. In addition, increased understanding of climate driven changes on the quality of zooplankton over time would enable a better assessment of how resilient different key species (i.e., copepods) may be to a additional effects.

D.3.1.9 Follow-up and Monitoring

As the base of the Arctic ecosystem, the ability to identify shifting trends in marine lower trophic levels is essential to understanding how the larger Arctic ecosystem is responding to effects of climate change. Follow-up and monitoring programs should focus on current baseline conditions of plankton, that includes data collected at local and regional scales in the BRSEA Study Area and seek to identify seasonal and inter annual trends on plankton and benthic communities. Given the rapid rate of change that is being observed in Arctic systems, acquiring a robust and continuous dataset on marine lower trophic levels would be important to understanding and predicting implications for higher trophic levels and the human environment.

Table D-26 Potential Residual Effects of Scenarios 1 – 4 on Marine Lower Trophic Levels

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Ice	• Limited activity during Ice Season therefore negligible effects on Marine Lower Trophic Levels	• Limited residual effects associated with routine discharge from vessels and GBS • Disturbance to benthic macroinvertebrates resulting from footprint of GBS	• Limited residual effects associated with routine discharge from vessels and GBS • Disturbance to benthic macroinvertebrates resulting from footprint of GBS • Disturbance to benthic macrofauna resulting from disposal of drilling muds and cuttings	• Limited residual effects associated with routine discharge from vessels and FPSO • Limited disturbance to benthic macroinvertebrates resulting from seabed manifolds and anchors • Disturbance to benthic macrofauna resulting from disposal of drilling muds and cuttings
Spring Transition	• Limited residual effects associated primarily with routine discharge from vessels • Effects may be amplified if they occur during plankton bloom • Negligible effects of artificial light	• Limited residual effects associated with routine discharge from vessels and GBS • Disturbance to benthic macroinvertebrates resulting from footprint of GBS • Effects may be amplified if they occur during plankton bloom	• Limited residual effects associated with routine discharge from vessels and GBS • Disturbance to benthic macroinvertebrates resulting from footprint of GBS • Disturbance to benthic macrofauna resulting from disposal of drilling muds and cuttings • Effects may be amplified if they occur during plankton bloom	• Limited residual effects associated with routine discharge from vessels and FPSO • Limited disturbance to benthic macroinvertebrates resulting from seabed manifolds and anchors • Disturbance to benthic macrofauna resulting from disposal of drilling muds and cuttings • Effects may be amplified if they occur during plankton bloom

Table D-26 Potential Residual Effects of Scenarios 1 – 4 on Marine Lower Trophic Levels

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Open Water	• Limited residual effects associated primarily with routine discharge from vessels • Effects may be amplified if they occur during plankton bloom • Negligible effects of artificial light	• Limited residual effects associated with routine discharge from vessels and GBS • Disturbance to benthic macroinvertebrates resulting from footprint of GBS • Effects may be amplified if they occur during plankton bloom	• Limited residual effects associated with routine discharge from vessels and GBS • Disturbance to benthic macroinvertebrates resulting from footprint of GBS • Disturbance to benthic macrofauna resulting from disposal of drilling muds and cuttings • Effects may be amplified if they occur during plankton bloom	• Limited residual effects associated with routine discharge from vessels and FPSO • Limited disturbance to benthic macroinvertebrates resulting from seabed manifolds and anchors • Disturbance to benthic macrofauna resulting from disposal of drilling muds and cuttings • Effects may be amplified if they occur during plankton bloom
Fall Transition	• Limited residual effects associated primarily with routine discharge from vessels • Negligible effects of artificial light	• Limited residual effects associated with routine discharge from vessels and GBS • Disturbance to benthic macroinvertebrates resulting from footprint of GBS	• Limited residual effects associated with routine discharge from vessels and GBS • Disturbance to benthic macroinvertebrates resulting from footprint of GBS • Disturbance to benthic macrofauna resulting from disposal of drilling muds and cuttings	• Limited residual effects associated with routine discharge from vessels and FPSO • Limited disturbance to benthic macroinvertebrates resulting from seabed manifolds and anchors • Disturbance to benthic macrofauna resulting from disposal of drilling muds and cuttings.
Legend				
• Least effect – No to minor effect on habitat, behaviour, and/or mortality risk				
• Moderate effect – Moderate effect on habitat, behaviour, and/or mortality risk				
• High effect – Major effect on habitat, behaviour, and/or mortality risk				
• Greatest effect – Severe effect on habitat, behaviour, and/or mortality risk				

Table D-27 Potential Effects of a Large Oil Release Event (Scenario 5) for Marine Lower Trophic Levels

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• Least effects because oil (and volatiles) would be encapsulated into the ice, be relatively stationary, and could be removed mechanically or burned.	• Moderate effects because oil (and volatiles) would be encapsulated into the ice, be relatively stationary, and could be removed mechanically or burned.	• Least effects because oil (and volatiles) would be encapsulated into the ice, be relatively stationary, and could be removed mechanically or burned.
Spring Transition	• Moderate effects because oil would be slow spreading and in water column (dissolution, dispersion, entrainment), slick may be contained by ice, and facilitate treatment by mechanical methods or in situ-burning.	• Moderate effects because oil would be slow spreading and in water column (dissolution, dispersion, entrainment), slick may be contained by ice, and facilitate treatment by mechanical methods or in situ-burning.	• Moderate effects because oil would be slow spreading and in water column (dissolution, dispersion, entrainment), slick may be contained by ice, and facilitate treatment by mechanical methods or in situ-burning.
Open Water	• High effects because oil would be fast spreading, in water column (dissolution, dispersion, entrainment); use of booms and herders could facilitate treatment by mechanical methods or in situ-burning.. • Greatest potential effects if spill occurred at a biological hotspot or reached the shoreline during this season of high productivity.	• High effects because oil would be fast spreading, in water column (dissolution, dispersion, entrainment); use of booms and herders could facilitate treatment by mechanical methods or in situ-burning. • High potential effects if spill occurred at a biological hotspot during this season of high productivity. • Impact on shoreline communities would be limited due to dynamics of the plume.	• High effects because oil would be fast spreading, in water column (dissolution, dispersion, entrainment); use of booms and herders could facilitate treatment by mechanical methods or in situ-burning. • High potential effects if spill occurred at a biological hotspot during this season of high productivity. • Impact on shoreline communities would be limited due to dynamics of the plume.
Fall Transition	• Moderate effects because oil would be slow spreading, in water column (dissolution, dispersion, entrainment); use of booms and herders could facilitate treatment by mechanical methods or in situ-burning.	• Moderate effects because oil would be slow spreading, in water column (dissolution, dispersion, entrainment); use of booms and herders could facilitate treatment by mechanical methods or in situ-burning.	• Moderate effects because oil would be slow spreading, in water column (dissolution, dispersion, entrainment); use of booms and herders could facilitate treatment by mechanical methods or in situ-burning.

Table D-27 Potential Effects of a Large Oil Release Event (Scenario 5) for Marine Lower Trophic Levels

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Longer-term/ Multi-year	• Potential for long-term effects if oil is encapsulated in ice • Rapid regeneration times for plankton communities and limited direct effect on benthic macrofauna could reduce severity of long-term effects	• Potential for long-term effects if oil is encapsulated in ice • Rapid regeneration times for plankton communities and limited direct effect on benthic macrofauna could reduce severity of long-term effects	• Potential for long-term effects if oil is encapsulated in ice • Rapid regeneration times for plankton communities and limited direct effect on benthic macrofauna could reduce severity of long-term effects
Legend			
• Least effect – No to minor effect on habitat, behaviour, and/or mortality risk			
• Moderate effect – Moderate effect on habitat, behaviour, and/or mortality risk			
• High effect – Major effect on habitat, behaviour, and/or mortality risk			
• Greatest effect – Severe effect on habitat, behaviour, and/or mortality risk			

D.3.2 Marine Fish and Habitat

D.3.2.1 Scoping

D.3.2.1.1 IDENTIFICATION OF INDICATORS

Indicators for marine fish and fish habitat have been selected based on their importance to the Inuvialuit for harvesting, their ecological value, or their utility as an indicator of potential effects. For the purposes of the BRSEA, the following species have been selected as indicators:

- Arctic cisco – traditionally harvested, abundant along coastlines, and spawn in the Mackenzie River system
- Least cisco – traditionally harvested, common along Tuktoyaktuk Peninsula (feeding and overwintering)
- Dolly Varden char – traditionally harvested and anadromous life history utilizing habitat seasonally across the BRSEA Study Area
- Arctic char – traditionally harvested and anadromous life history utilizing habitat seasonally across the BRSEA Study Area
- Demersal fish species within potential scenario area (e.g., four horn sculpin or arctic flounder within the plume) – close association with seabed habitat and at potential for contaminant uptake from sediments
- Arctic cod – closely associated with under-ice habitat and generally considered a keystone species in the region

Not all species harvested by the Inuvialuit have been selected as indicators. The traditionally-harvested species selected as indicators would provide analogous information for the other harvested species (e.g., herring, whitefish, coney).

D.3.2.1.2 SPATIAL BOUNDARIES

The spatial boundary for the assessment of marine fish and fish habitat includes all marine waters of the ISR (i.e., the BRSEA Study Area).The species selected as indicators range throughout the BRSEA Study Area except for Dolly Varden char, which only occur west of the Mackenzie estuary and Arctic char, which occur east and north of Tuktoyaktuk Peninsula. Temporal and spatial overlap of activities with fish and their habitat would be expected regardless of where or when human activities are occurring within the region.

D.3.2.1.3 TEMPORAL BOUNDARIES

The assessment of potential effects on marine fish and fish habitat encompasses a 30-year period between 2020 – 2050.

D.3.2.1.4 ASSESSMENT OF POTENTIAL EFFECTS

The assessment of potential effects on marine fish and fish habitat considers residual effects on the population, not on individual fish. Qualitative characterization of potential residual effects on marine fish and fish habitat associated with each scenario is based on the characterization terms defined in Table D-28.

Table D-28 Characterization of Residual Environmental Effects on Marine Fish for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect on the VC	**Positive**—a net benefit to the health, mortality or habitat or behaviour **Adverse**—a reduction or influence on the health, mortality, habitat or behaviour that could result in a change in the status or resiliency of the population **Neutral**—no net change in the viability, status or resiliency of the population
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	Typically expressed qualitatively as: **Negligible**—no measurable change in health, mortality, habitat or behaviour and no measurable effect on the population **Low**—a measurable change in the status or resiliency of the population, but would not affect the long-term sustainability of the population **Moderate**—measurable change in the status or resiliency of the population, with potential to affect the long-term sustainability of the population **High**—measurable change with relative certainty of affecting the long-term sustainability of the population
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the local area around the activity **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area) **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area)
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity **Continuous**—residual effect occurs continuously for the duration of the activity
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to one phase or season (e.g., seismic survey, exploration drilling) **Medium-term**—residual effect extends through multiple seasons or years (e.g., production phase) **Long-term**—residual effect extends beyond the life of the project (e.g., beyond closure) **Permanent**—measurable parameter unlikely to recover to existing conditions

Table D-28 Characterization of Residual Environmental Effects on Marine Fish for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.3.2.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

The environmental effects on marine fish associated with human and industrial activities and infrastructure include:

- habitat alteration (through alteration of the seabed or under ice habitat)
- effects on health (due to injury or increased potential for contaminant exposure)
- behavioural change (resulting from seismic noise).

Changes in marine fish as a result of these effects can also affect Inuvialuit fish harvesting and prey availability to higher trophic level animals such as whales and seals. Potential effects of a large oil release on marine fish and fish habitat can include toxicity, effects on health of adult and juvenile fish, behavioural changes and avoidance of habitat; these effects are discussed further in Section D.3.2.6.

Seasonal vessel traffic (e.g., shipping, research, military, tourism) during ice-free periods is predicted to have minimal effects on marine fish and fish habitat since these activities are expected to be dispersed throughout the BRSEA Study Area and of short duration at any one location.

While the presence of vessels and structures is not expected to have substantial effects on marine fish and fish habitat, Inuvialuit communities raised concerns regarding the disposal or exchange of bilge water and ballast water from vessels and platforms in offshore waters (KAVIK-AXYS Inc. 2009). Ballast water exchange is regulated through the Ballast Water Control and Management Regulations under the Canada Shipping Act while discharge of bilge water is regulated through the Arctic Water Pollution Act (Table 2-5). Discharge of bilge and ballast is typically not permitted in Canadian waters and, if discharged, must be treated to a maximum threshold of 15 mg/L or less. Sewage, including grey water, must also be treated before discharge (e.g., Offshore Waste Treatment Guidelines (N.W.T. NEB 2010), MARPOL: Table 2-5). Given that the effect from the presence of vessels is a low to negligible concern and issues associated with discharge from vessels and platforms are regulated, these potential effects from vessel traffic and the operation of permanent structures (e.g., GBS, FPSO) are not considered further in this assessment.

Although growth in tourism may increase sport fishing pressure on anadromous coastal fish, sport fishing is regulated through the Northwest Territories Sport Fishing Regulations and co-managed through the Fisheries Joint Management Committee and Fisheries and Oceans Canada. As a result, this potential effect is not carried forward in the assessment.

Ship anchorages and overwintering of vessels could occur in the vicinity of service and supply bases such as Tuktoyaktuk Harbour and Summers Harbour. With proper management of vessels in these harbours and adherence to waste management requirement, (Table 2-5), the range of potential effects on marine fish and fish habitat is predicted to be localized, low magnitude and reversible, although effects could occur irregularly over the life of the service and supply base. Therefore, effects associated with ship anchorages and overwintering of vessels are not considered further in this assessment.

Aside from seismic noise, underwater noise from in-water construction, drilling, vessels maneuvering and docking at GBS platforms and the FPSO could cause some temporary behavioural effects on fish, such as startle responses and avoidance (Feist et al. 1996; Schwarz and Greer 1984). Because these structures do not represent barriers to fish movements, fish would be able to avoid this type of underwater noise. The behavioural effects would be intermittent and reversible and would not be expected to adversely affect fish populations. The potential effect of in-water construction, platform operation and drilling and vessel noise on fish is not considered further in this assessment.

The effects of ice breaking on under-ice Arctic cod habitat is largely unknown. Arctic cod are found in cold water masses, occupying sympagic (ice related), pelagic and benthic environments (Hop and Gjøsæter 2013). Larval and juvenile arctic cod are directly affiliated with sea ice, occupying small cracks where they are afforded some predator-protection, and where they feed on zooplankton (Hamilton et al. 2015). In the Barents Sea, Arctic cod abundance has decreased, and the 0-age class has shifted its distribution northeastward over the last decade as part of the rapid 'borealization' of the fish community of that region (i.e., adaptation of fish to sub-arctic conditions). Given the small spatial extent and rapid refreezing of ice cover once vessels have passed, effects on marine fish, especially juvenile Arctic cod, are expected to be adverse, but negligible in magnitude and limited to the immediate area around the icebreaking activity. Effects of icebreaking and associated vessel movements on other marine fish indicators are predicted to be similar to those described for Arctic cod. As a result, effects of ice disturbance on marine fish and fish habitat is not discussed further.

Potential Effects of Seabed Disturbance

Seabed disturbance such as preparation of the sea floor for infrastructure (e.g., the GBS for wind turbines, the GBS loading platform for LNG and condensate, the associated dual pipelines, the GBS for drilling and oil production, installation of manifolds and pipe bundles in deep water, and spudding of wells in deep water) would alter seabed habitat and affect benthic fish and invertebrate prey populations in the disturbed area (Newell et al. 1998). Seabed disturbance can also cause increased sediment concentrations, smothering of organisms adjacent to the disturbance, and potentially release contaminants that may be present in the seabed material (Victoria et al. 2015). Effects such as loss of habitat or decreased habitat quality for marine fish are dependent on the location and availability of alternate suitable habitat.

POTENTIAL EFFECTS OF UNDERWATER NOISE

As discussed above, this assessment focuses on potential effects of seismic noise on marine fish. The effects of seismic activities on marine fish has been well studied (McCauley et al. 2000, Slotte et al. 2004, Løkkeborg et al. 2012). Effects include behavioural disturbance such as startle response (Wardle et al. 2001) and altered swimming behaviour (Pearson et al. 1992). The use of seismic air guns has also resulted in changes to the horizontal and vertical distributions of pelagic and ground fish (Engås and Løkkeborg 2002; Slotte et al. 2004), and physical damage to the fish hearing apparatus (Carroll et al. 2017).

Physical injury of fish from seismic activities is mostly related to exposure of fish to air gun noise at short range, including causing developmental abnormalities in fish larvae (Kostyuchenko 1973, Booman et al. 1996; Carroll 2017); however, such occurrences are unlikely to negatively affect fish stocks and in some cases have been correlated to higher catches (presumably due to changes in distribution) (Carroll et al. 2017; Dalen and Knutsen 1987). One study investigated the effects of broad whitefish hearing from use of air guns in the Mackenzie River and found they were not substantially affected by exposure to airgun noise in rivers (Popper et al. 2005).

Given the intermittent timing of seismic survey activity, the greatest magnitude of effect from seismic noise on marine fish is likely within surface waters that are in proximity to seismic start-up (i.e., exposed to noise without warning), and to small or larval fish or eggs in surface waters which are unable to actively avoid approaching seismic vessels., Of note, adult fish and active swimmers are likely to avoid approaching vessels if seismic noise is audible from distance (Carroll et al. 2017). Benthic and demersal species in deeper water are more likely to experience behavioural disturbance rather than injury or mortality even if exposed to seismic noise (Popper and Hawkins 2019). There is currently no conclusive evidence that seismic noise causes mortality in either fish or invertebrates; most experimental results showing such physical effects were the result of exposure of caged marine fish specimens to air guns at direct proximity (Carroll et al. 2017; Popper and Hawkins 2019).

A summary of potential impacts and effects on marine fish and fish habitat is provided in Table D-29.

Table D-29 Summary of Potential Impacts and Effects on Marine fish and fish habitat

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Air Emissions	• vessel transits • seismic surveys • drilling • operational and maintenance activities to vessels, production platform, and wells • helicopters, low flying aircraft, and snowmobiles	• no interaction	• NA	• N/A

Noise (in-air and underwater)	• vessel transits (engine, propeller, and ice-breaking activities)
	• seismic surveys
	• drilling
	• operational and maintenance activities to vessels, production platform, and wells
	• helicopters, low flying aircraft, and snowmobiles
		• underwater noise produced by vessels, and icebreakers is audible to fish
		• noise associated with seismic airguns can injure or kill fish depending on proximity and result in behavioural changes and avoidance of ensonified areas
		• drilling is audible to some fish
			• potential effects due to seismic noise can include:
			  ◦ change in behaviour, including startle response or displacement from habitat
			  ◦ change in mortality risk due to injury or mortality (from sound pressure levels associated with seismic airguns)
			• potential effects due to noise from vessel traffic and ice-breaking are anticipated to be localized, temporary, limited to individual fish, and thus negligible in magnitude
				• change in fish distribution and abundance relative to seismic activities.

Artificial Light	• lighting used on nearshore infrastructure (wind turbines, marine infrastructure), offshore platforms and vessels	• artificial light during the Open Water Season can attract fish near the surface	• residual effects on fish populations are expected to be localized and of negligible magnitude • **further assessment of this impact is not warranted**	• N/A

Table D-29 Summary of Potential Impacts and Effects on Marine fish and fish habitat

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters

Seabed Disturbance	• subsea well, manifold, and pipeline installations and repairs, including dredging	• alteration of marine fish habitat through site preparation for and installation of pipelines, and bottom-founded structure (GBS, manifolds) and dredging around ports and harbours
		• loss of marine fish habitat from marine infrastructure, wells and manifolds
			• alteration of marine fish habitat could result in temporary reduction in food supply and temporary habitat loss for fish
			• increase in suspended sediment effects on marine fish and fish habitat
			  • smothering by sediments
			  • contaminant mobilization from sediment disturbance
			• adherence to regulations under the *Fisheries Act* results in no net loss of marine fish habitat
				• quantify seabed area altered or lost
				• suspended sediment concentrations

Ice Disturbance	• icebreakers transiting through sea ice (ice management, support, transport) • presence of structures on/in sea ice or open water (drillships, platforms, wind turbines)	• ice breaking of Arctic cod under-ice habitat	• ice breaking activities could reduce the ice algae production, thereby reducing the zooplankton community and altering prey availability to Arctic cod • effects are likely to be local and negligible in magnitude • **Further assessment of this impact is not warranted**	• NA
Vessel Wake	• vessel use during Open Water Season (commercial, personal use, tourism, sea lift, military, research, harvesting)	• no interaction	• N/A	• N/A

Table D-29 Summary of Potential Impacts and Effects on Marine fish and fish habitat

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Routine Discharges	• air emissions • drilling muds, drill cuttings and disposal • sewage and food waste • cooling water and deck drainage	• drill cutting disposal temporarily altering or degrading marine fish habitat	• potential residual effects on fish health are possible but with mitigation measures in place (Table 2-5) direct potential residual effects on behaviour, health, habitat and mortality risk, are expected to be negligible in magnitude • **further assessment of this impact is not warranted**	• NA
Vessel Collision	• vessel transits (shipping, tankers, icebreakers, personal watercraft)	• no interaction	• N/A	• N/A
Oil Spill	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• death or reduced health of fish • alteration of habitat	• oil toxicity may kill fish or fish eggs or lead to health effects through direct exposure or intake of contaminated prey • oil on the surface of the water or within the water column can cause avoidance by fish of the affected spill area leading to a temporary loss of habitat	• contaminant loads in fish tissue • direct fish mortality by species • egg viability or larval effects (e.g., deformities) • fish population trends

D.3.2.2 Scenario 1: Status Quo

D.3.2.2.1 Potential Impacts and Effects of Routine Activities

Description of Effect Pathway

Site preparation and installation of GBSs for offshore wind turbines would result in a small loss of benthic habitat used by fish.

Description of Range of Potential Effects

The effects of habitat loss from offshore GBSs for wind turbines would be dependent on the number of structures constructed, their location, and footprint size. Effects would be greatest during site preparation and installation. Effects would be restricted to the seabed footprint and a limited radius around the GBS (e.g., sediment transport) and would primarily affect benthic species and habitats.

Effects of Climate Change on Potential Effects

The reproductive strategies of some Arctic fish species are linked to the melting of sea ice and therefore changes in timing of ice melt. Lengthening of the Open Water Season (Galley et al. 2016) may have a negative effect on some Arctic fish species (Frainer et al. 2017). Modelling reported by Steiner et al. (2019) suggests a decline in Arctic cod abundance due to climate change. Fish populations that are already stressed by climate change-induced changes to habitat, may be more sensitive to potential effects of human activities in the region. Climate change could have the opposite effect, too, by increasing light availability and temperature in surface waters and thus fueling primary productivity and bottom-up food web processes (Bouchard et al. 2017).

Although poorly understood, a warming Arctic could drive northward range expansions of species limited to more southerly latitudes by ice (e.g., the forage fish capelin, *Mallotus villosus or Pacific sand lance, Ammodytes hexapterus*), or cause ice-dependent species to move northward concurrent with receding ice (e.g., Arctic cod). Changes in species distributions could promote new or more pervasive interspecific interactions with unknown consequence, especially among fish species with similar dietary preferences like capelin and Arctic cod), which could favour productivity of some fish species at the expense of others (McNicholl et al. 2015; Steiner et al. 2019). Climate change has been attributed to capelin displacing Arctic cod within the food chain in Hudson Bay (Fortier et al. 2015).

Warmer sea temperatures also may increase the potential for new fish species to establish within the BRSEA Study Area, with resulting shifts in species composition, distribution, resource competition, and migratory behaviour of resident and new fish species (Stantec 2013a). Reduction in ice cover as a result of climate change may make young Arctic cod, which use sea ice as a refuge, more vulnerable to predation, and also could lead to changes in availability of their prey items, such as larger copepod species (Fortier et al. 2015). Ice breaking activities may contribute more substantially to these effects on ice in the future. Expected changes in contaminant levels in the water column due to climate change (Greenan et al. 2018; Stantec 2013a) and increasing acidification of the Arctic Ocean (Greenan et al. 2018) also may increase sensitivity of fish to effects from human activities.

D.3.2.2.2 MITIGATION AND MANAGEMENT

General mitigation and management measures (Section 2.4) should be implemented to reduce potential effects to marine fish and fish habitat and include:

- development and implementation of environmental management plans for site preparation, installation and operation of offshore wind turbines
- use of least-risk work windows for in-water construction (e.g., dredging) to avoid sensitive life history stages of fish

Additional details are provided in Appendix F.

D.3.2.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Potential effects from Scenario 1 are expected to be negligible since there is little interaction with marine fish and fish habitat. The loss of seabed marine fish and fish habitat due to offshore wind farm(s) would be small given the broad distribution and general dominance of clay, silt and sand habitat throughout the region (Jerosch 2013). Residual effects are predicted to be adverse and long-term, but low magnitude, restricted to the immediate vicinity of the GBSs (i.e., local), and reversible. As similar activities have occurred in the BRSEA Study Area (e.g., construction of artificial islands, installation of GBS platforms) and elsewhere, the effects are well understood and the confidence in this prediction is high.

Climate change is likely to result in effects on marine fish habitat, distribution, and resiliency in the region, which could alter the characterization of residual effects. Certainty around how this may influence the prediction of residual effects on marine fish and fish habitat is low, although there is general consensus that some species would benefit from a warmer Arctic, whereas others may suffer either directly from changes to the physical environment or indirectly via bottom-up or top-down ecological processes (e.g., Fortier et al. 2015, McNicholl et al. 2015; Steiner et al. 2019). A precautionary approach should be taken so that changes in marine fish populations in the region are monitored and potential effects are identified and mitigated with an adaptive approach.

CUMULATIVE EFFECTS

Given the low magnitude of residual effects on marine fish and fish habitat from activities associated with Scenario 1, it is unlikely that cumulative effects from concurrent activities in the region would have a measurable effect on marine fish populations or their habitat in the region. As discussed above, climate change induced effects on marine fish and fish habitat could reduce overall resiliency of populations and communities and result in lower ability to withstand effects from multiple activities.

D.3.2.3 Scenario 2: Export of Natural Gas and Condensates

D.3.2.3.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Seabed disturbance from directional drilling for the dual pipelines (one for LNG and one for condensate) from land to approximately 1 km offshore would be spatially separated from marine fish habitat (i.e., below the water column and seabed) and is not expected to affect marine fish and fish habitat; therefore, it is not considered further.

Site preparation for the sections of dual pipelines that are in nearshore water following emergence from the directional drilling (i.e., dredging and possible trenching for protection from ice keels) would temporarily disturb and remove benthic marine fish habitat along the pipeline corridor. These activities would resuspend sediment into the water column during the removal of seabed material (e.g., suction dredging trenching for the pipeline if required). Sediment would also be resuspended during refill of the trenched areas or covering of the pipeline for protection. Benthic fish may be inadvertently captured during the removal of seabed material (e.g., suction dredging) resulting in some mortality of benthic fish.

The GBS loading facility would be transported to its laydown site 15-20 km offshore and occupy approximately 2 ha of seabed resulting in a loss of marine fish habitat. These activities are most likely to affect demersal fish like sculpin and flounder. In contrast, coregonids and Dolly Varden char mainly remain close to the shoreline (Bond and Erickson 1989) and, therefore, should not be affected by these activities.

Propeller rotation from ships transiting to and from Summers Harbour could crop the upper layer of the kelp bed located to the west of the entrance to Summer Harbour (D. Chiperzak 2019, pers. comm.). Kelp beds, which are rare in the Beaufort Sea, can provide feeding, rearing and spawning habitat for a variety of marine species (Filbee-Dexter et al. 2019). A reduction in the kelp bed may have a negative effect on species that use it. However, these effects could be avoided by establishing a shipping channel for Summers Harbour that avoids the kelp bed.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Site preparation and installation of the two pipelines would have a localized and temporary effect along the pipeline route. The range of effects is low to moderate since most demersal fish would be able to escape dredging and trenching activities, although some species within the construction footprint or in areas of heavy sedimentation are expected to be killed. The denuded construction footprint would be recolonized by species inhabiting surrounding sediments, following established patterns of colonization and succession in disturbed marine sediments (Rhoads and Germano 1986). Following installation and backfilling where required, it is expected that benthic habitat would recover naturally beginning almost immediately after the disturbance; full recovery to pre-disturbance condition could take days to decades depending on scale of disturbance and the dynamics of local biophysical conditions (Norkko et al. 2006). Moreover, ecosystem recovery is expected to be faster where project-related disturbances (like dredging) is similar to natural re-occurring disturbances to an ecosystem. For example, the natural seabed in the assessment region is adapted to ice-scour, which is a similar type of physical disturbance to dredging or trenching; hence, the local benthic flora and fauna are likely adapted to small local disturbances to the seabed. Studies from other geographic regions have reported post-dredging recovery of the macrobenthic community to occur between one to four years (Desprez 2000; Newell et al. 1998; Blanchard and Feder 2003; Bolam and Rees 2003). In a study of Arctic ice scour, Conlan and Kvitek (2005) found 65 – 84% of the benthic biomass and diversity had returned to reference condition after 8 to 9 years. In areas where localized disturbances to soft-sediment habitat persist, higher order piscivores and predators would retain access to habitat and prey given the clay, silt and sand ecosystem is broadly distributed and available throughout the region (Jerosch 2013).

Installation of the GBS loading platform would result in a small loss of seafloor habitat (i.e., ~2ha) and temporary resuspension of sediment as a result of ship movements, anchoring and placement of the GBS. Effects would be localized to the footprint of the GBS loading platform and an area around the footprint where sediment would be transported and settle. The footprint would affect only a small area of available marine fish habitat on the continental shelf, and sediment effects would be short-term in duration (the period of installation plus several hours to a day for settling) and localized to the footprint and an adjacent buffer around the footprint where sediment would settle. Operation of the GBS loading platform and movements by LNG carriers and condensate tankers would result in localized effects including underwater noise, vibration, temporary avoidance of habitat, possible resuspension of sediment and loss of habitat. Some effects would be short-term and rapidly reversible (habitat avoidance), while habitat loss would persist until removal of the GBS and decommissioning.

The effects of vessels on the kelp bed near Summers Harbour could vary depending on the number of transits to and from Summers Harbour and the location of shipping routes in and out of the harbour. It is not known if the kelp bed can be avoided safely or if the area of kelp bed crossed can be reduced. Because fish use of this kelp bed is unknown, the range of effect cannot be confidently predicted.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Effects of climate change on potential effects are the same as described for Scenario 1 (Section D.3.2.2.1).

D.3.2.3.2 MITIGATION AND MANAGEMENT

Mitigation measures for the potential effects of Scenario 2 activities on marine fish and fish habitat would include Inuvialuit, federal and territorial requirements and guidelines (Section 2.4). Additional mitigation and management measures to reduce potential effects on marine fish and fish habitat include:

- establish and implement environmental management plans for each of the components of Scenario 2
- identify routing for the dual pipelines to avoid sensitive habitats or key areas for marine fish
- conduct site preparation activities, where possible, under relatively calm conditions to reduce sediment dispersal
- use measures to reduce sediment resuspension and contain sediment dispersion (e.g., modeling of potential sediment dispersion to inform mitigation, silt curtain, choice of dredging equipment)
- confirm and mark anchorages in both harbours to reduce effects on marine fish habitat

D.3.2.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Potential effects of site preparation activities (e.g., suction dredging, trenching), although adverse, would be temporary and reversible and are similar to natural disturbances caused by ice-scour and sediment precipitation from the Mackenzie River plume. Once the pipelines and GBS are installed, backfilling and natural transport of sediment would aid in habitat recovery in disturbed areas, including recolonization of benthic food sources for fish, although areas that have been denuded via dredging or disposal of large volumes of sediments (i.e., > 50 cm thickness) may display community level differences for up to a decade as the benthos recovers naturally (see discussion and references in Section D.3.2.3.1). While this effect is adverse, benthic habitat dominated by clay, silt and sand is widely available throughout the Mackenzie estuary and the continental shelf (Jerosch 2013). The magnitude of the effect is predicted be low during site preparation and negligible after the trench is infilled. Residual effects of disturbance would be medium term, localized to the site preparation area and reversible.

Once the GBS loading facility is placed on the seabed, it would result in a long-term loss of 2 ha of marine fish habitat until decommissioning. With adherence to regulations under the Fisheries Act (e.g., habitat compensation in another area), it should be possible to achieve a no net loss of marine fish habitat. Recovery of habitat within the affected footprint would be expected to occur within a period of one to 10 years once the GBS is removed. Since similar habitat is widely available and physical disturbances to the seabed would be akin to natural disturbances caused by ice scour, the magnitude of residual effects from habitat loss is predicted to be negligible in magnitude, long-term, reversible and limited to the footprint.

Effects of transiting through the kelp bed to and from Summers Harbour are difficult to assess since there no data on the use of the kelp bed by fish in this specific area. However, kelp beds are known to be important habitat for a variety of macroinvertebrates and fish in other arctic regions and farther south (Filbee-Dexter 2019), and kelp presence is used by DFO for identifying Ecologically and Biologically Significant Areas in the north Pacific for marine use planning (e.g., Rubidge et al. 2018). Moreover, kelp distribution is severely limited in the assessment region by available of rocky substrates (Jerosch 2013) in addition to general limiting factors such as ice cover, scour and colder than optimal growing temperatures (Filbee-Dexter 2019). If the kelp bed cannot be safely avoided, a residual effect could occur; however, the scale of this effect is unknown and dependent on the area of the kelp bed which may is disturbed.

Overall, potential residual effects of habitat disturbance and habitat loss for marine fish are predicted to be negligible or low in magnitude. Prediction confidence is high for effects of site preparation and infrastructure installation, but low for cropping of the kelp bed.

The influence of climate change on the prediction of residual effects on marine fish is similar to that described for Scenario 1.

CUMULATIVE EFFECTS

Given the negligible predicted residual effects from other activities under Scenario 1 and low magnitude effects from seabed disturbance in Scenario 2, remaining cumulative effects are anticipated to be low.

Climate change may exacerbate cumulative effects given that fish populations may already be stressed by climate change induced changes to habitat and thus may be more sensitive to potential effects of human activities in the region.

D.3.2.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.3.2.4.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Potential impacts and associated effects from seabed preparation and installation of infrastructure on marine fish are similar to those of Scenario 2 except that the development is located in deeper water and further offshore (i.e., ~80 km). No pipelines would be required on the seabed, and drilling activities would occur from within the footprint of the GBS loading platform. The installation of the GBS loading platform would result in the loss of marine fish habitat of approximately 2 ha.

Underwater noise generated by seismic surveys may result in localized and temporary changes in behaviour of marine fishes or cause injury, depending on distance from the sound source.

As noted for Scenario 2, propeller rotation from ships transiting to and from Summers Harbour could crop the upper layer of the kelp bed located to the west of the entrance to Summer Harbour (D. Chiperzak 2019, pers. comm.).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The range of potential effects from seabed disturbance on marine fish are similar to those of Scenario 2 except there is no site preparation or installation of pipelines.

Effects of seismic surveys on marine fish would occur during the Open Water Season and affect pelagic and benthic species, causing avoidance, potential injury and mortality (Popper and Hawkins 2016; Carroll et al. 2017). Cod have been shown to respond with a weakened swimming response after repeated exposure to underwater sound sources (Mueller-Blenkle et al. 2010). Sudden changes in noise induced pressure can result in damage of major organs and tissues, potentially increasing mortality risk (Halvorsen et al. 2012a; Halvorsen et al. 2012b; Popper et al. 2014).The severity of injury varies with the intensity of the underwater noise exposure, the life stage, and the physiology of fish (i.e., whether a swim bladder is present and functions in hearing). During exposure to intense sounds pressures, negatively-buoyant fish without a swim bladder (e.g., most adult flatfish) are the least sensitive to barotrauma, whereas fishes with swim bladders that are used for hearing (e.g., herring), and fish eggs, are the most sensitive to barotrauma ((Halvorsen et al. 2012a; Halvorsen et al. 2012b; Popper et al. 2014).

Because fish use of the kelp bed near Summers Harbour is unknown, the effects of vessels on the kelp bed and marine fish cannot be confidently predicted (see Scenario 2).

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Effects of climate change on potential effects on marine fish and fish habitat are the same as what was described for Scenarios 1 and 2.

D.3.2.4.2 MITIGATION AND MANAGEMENT

The mitigations measures proposed for Scenario 3 would be similar to those described for Scenarios 1 and 2. Additional general mitigation and management measures to reduce potential effects to marine fish and fish habitat include:

- design and implementation of an Environmental Effects Monitoring (EEM) program to establish baseline health information for fish and benthic habitat for future effects to be measured against
- use of ramp-up procedures when starting airguns during seismic survey

D.3.2.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

The seabed habitat that would be temporarily lost or altered is not a limiting factor and is widely available in the region (Jerosch 2013). With adherence to regulations under the Fisheries Act (e.g., habitat compensation in another area), it should be possible to achieve a no net loss of marine fish habitat. The magnitude of residual effects is predicted to be low, limited to the footprint, long-term and reversible.

Residual effects of underwater noise associated with seismic exploration are anticipated to be adverse and of low to moderate magnitude depending on the species, life stage and proximity to the noise source. Effects would be local, restricted to the immediate area of those activities, and be continuous for the duration of the survey. Effects are expected to be reversible in the short term (hours to days) following cessation of the noise source.

If the kelp bed near Summers Harbour cannot be safely avoided, a residual effect could occur; however, the scale of this effect is unknown and dependent on the area of the kelp bed which may is disturbed.

Prediction confidence is moderate for the GBS facility and seismic survey but low for ice-breaking potential effects and cropping of the kelp bed since the knowledge level is poor for these last two effects.

The influence of climate change on the prediction of residual effects is the same as what was described for Scenarios 1 and 2.

CUMULATIVE EFFECTS

Cumulative effects associated with Scenario 3 would be similar for those described for Scenario 2. The contribution of seismic surveys to cumulative effects in the region is expected to be negligible to low since the survey would be completed over one Open Water Season and potential effects are anticipated to be localized to a small radius around the sound source (e.g., up to several kilometers), and restricted to the footprint of the lease area. Cumulative effects may be exacerbated by climate change mainly due changes in ice cover that may affect Arctic cod populations; however, it may be difficult to dissociate effects from oil and gas development from effects of climate change.

D.3.2.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.3.2.5.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Potential effects on marine fish and fish habitat resulting from activities associated with Scenario 4 are similar to those described for Scenario 3 (Section D.3.2.4). However, since the production platform (i.e., FPSO) would be floating and in deep water (>400 m) over the continental slope (approximately 100 km offshore), the footprint on the seabed and the nature of potential disturbance to marine fish habitat on the seabed is different. The 3D seismic program is also larger than in Scenario 3 (100,000 ha over 120 days vs 60,000 ha over 56 days), as is the drilling program (see below).

Exploration wells (two in total) and delineation wells (two in total) from drill ships during several successive Open Water seasons would result in the alteration of approximately 1 ha of benthic marine fish habitat per well (BOEM 2015) (i.e., total of 8 ha). Within the vicinity of each well area, the discharge of water-based mud and drill cuttings would create a sediment plume, altering the water column, which may temporarily affect zooplankton abundance and diversity which are preyed upon by fish. While discharge of drill cuttings around the drill site would result in deposition of 1–2 m of material next to the wellsite, this is expected to dissipate to ~ 1 cm within 1 ha surrounding the core (BOEM 2015). Given the size of the affected areas, effects caused by the deposition of drill cuttings and water-based mud on marine fish and fish habitat would be localized around each of the drill sites. Since re-establishment of soft-bottom benthic communities is expected to occur with one or two Open Water seasons, even in areas where waste sediments accumulate to several meters and denude the natural seabed, the habitat effects for marine fish would only persist for a moderate duration and are reversible (e.g., Edgell et al. 2017).

Contaminants within the water-based drill muds may drift with currents for several km from the drill centre (e.g., barium, mud hydrocarbons). Although detectable to several kilometers, the related contaminants are not expected to have toxic effects on benthic and demersal invertebrates and fish, as was shown near drill centres on the Grand Banks for marine amphipods, snow crab, scallop, and American plaice) (Husky Energy 2019; Suncor Energy 2018). Biomass may be reduced within 1-2 km of drill centres during periods of drilling, which was shown especially in the early years of drilling the White Rose and Terra Nova fields on the Grand Banks (Terra Nova 2018). This trend was driven by relatively low abundances of polychaete worms near the drill site, which is arguably a response to sedimentation effects rather than toxicity of sediments (Husky Energy 2019; Suncor Energy 2018).

For oil production, approximately 50 production and injection wells would be developed in sequence using a dynamically positioned drill ship. Wells would be drilled over a number of years during the Open Water and early Fall Transition seasons (i.e., 5 months). Each well would involve site preparation (e.g., creation of the glory hole), followed by drilling to install the first casing. As with the exploration and delineation wells, there would be a discharge of water-based muds and drill cuttings into the water column with the same temporary effect as the other drilling programs, but potentially with a wider plume (given the larger footprint of the manifolds) over a longer period.

Once the directionally drilled wells are complete at a site (i.e., 8-10 per site), the site would be prepared for installation of the manifolds. Each manifold would require disturbance of an area up to 2 ha in size. A total of 6 manifolds would be installed. This would create a net loss of benthic habitat of approximately 12 ha.

The Floating Production, Storage and Offloading vessel (FPSO) and wareship would take up approximately 2 ha of sea surface space with minimal effects on marine fish and fish habitat. Anchoring of the FPSO and wareship would cause some irregular and dispersed disturbances to the seabed in the direct vicinity of the development.

Description of Range of Potential Effects

The range of potential effects from seismic activities is similar to what was described for Scenario 3, but would cover a larger area.

Effects from disturbance of the seabed from site preparation for drilling, site preparation and installation of the manifolds and anchoring of the FPSO and wareship would range from low to moderate, depending on the importance of the benthic marine fish habitat that is lost or disturbed. With adherence to regulations under the Fisheries Act (e.g., habitat compensation in another area), it should be possible to achieve a no net loss of marine fish habitat.

Drilling effects on benthic fish behaviour would occur during the Open Water and early Fall Transition seasons. These effects are not expected to interfere with many of the benthic fish spawning periods. The range of effects from discharging water-based muds and drill cuttings would be negligible to low for marine fish and fish habitat since the plume created by cuttings discharge would be localized and temporary (i.e., the duration of the specific drilling program at a site). While cuttings discharge around the drill site would result in deposition of 1–2 m of material next to the drill site, this is expected to dissipate to ~ 1 cm within 1 ha surrounding the core (BOEM 2015). Given the size of the affected areas, effects of drill cuttings and water based mud on marine fish and fish habitat are predicted to be localized around each of the drill sites and would not affect the availability of benthic habitat over the continental shelf and slope of the BRSEA Study Area. Since re-establishment of benthic communities on the drill cuttings and sediment is expected to occur with 1-2 Open Water seasons, effects would be moderate in duration and are reversible.

As described for Scenario 2, propeller rotation from ships transiting to and from Summers Harbour could crop the upper layer of the kelp bed located to the west of the entrance to Summer Harbour (D. Chiperzak 2019, pers. comm.).

Effects of Climate Change on Potential Effects

Effects of climate change on potential effects to marine fish are similar to this described for Scenarios 2 and 3.

D.3.2.5.2 *MITIGATION AND MANAGEMENT*

Mitigation measures for marine fish in Scenario 4 are similar to those described for Scenario 2 and 3.

D.3.2.5.3 *EFFECTS CHARACTERIZATION*

RESIDUAL EFFECTS

The loss of benthic marine fish habitat and alteration of marine fish habitat would occur through the preparation of sites and subsequent drilling or installation of infrastructure (e.g., manifold), as well as from anchoring of the FPSO and wareship. The magnitude of the residual effect is predicted to be negligible to low since similar marine fish habitat is widely available within the BRSEA Study Area. Further, with adherence to regulations under the Fisheries Act (e.g., habitat compensation in another area), it should be possible to achieve a no net loss of marine fish habitat. Effects would be limited to the immediate area of the footprint for site preparation for drilling and infrastructure (and an area of sediment deposition around each site), moderate term (i.e., several Open Water seasons), and reversible through natural recolonization of benthos.

Residual effects of underwater noise associated with the 3D seismic exploration are anticipated to be adverse and of low to moderate magnitude depending on the species, life stage and proximity to the noise source. Effects would be local, restricted to the immediate area of those activities, and be continuous for the duration of the survey.

Because fish use of the kelp bed near Summers Harbour is unknown, the effects of vessels on the kelp bed and marine fish cannot be confidently predicted (see Scenario 2).

Confidence in these predictions is moderate given limited understanding of benthos recovery to physical disturbance or Arctic kelp ecology. The influence of climate change on the prediction of residual effects is the same as what was described for Scenario 1 and 2.

CUMULATIVE EFFECTS

Exploration, development and operations activities in Scenario 4 could overlap in time or by geographic location with the effects of other past, present and future activities in Scenario 1. While different activities in Scenario 4 and Scenario 1 would result in disturbance to and loss of seabed habitat (e.g., site preparation and installation of infrastructure and drilling), these effects would be restricted to the immediate area around the footprint for infrastructure and are unlikely to overlap. As a result, cumulative effects from habitat disturbance or habitat loss for marine fish are expected to be negligible. Cumulative effects related to climate change may occur due to changes in ice cover, which may affect Arctic cod populations; however it may be difficult to dissociate effects from oil and gas from effects of climate change.

D.3.2.6 Scenario 5: Large Oil Release Event

D.3.2.6.1 POTENTIAL IMPACTS AND EFFECTS OF A LARGE OIL RELEASE

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on lower marine trophic levels from such an event may differ slightly from what is described below for surface or subsea releases.

DESCRIPTION OF EFFECT PATHWAY

Oil that is spilled on the surface or dispersed into the water column can affect marine fish and fish habitat through direct contact (gill fouling) and ingestion of oiled prey items, which can affect health, growth rates, productivity, and movement (Langangen et al. 2017; Johansen and Esbaugh 2017). Oil in sediments or along shorelines can alter and degrade habitat. Local harvesting may be affected as residents may be asked to not harvest (i.e., an area closure) or may choose to not harvest fish they feel is tainted (see Section D.4).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Toxicity effects on fish from spills can occur through different pathways such as direct oiling, ingestion of oil, and accumulation of contaminants within tissues (Chang et al. 2014). Spawning areas and areas of egg and larval drift may be most vulnerable to oil due to the sensitivity of fish eggs and larvae to oil exposure (Hjermann et al. 2007, Rooker et al. 2013). Larval fish and eggs are vulnerable to toxic effects from oil spills due to their small size, underdeveloped membranes, and their position in the upper water column close to surface slicks and associated dissolved or dispersed oil (Langangen et al. 2017); this can result in lethal or sub-lethal effects on fish larvae and eggs (Meier et al. 2010, Scott and Sloman 2004). Lake whitefish showed an increase in larval deformities due to oil contamination (Debruyn et al. 2007) with similar effects on marine fish eggs (Incardona et al. 2012). Other effects from oil spills can include fish tainting (Yender et al. 2002), making them inedible due to taste or unsafe to eat if concentrations of contaminants are sufficiently high (in this case, government authorities would close the area to fishing).

The effects from oil spills on marine fish habitat can vary depending on the amount of time that oil remains in the water and the period of time before it reaches a shoreline (Chang et al. 2014). Shoreline effects can be long-term (Nixon and Michel 2018).

The greatest effect of a large oil release on marine fish and fish habitat would likely result from a surface spill inside the plume, especially during the Open Water Season. Oil could spread and contaminate coastal and nearshore marine fish habitats that are important nursery and spawning grounds and important for coastal migration. This would result in effects on health and productivity of anadromous and coastal fishes (e.g., char, cisco) which are of importance to the Inuvialuit. It also could affect herring that use this area during the Open Water Season for feeding and congregating before entering embayments such as Tuktoyaktuk Harbour for spawning (IMG Golder and Golder Associates 2014: 3). Herring are also an important fish for traditional harvesting by the Inuvialuit (IMG Golder and Golder Associates 2014: 3)

A surface spill outside the plume during the Open Water Season would likely remain predominantly in the upper surface layer with some dispersal and dissolution into the water column. This would result in effects on water quality within the surface layers of the seawater. The change in water quality would affect larval and young fish, primarily Arctic cod in the upper surface layer, although other marine fish species may also be affected. As a result of offshore currents and the effect of the Mackenzie plume, there is less potential for oil to reach nearshore areas, thereby reducing potential effects on anadromous fish populations since these species remain in nearshore water during the Open Water Season.

Large surface release events within or outside the Mackenzie River plume during the Ice Season or periods of partial ice (e.g., early Spring Transition or late Fall Transition seasons) would have fewer immediate effects on the water quality within the water column and, as a result, effects on fish would be less severe. However, spills during these periods could affect young Arctic cod or eggs along the under-ice surface, leading to mortality and or an adverse change in fish health. The total area affected by oil also may be reduced by ice restricting oil movement.

A sub-sea release of oil outside the plume would affect a greater extent of the water column, including marine fish habitat along the seabed. Oil flowing towards the surface would affect pelagic fish species, causing mortality and adverse effects to fish health. On the outer shelf, Pacific herring may be affected, while in deeper waters along the slope, aggregations of adult Arctic cod may be affected at depth, with eggs, larval fish, and young Arctic cod affected at the surface.

During the Ice Season, oil would rise to the underside of the ice and be encapsulated as it enters brine channels in forming ice. A subsea oil release during the Ice Season would have similar effects on demersal and pelagic fish as in the Open Water Season. During the Ice Season, there is limited potential for oil from a subsea release to reach nearshore areas, thereby reducing potential effects on anadromous fish populations. However, release of oil from the ice during the ice melt during the following Spring Transition and Open Water seasons could result in some oil reaching nearshore areas, particularly in areas to the west of the Mackenzie River as a result of ice drift overwinter.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Effects of climate change may modify the effects of a large oil release on marine fish and fish habitat through two pathways. First, climate change is likely to result in reductions in the duration and extent of ice cover in the BRSEA Study Area. Reductions in ice cover would allow oil to potentially spread over a larger area during periods of no ice cover, thereby affecting marine fish over a wide area. Secondly, changes in water quality as a result of climate , such as increased acidification of the water, would affect fish health and subsequently make them more susceptible to contamination from an oil spill.

D.3.2.6.2 MITIGATION AND MANAGEMENT

Oil spill response planning and measures are discussed in Sections 2.13 and 3.10.5.3. Additional details are provided in Appendix F.

D.3.2.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Potential residual adverse effects on marine fish and fish habitat from a large oil release event are expected to be moderate to high magnitude, regional to extra-regional (given the potential spread of an oil slick along the coastline). Depending on the type and volume of oil, its geographic extent and trajectory, effects on nearshore and coastal habitats for fish, natural weathering, and the effectiveness of spill response measures, the duration of effects could range from several years to long-term. With continued spill response, shoreline cleanup measures and habitat restoration, potential effects would reversible, but effects could be long-term (fish health and population dynamics). Additional information on effects of a large oil release on coastal habitats is provided in Section D.2.6.6.

D.3.2.7 Summary of Residual Effects

A summary of effects from routine activities on marine fish and fish habitat in Scenarios 1 through 4 is provided in Table D-30. A summary of effects of a large oil release event on marine fish and fish habitat is provided in Table D-31.

Table D-30 Potential Residual Effects of Scenarios 1 – 4 on Marine fish and fish habitat

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Ice	• Minimal interaction with human activities given limited overlap with marine fish and fish habitat • Small loss of seabed habitat due to GBS for wind turbines	• Alteration of marine fish habitat along the dual subsea pipeline and loss of habitat due to the GBS loading platform	• Small loss of seabed habitat due to GBS platform and seabed disturbances due to anchoring of wareship	• Small loss of seabed due to manifolds and disturbance of seabed due to anchoring of FPSO and wareship
Spring Transition	• Minimal interaction with human activities given limited overlap with marine fish and fish habitat • Small loss of seabed habitat due to GBS for wind turbines	• Alterations of marine fish habitat along the dual subsea pipeline and loss of habitat due to the GBS loading platform	• Small loss of seabed habitat due to GBS platform and seabed disturbances due to anchoring of wareship	• Small loss of seabed due to manifolds and disturbance of seabed due to anchoring of FPSO and wareship
Open Water	• Minimal interaction with human activities given limited overlap with marine fish and fish habitat • Increased fishing pressure from tourism on coastal fish species • Small loss of seabed habitat due to GBS for wind turbines	• Alteration of marine fish habitat along the dual subsea pipeline and loss of habitat due to the GBS loading platform • Mortality of benthic fish during site preparation for dual subsea pipelines and GBS loading platform	• Spatial and temporal overlap with marine fish and fish habitat • Small loss of seabed habitat • Seismic activities may cause injury and behavioural effects on fish • Mortality of benthic fish during site preparation for GBS platform	• Spatial and temporal overlap with marine fish and fish habitat • Small loss of seabed habitat • Seismic activities may cause injury and behavioural effects on fish • Mortality of benthic fish during site preparation for manifolds

Table D-30 Potential Residual Effects of Scenarios 1 – 4 on Marine fish and fish habitat

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Fall Transition	• Minimal interaction with human activities given limited overlap with marine fish and fish habitat • Small loss of seabed habitat due to GBS for wind turbines	• Alteration of marine fish habitat along the dual subsea pipeline and loss of habitat due to the GBS loading platform	• Small loss of seabed habitat due to GBS platform and seabed disturbances due to anchoring of wareship	• Small loss of seabed due to manifolds and disturbance of seabed due to anchoring of FPSO and wareship
Legend				
• Least effect – No to minor effect on marine fish and fish habitat				
• Least effect -- Minimal effect on marine fish and fish habitat				
• Moderate effect – Moderate effect on marine fish and fish habitat				
• High effect – Major effect on marine fish and fish habitat				
• Greatest effect – Severe effect on marine fish and fish habitat				

Table D-31 Potential Effects of a Large Oil Release Event (Scenario 5) for Marine fish and fish habitat

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• Localized physiological effects and mortality of marine fish	• Localized physiological effects and mortality of fish especially Arctic cod and benthic species and habitat • Degradation of marine fish habitat in the water column and under-ice habitat	• Localized physiological effects and mortality of marine fish especially Arctic cod
Spring Transition	• Mortality of larval fish and to lesser extent juvenile and adult fish • Potential effects on coastal over-wintering and migrating fish	• Physiological effects, mortality of marine fish and habitat loss or disruption • Degradation of marine fish habitat in the water column • Reduced probability of spill entering nearshore areas due to ice during early part of season	• Physiological effects and mortality of marine fish especially Arctic cod • Reduced probability of spill entering nearshore areas due to ice during early part of season
Open Water	• Physiological effects, mortality of marine fish and habitat loss or disruption , especially along coast and nearshore	• Physiological effects, mortality of marine fish and habitat loss or disruption • Degradation of marine fish habitat in the water column	• Physiological effects and mortality on pelagic fish and habitat
Fall Transition	• Mortality of larval fish and to lesser extent juvenile and adult fish • Potential effects on coastal over-wintering and migrating fish	• Physiological effects, mortality of marine fish and habitat loss or disruption • Degradation of marine fish habitat in the water column • Reduced probability of spill entering nearshore areas due to ice during late part of season	• Physiological effects and mortality of marine fish • Reduced probability of spill entering nearshore areas due to ice during late part of season

Table D-31 Potential Effects of a Large Oil Release Event (Scenario 5) for Marine fish and fish habitat

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Longer-term/ Multi-year	• Potential long-term degradation of marine fish habitat. Physiological effects and mortality of fish. Potential effects to fish populations (e.g., one or more year classes) in the area directly affected by the spill, especially coastal anadromous fish.	• Degradation of marine fish habitat. Physiological effects and mortality of fish. Potential effects to fish populations	• Degradation of marine fish habitat. Physiological effects and mortality of fish. Potential effects to fish populations
Legend			
• Least effect – No to minor effects on marine fish and fish habitat			
• Moderate effect -- Moderate alterations marine fish and fish habitat			
• High effect -- Major alterations to marine fish and fish habitat			
• Greatest effect – Severe alterations to marine fish and fish habitat			

D.3.2.8 Gaps and Recommendations

Several information gaps remain to better understand the effects from oil and gas activities on marine fish and fish habitat, and include:

- kelp beds are not common in the BRSEA Study Area but could play an important role to a number of marine fish species in the region. The kelp beds, such as the bed near the western approach to Summers Harbour, should be studied to evaluate their importance to marine fish and fish habitat and identification of potential mitigation measures to reduce or avoid effects to kelp beds.
- the relationship and importance of the under-ice algae and associated zooplankton to young Arctic cod has been documented; however, little is understood about how ice-breaking and the timing of ice-breaking affects ice algae growth and associated zooplankton communities. Vessel transits through ice can potentially affect productivity along long tracks of under-ice habitat, which could have a subsequent effect on young Arctic cod. Since Arctic cod are a keystone species in the marine ecosystem of the BRSEA Study Area, a better understanding of how ice-breaking affects this important habitat is required.
- stock delineation of Arctic cod is unknown, including how each stock may contribute to the overall productivity of the ecosystem within the BRSEA Study Area. To improve the understanding of effects from oil and gas activities or from a large oil release event, an understanding of stock structure of Arctic cod is required.
- Arctic Char and Dolly Varden populations and geographic boundaries have not been established for Beaufort Sea fishes. Conducting fish surveys to fill this gap are needed to be able to assess the effects of human activities on these populations with more confidence.
- update underwater noise profiles for modern offshore platforms to support assessment of potential effects of platform generated noise during exploration and operation on marine biota

In addition to these information gaps, the following studies or planning programs are recommended.

- develop a Tuktoyaktuk Harbour Management Plan that incorporates community areas of importance and fishing locations
- map Pacific herring locations in Tuktoyaktuk Harbour
- update fish baseline information in areas where development is proposed. Baseline data collected should include marine fish presence, habitat descriptions and use of habitat within the development area
- given the diversity of habitats used by different marine fish life stages and their sensitivities to different disturbances, project-specific environmental assessments should consider life-stage specific effects

D.3.2.9 Follow-up and Monitoring

Specific monitoring programs should be established through the regulatory process for proposed developments in the Inuvialuit Settlement Regio. Recommended general monitoring programs include:

- prior to the start of a proposed offshore oil or gas development (including seismic surveys), reinstate the fish component of the Inuvialuit harvest study and continue to monitor at intervals throughout the project development. This study would assist in determining potential effects from oil and gas activities on fish harvesting.
- conduct baseline studies of contaminants in anadromous fish species prior to initiating oil and gas development and continue to monitor at intervals (e.g., 3-5 years) throughout the project development. This data would provide information on potential effects from oil and gas activities and help evaluate effects if an oil spill occurred. Data should be collected on selected anadromous and marine fish.
- monitoring of the total ice-covered area affected by ice breaking in relation to Arctic cod habitat. In conjunction with this program, monitoring should also be conducted on the productivity of ice-algae in areas where ice breaking has occurred and compared with ice areas not affected by ice breaking. This monitoring would provide information on the effects of ice breaking on Arctic cod under-ice habitat.

D.3.3 Migratory Birds

D.3.3.1 Scoping

D.3.3.1.1 IDENTIFICATION OF INDICATORS

The assessment of potential effects on migratory marine birds focuses on species such as geese, brants, swans, loons, and shorebirds (i.e., non-seabird species groups) (Section 7.2.4); sea ducks are included in the discussion of seabirds (Section D.3.4).

The assessment focuses on potential effects on migratory marine birds that use nearshore and coastline habitats within the BRSEA Study Area during their annual cycle (e.g., migration, breeding). Migratory birds which predominantly use terrestrial habitats (e.g., tundra areas) for all or most of their life phases in the Arctic are not likely to be affected by offshore activities (Sections 3.7 to 3.9) and would more vulnerable to onshore activities during breeding, particularly in areas recognized as important migratory bird habitat (Latour et al. 2008). As noted in Chapter 1, effects to terrestrial areas are outside the scope of the BRSEA and are not considered further in this section.

For effects where interactions with migratory marine birds are likely and effects are expected to be similar among different migratory marine bird species, potential effects are assessed for the group and not for individual indicator species. However, exceptions are noted where potential interactions may differ (e.g., loons using offshore leads for foraging post-breeding). For the remainder of this section, the term migratory birds will be used to refer to predominantly marine species as described above

D.3.3.1.2 SPATIAL BOUNDARIES

As described in Section 7.2.7, geese, brants, swans, loons and shorebirds are present throughout the BRSEA Study Area, although most species spend their time onshore during the breeding season (i.e., May to early August). Given predicted impacts of climate change on breeding habitat in the region and uncertainty in how climate change and the anticipated increase in human use and development in higher latitudes may alter the distribution and abundance of migratory birds, the spatial boundary for migratory birds is defined as the marine waters of the ISR (i.e., all of the BRSEA Study Area) (see Figure 7-48), including coastline habitat; nearshore areas, and offshore leads during the Spring Transition Season).

D.3.3.1.3 TEMPORAL BOUNDARIES

The assessment of potential effects on migratory birds encompasses a 30-year period between 2020 – 2050.

D.3.3.1.4 ASSESSMENT OF POTENTIAL EFFECTS

The assessment of potential effects on migratory birds considers residual effects on the population, not on individual birds. Based on the established spatial boundaries, the discussion and characterization of effects are assessed in the context of the bird populations within the BRSEA Study Area (not national populations). Qualitative characterization of potential residual effects on migratory birds associated with each scenario is based on the characterization terms defined in Table D-32.

Table D-32 Characterization of Residual Environmental Effects on Migratory Birds for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect on the VC	**Positive**—a net benefit to health, mortality, habitat or behaviour **Adverse**—a reduction or influence on the health, mortality, habitat or behaviour that could result in a change in the status or resiliency of the population **Neutral**—no net change in the viability, status or resiliency of the population
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no measurable change in health, mortality, habitat or behaviour (i.e., no change in abundance or distribution) **Low**—a measurable change in the distribution of the population, but would not affect the long-term sustainability of the population **Moderate**—a measurable change in the distribution and abundance of the population, with potential to affect the long-term sustainability of the population **High**—a measurable change with relative certainty of affecting the long-term sustainability of the population

Table D-32 Characterization of Residual Environmental Effects on Migratory Birds for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the local area around the activity **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area) **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area)
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity **Continuous**—residual effect occurs continuously for the duration of the activity
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to one phase or season (e.g., seismic survey, exploration drilling) **Medium-term**—residual effect extends through multiple seasons or years (e.g., production phase) **Long-term**—residual effect extends beyond the life of the project (e.g., beyond closure) **Permanent**—measurable parameter unlikely to recover to existing conditions
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.3.3.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

Migratory birds in the Arctic are sensitive to disturbance during the nesting, brood-rearing, moulting, and migration periods (Latour et al. 2008). Issues and concerns about effects of human activities on migratory birds are related to offshore construction and operations during the Open Water and the Spring Transition seasons. Primary issues and concerns about migratory birds are linked to sensory disturbance from noise (vessels, helicopters, low level aircraft), and attraction to light creating the potential for collisions with vessels/offshore platforms in nearshore habitats (or further offshore during migration).

Inuvialuit from Tuktoyaktuk expressed concern regarding the effect of in-air noise on geese and migration routes for other birds and recommended that the bird sanctuary in the Kendall Island area be avoided between April and November (Devon Canada Corporation 2004b:35). Similarly, Inuvialuit from Inuvik noted that helicopter and airplane traffic has driven geese migration farther east and away from the delta (KAVIK-AXYS Inc. 2004a: 4-6). Flights from Tuktoyaktuk to Summers Harbour could have larger disturbance footprints than flights to the offshore platforms due to the duration of the flight and greater overlap with seabird habitats.

As discussed in Section 7.2.4.4, migrating seabirds are heavily dependent upon open water leads for feeding and resting (Latour et al. 2008). The degradation of these open-water areas associated with contaminants or disturbance from increased ship traffic or oil spills, could result in severe negative effects on the birds via effects on their physical and biological habitat.

For the migratory bird VC, potential effects due to routine activities include:

- change in behaviour: flight response or alteration of habitat use resulting from sensory disturbance that could ultimately affect the ability of an animal to forage/breed; these effects are generally linked with activities that produce sounds that could induce habitat avoidance. Other pathways that may be linked with change in behaviour include physical disturbance resulting in displacement, artificial lighting, particularly during migration, and presence of humans.
- change in mortality risk: injury or death resulting from the physical impact of a project activity such as vessel strike, flaring or collision with platforms
- change in health includes effects due to increased exposure to contaminants in the sediment or water column (e.g., oil spill). The pathway for this effect can be direct (e.g., direct exposure or contact with contaminants) or indirect (e.g., through consumption of contaminated prey) and result in decreased reproductive success or decreased survival.

Potential effects of habitat alteration resulting from routine activities on migratory birds are discussed below. Potential effects of an oil spill on migratory birds are discussed in Section D.3.3.6.

As discussed in Section 7.2.4.3, geese, brants, swans, loons and shorebirds use nearshore open water and coastlines during the spring and summer months (i.e., during breeding, moulting and staging/migration), although they spend the majority of their time onshore in various wetlands and waterbodies, as well as tundra habitat. Pacific loons and red-throated loons use offshore leads during spring migration (Dickson and Gilchrist 2002). Consequently, interactions with human activities (e.g., collisions with vessels and platforms) in offshore areas during the Spring Transition and Open Water seasons depend on the species and activity. Based on the migratory patterns of these birds, potential interactions during the Ice Season and Fall Transition Season would be infrequent as their presence in the BRSEA Study Area is generally from early May to late September. Potential effects on migratory birds resulting from activities that occur during the Ice Season and Fall Transition Season are not discussed further.

POTENTIAL EFFECTS OF NOISE

Migratory birds using coastline, nearshore or offshore areas (i.e., offshore leads during the spring) could be affected by in-air noise. Potential effects on migratory birds from noise could result from low flying aircraft (e.g., helicopters), flare noise, vessel traffic or seismic surveys. Depending on the activity and associated level of noise production, migratory birds may adjust patterns of habitat use or behaviour due to noise-based sensory disturbance. For in-air noise transmission, Gladwin et al. (1988) found that migratory birds, depending on the noise level, can be disturbed by noise levels up to 500 m to 1,200 m away.

Sustained aircraft noise in the vicinity of bird aggregations, particularly active breeding colonies, can cause birds to flush from breeding or foraging habitats for extended periods (Harris 2005). If foraging during staging/migration, brood-rearing, or nesting is interrupted based on behavioural responses to noise, this can have consequences for the health and survivorship of migratory birds. Snow geese are known to be sensitive to aircraft overflights and would exhibit a startle response to low flying aircraft (Belanger and Bedard 1989); Inuvialuit communities have expressed concerns about the timing and height of aircraft flying over migratory bird breeding areas (e.g., ICCP 2016:62; PCCP 2016:82).

Similar to aircraft, vessel traffic has potential to cause sensory disturbance to migratory birds. Several studies investigating patterns of bird displacement by transiting vessels suggest marine traffic can elicit a diving or flushing (i.e., avoidance) response in waterbirds (Bellefleur et al. 2009; Hentze 2006 in Nunami Stantec 2018; Schwemmer et al. 2011). Larger aggregations of birds are more sensitive to vessel traffic (i.e., would flush at increased distances) (Schwemmer et al. 2011). In turn, this can reduce the time and efficiency of foraging and nesting or reduce energy reserves for migrating individuals (Bellefleur et al. 2009; ECCC 2016b in Nunami Stantec 2018; Madsen 1995; Schwemmer et al. 2011). This can have adverse effects on the fitness of displaced individuals (Kaiser et al. 2006; Ronconi and St Clair 2002; Velando and Munilla 2011).

Migratory birds using the marine environment may also adjust patterns of habitat use or behaviour in response to in-air noise produced during marine seismic exploration surveys (i.e., avoidance of disturbed areas), or in response to marine infrastructure or activities (Agness et al. 2013; Ronconi and St Clair 2002; Schwemmer et al. 2011). For the migratory birds VC, loons would be the most likely species to be affected by offshore seismic activity. Implementation of standard mitigation and monitoring measures during seismic surveys would reduce potential effects of underwater noise levels on swimming and diving migratory birds (e.g., loons). A marine wildlife monitoring program would provide ongoing monitoring of a radius around the seismic vessel to confirm that migratory birds (including seabirds) would not be exposed to underwater noise levels that result in injury.

Potential Effects of Artificial Light

Artificial lighting sourced from marine infrastructure or seismic and drilling vessels may affect bird behaviour and increase mortality risk (Wiese et al. 2001); attraction of waterbirds to offshore structures is a research priority for the Environmental Studies Research Fund (for east coast offshore oil and gas operations). Waterbirds (and songbirds) have been documented to adjust migration and foraging patterns in response to artificial lighting (Gauthreaux and Belser 2006; Montevecchi 2006; Van Doren et al. 2017). Many bird species are active during the night to avoid daytime predators or improve foraging on vertically migrating or bioluminescent prey or on nocturnally migrating invertebrates (Rich and Longcore 2006 cited in Nunami Stantec 2018). Birds that migrate nocturnally often orientate on star patterns in coastal and offshore environments and interference from artificial light can disrupt seasonal migration patterns by impairing visibility of the stars and, hence, the ability to navigate (Rich and Longcore 2006 cited in Nunami Stantec 2018).

When birds are attracted to artificial light, they may be injured or killed as a result of colliding with lights or adjacent infrastructure; birds can also deplete energy reserves by trying to reach, or continuously circling, lit structures (Merkel and Johansen 2011; Montevecchi 2006; Wiese et al. 2001). Birds that become grounded from exhaustion or injury (from non-lethal collisions) can be susceptible to predation (BirdLife International 2019; Longcore et al. 2013). Inclement weather such as fog or rain can increase the potential for collision for birds that adjust flight patterns under poor conditions and because suspended moisture increases light refraction (Black 2005 cited in Nunami Stantec 2018; Longcore et al. 2013; Merkel and Johansen 2011). In general, more bird collisions occur in coastal environments than in offshore waters due to the higher concentration of lights in coastal regions (Merkel and Johansen 2011). Among waterbirds, species within the family Alcidae (murres, guillemots, auklets, puffins) and the order Procellariiformes (albatrosses, petrels and shearwaters) are more susceptible to light-induced attraction and mortality compared to other guilds (BirdLife International 2012; Black 2005 cited in Nunami Stantec 2018; Rich and Longcore 2006 cited in Nunami Stantec 2018; Wiese et al. 2001).

As large-scale passerine migration does not occur in the BRSEA Study Area, the potential for collisions due to artificial lighting for passerines in the Arctic is low (Day et al. 2015).

POTENTIAL EFFECTS ON HABITAT AND PREY AVAILABILITY

Changes in the presence, abundance, and distribution of marine vegetation, invertebrates, and fish communities can alter the availability or distribution of foraging opportunities for coastal waterfowl, seabirds, and shorebirds. Birds may adjust to changes in prey availability by finding alternative foraging sites, using a larger area to sustain feeding requirements, or spending more time in the marine environment (e.g., away from nesting sites) to locate prey.

Physical disturbance also can result from marine infrastructure that may impose physical or perceived barriers for access to important habitats if situated in a way that excludes birds from specific areas that provide important resources (e.g., breeding habitat, migratory staging areas, open water foraging sites) within the BRSEA Study Area. Generally, behavioural responses would likely vary between species and groups (Rodgers and Schwikert 2002; Schwemmer et al. 2011). However, it is expected that during the review of specific projects, that habitat protection setbacks and timing windows to protect sensitive nesting and staging habitat would be included in the conditions for approval and in permitting.

SUMMARY OF EFFECTS ON MIGRATORY BIRDS

The relationship between human activities, interactions, impacts and potential effects on migratory birds are summarized in Table D-33. The potential effects carried forward are discussed in the following scenario specific assessments.

Table D-33 Summary of Potential Impacts and Effects on Migratory Birds

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Air Contaminant and GHG Emissions	• vessel transits • seismic surveys (2D, 3D, 4D) • drilling and cutting • operational and maintenance activities to vessels, production platform, and wells • helicopters, low flying aircraft, and snowmobiles	• no interaction	• NA	• NA
Noise (in-air and underwater)	• vessel transits (engine, propeller, and ice-breaking activities). • seismic surveys, (2D, 3D, 4D), drilling • operational and maintenance activities to vessels, production platform, and wells, • helicopters, low-flying aircraft and snowmobiles.	• startle response (i.e., flushed off nests) or disorienting response while traveling in areas subjected to ambient noise from helicopters or low-flying aircraft • avoidance of areas subjected to ambient noise from vessels and activities at surface, helicopters or low-flying aircraft (staging and nesting birds)	• potential residual effects on migratory birds are possible; with mitigation in place (e.g., wildlife monitors, use of safety radii, minimum aircraft altitudes, seasonal and designated shipping routes) • potential residual effects on behaviour and mortality risk may be reduced but require further assessment	• counts of birds flushed; eggs/chicks lost during activities • seasonal vessel and aircraft activity (ha and % of area by month in designated travel corridors and movement areas where low level flights and vessel activity could occur) • change in population size
Artificial Light	• lighting used on nearshore infrastructure (e.g., wind turbines, marine infrastructure), offshore platforms and vessels • lighting for offshore developments (e.g., offshore platforms and vessels)	• attraction or disorientation of migratory birds to artificially lit structures and subsequent mortality resulting from collisions with structures (during migration)	• potential residual effects on migratory birds are possible; with mitigation in place (e.g., wildlife monitors, alternate lighting strategies) • potential residual effects on behaviour and mortality risk may be reduced but require further assessment	• estimated change in rates of mortality or injury
Seabed Disturbance	• subsea well manifold, and pipeline installations and repairs	• no interaction	• NA	• NA

Table D-33 Summary of Potential Impacts and Effects on Migratory Birds

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Ice Disturbance	• icebreakers transiting through sea ice (ice management, support, transport) • presence of structures on/in sea ice or open water (drillships, platforms, wind turbines).	• no interaction	• NA	• NA
Vessel Wake	• vessel use during Open Water Season (commercial, personal use, tourism, sea lift, military, research, harvesting).	• minimal interaction (i.e., short term transitory effect for species in offshore areas)	• NA	• NA
Routine Discharges	• air emissions • bilge and ballast water • drilling muds and lubricating fluids • drill cuttings and disposal • sewage and food waste • cooling water and deck drainage	• effects on prey source resulting in shifts in availability or quality of food for birds • assumes waste treatment standards are followed, especially with regard to oily waste (i.e., zero discharge or treatment of waste stream)	• potential residual effects on migratory birds are possible but with best practices and mitigation in place • potential residual effects on behaviour, health, mortality risk, and habitat are expected to be negligible in magnitude • **further assessment of this impact is not warranted.**	• NA
Vessel Collision	• vessel transits (shipping, tankers, icebreakers, personal watercraft)	• no interaction	• NA	• NA
Oil Spill	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from a subsurface location (well head, pipeline)	• effects on prey source resulting in shifts in availability or quality of food for birds • attraction of birds to oil spill and sheens and subsequent mortality resulting from hypothermia, ingestion of oil through oil fouled prey or through self-grooming oil fouled feathers	• potential residual effects on migratory birds are possible; with mitigation in place (e.g., spill clean-up protocol) • potential residual effects on behaviour, habitat, health and mortality risk may be reduced but require further assessment	• estimated change in rate of mortality or injury (i.e., number of oiled birds)

D.3.3.2 Scenario 1: Status Quo

D.3.3.2.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Activities or infrastructure that operate during the Open Water and Spring Transition seasons (i.e., renewable energy, low level aircraft, icebreaking, tourism, scientific research, military vessels and exercises) may overlap with migratory bird use of habitat for nesting, brood-rearing, moulting, and migration periods. These activities may affect habitat use indirectly by causing sensory disturbance to birds during these critical periods, or potentially result in fatalities or injuries due to collisions. In turn, this may affect availability of migratory birds for traditional hunting.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Disturbance resulting from human activity (e.g., vessels, aircraft) can result in change in behaviour; these effects are primarily during the Open Water Season since the majority of migratory birds are using onshore habitats during the Spring Transition Season. Increased vessel transits through the Beaufort Sea and east through Amundsen-Queen Maude Gulf or the Northwest Passage during the Open Water Season can disturb birds, causing avoidance of important habitat (e.g., foraging areas, moulting concentrations, resting areas, and breeding colonies). Migratory birds that are disturbed while brood-rearing during the Open Water Season or while staging in preparation for migration could be scared away from active nests or foraging areas, resulting in loss of food opportunity, and increased energy expenditure to replace that lost food source. Birds that are flushed from active nests may abandon the nest, resulting in the failure of the nest. During the Spring Transition Season, there is the potential for species such as loons using offshore leads to be affected.

Presence of structures in offshore areas (e.g., gravity-based offshore wind turbines) can result in direct mortality if birds were to collide with the structures.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

For migratory birds, the effects of climate change would likely be primarily felt onshore including breeding distribution (e.g., distribution of nesting habitat), earlier springs, and changing food peaks (assuming timing of migration is unaltered). For birds that use offshore leads during the Spring Transition Season (e.g., loons), the increasing extent and duration of the length of the Open Water Season (Laidre et al. 2015) and thinner ice may decrease the need for ice-breaking; however, there could be a corresponding increase in vessel traffic and an extended period of open water. Increased vessel traffic may result in further alteration of migratory bird use of offshore and coastal habitats (e.g., geese, brants, shorebirds).

D.3.3.2.2 MITIGATION AND MANAGEMENT

General mitigation measures and standard operational procedures associated with the protection of wildlife from human impacts should be employed. Measures specific to the protection of migratory birds from human impacts under Scenario 1 include:

- habitat protection setbacks and timing windows to protect sensitive nesting and staging habitat from sensory disturbance
- use of existing and common travel routes by vessels and icebreakers where possible and practical
- designing and locating wind turbines (e.g., larger and fewer) to reduce the proportion of birds at potential for collision (e.g., consider movements and timing of movements of resident species, visibility of turbines, and flight patterns) (e.g., Gartman et al. 2016)
- prohibiting unnecessary harassment of birds by vessels and aircraft
- adhering to IGC flight guidelines and recommended minimum flight altitudes (Appendix F, where possible
- properly containing and disposing of waste to reduce attraction of birds to vessels
- maintaining strict refueling procedures to reduce the potential for fuel spills
- prohibiting discharge of bilge water and other waste streams (Section 2.5)

. Additional details are provided in Appendix F

D.3.3.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Although activities associated with Scenario 1 are expected to increase in frequency and seasonal extent over the next 30 years, the effects associated with offshore activities and aircraft traffic and the overlap with areas occupied with migratory birds are expected to be minimal (i.e., infrequent, short-term [i.e., transitory] and dispersed (effects would occur in small and site-specific areas over a large region); effects that occur during the Open Water and Spring Transition seasons are expected to result in low magnitude residual effects on migratory bird populations in the region. Effects from offshore activities during the Spring Transition Season are only anticipated to affect loons staging in offshore leads.

Changes in timing and duration of ice formation and melt due to climate change may extend the duration of human activities within the BRSEA Study Area as the Open Water Season extends. As a result, migratory birds have the potential to be exposed to longer periods of in-air noise and collision with vessels or infrastructure in Scenario 1. However, this is not expected to modify the effects characterizations.

Potential effects on migratory bird behaviour and mortality risk are expected to be adverse. However, with application of mitigation and planning measures to maintain aircraft above minimum altitudes, avoidance of important bird nesting and staging habitat during sensitive periods, and use of seasonal and designated shipping routes, potential effects are predicted to be low and limited to the immediate vicinity around the footprint of the activity. Potential effects would be multiple irregular events with short-term duration and reversible in nature.

Climate change impacts to migratory bird habitat are expected to occur over the 30-year assessment period; therefore the prediction of residual effects is made with low certainty. Ongoing research and monitoring of migratory bird populations in the region should be continued and robust adaptive management strategies should be put in place to maintain the sustainability of bird populations.

CUMULATIVE EFFECTS

Since most of the activities associated with Scenario 1 would occur during the Open Water Season, there is the potential for cumulative residual effects on migratory birds in the region. Changes in migratory bird habitat quality and availability due to climate change could amplify effects and exert substantially more pressure on bird populations to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change and result in higher magnitude effects.

D.3.3.3 Scenario 2: Export of Natural Gas and Condensates

D.3.3.3.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Activities or infrastructure that operate during the Open Water and Spring Transition seasons (i.e., low level aircraft, directional drilling of the subsea pipelines (out to about 1 km from shore), installation of a dual pipeline out to the GBS, installation and operation of the GBS, icebreaking around the GBS, vessel traffic, including LNG carriers and condensate tankers) would overlap with migratory bird use of habitat for nesting, brood-rearing, moulting, and migration periods. These activities may affect habitat use indirectly by causing sensory disturbance to birds during these critical periods, or potentially result in fatalities or injuries due to collisions (e.g., loons using offshore areas for staging or foraging). This could affect the availability of migratory birds for traditional hunting.

Of note, land-based activities associated with construction, operation and decommissioning of the gas plant and associated infrastructure would have a much greater potential to affect migratory birds. Because the BRSEA only includes the marine areas of the ISR, assessment of these activities is outside the scope of this assessment.

Helicopters used for crew transport would only be taking off and landing from the land base and the vessel or platform associated with the development. Although this activity would startle migratory birds in the vicinity and likely cause them to leave the area, the potential effect would be limited to a temporary stress response and abandonment of the immediate area around the vessel or platform. Helicopters used for ice reconnaissance or other project related activity would be required to maintain appropriate elevation to reduce potential effects on birds (e.g., loons) in open water habitat.

The nearshore nature of the infrastructure associated with Scenario 2 has a higher relative potential to affect migratory birds using nearshore areas during the Spring Transition and the Open Water seasons (i.e., during spring and fall migration) than Scenarios 3 and 4 (where infrastructure activities are > 80 km offshore).

Description of Range of Potential Effects

Disturbance of migratory birds resulting from human activity (e.g., vessels, low-level aircraft) can result in changes in behaviour; these effects would be most pronounced during the Open Water Season since the majority of migratory birds would be using onshore habitats during the breeding season. It is anticipated that the amount of low-level aircraft travel would increase for Scenario 2 (compared to Scenario 1). Migratory birds that are disturbed while brood-rearing or while staging in preparation for migration during the Open Water Season may be flushed away from active nests or foraging areas, resulting in loss of food opportunity and increased energy expenditure to replace that lost food source. Birds that are flushed from active nests may abandon the nest, resulting in the failure of the nest.

Presence of structures in nearshore areas (e.g., the GBS, LNG carriers and condensate tankers) can result in direct mortality if birds were to collide with the structures or avoidance if areas used for feeding or staging during the Spring Transition (e.g., loons using offshore leads and geese and brants using coastal areas during spring migration) and Open Water seasons.

Effects of Climate Change on Potential Effects

Similar to Scenario 1, the effects of climate change on migratory birds would likely be felt primarily onshore, including breeding distribution (e.g., distribution of nesting habitat) and earlier springs changing the food peak (assuming timing of migration is unaltered). For birds that use offshore leads during the Spring Transition Season (e.g., loons), the increasing extent and duration of the length of the Open Water Season (Laidre et al. 2015) may result in an increase in the duration of oil and gas activities and associated effects. Increased vessel traffic may result in further alteration of migratory bird use in nearshore and coastal areas.

D.3.3.3.2 Mitigation and Management

Mitigation measures related to potential effects from Scenario 2 activities are similar to those discussed for Scenario 1. In addition:

- implement light management measures on coastal infrastructure and GBS to alter light spectrum and provide sky shielding, thus minimizing sensory disturbance and potential injury

D.3.3.3.3 Effects Characterization

Residual Effects

Potential effects on migratory bird behaviour and mortality risk are expected to be adverse. However, with application of mitigation and planning measures (e.g., maintain aircraft above minimum altitudes wherever possible when flying over important bird nesting and staging habitat, and using seasonal and designated shipping routes), potential effects are predicted to be low and limited to the immediate vicinity around the footprint of the activity. Therefore, changes in behaviour of migratory birds as a result of habitat alterations from aircraft and vessel traffic and the presence of platforms (sensory disturbance and artificial lighting effects) are predicted to be localized and would range from short to medium term. Effects are anticipated to be multiple and irregular. The magnitude of the effect is considered to be low and are not anticipated to affect the long-term sustainability of migratory bird populations in the region.

Changes in mortality risk (i.e., due to collisions with infrastructure or vessels due to artificial lighting) are anticipated to be localized and medium-term. Since effects of light on birds would only occur during the Spring Transition Season (i.e., when birds are arriving) or late summer (i.e., Open Water Season) when twilight occurs, effects are anticipated to be multiple and irregular. Although the effect is adverse, it is not anticipated to affect the sustainability of bird populations in the region.

With climate change induced changes to migratory bird habitat expected to occur over the 30-year assessment period, the prediction of residual effects is made with low certainty, and should be followed up with ongoing research and monitoring of migratory bird populations in the region and robust adaptive management strategies in place to maintain the sustainability of bird populations.

CUMULATIVE EFFECTS

Activities associated with the development of infrastructure and export of natural gas and condensate, may result in cumulative effects to migratory birds if they become aggregated in time or by geographic location with activities associated with Scenario 1 (e.g., commercial shipping, renewable energy, tourism).

Since most of the activities associated with Scenario 2 are either year-round or occur during the Open Water Season, there would be temporal overlap of these activities with migratory birds during Spring Transition and Open Water seasons, and potential for cumulative residual effects on migratory birds in the BRSEA Study Area.

Cumulative effects on migratory birds have the potential to extend across the region and be long-term in duration. Effects are predicted to be multiple irregular events and, although they may be adverse, are anticipated to be low to moderate in magnitude. With the application of mitigation measures, including the implementation of co-management measures, they are not expected to affect the sustainability of migratory birds in the region.

Changes in migratory bird habitat quality and availability due to climate change could amplify effects and exert substantially more pressure on bird populations to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change to result in higher magnitude effects.

D.3.3.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.3.3.4.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Similar to Scenario 2, there would be activities or facilities that operate year-round; this includes low level aircraft from the mainland, installation and operation of the GBS and wareship, icebreaking around the GBS and wareship, year-round transits by tankers (using a route west of the Beaufort Sea for outbound and inbound transits), and other vessel traffic. These activities and facilities would overlap with migratory bird use of habitat for nesting, brood-rearing, moulting, and migration periods during the Open Water and Spring Transition seasons. Some activities may affect habitat use indirectly by causing sensory disturbance to birds during these critical periods, or potentially result in fatalities or injuries due to collisions. This could affect the availability of migratory birds for traditional hunting. Because the GBS and wareship are located >80 km offshore, these facilities and associated activities would have no or minimal effects on onshore habitat but could affect offshore use for foraging, moulting and migration.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Disturbance resulting from human activity (e.g., 3D seismic, vessels and tankers, low-level aircraft, offshore platforms and associated activities) can result in changes in behaviour. It is anticipated that the amount of low-level aircraft travel would be similar to Scenario 2. In nearshore/coastal areas, migratory birds that are disturbed while brood-rearing or staging in preparation for migration may be flushed away from active nests or foraging areas, resulting in loss of food opportunity, and increased energy expenditure to replace that lost food source. Birds that are flushed from active nests may abandon the nest, resulting in the failure of the nest.

Since most activities and infrastructure associated with Scenario 3 would be located on the continental shelf (i.e., >80 km offshore, outside nearshore areas), there would be a higher relative potential to affect migratory birds using offshore areas (including offshore leads) during the Spring Transition and the Open Water seasons (i.e., during spring and fall migration). Offshore activities for Scenario 3 would primarily affect loons; however, geese and brants staging in coastal areas may be affected by aircraft transiting to the offshore.

Direct mortality from collisions with the GBS and wareship, tankers, supply vessels and seismic vessels could occur as could habitat avoidance if these areas are used for feeding or staging (e.g., loons during migration). However, it is expected that, during the review of specific projects, habitat protection setbacks and timing windows to protect sensitive feeding or staging habitat would be included in the conditions for approval and in permitting.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Similar to Scenario 2, the effects of climate change on migratory birds would likely be felt primarily onshore including breeding distribution and changing food peaks with earlier springs (assuming timing of migration is unaltered). For birds that use offshore leads during the Spring Transition Season, the increasing extent and duration of the length of the Open Water Season (Laidre et al. 2015) may result in an increase in the duration of oil and gas activities and associated effects. Increases in vessel traffic also may result in further alteration of migratory bird use in offshore areas.

D.3.3.4.2 MITIGATION AND MANAGEMENT

Mitigation measures related to potential effects from Scenario 3 activities are similar to those described for Scenario 2.

D.3.3.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Potential effects on migratory bird behaviour and mortality risk are expected to be adverse. However, with application of mitigation and planning measures to maintain aircraft above minimum altitudes, avoidance of important bird nesting and staging habitat by aircraft, and use of seasonal and designated shipping routes, potential effects are predicted to be low and limited to the immediate vicinity around the footprint of the activity. Therefore, changes in behaviour of migratory birds as a result of habitat alterations from aircraft and vessel traffic (including icebreakers) are predicted to be multiple and irregular events which are localized and short-term in duration.

Sensory disturbance due to offshore drilling and production activities are predicted to only affect loon species, primarily during migration. These effects are predicted to be localized and range from short- (e.g., seismic vessels, vessel transits, aircraft) to long-term (presence of the GBS and wareship, production activities and decommissioning) durations. The magnitude of these effects is considered to be low and are not anticipated to affect the long-term sustainability of migratory bird populations in the region.

Artificial lighting from the GBS and wareship, seismic vessels, tankers and supply vessels may result in increased potential for injury or mortality from collisions. Changes in mortality risk are anticipated to be localized and medium-term. Since effects of light on birds would only be during the Spring Transition Season (i.e., when birds are arriving) or late Open Water Season when twilight occurs, effects are anticipated to be multiple and irregular. Few to no migratory birds would be present during Fall Transition and Ice seasons. Although the effect is adverse, it is not anticipated to affect the sustainability of the bird populations in the region.

As climate change impacts to migratory bird habitat is expected to occur over the 30-year assessment period, the prediction of residual effects is made with low certainty, and should be followed up with ongoing research and monitoring of migratory bird populations in the region and robust adaptive management strategies in place to maintain the sustainability of bird populations.

CUMULATIVE EFFECTS

Cumulative effects to migratory birds could occur if activities associated with the hypothetical development and production of oil reserves from existing SDLs become aggregated in time or by geographic location with activities associated with Scenario 1 (e.g., commercial shipping, renewable energy, tourism). For example, tanker transits or supply vessel movements could overlap in time and space with other vessel movements and overlap with important offshore habitat for migratory birds.

As most of the activities associated with Scenario 3 are either year-round or occur during the Open Water Season (e.g., seismic activities, resupply vessels), there would be overlap with migratory birds during Spring Transition and Open Water seasons. Therefore, there is the potential for cumulative residual effects on migratory birds in the region. However, offshore drilling activities are expected to have limited effects on migratory birds, except potentially with loons using offshore areas during staging and foraging.

Cumulative effects on migratory birds have the potential to extend across the region and be long-term in duration. Effects are predicted to be multiple irregular events and, while adverse, are anticipated to be low to moderate in magnitude. With the application of mitigation measures, including the implementation of co-management measures and operational guidelines, they are not expected to affect the sustainability of migratory birds in the region.

Changes in onshore/coastline migratory bird habitat quality and availability due to climate change could amplify effects and exert substantially more pressure on bird populations to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change to result in higher magnitude effects.

D.3.3.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.3.3.5.1 Potential Impacts and Effects of Routine Activities

Description of Effect Pathway

Effect pathways for Scenario 4 would be similar to Scenario 3. However, the FPSO, wareship and associated tanker and other vessel movements would be active further offshore (i.e., >100 km) than Scenario 3. There also would be in- and outbound tanker transits eastward of the Beaufort Sea through the Northwest Passage or Amundsen – Queen Maude Gulf. These transits would be closer to land than the offshore activities.

Description of Range of Potential Effects

The range of potential effects for Scenario 4 would be similar to Scenario 3; the only exception being that activities and infrastructure associated with Scenario 4 would be further offshore (i.e., on slope of the continental shelf) and tanker movements east of the Beaufort Sea may be closer to shore than offshore activities. This would include tankers moving into the Amundsen Gulf near the Bathurst Peninsula, where thousands of birds may be present during the Open Water Season during breeding and moulting in lowland habitats when they are most sensitive to disturbance (Latour et al. 2008).

Effects of Climate Change in Potential Effects

Effects of climate change on potential effects associated with Scenario 4 would be similar to Scenario 3.

D.3.3.5.2 Mitigation and Management

Mitigation measures related to potential effects from Scenario 4 activities are similar to those discussed for Scenario 2.

D.3.3.5.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Potential effects on migratory bird behaviour and mortality risk would be adverse. However, with application of mitigation and planning measures to maintain aircraft above minimum altitudes and avoidance of important bird nesting and staging habitat, as well as use of seasonal and designated shipping routes, potential effects are predicted to be low and limited to the immediate vicinity around the footprint of the activity. Changes in the behaviour of migratory birds as a result of habitat alterations from aircraft and vessel traffic (including tankers and icebreakers) are predicted to be multiple and irregular events which are localized and short-term in duration. Effects are anticipated to be.

Sensory disturbance and effects of artificial lighting on bird behaviour due to offshore seismic exploration vessels, drilling activity and production infrastructure (drillship, the FPSO, wareship, tankers and supply vessels) could affect loon species, primarily during migration. These effects are predicted to be localized and range from short- (seismic exploration and exploration drilling) to long-term (production and decommissioning) durations. The magnitude of these effects is expected to be low, as habitat alterations would change baseline conditions but are not anticipated to affect the long-term sustainability of migratory bird populations in the region.

Artificial lighting from marine infrastructure or seismic and drilling vessels and tankers may result in increased potential for injury or mortality from collisions. Changes in mortality risk are anticipated to be localized and medium-term.

Since effects of light on birds would only occur during the Spring Transition Season (i.e., when birds are arriving) or late summer (i.e., Open Water Season) when twilight occurs, effects are anticipated to be predicted to be adverse, multiple and irregular events which are localized and short-term in duration; these effects are not anticipated to affect the sustainability of the bird populations in the region.

With climate change-induced changes to migratory bird habitat expected to occur over the 30-year assessment period, the prediction of residual effects is made with low certainty, and should be followed up with ongoing research and monitoring of migratory bird populations in the region and robust adaptive management strategies in place to maintain the sustainability of bird populations.

CUMULATIVE EFFECTS

Cumulative effects to migratory birds could occur if activities associated with exploration and hydrocarbon development in deep water (>400 metres; Scenario 4) become aggregated in time or by geographic location with activities associated with Scenario 1 (e.g., commercial shipping, renewable energy, tourism). For example, tanker transits or supply vessel movements could overlap in time and space with other vessel movement or military or research cruise, and overlap important offshore habitat for migratory birds.

Since most of the activities associated with Scenario 4 are either year-round (e.g., production, tanker transits) or occur during the Open Water Season (e.g., seismic exploration), these activities would overlap when migratory birds are present in the region (i.e., during Spring Transition and Open Water seasons), and there is potential for cumulative effects on migratory birds. However, it is expected that offshore oil and gas activities and vessel movements would have limited effects on migratory birds, except potentially with loons which use areas far offshore during staging and foraging.

Cumulative effects on migratory birds have the potential to extend across the region and be long-term in duration. Effects are predicted to be multiple irregular events and, although they may be adverse, are anticipated to be low to moderate in magnitude. With the application of mitigation measures, including the implementation of co-management measures, they are not expected to affect the sustainability of migratory birds in the region.

Changes in onshore/coastline migratory bird habitat quality and availability due to climate change could amplify effects and exert substantially more pressure on bird populations to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change to result in higher magnitude effects.

D.3.3.6 Scenario 5: Large Oil Release Event

While the Large Oil Release Event is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels. If the fuel tanks for these vessels were affected (e.g., punctured during a collision), large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on migratory birds from such an event may differ slightly from what is described below for surface or subsea releases.

D.3.3.6.1 Potential Impacts and Effects of a Large Oil Release

Description of Effect Pathway

Marine oil spills have the potential to adversely affect migratory birds as a result of direct and indirect exposure to oil (Leighton 1993). Oil spills can affect migratory bird health, behaviour, mortality risk and habitat in the following ways (after Nunami Stantec 2018):

- reduction of waterproofing, insulating, and buoyancy properties of feathers due to direct contact with oil (i.e., adsorption) leading to hypothermia and mortality
- loss or degradation of habitat
- reduction in prey species due to oil-based mortality
- sublethal effects due to ingestion, inhalation, or adsorption of oil through preening or consumption of contaminated prey

Adsorption of oil particles on bird feathers reduces their waterproofing, insulating, and buoyancy properties, and can result in death due to starvation, hypothermia, asphyxiation, or drowning (Leighton 1993; Wiese 2002). Birds that rest on and forage from the ocean surface (e.g., sea ducks, alcids) are most vulnerable to surface oil since they interact repeatedly with the ocean surface (Piatt et al. 1990; Wiese and Ryan 2003). Gulls, terns, and jaegers are considered less vulnerable to oil spills based on the relative amount of time they are airborne. Shorebirds are more likely to be directly and indirectly affected by an oil spill if it occurs during migratory or breeding periods and oil encounters shoreline habitats (Camphuysen 1998; Szaro 1977; Wiese and Ryan 2003).

Demographic-level effects on migratory birds due to oil spills can also occur due to loss or degradation of habitat, reduction in forage opportunities from oil-based mortality among prey species, reduced breeding success due to loss of breeding adults, reduced survivorship of eggs and young from oil transfer at the nest (Szaro 1977), and reduction in overall adult survival rates (Wiese et al. 2004a). Reproductive losses would be of greatest concern for species with lower productivity (e.g., small clutch sizes, limited availability of nesting habitat). Localized spills near active migratory bird breeding colonies have potential for large, long-term consequences, particularly if they result in mortality rates among breeding individuals (Nunami Stantec 2018).

Birds can ingest oil by preening feathers or through ingestion of contaminated prey. Oil that is inhaled, absorbed, or ingested can also exert debilitating or sublethal toxicity on internal tissues and organs, including: immune suppression, oxidative stress in the liver and kidneys, depressed reproductive performance, embryotoxicity, and increased susceptibility to disease (Eisler 1987; Leighton 1993). The extent to which sublethal effects are expressed among birds is influenced by a number of factors including their annual or seasonal dependency on coastal habitats for foraging, the duration and seasonality of exposure, and the composition of their diet (Neff et al. 2006; Trust et al. 2000). Long-term effects from indirect exposure can have wide-ranging demographic consequences on migratory bird populations (Leighton 1993; Szaro 1977; Wiese et al. 2004b).

Description of Range of Potential Effects

For migratory birds, oil spills may result in changes in habitat, behaviour, health and mortality risk. If an oil spill were to occur, migratory birds using coastlines or offshore areas are generally considered to be at high potential for exposure to oil compared to most other wildlife species. The magnitude of effects of an oil spill on migratory birds is dependent on the time of year, location, the volume spilled, spill response mobilization time, effectiveness of containment measures, ecological conditions (e.g., timing and use of habitat), and environmental and oceanographic conditions (e.g., exposure to sunlight, wave action, and currents) (Piatt et al. 1990).

Specifically this assessment, there are three main considerations when determining the potential effect of a large oil release on migratory birds: the location of the spill in the BRSEA Study Area (i.e., within or outside the Mackenzie River plume), the timing of the spill (i.e., oceanographic season), and whether the release is at the surface or sub-surface (see Section 3.10 for discussion). These factors, in combination with the life history of bird species, are used to assess the effect of a spill on migratory birds (e.g., species that use offshore areas versus species that use coastlines, timing of migration, diving versus non-diving birds). For example, migratory birds that rest on the ocean surface nearshore and further offshore (e.g., loons, geese) have high potential for direct exposure to surface oil, while shorebirds are more likely to be directly and indirectly affected if an oil spill affects shoreline habitats.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Ice-dependent or ice-associated animals are likely to already be more stressed as a result of habit loss or changes associated with climate change (Ferguson et al. 2017; Mauritzen et al. 2003). Climate change may also affect migratory patterns, habitat and food availability for migratory birds (throughout their migratory range). If stressed, these animals may have an increased mortality risk and be more susceptible to effects of oil (e.g., change in prey availability, increased disturbance from spill response activities)

D.3.3.6.2 MITIGATION AND MANAGEMENT

Mitigation measures and standard operational procedures associated with the protection of wildlife from potential oil spills are discussed on Section 2.13 and 3.10.5.3. Additional details are provided in Appendix F.

D.3.3.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Depending on the interaction of migratory birds with oil releases, the effects of oil spills on birds could range from local to transboundary and from short-term to long-term in duration. Regardless of the timing (season) and location of a spill, there is the potential for oil to be transported to coastlines that are used by migratory birds during the Spring Transition and Open Water seasons. Given that oil spills are considered an accident or malfunction, they are predicted to be irregular in occurrence. There is potential for an oil spill to be highly adverse and, in an extreme event, the viability of local or regional migratory bird populations could be affected. The extent of these effects would depend on the volume of oil spilled, spill response mobilization time, effectiveness of containment measures, and ecological, environmental, and oceanographic conditions, as well as the extent of temporal and spatial overlap between the spill and use of key habitats by birds.

Given the sensitivity of migratory birds to oil releases, prevention of such releases must be a priority for offshore oil and gas development. If a large release was to occur, a rapid, well planned and well executed response is essential to help reduce potential adverse effects on migratory birds.

D.3.3.7 Summary of Residual Effects

Potential residual effects of Scenarios 1 – 4 and a large oil release event on migratory birds are summarized in Table D-34 and Table D-35.

Table D-34 Potential Residual Effects of Scenarios 1 – 4 on Migratory Birds

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Ice	• No interaction with human activities as migratory birds are not present during this season.	• No interaction with human activities as migratory birds are not present during this season.	• No interaction with human activities as migratory birds are not present during this season.	• No interaction with human activities as migratory birds are not present during this season.
Spring Transition	• Overlap with shipping, tourism, research, and gravity-based offshore wind turbines may cause disturbance or alteration to habitat	• Activities that overlap with staging areas (e.g., offshore leads for loons, coastal areas for geese and brant); may cause alteration to habitat use and mortality risk	• Activities that overlap with staging areas (e.g., offshore leads for loons, coastal areas for geese and brant); may cause alteration to habitat use and mortality risk	• Activities that overlap with staging areas (e.g., offshore leads for loons, coastal areas for geese and brant); may cause alteration to habitat use and mortality risk
Open Water	• Overlap with shipping, tourism, research, and gravity-based offshore wind turbines. Sensory disturbance from vessel and aircraft activity would be the main effect.	• Overlap with activities may change behaviour of nesting/brood-rearing/moulting birds due to sensory disturbance from vessel and aircraft activity. • Potential for effects from artificial lighting and collisions with vessels/platforms (mortality risk)	• Overlap with activities may change behaviour of nesting/brood-rearing/moulting birds due to sensory disturbance from vessel and aircraft activity. • Potential for effects from artificial lighting and collisions with vessels/platforms (mortality risk)	• Overlap with activities may change behaviour of nesting/brood-rearing/moulting birds due to sensory disturbance from vessel and aircraft activity. • Potential for effects from artificial lighting and collisions with vessels/platforms (mortality risk)

Table D-34 Potential Residual Effects of Scenarios 1 – 4 on Migratory Birds

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Fall Transition	• Minimal interaction with human activities as majority of migratory birds would have migrated from region	• Minimal interaction with human activities as majority of migratory birds would have migrated from region	• Minimal interaction with human activities as majority of migratory birds would have migrated from region	• Minimal interaction with human activities as majority of migratory birds would have migrated from region
Legend				
• Least effect – No to minor effect on migratory bird habitat, behaviour, and/or mortality risk				
• Moderate effect -- Moderate effect on migratory bird habitat, behaviour, and/or mortality risk				
• High effect -- Major effect on migratory bird habitat, behaviour, and/or mortality risk				
• Greatest effect – Severe effect on migratory habitat, behaviour, and/or mortality risk				

Table D-35 Potential Effects of a Large Oil Release Event (Scenario 5) for Migratory Birds

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• If oil clean-up/recovery efforts are incomplete, lingering oil could have interactions with birds during Spring Transition and Open Water seasons (see below).	• If oil clean-up/recovery efforts are incomplete, lingering oil could have interactions with birds during Spring Transition and Open Water seasons (see below).	• If oil clean-up/recovery efforts are incomplete, lingering oil could have interactions with birds during Spring Transition and Open Water seasons (see below).
Spring Transition	• Effects to nearshore habitat, health, mortality risk, and behaviour. Birds staging in offshore leads and coastal areas could be affected by oil contact and ingestion	• Effects to nearshore habitat, health, mortality risk, and behaviour. Birds staging in offshore leads and coastal areas could be affected by oil contact and ingestion	• Effects to nearshore habitat, health, mortality risk, and behaviour. Birds staging in offshore leads and coastal areas could be affected by oil contact and ingestion
Open Water	• Effects to nearshore habitat, health, mortality risk, and behaviour. Birds foraging and staging in offshore areas could be affected by oil contact and ingestion	• Effects to nearshore habitat, particularly to far east and west of Mackenzie Plume, health, mortality risk, and behaviour. Birds staging in offshore leads and coastal areas could be affected by oil contact and ingestion	• Effects to nearshore habitat, particularly to far east and west of Mackenzie Plume, health, mortality risk, and behaviour. Birds staging in offshore leads and coastal areas could be affected by oil contact and ingestion
Fall Transition	• Limited or negligible direct interaction as majority of birds have migrated from region. If clean-up is incomplete, could have effects during following Spring Transition and Open Water seasons (see above).	• Oil would have no direct interaction as majority of birds have migrated from region. If clean-up is incomplete, could have effects during following Spring Transition and Open Water seasons (see above).	• Limited or negligible direct interaction as majority of birds have migrated from region. If clean-up is incomplete, could have effects during following Spring Transition and Open Water seasons (see above).

Table D-35 Potential Effects of a Large Oil Release Event (Scenario 5) for Migratory Birds

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Longer-term/ Multi-year	• Long-term effects from direct and indirect exposure can have wide-ranging demographic consequences on populations; include decreased survivorship due to effects on food quality and chronic health effects from lingering oil.	• Long-term effects from direct and indirect exposure can have wide-ranging demographic consequences on populations; include decreased survivorship due to effects on food quality and chronic health effects from lingering oil.	• Long-term effects from direct and indirect exposure can have wide-ranging demographic consequences on populations; include decreased survivorship due to effects on food quality and chronic health effects from lingering oil.
Legend			
• Least effect – No to minor effect on migratory bird habitat, behaviour, and/or mortality risk			
• Moderate effect -- Moderate effect on migratory bird habitat, behaviour, and/or mortality risk			
• High effect -- Major effect on migratory bird habitat, behaviour, and/or mortality risk			
• Greatest effect – Severe effect on migratory bird habitat, behaviour, and/or mortality risk			

D.3.3.8 Gaps and Recommendations

Overall, knowledge of migratory bird use of offshore areas in the BRSEA Study Area is limited and additional data is required. Current data (post-1990s), including the incorporation of TLK, on population status, distribution (including seasonal distribution during Spring Transition and Open Water seasons; migration patterns), and habitat use of migratory birds (including seabirds; see Section D.3.4.8) in the BRSEA Study Area is critical to understanding how human activity and climate change are influencing populations in the region.

D.3.3.9 Follow-up and Monitoring

It is recommended that continued monitoring of migratory bird population densities and breeding success, seasonal migration patterns, and sensitive breeding and foraging habitat be undertaken to better understand the potential effects on migratory birds of future offshore oil and gas activities in the BRSEA Study Area. Specific needs include:

- monitor seabird interactions with low-level aircrafts, helicopters, and vessels currently in use within the BRSEA Study Area. The following data should be collected:
    - *aircraft disturbance (in-situ observations)*: Counts of birds that are flushed, time to resume nesting activities, number of eggs/young lost.
    - *vessel disturbance (wildlife monitors*): Species, number of birds, behaviour, type of interaction if any, weather conditions, season, flight direction. Data about vessel (type, speed, direction).

Should oil and gas development proceed in the BRSEA Study Area, the following monitoring programs are recommended:

- use of TLK and inclusion of Inuvialuit in the planning and conduct of monitoring programs to fill knowledge data gaps and design adaptive management approaches. As noted by TLK holders, the Inuvialuit do not oppose development, but they want industry to involve local people and to comply with the Inuvialuit CCPs (Devon Canada Corporation 2004b: 18-35).
- identify migratory bird species with a high potential for collision with marine structures. In areas where collisions are likely, use radar technology before, at the start of, and during the activities to assess this effect (e.g., offshore for wind turbines; GBS loading platform, FPSO).
- monitor migratory bird response to selective removal of light pollution during nights with substantial bird migration and assess if this is an effective mitigation measure for bird collisions associated with lighted structures
- use tracking technology for migratory birds to provide data to model habitat use and residency time within an area (Wakefield et al. 2009). This information can be used to inform the effects assessments for routine activities and predict effects of a large oil release event, including the potential for exposure of different species. Such modeling can be a valuable tool during the early stages of spill response to provide spatial links between spill sites and bird habitat use (Montevecchi et al. 2012).

D.3.4 Seabirds

D.3.4.1 Scoping

D.3.4.1.1 IDENTIFICATION OF INDICATORS

Seabirds are valued components of marine and coastal ecosystems in the BRSEA Study Area because of their ecological value as indicators of environmental changes, regulatory considerations as migratory birds, and their socio-cultural and economic value for Inuvialuit communities.

Three seabird species with different life history foraging ecology and use of marine habitats were chosen as indicators: Thick-billed Murre (*Uria lomvia*; hereafter murres); Pacific Common Eider (*Somateria mollissima,* hereafter eiders); and Sabine's Gull (*Xena Sabine,* hereafter gulls*)*,. These three indicators are used to predict potential effects on seabirds, including changes in their use of the marine environment within the BRSEA Study Area, on both the ocean surface and vertically, within the water column.

D.3.4.1.2 SPATIAL BOUNDARIES

The seabird indicators are present on the continental shelf and slope areas of the BRSEA Study Area mainly during the Open Water and ice-transition seasons. The spatial boundary of the three seabird indicators is likely to change with the expansion of open water in nearshore areas and the extension of the Open Water Season as a result of climate change within the Beaufort Sea. Consequently, the spatial boundary for this VC encompasses the entire BRSEA Study Area (see Figure 7-48). This spatial boundary encompasses potential present and future impacts associated with the five scenarios for the BRSEA (see Chapter 3).

D.3.4.1.3 TEMPORAL BOUNDARIES

The assessment of potential effects on seabirds encompasses a 30-year period between 2020 – 2050.

D.3.4.1.4 ASSESSMENT OF POTENTIAL EFFECTS

The assessment of potential effects on seabirds considers effects on the regional populations of the three indicator species within the BRSEA Study Area. Qualitative characterization of potential residual effects is based on the characterization terms defined in Table D-36.

Table D-36 Characterization of Residual Environmental Effects on Seabirds for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect on the VC	**Positive**—a net benefit to the health, mortality or habitat or behaviour that could result in a change in the status or resiliency of the seabird population. **Adverse**—a reduction or influence on the health, mortality, habitat or behaviour that could result in a change in the status or resiliency of the seabird population. **Neutral**—no net change in the viability, status or resiliency of the seabird population.
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no meaningful change in health, mortality, habitat or behaviour. **Low**—a small level change in the status or resiliency of the seabird population but would not affect the long-term sustainability of the seabird population. **Moderate**—a medium level change in the status or resiliency of the seabird population, with potential to affect the long-term sustainability of the seabird population. **High**—a large change with relative certainty of affecting the long-term sustainability of the seabird population.
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity. **Local**—residual effects extend into the local area around the activity. **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area). **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area).
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once. **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity. **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity. **Continuous**—residual effect occurs continuously for the duration of the activity.
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to one phase or season (e.g., seismic survey, exploration drilling). **Medium-term**—residual effect extends through multiple seasons or years (e.g., production phase). **Long-term**—residual effect extends beyond the life of the project (e.g., beyond closure). **Permanent**—measurable parameter unlikely to recover to existing conditions.
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation. **Irreversible**—the effect is unlikely to be reversed.

Table D-36 Characterization of Residual Environmental Effects on Seabirds for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity. **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring.

D.3.4.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

The primary issues and concerns for seabirds are human activities that result in habitat disturbance through in-air and underwater noise (e.g., vessel and tanker traffic, seismic surveys, aircraft and helicopters, platform operations), habitat alteration (e.g., routine discharges), direct mortality from collisions (e.g., offshore platforms and vessels) and exposure to sheens and oil spills (Table D-37). Scenario activities would overlap with seabirds during the Spring Transition, Open Water and Fall Transition seasons when these species are present in the BRSEA Study Area.

POTENTIAL EFFECTS OF NOISE

Helicopters, low-level aircraft and vessels produce low frequency in-air noise that can disturb nesting, moulting and migrating activities of seabirds within the BRSEA Study Area. Possible effects of in-air noise include increased energy expenditure of birds due to escape reactions, increased heart rate, decreased food intake due to interruptions, temporary loss of suitable habitat and increased egg loss or chick mortality (Ellis et al. 1991; Trimper et al. 2003; Komenda-Zehnder et al. 2003; Mallory et al. 2009).

Seabird reactions to in-air noise from overflights and vessel are variable depending on species, previous exposure levels, location, altitude, proximity, and frequency of disturbance (Schwemmer et al. 2011; Hoang 2013). Airborne noise would be expected to affect nesting murres and gulls more than eiders because they are more sensitive to disturbance than breeding eiders. Murre and gulls easily flush off their nests, increasing the mortality risk of eggs and chicks due to predation (Mallory et al. 2009; Stenhouse et al. 2001; Brisson-Curadeau et al. 2017). Eiders are likely to be susceptible to noise effects during migration and moulting in staging areas (Figure 7-48).

Inuvialuit from Tuktoyaktuk noted that flights from Tuktoyaktuk to Summers Harbour could have larger disturbance footprints than those to the platform facilities due to the duration and greater overlap with seabird habitats (Devon Canada Corporation 2004b:35).

The BRSEA Study Area is already disturbed by aircraft and marine vessels, thus local seabirds already have some level of exposure to in-air noise. Although these events would be multiple and irregular, the magnitude is expected to be low, with specific events dispersed over a wide area. After mitigation measures are in place (e.g., minimum aircraft altitudes, seasonally-designated shipping routes, avoidance of specific areas during certain seasonal windows, and use of wildlife monitors), residual effects of in-air noise on behaviour, habitat, health, and mortality risk of the three seabird indicators are expected to be short-term and transitory.

Seabirds can be exposed to underwater noise produced from commercial shipping, tankers, supply vessels, sonar systems, and seismic surveys and drilling during oil and gas exploration (Southall et al. 2007). Seismic surveys produce the most intense man-made ocean noise (Hildebrand 2009). As in-air sound from the air gun array is substantially reduced or muffled, the effect on seabirds on the sea surface or in flight is expected to be minor. Underwater noise would most affect diving seabirds. Murres and eiders are able to spend extended periods of time underwater and dive to deep depths in search of prey (murres: up to 200 m, Gaston and Hipfner 2000; Paredes et al. 2015; eiders: >15 m, Alexander et al. 1997). Such foraging strategies may expose them to underwater noise, particularly that produced by seismic vessels that utilize air guns. (Richardson et al. 1995).

Loud underwater noise produced by seismic vessels could affect diving seabirds (murres and eiders) through direct physical damage with the potential for mortality and, indirectly, by exclusion from feeding areas, alterations to behaviour and subsequent health effects. Specific investigations on the severity of underwater noise effects on seabirds are lacking. In Davis Strait, Stemp (1985) found no evidence of seismic effects on marine bird mortality or distributional effects. Underwater noise from seismic surveys can change habitat use or behaviour of seabirds and prey (Ronconi et al. 2015; Pichegru et al. 2017). African Penguins (*Spheniscus demersus)* exposed to seismic surveys within 100 km of their colony showed a strong avoidance of their preferred foraging areas during seismic activities, foraging substantially further from the survey vessel when in operation, while increasing their overall foraging effort (Pichegru et al. 2017). Lacroix et al. (2003) found that Long-tailed ducks (*Clangula hyemalis*) in the Beaufort Sea had no adverse effects of seismic activity on movement or diving behaviour, although the ability to detect subtle disturbance effects was limited.

Potential Effects of Artificial Lighting

Artificial light used for routine operations on platforms and vessels, as well as flares from burning oil or gas, are sources of attraction for seabirds (Sage 1979; Wiese et al. 2001; Montevecchi 2006; Ronconi et al. 2015).

Attraction of seabirds to artificially lit platforms may result in direct mortality or injury through collisions with facility infrastructure, incineration by flares or by stranding on the platform (Baird 1990; Montevecchi et al. 1999; Wiese et al. 2001). Light-induced bird strike incidents occur on a regular basis on vessels that operate in Southwest Greenland during winter (an area with more open water than the BRSEA Study Area), especially in coastal areas (< 4 km offshore) when visibility is poor and mostly between November and January (Merkel 2010). Seabirds are absent from the BRSEA Study Area during the Ice Season and darkest period of the year.

Drowning and mortality of eiders at platforms in Alaska has been associated with moon phase (full and waxing moons), changing barometric pressure, and high probability of fog (Day et al. 2005). Under fog or drizzle conditions, the moisture droplets in the air refract the light and greatly increase the illuminated area, thereby extending the distance over which artificial light interacts with birds (Wiese et al. 2001).

Oil and gas platforms in the ocean may act as artificial reefs, creating habitat conditions attractive to fish and invertebrates (Fabi et al. 2004), thus enhancing local marine food supply and creating foraging opportunities for seabirds (Ortego 1978). This effect is particularly pronounced at night when gulls forage around lights and flares that attract prey (presumably zooplankton and/or small fishes) to surface waters (Montevecchi 2006). Thus, offshore platforms may create additional foraging opportunities for gulls that normally forage by daylight, thus supplementing their diets and, potentially, increasing their survival and reproductive success; though these "opportunities" must be balanced with the potential for mortality (Ronconi et al. 2015).

Seabird interactions with platforms due to artificial light would be multiple and irregular events. After mitigation measures (e.g., wildlife monitors, light management[15]) are in place, residual effects on seabird behaviour, habitat, health, and the mortality risk are expected to be low in magnitude. Shielding lights downward has also been shown to reduce attraction (Reed et al. 1985).

POTENTIAL EFFECTS OF HABITAT DISTURBANCE

Habitat disturbance could affect seabird health through increased energy expenditure due to their exclusion from feeding areas and prey sources, mortality risk due to collisions and exposure to accidental discharges of oil (discussed under Scenario 5 below). Alcids tend to avoid platforms possibly because they are prone to disturbance from vessels (Ronconi and St Clair 2002). Indirect effects caused by changes in traveling routes to avoid offshore facilities (Desholm and Kahlert 2005) may result in increased energetic demands (Masden et al. 2010). However, these events are expected to be low in magnitude except in areas where platforms are located in proximity to productive sites for seabirds that are associated with discrete physiographic features along the continental shelf edge and slopes (e.g., upwellings) (Hedd et al. 2011). The presence of offshore platforms, vessels and their operations year around over 30-year period could have residual effects on the behaviour, habitat and health of seabirds.

An assessment of the sensitivity of birds to offshore wind energy projects on the Atlantic Outer Continental Shelf ranked the three seabird indicators selected here as highly vulnerable to collisions. Murres and eiders also ranked high in their sensitivity to displacement (Robinson Willmott et al. 2013).

POTENTIAL EFFECTS OF ROUTINE DISCHARGES

Routine discharges of waste are regulated under a number of different federal instruments (Section 2.5). While many liquid wastes and most solid wastes must be collected, stored and transported to shore for treatment or disposal, discharges of water-based mud, drill cuttings and sand is likely for deepwater drilling. Some wastewater streams can also be discharged if standards for oil content and other substances are met. These discharges from platforms (e.g., GBS, FPSO) and vessel operations would be multiple and regular events; however, it is assumed that projects would be expected to stringently follow waste discharges regulations and guidelines. It should be noted that in calm conditions, discharges within

[15] For example, modifying the wavelength and intensity of lighting and light colors has been shown to influence the degree of attraction and likelihood of bird mortality (Ronconi et al. 2015))

allowable levels can result in formation of hydrocarbon sheens (Fraser et al. 2006; Morandin and O'Hara 2016). Seabirds are especially vulnerable to contact with oil, including sheens. Small amounts of oil from sheens can affect the structure and function of seabird feathers (O'Hara and Morandin 2010), which can cause a heightened metabolic rate (increased energy expenditure) and mortality, as well as behavioural changes, such as increased time spent preening at the expense of foraging and breeding (Morandin and O'Hara 2016).

With appropriate screening and selection of chemicals (including use of non-toxic drilling fluids) in accordance with the *Offshore Chemical Selection Guidelines*, and proper disposal of drill muds and cuttings in accordance with the OWTG, effects on birds due to disposal of drilling muds, cuttings and associated waste materials should be low to negligible.

Potential Effects of Large Oil Releases

As described for migratory birds, large oil releases can adversely affect seabird health, behaviour, mortality risk and habitat through effects on plumage and susceptibility to hypothermia; loss or degradation of habitat; reduction in prey species and sublethal effects (Nunami Stantec 2018). Potential effects are discussed in more detail in the assessment for Large Oil Release Events (Section D.3.4.6)

Summary of Potential Effects on Seabirds

The relationship between human activities, interactions, impacts and potential effects on seabirds are summarized in Table D-37. Although activities and associated impacts are similar across the Status Quo and the three oil and gas development scenarios, potential effects of each scenario are discussed independently to identify specific interactions that may result from variation in timing, spatial extent, or geographic location for each scenario.

Table D-37 Summary of Potential Impacts and Effects on Seabirds

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Noise (in-air and underwater)	• vessel transits (engine, propeller, and ice-breaking activities) • seismic surveys • drilling • operational and maintenance activities to vessels, production platform, and wells • helicopters, low flying aircraft, and snowmobiles	• injury to diving seabirds from underwater noise produced by seismic air guns (murres and eiders) • disorienting and avoidance of areas subjected to in-air noise from helicopters or low-flying aircraft (all indicator species) • flushing off nests (gulls and murres)	• potential residual effects on seabirds are possible but, with mitigation in place (e.g., wildlife monitors, use of safety radii, minimum aircraft altitudes, seasonal and designated shipping routes), potential residual effects on behaviour, health, mortality risk, and habitat is expected to be of low magnitude	• counts of birds flushed, eggs/chick lost during activities. • change in population size • change in nesting sites. • change in migration routes
Artificial Light	• lighting used on nearshore infrastructure (wind turbines, marine infrastructure), offshore platforms and vessels	• attraction to artificially lit structures or disorientation and subsequent mortality resulting from collisions or burning (flares) (all indicator species) • exclusion from feeding habitat (murres and eiders) • increased feeding opportunities due to prey attraction to artificial light (gulls)	• potential residual effects on seabirds are possible but with mitigation in place (e.g., wildlife monitors, light management), potential residual effects on behaviour, health, mortality risk, and habitat expected to be low in magnitude	• counts of interactions and dead birds • change in migration routes
Seabed Disturbance	• sub-sea well, manifold, and pipeline installations and repairs	• exclusion of feeding areas and increase in foraging effort (eiders)	• potential residual effects on seabirds are possible but after mitigation measures are in place (e.g., wildlife monitors, best industrial practices in waste management and structure maintenance) changes in habitat, behaviour, health and mortality risk is expected to be negligible in magnitude	• NA

Table D-37 Summary of Potential Impacts and Effects on Seabirds

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Ice/Open Water Disturbance	• icebreakers transiting through sea ice (ice management, support, transport) • presence of structures on/in sea ice or open water (drillships, platforms, wind turbines)	• exclusion of feeding areas during the open season and increase in foraging effort (all species indicators)	• change in behaviour • change in health • change in habitat	• changes in foraging ranges and migration routes • change in body condition • change in population numbers
Routine Discharges	• air emissions • bilge and ballast water • drilling muds and lubricating fluids • drill cuttings and disposal • sewage and food waste • cooling water and deck drainage	• effects on habitat and prey availability (all species indicators) • toxicity of prey due to ingestion of contaminants (e.g., PAHs). All species indicators	• potential residual effects on seabirds are possible but with mitigation measures in place (zero discharge policy for oil based muds, meeting guidelines for offshore disposal) direct potential residual effects on behaviour, health, habitat and mortality risk, are expected to be negligible in magnitude	• NA
Vessel Collision	• vessel transits (shipping, tankers, icebreakers, personal watercraft)	• impact with vessel or propeller (all species indicators)	• potential residual effects on seabirds are possible but with mitigation in place (e.g., wildlife monitors, light management), potential residual effects on behaviour, health, mortality risk, and habitat expected to be low in magnitude	• counts of injured or dead birds

Table D-37 Summary of Potential Impacts and Effects on Seabirds

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Oil Spill	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• direct mortality due hypothermia and starvation • effects on prey source resulting in shifts in availability or quality of food for seabirds (all species indicators) • Ingestion of oil through preening of oiled feathers • Toxicity to eggs if incubation occurs by oiled adult	• change in behaviour • change in health • change in mortality risk • change in habitat • given the low recovery rates of seabirds from extensive adult mortality (k-selected species). long-term residual effects in local populations is expected.	• counts of oiled birds • change in population size

D.3.4.2 Scenario 1: Status Quo

D.3.4.2.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

The activities associated with Scenario 1 are expected to spatially and temporally overlap with breeding, moulting and migration movements of seabirds.

Only activities that occur during the Open Water and Spring and Fall Transition seasons would overlap with murre, eider and gull habitat use (nearshore, continental shelf and slope) and result in interactions with anthropogenic activity. These activities are assumed to occur continuously (renewable energy) or at moderate to high frequency such as low-level aircraft and vessel activity (commercial, tourism, sea lift, military, research). The latter includes aircraft and vessels movements across the Beaufort Sea, as well as in channels to the east of the Beaufort Sea (e.g., Northwest Passage and Amundsen-Queen Maude Gulf).

Offshore wind facilities during construction and operation could affect bird populations directly through mortality from collisions and indirectly through residual effects in health due to displacement from foraging areas. However, it is assumed that through the environmental review process, approvals would include conditions on avoidance of sensitive and important habitat, including seabird breeding colonies that are located in several Marine Protected Areas (Anguniaqvia Niqiqyuam or ANMPA, Tarium Niryutait or TNMPA) and/or Migratory Bird Sanctuaries (Cape Parry, Banks Island). These areas of marine habitat and the species that use these areas are protected under the *Migratory Birds Convention Act* and the Migratory Birds Regulations, Environment and Climate Change Canada.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The main anticipated effect on seabirds under this scenario is habitat disturbance of nesting and feeding areas with potential residual effects on behaviour, health and mortality risk.

Noise disturbance from aircraft can cause murres and gulls to flush from their nests, increasing the potential for egg/chick predation (Brown 1990). Vessel activities can displace prey and their predators from preferred foraging areas, causing an increase in energy expenditure with potential residual effects on body condition (Rojek et al. 2007).

Ship transits eastward through Amundsen – Queen Maude Gulf and the Northwest Passage during the Open Water Season (e.g., cruise ships, cargo and other vessels, community resupply vessels, military vessels, research vessels), that are through or close to high use areas for seabirds could result in sensory disturbance to seabirds and result in changes in foraging activities or avoidance of habitat.

Offshore wind facilities during both construction and operation may affect bird populations directly through mortality from collisions and indirectly through displacement that affects population fitness (Robinson Willmott et al. 2013; Thaxter et al. 2017). An assessment of the sensitivity of birds to offshore wind energy projects on the Atlantic Outer Continental Shelf ranked the three seabird indicators considered in this assessment as highly vulnerable to collisions. Murres and eiders also ranked high in their sensitivity to displacement (Robinson Willmott et al. 2013).

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Predicted increases in the extent and duration of the Open Water Season would allow increases in vessel traffic in the region; as a result, disturbance of seabirds and habitat could increase in frequency and potentially in magnitude (increased area and routes), and have residual effects on health and mortality risk for murres, gulls and eiders. Increases in foraging habitat disturbance would put pressure on seabird populations, potentially resulting in shifts in range, migration routes, habitat use, or prey sources. Use of wind farms as an alternate to fossil fuel generation of energy would need to be balanced with the potential risks for seabirds. Fog, which is predicted to increase in frequency, could potentially increase the rate of bird collisions with wind farms.

At the same time, larger open water areas may increase open water foraging habitat in space and time. The quality of such potential new habitat is unknown. A recent study suggests that increased warming would facilitate an increase in intertidal mussel abundance in Greenland, and potentially, across the Arctic (Thyrring et al. 2017), which may benefit eiders in the region.

Finally, a possible increase in ocean pollution due to increased human activity in the BRSEA Study Area (commercial shipping, research and tourism vessels, local transportation) could have residual effects on seabird health and ultimately fitness.

D.3.4.2.2 MITIGATION AND MANAGEMENT

General mitigation measures and standard operational procedures associated with the protection of wildlife from human impacts should be employed. Measures specific to the protection of seabirds from human impact include:

- habitat protection setbacks and timing windows to protect sensitive breeding, moulting and staging habitat from aircraft and vessel disturbance
- establishing safe vessel routes and operations protocols to avoid seabirds and sensitive seabird habitats; this would be especially important for routes to the east of the Beaufort Sea
- avoidance of low-level aircraft operations where not required as per Transport Canada protocols
- maintaining strict re-fueling procedures to reduce the potential for fuel spills
- prohibiting unnecessary harassment of birds by vessels, crew members and support aircraft
- implementing a Seabird Management Plan that includes seabird monitoring for vessel-related activities
- properly containing and disposing of waste to reduce attraction of birds (i.e., gulls) to vessels
- designing and locating wind turbines (e.g., larger and fewer) to reduce the proportion of birds at potential for collision (e.g., consider movements and timing of movements of resident species, visibility of turbines, and flight patterns) (e.g., Gartman et al. 2016)

Additional details are provided in Appendix F.

D.3.4.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Activities associated with Scenario 1 that overlap with seabird marine habitat use are expected to increase in frequency and seasonal extent over the next 30 years. Residual effects on seabird behaviour, health and mortality risk are expected to increase with adverse effects on local seabird populations. However, the events associated with habitat disturbance (air and underwater noise, artificial lights, physical displacement) are expected to be multiple and irregular in frequency, dispersed over a wide area, short-term in duration and reversible.

During the Open Water Season, transits by cruise ships, cargo and other vessels, community resupply vessels, military vessels, and research vessels across the Beaufort Sea and in channels to the east of the Beaufort Sea (e.g., Amundsen – Queen Maude Gulf and the Northwest Passage) may cross through or be close to high use areas for seabirds; these portions of the transits could result in changes to behaviour, foraging patterns, avoidance of the immediate area by seabirds, changes in health and increased mortality risk (e.g., striking upper structures on vessels). Vessels should be required to follow specific procedures to reduce interactions with large concentrations of seabirds; this might include spatial and temporal restrictions on specific shipping routes, use of wildlife monitors, enforcement of safety radii and associated operational measures (e.g., slower speed, maintaining a consistent course and speed, light management). With mitigation, these transits are predicted to result in multiple and irregular, dispersed, and short-term effects on seabirds, which are reversible (i.e., within hours to a day of passage) and could affect a medium portion of the populations along these routes; effects could range from low to moderate depending on how well mitigation measures are followed.

There is potential for mortality of seabirds due to collisions with wind turbines. This needs to be accounted for through appropriate planning and mitigation measures (e.g., wind turbine placement and design).

Although the activities under Scenario 1 would adversely affect seabirds, residual effects on the viability of local populations are expected to be low after thorough planning and assessment of activities, application of specific conditions, including use of industry best practice and regulations/guidelines, and use of site- and temporally specific mitigation measures (e.g., avoidance of sensitive areas and important habitat, flight altitude restrictions, use of standard shipping and aircraft routes; reduced vessel speeds in specific areas, light management). A review of current methods for industry best practices (vessel traffic, waste disposal) and planning is recommended to account for impact of human activities due to climate change.

CUMULATIVE EFFECTS

Current effects of human activities in the BRSEA Study Area are predicted to remain the same or increase over the period of 2020-2050. As a result of increased vessel traffic and new activities (e.g., offshore wind energy), cumulative effects on seabirds could occur and include changes in behaviour, health and mortality risk. Murres and gulls, which are highly vulnerable to habitat displacement and airborne noise disturbance at their breeding colonies, are expected to have increased residual effects on the health and mortality risk (e.g., chicks). The presence of wind farms would also increase the mortality risk due to collisions. Eiders may be most vulnerable due to their massive movements during spring migration. Increases in the occurrence of storm surges associated with climate change could also affect nesting and foraging of seabirds in nearshore areas with potential effects on health and fitness. Because effects would be dispersed across a wide area and be irregular in occurrence, residual cumulative effects are expected to be low or negligible after mitigation measures are in place, including careful planning of offshore wind energy projects in the BRSEA Study Area.

D.3.4.3 Scenario 2: Export of Natural Gas and Condensates

D.3.4.3.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Activities associated with Scenario 2 are expected to spatially and temporally overlap with breeding, moulting and migration movements of the seabird indicators.

The main activities that would have an effect on the behaviour, health, habitat use and mortality risk for seabirds are the presence of GBS facility (10 km offshore), associated transits of dual tankers (westward), and low-level aircraft and helicopters year-round (effects pathways for aircraft and vessel disturbance are the same as described under Scenario 1). Flights to Summers Harbour (350 km one way) are expected to have a greater effect on breeding and migrant seabirds because of duration (1.5 h one way transit) and proximity to Cape Parry (nesting habitat for the only thick-billed murre colony in the western Canadian Arctic). Routing of aircraft away from Cape Parry would help mitigate this effect.

Activities associated with the GBS loading platform in nearshore areas would have more effect on eiders and gulls than murres due to their life-history and feeding habits; these effects are most likely to occur during the Open Water and the Spring/Fall Transition seasons when seabirds are present in the BRSEA Study Area.

Other activities such as the installation of the GBS loading platform and dual pipelines, sealifts, decommissioning of the GBS loading platform, and capping and filling of subsea portions of the pipelines are expected to have low to negligible effect on seabirds due to their short- to medium-term duration (i.e., one Open Water Season) and low frequency. It is assumed that project approvals would have conditions to adhere to spatial and temporal windows of activity to reduce effects to seabirds.

Description of Range of Potential Effects

Eiders and gulls would have higher potential for mortality due to collisions with the GBS structure and vessels (tanker transit year around) as a result of light attraction or disorientation on fog days) than murres (see Section D.3.4.1.5). Moreover, given the eastern location of the murre colony, interactions with GBS facility (collisions) is expected to be restricted to the non-breeding season (spring/fall transition) and be low in magnitude.

The nearshore habitat used by murres and gulls during the at-sea stage of chick care and by eiders during spring/fall for migration staging (Section 7.3.4) would overlap with operations of the GBS loading platform and tanker transits. These interactions could result in the displacement of birds from their feeding areas with potential residual effects on chick mortality and adult health due to increased energy expenditure.

Habitat disturbance due to airborne noise (aircraft, helicopters) could result in egg loss and chick mortality due to predation (Rojek et al. 2007). These effects are expected to be greater for murres and gulls than eiders given their higher sensitivity to disturbance. However, most vessel transits and flights would occur far from the main colonies. It is also assumed that aircraft flights for this type of development would maintain minimum flight altitudes (EIRB 2011, Appendix F) and use designated flight routes to reduce effects to seabirds.

Seabird interactions with the GBS loading platform, vessels and aircraft (e.g., changes in behaviour and habitat use) would be multiple and irregular events and would be dispersed over a large area.

Effects of Climate Change on Potential Effects

Climate change would likely extend the Open Water Season, potentially changing the diversity and distribution of prey nearshore. The presence of the GBS loading platform, in combination with human activities and vessel and aircraft movements, is expected to result in disturbance of seabirds and habitat in the immediate vicinity of the development. This could have highly localized and minor effects on prey availability (e.g., Burke et al. 2005) for the three seabird indicators that use the coastal areas (adult and young) as corridors late in the breeding season.

Increases in the frequency of storms and storm surges would increase habitat disturbance in nearshore area and could affect nesting and feeding for eiders and gulls later in the breeding season with potential residual effects on behaviour, health and fitness. The predicted increase of mussels in the Arctic due to increased temperatures (Thyrring et al. 2017), if it were to occur, could have a positive effect on eider health and partially counteract residual effects of habitat disturbance associated with the activities of Scenario 2.

The longer Open Water Season and associated increases in vessel use and duration of use, could result in increased interactions between seabirds and vessels (tankers and supply vessels) resulting in minor residual effects in health and fitness (i.e., highly dispersed and irregular interactions of short-duration).

D.3.4.3.2 MITIGATION AND MANAGEMENT

Mitigation and management measures for Scenario 2 activities (helicopters, low-level aircrafts, and vessel disturbance) include are similar to those listed under Scenario 1. In addition:

- Selecting appropriate light color, wavelength and intensity for lighting on the GBS loading platform and vessel to reduce bird attraction to platforms and vessels; avoiding the use of unnecessary lighting, shading; and directing lights towards the deck to reduce bird collisions.
- Powerful search lights, essential for the safe operation of vessels in icy waters and for larger vessels (>150 BT) are also required by regulation. However, priority should be given to investigate alternative green light sources (low in red light which appear to attract seabirds, Ronconi et al. 2015), perhaps combined with image enhancing ice lookout techniques (Merkel 2010).

Additional details are provided in Appendix F.

D.3.4.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Residual effects on behaviour, health and mortality risk as a result of activities associated with Scenario 2 are expected to be higher for eiders and gulls than murres given their more coastal range, feeding habitats and life history (see Section 7.3.5). Collisions with the GBS loading platform and vessels, displacement from potential feeding areas, and habitat alteration could result in low levels of direct mortality of adults or have indirect effects on health and fitness (increased energy demands). Murre interactions with activities nearshore (GBS loading platform and operations) would be seasonal (at-sea chick care) and low in magnitude. Seabird interactions with activities that result in habitat disturbance (vessel traffic, aircraft/helicopters, lights) are expected to be multiple and irregular in frequency, dispersed over a large area (i.e., vessel transits, aircraft) with short-term duration. With the application of mitigation measures (e.g., spatial and temporal restriction on certain activities, avoidance of sensitive areas and important habitat, monitoring at the GBS facility and on vessels, light management, and best practices during vessel activities and operation of the GBS loading platform), residual effects are expected to be low in magnitude for the seabirds.

CUMULATIVE EFFECTS

Human activities have already affected and are expected to continue to affect, seabirds and their associated habitat in the BRSEA Study Area (Section 3.6; Scenario 1). Some activities may increase due to new or additional activities and/or climate change. As a result, the combination of existing and future Status Quo activities in combination with activities in Scenario 2, could lead to cumulative effects that may potentially affect the behaviour, health and mortality risk for seabirds, but mainly for eiders and gulls (nearshore/coastal foragers).

Cumulative effects of airborne noise (e.g., chick predation) and habitat disturbance (adult collisions with GBS loading platform) could increase mortality risk. Similarly, cumulative effects of vessel disturbance could increase residual effects on health and fitness as a result of disturbance, changes in habitat use and associated increased energy demands.

Together, these effects have the potential to be long-term in duration and cumulatively affect seabird species. However, given that most of the operations are largely focused on the western side of the BRSEA Study Area (e.g., dual-action tanker transport of gas westward), and the remaining activities are dispersed (e.g., cruise ship, cargo, military and research vessels, supply vessel transits and flight to and from Summers Harbour and Tuktoyaktuk), residual effects not expected for regional seabird populations. Effects are predicted to be multiple irregular events dispersed over a large area, adverse, ow to moderate in magnitude, short-term and reversible. With the application of mitigation measures, cumulative effects are not expected to affect the population viability of murres, eiders and gulls in the region.

D.3.4.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.3.4.4.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

The activities associated with Scenario 3 would overlap with habitat use of the three seabird indicators particularly during the Open Water and the Spring and Fall Transition seasons. Residual effects on seabird species health may persist from activities performed during the Ice Season (such as the dual-action carrier/tanker transport of oil westward, drilling and oil production).

The main activities that could affect the behaviour, health, habitat and mortality risk for seabirds are the presence of the GBS and wareship, seismic surveys, operations on the GBS (e.g., well drilling and oil production), the frequent use of a dual tanker (westward once every 5 days), and use of low-level aircraft and helicopters year-round. Ships transits and aircraft flights to and from Summers Harbour (350 km one way transit) are expected to have effects on behaviour and habitat use of seabirds because of the duration (15 h one way for vessels, 1.5 h one way for aircraft) and potential proximity to Cape Parry (murre colony). Routing of vessels and aircraft away from Cape Parry would help mitigate this effect.

Underwater noise produced by seismic surveys would potentially overlap with foraging diving seabirds (eiders and murres). Given the foraging ranges of murres and the location of the breeding colony (east of the GBS platform), interactions are expected to be minimal.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The activities associated with Scenario 3 are expected to spatially and temporally overlap with breeding, moulting and migration movements of seabirds.

Given the location of the GBS facility (80 km offshore) on the continental shelf, there would be potential for mortality from collisions with the platform and vessels due to light attraction and disorientation during fog days. Mortality or injury from collisions are expected to be lower for breeding murres and gulls due to the location of their main breeding colonies but higher for eiders during spring migration given their extensive use of the continental shelf and the location of staging areas (Figure 7-48). Lesser effects are expected during the Fall Transition Season because eider migration is more dispersed.

In-air noise disturbance (aircraft and helicopters) near breeding colonies could result in egg loss and chick mortality due to predation. This activity could affect mainly breeding murres and gulls but also moulting eiders in staging areas and migrating birds (change in routes) with potential effects on their health and fitness. Flights to Summers Harbour (near colonies) could have a greater effect than those to and from Tuktoyaktuk.

Underwater noise (seismic surveys) and tanker traffic could have effects on the behaviour, health and fitness of diving seabirds (eiders and murres); however, little information is available for this effect on seabirds. The most likely effect of underwater noise for seabirds is the displacement from potential feeding areas with effects on energy expenditure. Although the seismic surveys would have a considerable footprint (60,000 ha) on the continental shelf, effects on seabird health and fitness are expected to be low to moderate because of the size of the footprint of the seismic activities relative to the continental shelf and slope in the BRSEA Study Area, and the one time occurrence and duration of the seismic program. Measures such as slow ramp-up and use of safety radii for seismic operations would also help reduce effects. Birds may be able to avoid the areas affected by seismic activity if they are predictable in space and time. Effects of underwater noise from vessels are expected to be multiple, irregular, dispersed over a wide area, and short-term.

Effects of Climate Change on Potential Effects

Climate change is likely to extend the Open Water Season on the continental shelf (Scenario 3) more than in the nearshore areas (Scenario 2). If supply vessels and other vessels are able to operate for longer periods, there could be additional potential for disturbance of seabirds and avoidance of certain areas of importance for foraging, resting or moulting. However, the extent of these effects is difficult to predict. The predicted increase of storms and storm surges may also make it more difficult for seabirds to find adequate resources on in the continental shelf, especially in fall, with potential subsequent effects on over-winter survival.

D.3.4.4.2 Mitigation and Management

Proposed mitigations and managements measures for Scenarios1 and 2 should be considered for oil development on the continental shelf (additional details are provided in Appendix F) in addition:

- Mitigation measures for the 3D seismic surveys should be consistent with the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment. Although these mitigation measures are primarily designed to reduce the potential for injury to marine mammals, implementation of a ramp-up procedure may also reduce the likelihood of a seabird diving near the source at its highest operating sound level.

D.3.4.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Activities associated with Scenario 3 (continental shelf) are expected to have residual effects on the behaviour, health and mortality risk for seabirds. The magnitude of the effect is expected to be higher for eiders because of their use of the continental shelf. The residual effect on murre and gull populations could be a concern if migration routes, currently unknown, coincide with the general location of the GBS platform and wareship and associated operations, including tanker transits, other vessel transits and aircraft overflights.

Mortality risk associated with interactions with the GBS platform (collisions with the platform or flare) are expected to be multiple and irregular in nature and of low magnitude relative to size of the regional population. As such, they are not expected to affect the population viability of seabirds in the region.

Seabird interactions with activities such as tanker movements, vessel traffic, and aircraft/helicopters overflights could result in disturbance of seabirds and use of habitat. These effects are expected to be multiple and irregular in frequency, dispersed over a wide area, be short-term and reversible.

With mitigation (e.g., spatial and temporal restrictions on activities close to sensitive or important habitat, light management, enforcing best practices during vessel activities, seismic surveys[16] and operations; proper management of waste streams; wildlife monitoring of interactions with the GBS facility, wareship, vessels), residual effects on seabird behaviour, habitat, health, and mortality risk are expected to be low in magnitude, short-term in duration, and reversible.

CUMULATIVE EFFECTS

Human activities have already affected, and are expected to continue to affect, seabirds and associated habitat in the BRSEA Study Area (Section D.3.2, Scenario 1). Some activities may increase due to new uses or projects and/or climate change. As a result, the combination of existing and future Status Quo activities in combination with activities in Scenario 3, could lead to cumulative effects that may potentially affect the behaviour, health and mortality risk of seabirds, but mainly of eiders and gulls (nearshore/coastal foragers).

Similar to Scenario 2, with the application of mitigation measures, cumulative effects of airborne noise and habitat disturbance are predicted to be multiple irregular events dispersed over a large area, adverse, low to moderate in magnitude and short-term. As such they are not expected to affect the population viability of murres, eiders and gulls in the region.

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[16] Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment; DFO 2007, Appendix A

D.3.4.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.3.4.5.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

The main activities of concern are activities that are high frequency, long duration, and have a large footprint and/or geographical extent that may affect the behaviour, health, habitat and mortality risk of seabirds. These include: the FPSO and wareship operation, drilling and oil production, seismic surveys, dual tanker transits (westward year-round and eastward during the Open Water Season), and overflights of large helicopters to and from the service and supply bases. Flights to Summers Harbour (350 km one way) for change of crews or FPSO resupply are expected to have greater potential to disturb seabird habitat because of the duration (~1.5 h one way) and potential proximity to Cape Parry. Routing of aircraft away from Cape Parry would help mitigate this effect.

Of the three seabird indicators, murres have the highest potential for being affected by activities associated with Scenario 4 because they are offshore foragers; however, some of these activities (e.g., seismic surveys, tanker traffic) would overlap with gull and eider populations, particularly in the Spring Transition Season.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The activities associated with Scenario 4 are expected to spatially and temporally overlap with breeding, moulting and migration movements of the seabirds.

Under this scenario, the total field of operation including FPSO facility (40,000-60,000 ha) and 3D seismic surveys (100,000 ha) would have a substantial footprint on the slope of the continental shelf. The habitat disturbance (exclusion of feeding areas) and mortality risk (collisions) associated with these activities could have residual effects on seabird health and fitness.

Probability of collisions of murres with the FPSO and wareship (> 100 km off the coast), tankers and other vessels due to light attraction would be restricted to periods outside the breeding season based on the location of Cape Parry and foraging ranges of murres. Although possible, eider and gull collisions with the FPSO platform, wareship and vessels are expected to be uncommon due to their reported ranges (see Section 7.3.4). Effects of underwater noise on diving seabirds (murres and eiders), mainly through habitat disturbance, is expected to be restricted to spring/fall migration and would mainly affect murres.

Effects of airborne noise (large helicopters) on seabirds that could cause temporary abandonment of nests by startled adults and direct mortality of chicks is expected to be greater for murres and gulls. Eiders are more resilient to nest disturbance. The helicopter traffic between Tuktoyaktuk and Summers Harbour is expected to occur more often under this scenario and, therefore, is expected to have greater potential residual effects on seabird fitness, particularly on murres, as compared to the other oil and gas development scenarios (Scenarios 2 and 3) or the Status Quo (Scenario 1). However, routing of aircraft away from Cape Parry and adherence to minimum flying altitudes (EIRB 2011, Appendix F) would help mitigate this effect.

Habitat disturbance due to tanker traffic in both directions (east and west from the Beaufort Sea) could have a greater geographical effect on seabird habitats than the other scenarios due to the number of transits (weekly year-round for the west, and monthly for the east during the Open Water Season). Residual effects from isolation of feeding areas could affect body condition to perform crucial activities (nesting, moulting) and to store sufficient energy reserves for migration and survival over winter.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

An increase in duration of the Open Water Season and the extent of open water could increase vessel movements and result in increased interactions between seabirds and vessels (tankers and non-related vessels).

Climate-related changes in sea temperature and food web structure along the continental slope would occur later than on the shelf or along the shore. Therefore, additive effects of habitat disturbance (change in feeding patterns such a prey type) for seabirds is expected to occur toward the end of the temporal boundary for this study.

Increases in storm frequency and storm surges from climate change could affect the ability of seabirds to find adequate resources near the continental shelf for breeding, moulting and building sufficient energy reserves for migration and overwinter survival. These effects are more likely to affect murres than gulls or eiders.

Increased fog in the region due to climate change could increase the probability of collisions with the FPSO platform, wareship, tankers and other vessels, with a direct effect on seabird mortality.

D.3.4.5.2 MITIGATION AND MANAGEMENT

Mitigation and management measures would be similar to those described for Scenarios 1, 2 and 3. In addition:

- Tanker transits eastward through Amundsen – Queen Maude Gulf and the Northwest Passage during the Open Water Season could result in interactions between vessels and seabirds in a number of areas that are through or close to high use areas for seabirds. Tankers and other vessels should be required to follow specific procedures to reduce interactions with large concentrations of seabirds; this might include spatial and temporal restrictions on specific shipping routes, use of wildlife monitors, and associated operational measures. However, as the proponent would be able to enforce specific requirements through a tanker acceptance program, managing tankers would likely be easier than managing the wider range of vessels expected to use this area as described in Scenario 1.

Additional details are provided in Appendix F.

D.3.4.5.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Over the 30-year period of the project, the residual effects of activities associated with Scenario 4 could result in changes in behaviour, health and mortality risk for seabirds.

The mortality risk due to collisions with the FPSO platform and wareship, as well as tankers and other vessel (> 100 km offshore) or burning by flaring events is expected to be higher for murres than gulls and eiders because they are offshore foragers. Staging areas of eiders in the BRSEA Study Area are found in coastal areas less than 20 m depth (Dickson and Smith 2013; Figure 7-48). Although Sabine's gull can be found off the continental shelf (75-150 km) in lower latitudes during migration, in higher latitudes they use coastal areas within the continental shelf (Day et al. 2001). Given that the development area for Scenario 4 is out of the range for breeding murres (200 km foraging range), the mortality risk would be limited primarily to migration. Moreover, collision rates with platforms is expected to be lower for murres than nocturnal seabirds (Montevecchi 2006).

Tanker transits (to the west and east from the Beaufort Sea) and helicopter traffic would overlap with eiders, murres and gulls in nesting colonies, migration routes and staging areas along the continental shelf. Residual effects include changes in health, fitness and possible mortality risk as a result of these interactions (exclusion from feeding areas, collisions, colony disturbance); these effects are expected to be multiple and irregular in nature, dispersed over a wide area, short-term in duration and reversible. Mitigation, including avoidance of nesting colonies, additional spatial and temporal avoidance of sensitive and important habitat, use of minimum aircraft altitudes, use of shipping routes (to avoid sensitive areas and seasonal periods), and wildlife monitors can be used to reduce effects. With mitigation, residual effects are expected to be low for murres, eiders and gulls.

CUMULATIVE EFFECTS

As described for Scenarios 2 and 3, human activities have already affected, and are expected to continue to affect, seabirds and associated habitat in the BRSEA Study Area (Section 3.6; Scenario 1). As a result, the combination of existing and future Status Quo activities, in combination with activities in Scenario 4, could lead to cumulative effects that may potentially affect the behaviour, health and mortality risk for seabirds.

Cumulative effects are similar to those described for Scenarios 2 and 3. However, vessel movements through Amundsen – Queen Maude Gulf and the Northwest Passage during the Open Water Season, would bring higher numbers of vessels in proximity to important areas for seabirds. These transits could include a variety of vessels including oil tankers, cruise ships, cargo vessels, and military and research vessels. The multiple types of vessels and vessel numbers would create a higher potential for cumulative effects of in-air noise (e.g., chick predation), behavioural changes (i.e., disturbance and habitat avoidance) and mortality risk (e.g., collisions of adults with vessels). This could result in effects on the health and fitness of seabirds and increased energy demands.

Together, these effects have the potential to be long-term in duration and cumulatively affect greater numbers than activities and development in the Beaufort Sea. This reflects the number and frequency of oil tankers and other vessels on the west route, as well as the greater concentration of vessel movements in the major channels to the east. Within the waterways to the east, effects are expected to be multiple and irregular events of short duration (i.e., each transit). For the Beaufort Sea and the west route, effects would also be multiple and irregular events, dispersed over a large area and short duration. Effects could overlap important seabird areas, and are predicted to be moderate to high, depending on the volume and frequency of ship traffic. As noted in Section D.2.4.5.2, environmental management and protection measures should be developed for use of the routes to the east (inbound or outbound). Similar measures should also be applied for transits along the western route and in the Beaufort Sea.

With the application of mitigation measures, these activities are not expected to affect the viability of seabird populations in the region under this scenario. However, current information of population numbers and colony sizes within the BRSEA Study Area is required to confirm this assessment.

D.3.4.6 Scenario 5: Large Oil Release Event

While the Large Oil Release Event is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels. If the fuel tanks for these vessels were affected (e.g., punctured during a collision), large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on seabirds from such an event may differ slightly from what is described below for surface or subsea releases.

D.3.4.6.1 POTENTIAL IMPACTS AND EFFECTS OF A LARGE OIL RELEASE

DESCRIPTION OF EFFECT PATHWAY

Seabirds are highly vulnerable to oiling because they spend most of their life cycle at sea and can use large areas and depths of the water column when traveling or feeding (Wiese et al. 2004a; Wiese et al. 2004b). In addition, seabirds that tend to raft together in flocks on the sea surface (all seabird indicators) or can dive to the seafloor (murres and eiders) have increased potential for oiling and toxicity from direct contact and ingestion (preening plumage) or indirectly through ingestion of contaminated prey (Wiese and Ryan 2003).

At smaller spatial scales, birds could be attracted to surface slicks since they resemble oceanographic fronts that can aggregate prey (Haney et al. 2014). Some seabirds may avoid small spills (Lorentsen and Anker-Nilssen 1993), however there is no consistent evidence for spill avoidance behaviour (French McCay and Rowe 2004) and it is unlikely to be a major factor in reducing effects on seabirds from a large oil release event (Haney et al. 2014).

Shortly after the breeding season, diving birds (murres and eiders) lose their wing feathers at once, leading to a period of temporary flightlessness (Gaston and Jones 1998; Goudie et al. 2000; Bridge 2004; Guillemette et al. 2007). In the event of an oil spill, moulting flightless seabirds could be trapped within the affected zone, particularly eiders, that concentrate in large numbers in staging areas.

Toxic hydrocarbons (e.g., PAHs) contained in crude oil droplets can be transported to the ocean floor by phytoplankton and zooplankton and be passed on throughout the food web. Released hydrocarbons can quickly move through the water column and food web, increasing the potential for toxicity of prey and top predators such as seabirds. Episodic abundance of phytoplankton can cause sinking of oil residuals and have long-term residual effects in the ocean seafloor around the spill site (Yan et al. 2016). Ocean floor contamination through direct sub-sea release or transport by lower trophic level organisms from the sea surface would particularly affect seabirds such as murres and eiders that can feed on benthic prey. Given the slow rate that PAHs dissolve in the ocean (Dilkes-Hoffman et al. 2019), the accumulation of PAHs could have long term effects on seabirds and potentially affect population viability. Because bivalves tend to concentrate PAHs (Meador et al. 1995; Oros and Ross 2005), eiders could experience greater effects on health due to the ingestion of contaminated bivalve prey.

Given the seasonal distributions of seabirds in the BRSEA Study Area, they would be directly affected by oil spills occurring during the Open Water and the Spring Transition seasons, and indirectly by oil releases during the Fall Transition and Ice seasons. Given seasonal distributions and movements, coastal seabirds, such as gulls and eiders, would be more affected by oil spills inside the plume. In contrast, murres would be more affected by oil spills offshore. All seabird indicators would be vulnerable to oil spills from tankers. The ecology and life-history of each seabird indicator would influence the extent of effects on their health, fitness and the mortality risk (see below).

Description of Range of Potential Effects

Direct mortality could occur through seabird encounters with crude oil floating on the water's surface through suffocation (e.g., excessive fouling), hypothermia, toxic effects of ingestion and starvation. Crude oil disrupts feather integrity, displacing insulating air between feathers, leading to loss of waterproofing, thermal insulation and buoyancy. Birds become unable to dive or fly so they cannot forage to feed. Fat reserves are depleted quickly and, ultimately, birds become severely hypothermic and emaciated, causing death (Piatt et al. 1990; Jenssen 1994). This is a particular concern for the BRSEA Study Area given the cold conditions in the Beaufort Sea.

Small amounts of oil from sheens has also been shown to affect the structure and function of seabird feathers (O'Hara and Morandin 2010), which can cause a heightened metabolic rate (increased energy expenditure), as well as behavioural changes such as increased time spent preening at the expense of foraging and breeding (Morandin and O’Hara 2016).

In the Beaufort Sea, oil contaminated leads, open water and melt-ponds appear to attract diving birds if the oil is of a sufficient quantity to calm the water surface (Milne and Smiley 1976). Although most evidence suggests that seabirds are attracted to oil spills, some birds may avoid oil spills (Lorentsen and Anker-Nilssen 1993); however, such avoidance could have residual effects on seabird health as a result of increased energy expenditure due to shifts in foraging ranges.

Oil can be dispersed over the body by preening and transported to the nest site, eggs and chicks (Lewis and Malecki 1984. Chicks and eggs are most susceptible to the negative effects of exposure to oil (even at low levels) (Morandin and O’Hara 2016). Chicks can be exposed to toxins by ingestion of contaminated prey that adults either regurgitate (gulls) or deliver whole (murres).

The potential effects on seabirds of a hypothetical large oil release event in the BRSEA Study Area would depend on the location of the spill in (i.e., within or outside the Mackenzie River plume), the timing of the spill (i.e., oceanographic season), wind and current conditions, and whether the release is at the surface or sub-surface. These factors, in combination with the ecology and life history of seabirds (including their conservation status and location of key nesting and moulting areas) would determine how an oil spill could affect seabirds.

An oil release during the Open Water Season would have the greatest effect on seabird populations due to the large footprint of the slick (e.g., the surface slick could expand easily), and density of birds present in the BRSEA Study Area.

During the Ice Season, oil that remains in or under the ice and in leads and brine channels could have effects on seabird health indirectly though habitat and prey alteration (abundance, quality), and the release of oil from melting of the ice during the following Spring Transition Season and formation of surface slicks.

An oil spill during the Spring Transition Season could have a severe effect on seabirds that move in groups numbering in the tens of thousands along the continental shelf of the southeastern Beaufort Sea. The leads along the edge of the landfast ice are particularly important for eiders and long-tailed ducks, comprising as much as 90% of the entire offshore bird migrant populations, for resting and feeding on the benthic and nektonic fishes and invertebrates found in shallow continental shelf waters (Milne and Smiley 1976). Both the sub-sea and surface release of oil on the continental shelf where many important staging areas are found for eiders (Figure 7-48) could have a severe effect on the viability of the regional population, which is currently in decline (e.g., PCCP 2016:137; OCCP 2016:127). In addition, an oil spill affecting seasonal productivity of prey within the BRSEA Study Area during the spring could influence food availability for seabirds and effects on breeding, moulting and survival overwinter.

If a surface release of oil was to occur from platforms or tankers within the Mackenzie plume during the Open Water Season, much of the oil would remain in coastal and nearshore areas (Table 3-12 and Table 3-13). Nesting seabirds (mainly eiders and gulls) foraging in these areas would have a high potential for mortality and health effects (i.e., accumulation of PAHs). Adult and chicks that use the coastline as a corridor during the at-sea chick care period (gulls and murres; Section 7.3.4) could be directly affected. If oil is carried inshore, particularly with a storm surge, it could eliminate a major portion of the annual production of young and pollute nesting sites for successive years. Chronic damage to vital nesting areas would substantially delay the recovery of bird populations following mortality from offshore spills (Milne and Smiley 1976).

A sub-sea release of oil during the Open Water Season or a surface release from a GBS or tanker incident outside the plume could have a severe and long term effects on seabirds, including high risks of mortality, and effects on habitat, health and behaviour. The sub-sea release would affect mainly diving seabirds because of their foraging ecology but could also affect surface feeders through ingestion of contaminated prey and the eventual formation of a surface slick. A surface release from a tanker or GBS could have severe effects on the viability of seabirds. Of note, if an oil spill were to occur near Cape Parry (e.g., tankers transit through Amundsen-Queen Maude Gulf) or if a slick was carried in proximity to Cape Parry, it could have severe and irreversible effects on the small thick-billed murre population (approx. 800 individuals).

By the end of the breeding season, birds seek protection in coastal waters during the moulting and fall migration period. Given that diving seabirds (murres and eiders) are flightless for several weeks during moult, they are highly vulnerable to effects of oil spill exposure. Although the fall migration is more staggered for eiders than the spring migration, their staging areas for moulting (Dickson and Smith 2013) could overlap with oil spills affecting coastal areas. Fall migration routes for murres, gulls and eiders are unknown.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

While specific effects of climate change on seabirds are not known, changes in the seasonal timing and extent of ice melt and open water, as well as ocean currents are expected to change the spatial and temporal distribution of pelagic and benthic organisms and fish that are the primary prey species for seabirds. Changes in coastal and marine habitats for seabirds could also affect foraging success, daily and seasonal movements, breeding and the development of energy reserves to support migration and overwintering. These stresses on seabirds would be exacerbated by effects from a large oil release.

Predicted changes in weather due to climate change would potentially extend the impact of oil spills in the region. For example, storm surges may disperse oil, increasing the footprint of the spill inside or outside the Mackenzie River plume. If oil is carried onshore in concert with a storm surge, it could eliminate a major portion of the annual production of young but also could pollute nesting sites in successive years.

D.3.4.6.2 MITIGATION AND MANAGEMENT

Mitigation measures and standard operational procedures associated with the protection of wildlife from potential oil spills are discussed in Sections 2.13 and 3.10.5.3.

D.3.4.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Seabirds are vulnerable to oil spills because they spend a large portion of their time on the surface where oil accumulates, their feather integrity is vulnerable to oil, they range widely, and adult mortality has a strong effect on populations. Hundreds of thousands of seabirds can die during large oil spills (Peterson et al. 2003; Haney et al. 2014). Given the relatively small population size of seabirds breeding in the Beaufort region, a large oil spill would likely have a severe effect on local and regional populations. This is a special concern for the Pacific common eider population, currently in decline within the BRSEA Study Area (e.g., PCCP 2016:137; OCCP 2016:127), and thick-billed murres, given their small and localized population near Cape Parry (the only breeding colony for the western Arctic population) (Latour et al. 2008).

Although interactions with oil sheens are irregular events, they could affect the small seabird populations of thick-billed murres and black guillemots within the BRSEA Study Area.

Residual toxicity effects on seabird populations can have a long-term effect on health, fitness and, ultimately, bird population numbers, particularly when spill response and cleanup measures are delayed, or not properly undertaken. For example, decades after the Exxon Valdez oil spill, the persistence of toxic subsurface oil and chronic exposures, even at sublethal levels, continued to affect wildlife in Prince William Sound, Alaska (Peterson et al. 2003). Barros et al. (2014) found that the numbers of chicks raised by breeding pairs of European shags, which are benthic feeders, were reduced in the ten years following the Prestige oil spill.

The chronic effects from other human activities and stressors from climate change could make seabirds more vulnerable to oil spill impacts (Wiese et al. 2004a). The recovery potential of a population can be weakened by other forms of pollution, hunting, fisheries or disturbance (e.g., commercial shipping, aircraft). If a large oil release event was to occur in the same location as these other events or during the same season, much greater and potentially long-term effects on seabird populations could result.

In the event of an oil spill, seabird populations may not be able to recover from extensive adult mortality, which could affect their viability at local and regional scales. Given the sensitivity of seabirds to oil releases, prevention of such releases must be a priority for offshore oil and gas development. If a large release was to occur, a rapid, well planned and well executed response is essential to help reduce potential adverse effects on seabirds.

D.3.4.7 Summary of Residual Effects

A summary of the effects of activities related to scenarios 1-4 on the three seabird indicators (Thick-billed Murre, Pacific Common Eider and Sabines' Gull) is provided in Table D-38. A summary of effects from a large oil release event is provided in Table D-39. Some effects are species-specific (murres, eiders, gulls) but others apply to seabirds in general.

D.3.4.8 Gaps and Recommendations

The following information would improve our understanding on the extent of overlap between the seabird indicators and the potential activities described under the different scenarios:

- update 1990s information on the location, status and population number of seabirds nesting in the study region
- determine the foraging ranges, diets and migration routes of Thick-billed Murres and Sabine's Gulls in the study region. Portions of the assessment for murres in this study were based on data published from eastern Canada colonies. These same information needs should be included in the Community Conservation Plans for the ISR Communities.
- develop an Inuvialuit baseline data collection program using information from harvested eiders (body condition), and TLK to identify observation points for annual birds counts during migration
- compile TLK and western scientific data for seabirds in advance of the start of development in a habitat area to provide an appropriate baseline
- collect baseline data on contaminant levels within species harvested by Inuvialuit (fish, invertebrates such as mussels) and eggs

Table D-38 Potential Residual Effects of Scenarios 1 – 4 on Seabirds

Season	Scenario 1: Status Quo	Scenario 2: Natural Gas Export Mid- Water	Scenario 3: Oil Development in Mid-Water	Scenario 4 Oil Development in Deep Water
Ice	• No overlap • Seabirds likely to be absent during the Ice Season.	• Minimal overlap • Seabirds likely to be absent during the Ice Season. Possible indirect localized effect on seabird health due to prey reduction could carry on into the following seasons.	• Minimal overlap • Seabirds likely to be absent during the Ice Season. Possible indirect localized effect on seabird health due to prey reduction could carry on into the following seasons.	• Minimal overlap • Seabirds likely to be absent during the Ice Season. Possible indirect localized effect on seabird health due to prey reduction could carry on into the following seasons.
Spring Transition	• Low to moderate (eiders) • Mortality risk due to collisions (wind farms) and residual effects on seabird health due increased energy expenditure from habitat disturbance (shipping, aircraft).	• Moderate overlap. • Mortality risk due to collisions during migration (GBS platform, vessels) and residual effects on health due increased energy expenditure from habitat disturbance (tankers, helicopters).	• Moderate to high (eiders) • Mortality risk due to collisions (GBS platform, vessels) and residual effects on health due increased energy expenditure from habitat disturbance (tankers, helicopters).	• Moderate overlap. • Potential for murre and gull mortality due to collisions (FPSO platform) and residual effects on health due increased energy expenditure from habitat disturbance (seismic surveys, helicopters).
Open Water	• Low to moderate (eiders) • Mortality risk due to collisions (wind farms) and residual effects on seabird health due increased energy expenditure from habitat disturbance (shipping, aircrafts). • Ship transits to east a concern	• Moderate overlap. • Mortality risk due to collisions (GBS platform, vessels) and residual effects on health due increased energy expenditure from habitat disturbance (tankers, helicopters).	• Moderate to high (eiders) • Mortality risk due to collisions (GBS platform) and residual effects on health due increased energy expenditure from habitat disturbance (seismic surveys, helicopters).	• Direct overlap (murres) • Mortality risk due to collisions (FPSO platform) and chick predation (helicopters). Residual effects on health due increased energy expenditure from habitat disturbance (dual-tanker transit, seismic surveys) • Tanker transits to east a concern

Table D-38 Potential Residual Effects of Scenarios 1 – 4 on Seabirds

Season	Scenario 1: Status Quo	Scenario 2: Natural Gas Export Mid- Water	Scenario 3: Oil Development in Mid-Water	Scenario 4 Oil Development in Deep Water
Fall Transition	• Low overlap • Mortality risk due to collisions (wind farms) and residual effects on seabird health due increased energy expenditure from habitat disturbance (shipping, aircrafts). • Ship transits to east a concern	• Moderate overlap. • Mortality risk due to collisions (GBS platform) and at-sea vessel interactions (flightless chicks and adults). Increased energy expenditure from habitat disturbance (tankers, helicopters).	• Moderate overlap • Mortality risk due to collisions (GBS platform) and at-sea vessel interactions (flightless chicks and adults). Increased energy expenditure from habitat disturbance (tankers, helicopters).	• Moderate overlap. • Potential for murre and gull mortality due to collisions (FPSO platform) and residual effects on health due increased energy expenditure from habitat disturbance (seismic surveys, helicopters). • Late season tanker transits to east a concern
Legend				
• Least effect – No to minor effect on seabird habitat, behaviour, and/or mortality risk				
• Moderate effect -- Moderate effect on seabird habitat, behaviour, and/or mortality risk				
• High effect -- Major effect on seabird habitat, behaviour, and/or mortality risk				
• Greatest effect – Severe effect on seabird habitat, behaviour, and/or mortality risk				

Table D-39 Potential Effects of a Large Oil Release Event (Scenario 5) for Seabirds

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume) (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• Oil could remain in and under the ice, in leads and brine channels • Could affect prey species abundance and quality affecting seabird health and fitness.	• Oil could remain in and under the ice, in leads and brine channels. • Could affect prey species abundance and quality affecting seabird health and fitness through ingestion of contaminated prey (e.g., eiders-bivalves).	• Oil could remain in and under the ice, in leads and brine channels • Could affect prey species abundance and quality affecting seabird health and fitness through ingestion of contaminated prey.
Spring Transition	• Oil in broken ice/open water could cause seabird mortality by direct oil exposure (starvation, hypothermia), ingestion of contaminated prey, or failure to find food in preparation for breeding.	• Oil in leads could cause eider and murre mortality by direct oil exposure (starvation, hypothermia), ingestion of contaminated benthic prey, or failure to find food in preparation for breeding.	• Oil in broken ice/open water could cause seabird mortality by direct oil exposure (starvation, hypothermia), ingestion of contaminated prey, or failure to find food in preparation for breeding.
Open Water	• Direct overlap with seabird habitat could lead to direct mortality of gulls, murres (adult and chick) and moulting eiders (males) due to oiling (starvation, hypothermia) and toxicity (contaminated prey).	• Direct overlap with seabird habitat could lead to mortality (adult and chick) due to oiling (starvation, hypothermia) and toxicity (contaminated benthic prey eaten by eiders or delivered to murre chicks).	• Direct overlap with seabird habitat (foraging, staging) could lead to mortality (adult and chick) due to oiling (starvation and hypothermia) and toxicity (contaminated prey).
Fall Transition	• Oil in broken ice/open water could cause seabird mortality by direct oil exposure (starvation, hypothermia), ingestion of contaminated prey, or failure to find food critical for survival overwinter.	• Oil in broken ice/open water could cause seabird mortality by direct oil exposure (starvation, hypothermia), ingestion of contaminated prey, or failure to find food critical for survival overwinter.	• Oil in broken ice/open water could cause seabird mortality by direct oil exposure (starvation, hypothermia), ingestion of contaminated prey, or failure to find food critical for survival overwinter.

Legend
• Least effect – No to minor effect on seabird habitat, behaviour, and/or mortality risk
• Moderate effect -- Moderate effect on seabird habitat, behaviour, and/or mortality risk
• High effect -- Major effect on seabird habitat, behaviour, and/or mortality risk
• Greatest effect – Severe effect on seabird habitat, behaviour, and/or mortality risk

D.3.4.9 Follow-up and Monitoring

As noted in Section D.3.3.9 for migratory birds, similar monitoring programs should be developed for seabirds and include:

- monitor seabird interactions with low-level aircrafts, helicopters, and vessels currently in use within the BRSEA Study Area. The following data should be collected:
  - *aircraft disturbance (in-situ observations)*: Counts of birds that are flushed, time to resume nesting activities, number of eggs/young lost.
  - *vessel disturbance (wildlife monitors*): Species, number of birds, behaviour, type of interaction if any, weather conditions, season, flight direction. Data about vessel (type, speed, direction).

Should oil and gas development proceed in the BRSEA Study Area, the monitoring programs should include:

- use of TLK and inclusion of Inuvialuit people in the planning and conduct of monitoring programs to fill data gaps of knowledge and develop adaptive management approaches
- identify areas with a high potential for bird collision marine structures using radar technology
- monitor bird responses to selective removal of light pollution
- use of tracking technology for seabirds to model habitat use and residency time within an area (Wakefield et al. 2009) to inform assessment of routine activities and potential large oil release events, and planning and implementation of spill responses (Montevecchi et al. 2012)

The following are concerns and recommendations from Inuvialuit residents to be considered for planning and implementation of project activities:

- Concern about change in migration routes and gap of knowledge on the effect of seismic activities on wildlife. "You mentioned the physical effects of seismic on marine mammals, fish and birds and the stuff that whales feed on, are there any studies on whether seismic scares away the feed for the whales when it is conducted in feeding zones or migration routes? Would whales change their migration route because their feed has been scared away? This is why we're hesitant to support work because there are so many unknowns" (KAVIK-AXYS Inc. 2009:10-6).
- Companies need to clean up their sites after they are done working: "…used to leave lots of garbage in the areas where they drilled and they had to let us people go out there and clean for them". "They can't be burying stuff [any]more; everything has to be hauled out," even the small garbage (KAVIK-AXYS Inc. 2004c: 4-5, 4-8). (While this is in reference to land-based activities, this has application to offshore activities.
- Tuktoyaktuk residents are concerned about the effects of a potential well blow-out or oil spill. They rely on marine animals for food and believe that, if there were a spill, it would have a large impact on their community due to ocean currents and the effects on the animals they harvest. "Anything man-made is going to break." People need to be convinced that the water and land are not going to be harmed prior to any drilling work (IMG Golder and Golder Associates 2011e: 13). They assert that even small spills can have an effect on wildlife as associated contaminants "goes through their whole system" (KAVIK-AXYS Inc. 2004c: 4-4, 4-5).

- Inuvik residents were comfortable with offshore drilling activity in the winter, but do not wish to see any activity during the harvesting season that could interfere with habitat areas or migration routes (KAVIK-AXYS Inc. 2004b: 4-1).
- Pollution and contamination are important concerns for Inuvialuit "Don't contaminate our land, our whales, or our water." (Devon Canada Corporation 2004b: 18-30, 18-31). "Who monitors ballast and bilge water? "Are you using environmental and wildlife monitors on the vessels?" "Will you have environmental monitors on board 24-7?" (KAVIK-AXYS Inc. 2009: 10-7).
- Aklavik TLK holders generally welcome industrial activity, providing that there are minimal impacts to their land resources and that local Aboriginal people are regularly informed and consulted (Devon Canada Corporation 2004b: 18-35).

D.3.5 Marine Mammals

D.3.5.1 Scoping

D.3.5.1.1 IDENTIFICATION OF INDICATORS

The selection of indicators for the marine mammal VC considers variations in spatial and seasonal use of habitat by the most common species in the BRSEA Study Area. All species of marine mammal hold cultural value to the Inuvialuit and are traditionally harvested. The following species were selected as indicators:

- beluga whale are associated primarily with shallow water habitat along the shelf and congregate in the Mackenzie estuary in the Open Water Season
- bowhead whale are residents during the Open Water Season and feed in the deeper waters of the Beaufort Sea and Amundsen Gulf
- ice seals (bearded and ringed seals) are year-round residents and are closely associated with the sea ice

D.3.5.1.2 SPATIAL BOUNDARIES

As described in Section 7.3.6, marine mammals are dependent on marine habitat throughout the BRSEA Study Area. Species-specific use and seasonal timing of use of habitat is considered in the characterization of potential effects. Given predicted impacts of climate change on marine mammals in the region, uncertainty in how that may alter habitat use, and the anticipated increase in human use and development in higher latitudes, the spatial boundary for marine mammals is the entire BRSEA Study Area (Figure 1-1) to capture potential present and future impacts throughout the marine waters of the ISR.

D.3.5.1.3 TEMPORAL BOUNDARIES

The assessment of potential effects on marine mammals encompasses a 30-year period between 2020 – 2050.

D.3.5.1.4 ASSESSMENT OF POTENTIAL EFFECTS

The assessment of potential effects on marine mammals considers residual effects on the population, not on individuals. Based on the established spatial boundaries and the distribution of marine mammal species in the BRSEA Study Area, the discussion and characterization of effects would be assessed in the context of the Eastern Beaufort Sea population of beluga whale, the Bering-Chukchi-Beaufort population of bowhead whale, and bearded and ringed seals, both of which have a circumpolar distribution. Qualitative characterization of potential residual effects on marine mammals associated with each scenario is based on the characterization terms defined in Table D-40.

Table D-40 Characterization of Residual Environmental Effects on Marine Mammals for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect on the VC	**Positive**—a net benefit to the health, mortality or habitat or behaviour **Adverse**—a reduction or influence on the health, mortality, habitat or behaviour that could result in a change in the status or resiliency of the marine mammal population **Neutral**—no net change in the viability, status or resiliency of the marine mammal population
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no measurable change in health, mortality, habitat or behaviour **Low**—a measurable change in the status or resiliency of the marine mammal population, but would not affect the long-term sustainability of the marine mammal population **Moderate**—measurable change in the status or resiliency of the marine mammal population, with potential to affect the long-term sustainability of the marine mammal population **High**—measurable change with relative certainty of affecting the long-term sustainability of the marine mammal population
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the local area around the activity **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area) **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area)
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity **Continuous**—residual effect occurs continuously for the duration of the activity

Table D-40 Characterization of Residual Environmental Effects on Marine Mammals for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to one phase or season (e.g., seismic survey, exploration drilling) **Medium-term**—residual effect extends through multiple seasons or years (e.g., production phase) **Long-term**—residual effect extends beyond the life of the project (e.g., beyond closure) **Permanent**—measurable parameter unlikely to recover to existing conditions
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.3.5.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

Potential effects on marine mammals are primarily linked to impacts of underwater noise associated with seismic exploration, dredging and preparation of subsea areas for infrastructure, vessels, drilling and icebreakers. Ice disturbance could result in potential effects on sea ice habitat that seals use for breathing holes and birthing lairs or, alternatively, enhance feeding opportunities for seals by creating localized pockets of unconsolidated ice that attract prey species. Increased large vessel activity in the area could lead to collisions with marine mammals and associated injury or death. Types of potential effects on marine mammals that could occur from routine activities associated with Scenarios 1 to 4 are discussed below. A summary of potential effects of a large oil release event on marine mammals is provided in Section D.3.5.6. As discussed below, interactions between marine mammals and scenario elements or activities, such as artificial light and routine discharges, are possible but, with standard mitigations in place, effects are expected to be negligible.

TLK holders explained that boat activity on the water is the single largest disturbance to whales, and that whales often do not return for several days after being disturbed by boat activity in Tuktoyaktuk Harbour (IMG Golder and Golder Associates 2011e: 9). They also stated that they believe that noise from project construction and boats in the travel corridor initially drive away the whales and seals, but that the mammals can become habituated to the noise and eventually return (IMG Golder and Golder Associates 2011e: 13).

Whales and seals have been observed to exhibit a startle response to low flying aircraft in direct proximity (Born et al. 1999). During the flights to and from land-based service and supply bases, helicopters for crew transport would only be taking off and landing from the service and supply bases and the vessel or platform associated with the development. Although this activity could startle animals in the immediate vicinity of the bases, platforms or vessels and cause them to leave the area, the potential effect would be limited to a temporary stress response and abandonment of the immediate area around the vessel or platform. Helicopters used for ice reconnaissance or other project related activity would be required to maintain appropriate elevations to reduce potential effects on wildlife inhabiting sea ice or open water habitat; specifically, helicopters (and other aircraft) are required to flying at altitudes greater 300 m to 400 m depending on the area and season (EIRB 2011, Appendix F). As potential effects of in-air noise from aircraft on marine mammals are expected to be negligible, they are not discussed further.

As benthic feeders, bearded seals may be indirectly affected if there are measurable effects anticipated for benthic populations. As discussed in Section D.3.1, potential effects of activities that result in disturbances to seabed habitats (e.g., dredging, site preparation for GBS, subsea pipelines) on benthic macrofauna are expected to be limited and would likely not affect the quality or quantity of prey available to bearded seals on a local or regional scale. Potential effects of seabed disturbance on marine mammals are not discussed further.

Routine discharges have the potential to affect benthic habitat and water quality and result in effects on lower trophic levels that are closely associated with these habitats. Top-level predators (e.g., marine mammals) that prey on these species can bioaccumulate contaminants resulting in effects on health. Given the restrictions imposed on routine discharges through the *Arctic Waters Pollution Prevention Act*, associated regulations, and standard best practices (Section 2.4), the potential for marine mammals to be affected by routine discharges is expected to be negligible and are not discussed further.

Effects on bowhead whale would be limited to the Spring and Fall Transition seasons (migration) and during the Open Water Season while they are utilizing feeding habitat in the Southern Beaufort Sea and Amundsen Gulf. Since this species is not present in the BRSEA Study Area during the Ice Season, potential effects on bowhead whale during the Ice Season are not discussed further.

Effects on beluga whales would be most prevalent during the Open Water Season and Spring Transition Season during ice breakup and to a lesser extent during the Fall Transition Season as they migrate out of the region. The Beaufort population is concentrated in the Mackenzie estuary in June/July, which coincides with the annual harvest. Beluga have been shown to forage at the seabed along the continental slope. However, given their association with the Mackenzie estuary and their tendency to utilize shallow water habitat as they migrate, they may be more susceptible to nearshore (continental shelf) disturbances than to disturbances that occur further offshore in the deeper waters of the continental slope. Since beluga whale are not present in the BRSEA Study Area during the Ice Season, potential effects on beluga whale during the Ice Season are not discussed further.

Seals are distributed throughout the BRSEA Study Area, often closely associated with sea ice. Although their distribution shifts throughout the year, interactions between seals and human activities would occur throughout their range (nearshore, continental shelf, and continental slope) year-round.

The relationship between human activities, interactions, impacts and potential effects are summarized in Table D-41. Although activities and associated impacts are similar across the Status Quo and the three oil and gas development scenarios, potential effects of each scenario are discussed independently to identify specific interactions that may result from the variation in timing, spatial extent, or geographic location that is assumed for each scenario.

Table D-41 Summary of Potential Impacts and Effects on Marine Mammals

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Noise (in-air and underwater)	• vessel transits (engine, propeller, and ice-breaking activities) • seismic surveys • drilling • dredging and sea bottom preparation • operational and maintenance activities on vessels, production platform, and wells • helicopters, low flying aircraft, and snowmobiles	• injury or disturbance from underwater noise produced by seismic air guns • behavioural disturbance or masking of whale vocalization resulting from vessel activity • startle response (e.g., abandoning haul out site) or avoidance of area by seals subjected to ambient noise from helicopters or low-flying aircraft	• change in behaviour • change in health	• change in population size • zone of influence for sensory disturbance and overlap with key habitat • Body Condition Index
Artificial Light	• lighting used on nearshore infrastructure (wind turbines, marine infrastructure), offshore platforms and vessels	• attraction of prey species (e.g., fish, plankton) to artificially lit structures could attract whales and seals, resulting in potential shift in habitat use.	• potential localized effects on individual animals are possible but with mitigation in place (e.g., light management), potential residual effects on behaviour, health, and habitat are expected to be negligible in magnitude • **further assessment of this impact is not warranted**	• NA
Seabed Disturbance	• subsea well, manifold, and pipeline installations and repairs	• effects of underwater noise associated with these activities are addressed above.	• **further assessment of this impact is not warranted**	• NA

Table D-41 Summary of Potential Impacts and Effects on Marine Mammals

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Ice Disturbance	• icebreakers transiting through sea ice (ice management, support, transport) • presence of structures on/in sea ice or open water (drillships, platforms, wind turbines	• habitat alteration due to physically breaking up sea ice • effects on prey source from alteration of sea ice habitat resulting in shifts in availability or quality of food for whales and seals • disturbance of seal birthing lairs and breathing holes • attraction of prey species (e.g., fish and plankton) to unconsolidated ice, attraction of whales and seals to exploit abundant food source • attraction of predator species (i.e., polar bear) to human structures results in increased potential for seal and whale mortality	• change in behaviour • change in health • change in mortality risk • change in habitat	• areal extent of habitat altered or lost (m^2) relative that available • change in population size • change in distribution or availability of prey species • zone of influence for sensory disturbance and overlap with key habitat • Body Condition Index
Routine Discharges	• air emissions • bilge and ballast water • drilling muds and lubricating fluids • drill cuttings and disposal • sewage and food waste • cooling water and deck drainage	• effects on prey source resulting in shifts in availability or quality of food for whales or seals	• potential residual effects on individual animals are possible but with mitigation in place, potential residual effects on behaviour, health, mortality risk, and habitat are expected to be negligible in magnitude • **further assessment of this impact is not warranted**	• NA

Table D-41 Summary of Potential Impacts and Effects on Marine Mammals

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Vessel Collision	• vessel transits (shipping, tankers, icebreakers, personal watercraft)	• impact with vessel or propeller	• change in mortality risk	• estimated change in rate of mortality or injury (e.g., evidence of injury or mortality)
Oil Spill	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• effects on prey source resulting in shifts in availability or quality of food for whales and seals • ingestion of oil through oil fouled prey or self-grooming oil fouled fur (i.e., seals) • disturbance of seal birthing lairs or breathing holes • inhalation of vapours • avoidance or attraction to oiled habitat and zone of increased human activity associated with clean up response	• Change in behaviour • change in health • change in mortality risk • change in habitat	• areal extent of habitat altered or lost (m^2) relative that available • change in population size • likelihood that sensory disturbance would disrupt localized movement corridors or patterns, or result in avoidance of preferred habitat • estimated change in rate of mortality or injury • modelled or observed estimate of change in prey quality, etc. • Body Condition Index

POTENTIAL EFFECTS OF UNDERWATER NOISE

Underwater noise has the potential to mask vocalizations (e.g., changes in communication space), change behaviour or cause injury to species exposed to it (Ellison et al. 2016; Richardson and Würsig 1997; Southall et al. 2007). Primary sources of underwater noise considered for the assessment of effects on marine mammals in the BRSEA Study Area are vessels (including icebreakers), dredging and sea bottom preparation for installation of infrastructure, seismic surveys, and drilling.

Impacts of underwater noise on bowhead and beluga whales are of primary concern during the Open Water Season when they are calving or feeding in the region. TLK holder commented that "Whale activity seems to be less, because of boat activities at the mouth of the river, they tend to go out right away into the deep water. If there are much activities the whales go way out and beluga hunters don't go way out to hunt" (ICC et al. 2006: 11-4 - 11-5). Bowhead and beluga whales may be affected to a lesser extent during the Spring and Fall Transition seasons when they are migrating into and out of the region. Seals would be subject to effects of underwater noise year-round since they are present in the BRSEA Study Area year-round.

Underwater noise levels in the BRSEA Study Area are anticipated to be highest during the Open Water Season since most vessels and seismic surveys are limited to operating in open water conditions. Underwater noise produced by icebreakers would be largely limited to the Spring and Fall Transition seasons in Scenario 1 and the Fall Transition, Ice and Spring Transition seasons for Scenarios 2 to 4. Other sources of anthropogenic underwater noise produced during the Ice Season would be associated with underwater drilling and noise transferred from on-ice activity (e.g., snowmobiles).

Potential effects on marine mammals depend on the time of year, intensity and duration of the noise, distance from the sound source, the ability for the animals to hear the noise (i.e., the animal's hearing frequency range), the species in question, its activity during noise exposure, and the novelty of the sound (Blackwell et al. 2013; Blackwell et al. 2015; Harwood et al. 2010). Typically, the levels of underwater noise produced during 2D and 3D seismic surveys, vessel and icebreaker transit, and exploration and production drilling exceed the National Oceanic and Atmospheric Administration (NOAA) recommended thresholds for behavioural change (i.e., 160 dB root mean square SPL (SPL rms) for impulsive sources and 120 dB SPL rms for continuous sources) (National Marine Fisheries Service 2018) at varying distances from the source.

Potential unmitigated effects of underwater noise associated with seismic surveys can range from injury or mortality of animals that are in direct proximity to the source, to changes in behaviour if they are further away from the source but still within the zone of elevated sound levels around the source (Southall et al. 2007). Bowhead whale have been shown to change calling rates, avoid areas where airguns are in use, and alter surface and diving behaviour (Blackwell et al. 2013; Blackwell et al. 2015; Harwood et al. 2010). Bowhead whales that form aggregations in productive feeding habitat may not be deterred by elevated noise levels, subjecting them to potential injury (Harwood et al. 2009; Richardson and Greene 1993). Temporary avoidance behaviour by beluga whales during seismic surveys has also been observed (Harwood et al. 2010). Ringed seals present in proximity to seismic surveys have been shown to abandon breathing holes and subnivean lairs, resulting in increased mortality risk, elevated stress levels, and lower survival of pups if they are prematurely excluded from the lair (Kelly et al. 1988). Communication masking as a result of seismic surveys has been noted as possible, depending on distance from the source, for ringed seals (Sills and Reichmuth 2016), bowhead whale, and potentially beluga (Guan et al. 2016).

Noise associated with underwater drilling and vessels (i.e., propeller cavitation) can induce bowhead whales to change calling rates (Blackwell et al. 2017) and alter feeding and surfacing behaviour (Richardson et al. 1990). Beluga whales within 1500 m were observed to respond to the onset of drilling noise playback by changing direction and moving away from the source (Awbrey and Stewart 1983). Ringed seals have shown varied responses, with records of displacement from breathing holes or abandonment of lairs during exploratory drilling activities (Harwood et al. 2010), and no substantial change in abandonment of subnivean lairs when exposed to noise from drilling activity (Harwood et al. 2007; Williams et al. 2006).

As noted earlier, TLK holders identified that boat and other activities on the water is the single largest disturbance to whales and seals (IMG Golder and Golder Associates 2011e: 9), and can initially drive away these species, but that animals become habituated and would eventually return (IMG Golder and Golder Associates 2011e: 13).

Noise produced by icebreakers has been shown to elicit startle response and avoidance behaviour in several marine mammal species including beluga whale and seals (Erbe and Farmer 2000; Finley and Greene 1993). Seals and walrus have also exhibited temporary displacement as a result of icebreaking activity, although such displacement is dependent on distance from the source. Icebreaker noise has also been shown to result in communication masking in beluga whales (e.g., Erbe and Farmer 1998; Erbe and Farmer 2000).

Potential Effects of Ice Disturbance

Icebreakers travelling through sea ice and the presence of offshore platforms during the ice and transition seasons (e.g., gravity-based offshore wind turbines, GBS, FPSO, moored wareships) can alter sea ice habitat for marine mammals, resulting in both positive and adverse effects on behaviour, health and mortality risk. Potential effects of ice disturbance are primarily associated with seals, but beluga and bowhead whales may also exhibit changes in behaviour when sea ice habitat is altered to create artificial leads through pack ice or when prey species are attracted to areas where ice has become unconsolidated.

Ringed seals create and maintain birthing lairs in the sea ice through the winter (Burns 1970; Finley et al. 1983), which may be damaged or abandoned when disturbed by transiting icebreakers. Breathing holes maintained by ringed and bearded seals (Cameron et al. 2010; Kelly et al. 2010a) may also be damaged resulting in abandonment and use of alternative breathing holes.

Damage or abandonment of lairs may result in increased predation by polar bear and arctic fox on ringed seal pups if they are whelped on the sea ice instead of in protective lairs (Kelly et al. 2010b). If birthing lairs are abandoned and newborn pups and mothers are required to move to alternative lairs, increased stress on pups and potential mortality may result from heat loss during the swim to the alternative lair (Kelly et al. 1988). An increase in mortality risk during icebreaking activity may also occur for seal pups if they are separated from their mother during the pup’s dependent period (Wilson et al. 2017).

Whales have been observed following leads in the ice that are created by icebreakers. Travelling through these artificial leads could result in animals getting caught in isolated areas of open water and subsequently trapped by sea ice (Stirling 1980). However, channels opened by a ship typically close quickly enough that this threat is short-term and minimal (Stirling and Calvert 1983). This is less potential for this to affect bowhead whales than beluga whales since bowhead whales have the ability to break through ice up to 60 cm thick and can escape potential entrapment (Finley 2001; George et al. 1989).

Ice-breaking and benthic habitat alterations from marine infrastructure may result in changes in prey distribution and productivity of under-ice and ice edge habitats. The productivity of under ice and ice edge habitats is important for arctic cod (Coad and Reist 2004), which are a key part of the diet of beluga (Richard et al. 1994), and ice-dependent seals (e.g., ringed seal (Yurkowski et al. 2016)). The distributions of seals and polar bear, which predate on them (Sections 7.3.6 and 7.3.7), are often strongly associated with the distribution of productive ice edge habitats (COSEWIC 2008; Kovacs 2016; Moore and Huntington 2008). Changes in benthic or pelagic prey distribution may lead to more energy expenditure in searching for prey, increased stress, and poor body condition (Moore and Huntington 2008). This can potentially result in behavioural changes (e.g., foraging activity) and can increase mortality risk. Ringed seals and bearded seals have been observed hauled out near drill rigs and artificial islands (Harwood et al. 2007; Moulton et al. 2005). The potential for leads to be formed in the lee of an offshore platform may result in increased open water habitat that may be utilized by ringed seals, bearded seals and walrus (Stirling 1988), resulting in changes in behaviour and distribution in the region.

POTENTIAL EFFECTS OF VESSEL COLLISION

The probability of a vessel striking a marine mammal depends on the frequency, speed, and route of the marine vessels, and the distribution and behaviour of marine mammals in the area. The chance of lethal injury to a whale struck by a large vessel is approximately 80% at vessel speeds over 15 kt (27.78 km/hr) and approximately 20% at 8.6 kt (15.92 km/hr (Vanderlaan and Taggart 2007)]). Data analyzed in Alaska waters documented no ship strikes of bearded or ringed seals over a five-year period (Helker et al. 2016). One percent of bowhead whales harvested in Alaska had scars from vessel collisions (George et al. 1994). TLK holders in Tuktoyaktuk stated that “if they are not abused or mistreated, whales and seals are naturally curious and may move too close to the drilling area where there is an increased chance of injury or death due to collisions with boats and other machinery” (IMG Golder and Golder Associates 2011e: 13). Vessel strikes between icebreakers and Caspian seal pups have been documented (Wilson et al. 2017), but a literature search found no records of icebreaker strikes involving the seal species present within the BRSEA Study Area.

D.3.5.2 Scenario 1: Status Quo

D.3.5.2.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

The primary effect pathways for Scenario 1 on marine mammals are associated with underwater noise and habitat disturbance caused by vessel activity (commercial, tourism, sea lift, military, research, harvesting, personal use, icebreakers). The physical presence of offshore GBS platforms associated with offshore wind development could affect seal habitat directly by physically altering sea ice habitat.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

An increase in vessel traffic in the region associated with tourism, personal use, research, or military activity would elevate underwater noise levels and result in adverse effects on marine mammals. Underwater noise produced by vessels can alter behaviour and result in communication masking or shifts in migration or usage of habitat within a limited area around the vessel where underwater noise levels exceed recommended thresholds for change in behaviour or physical injury. Beluga and bowhead whales migrate to the general area of the BRSEA Study Area for the Open Water Season specifically for feeding and moulting (Harwood and Smith 2002). Disturbance or displacement from important habitat can result in loss of food opportunities, and increased energy expenditure to replace that lost food source. This would be particularly detrimental to female and calf pairs. Seals may be disturbed by underwater noise from vessel activity and may be more sensitive to disturbance during pupping and breeding (Erbe et al. 2019).

As discussed above, there is potential for vessels to strike whales, resulting in injury or mortality. A vessel strike is a relatively rare occurrence and could result in injury or mortality; however, effects would be limited to the individual and the population would not be affected by such a low rate of occurrence.

Habitat alteration in the direct vicinity of an offshore platform (i.e., wind turbine) could attract seals that come to utilize suitable sea ice habitat and, in turn, attract polar bears to a concentrated prey source. Increased presence of polar bears around the platform could lead to increased mortality risk for seals from bear predation.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Climate induced changes to marine habitat over the 30-year assessment period are expected to result in a longer duration and a larger geographic extent of open water (Laidre et al. 2015). This shift in the distribution of sea ice and open water habitat is likely to affect marine mammals directly by altering the timing of migration and duration in the BRSEA Study Area by whales, distribution of prey species, and availability of suitable sea ice habitat for breathing holes and birthing lairs (seals). A longer Open Water Season and increased access to the region via the Bering and Chukchi Seas may result in more frequent occurrences of southern species like killer whale, grey whale or humpback whale, introducing more predation pressure and/or competition for food resources. Residents of the BRSEA region have noted how these changes could affect marine populations. TLK holders said that the highway for beluga whales is the open water polynyas, which stay open year round. The polynyas were observed to be moving closer to Banks Island, whereas they used to be further out to sea (IMG Golder and Golder Associates 2011c: 10).

In marine mammal populations that are already vulnerable to climate change, resilience to effects from human activities is likely to be reduced. It is uncertain what the ultimate impact of climate change on marine mammal populations may be, which makes the prediction of potential effects of human activities over such a large temporal scale difficult. In consideration of climate change impacts, prediction of effects on marine mammals over the long term should be made with low confidence. It is also recommended that ongoing research and monitoring of marine mammal populations in the region be undertaken to support robust adaptive management strategies focused on maintaining sustainability.

D.3.5.2.2 Mitigation and Management

General mitigation measures and standard operational procedures associated with the protection of wildlife from human impacts should be employed (e.g., Section 2.4). Measures specific to the protection of marine mammals from human impacts include:

- habitat protection setbacks and timing windows to protect sensitive foraging, migration, pupping, rearing, weaning or birthing lair habitat
- use of existing and common travel routes by vessels and icebreakers where possible and practical
- maintenance of a steady course and safe vessel speed by vessels (e.g., less than 10 knots) whenever possible
- wildlife monitoring program on vessels, icebreakers, and platforms to identify marine mammals in the area and maintain safe operating distance
- long term monitoring programs to collect additional data on population status, habitat use, body condition and response of marine mammals to human and development activities
- development and implementation of co-management strategies that define management goals and objectives and aligns standard marine mammal management policy across multiple marine users in the region (i.e., Beaufort Sea Beluga Management Plan [FJMC 2013])

Additional details are provided in Appendix F.

D.3.5.2.3 Effects Characterization

Residual Effects

Activities associated with Scenario 1 are largely occurring within the Open Water Season and are expected to increase in frequency and seasonal extent over the next 30 years, resulting in increased pressure on marine mammal populations in the BRSEA Study Area. Underwater noise can be audible to some species for many kilometres, but thresholds for change in behaviour and physical injury extend across a smaller radius around the source. Given the types of mitigation and management measures that would be employed (e.g., minimum aircraft altitudes, wildlife monitors, vessel speeds and routes, adherence to regional management plans and guidelines), disturbance from noise, ice disturbance, and vessel strikes are not expected to result in changes that would threaten the long-term viability of marine mammal populations in the region. While effects on marine mammals are expected to be adverse, potential effects are predicted to be low – moderate in magnitude, limited to the local area around the activity (i.e., residual effects extend into the immediate area around the activity) and dispersed. Potential effects would be multiple irregular events with short-term duration and reversible in nature.

Climate change is expected to alter physical and chemical ocean conditions (mainly sea ice, temperature, ocean acidification, and nutrients) which may alter the species composition, productivity, prey, habitats, and distribution and abundance of marine mammals in the Arctic (e.g., Bluhm and Gradinger 2008; Hamilton et al. 2017; Kovacs et al. 2011; Moore and Huntington 2008). With increasing extent and duration of the Open Water Season (Laidre et al. 2015) and thinner ice over the next 30 years, vessel traffic is expected to increase in frequency and seasonal extent . Given the unpredictable nature of how marine mammal populations might respond to impacts of climate change over the 30-year time period, the prediction and characterization of residual effects is made with low confidence. The influence of climate change may alter the prediction of magnitude from moderate to high magnitude, resulting in the potential to affect the long-term sustainability of the population.

CUMULATIVE EFFECTS

Increased intensity, longer duration and geographic overlap of human activities associated with Scenario 1 could increase the probability of exposure of marine mammals to underwater noise events and increase the footprint of the ensonified area around activities that occur simultaneously in space or time. The combined impact on sea ice habitat of multiple activities (e.g., transits of vessels in the mid- to late Spring Transition Season) could result in changes in mortality risk due to the potential of increased birthing lair abandonment by ringed seals (Kelly et al. 1988) and/or a lack of alternative birthing lairs that are not subject to disturbance. Cumulative effects could potentially extend across the region and outside the region, as beluga and bowhead whales spend part of the year outside of the BRSEA Study Area.

As discussed above, the rapid shift in marine mammal habitat quality and availability that is predicted to result from climate change could amplify effects and exert substantially more pressure on ecosystems to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change resulting in high magnitude effects on marine mammal populations.

D.3.5.3 Scenario 2: Export of Natural Gas and Condensates

D.3.5.3.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Vessel activities (tankers and icebreakers) and the physical presence of the GBS platform would affect marine mammal habitat directly by introducing underwater noise and physically altering sea ice habitat. Pathways for underwater noise are similar to those discussed for Scenario 1.

Changes in sea ice habitat (e.g., ice deformation and buildup and associated open water areas) would occur in the vicinity of the GBS platform and associated loading facility for the LNG carriers and condensate tankers, as well as from ice breaking around the platform and during carrier and tanker movements during the Ice Season and the Spring and Fall Transition seasons.

Description of Range of Potential Effects

The range of potential effects from activities associated with Scenario 2 are similar to those discussed above for Scenario 1 (Section D.3.5.2.1). In addition, regular (weekly) transits by LNG carriers and condensate tankers during the Ice Season would create openings in the pack ice during outbound and inbound transits; these long linear ice openings, while not open for long periods, may attract bowhead whales and beluga whales (i.e., bowhead whales have been observed to select leads with thin or slushy ice in the Alaska Beaufort Sea (George et al. 1986)). Whales may follow the open water tracts and become trapped in ice (George et al. 1986). Whales may also be able to reach the BRSEA Study Area earlier in the Spring Transition Season by following a combination of these icebreaker tracts and leads in the ice.

The change in ice habitat and creation of open water areas would result in alteration of seal habitat within a limited radius around the platform, potentially enhancing feeding opportunities. Seals that concentrate in the local area around the GBS to feed could be at increased risk of predation by polar bears.

Effects of Climate Change on Potential Effects

The effects of climate change on potential effects from activities associated with Scenario 2 are anticipated to be similar to those discussed above for Scenario 1.

D.3.5.3.2 Mitigation and Management

Mitigation and management measures described for Scenario 1 would also be applicable to deal with similar effects described for Scenario 2. Additional details are provided in Appendix F.

D.3.5.3.3 Effects Characterization

Residual Effects

With the implementation of mitigation and management measures (e.g., minimum aircraft altitudes, wildlife monitors, reduced vessel speeds and standard routes, and adherence to regional management plans and guidelines), disturbance from noise, ice disturbance, and vessel strikes associated with Scenario 2 are not expected to result in changes that would threaten the long-term viability of marine mammal populations in the region. While effects on marine mammals are expected to be adverse, potential effects are predicted to be low – moderate in magnitude and limited to the local area around the activity. Potential effects of underwater noise and ice disturbance would be multiple regular events, often well dispersed across the BRSEA Study Area, with short-term duration and reversible in nature. Effects of vessel strikes on bowhead whales are predicted to be uncommon (i.e., an accidental event) and long-term duration (i.e., replacement of the individual through recruitment). The number of animals that might be affected each year is not known.

The influence of climate change on the prediction of potential effects of Scenario 2 is expected to be similar to what was described for Scenario 1. Given the unpredictable nature of how marine mammal populations might respond to impacts of climate change over the 30-year time period, the prediction and characterization of residual effects is made with low confidence. The influence of climate change may alter the prediction of magnitude from moderate to high magnitude, resulting in the potential to affect the long-term sustainability of the population.

CUMULATIVE EFFECTS

Activities associated with Scenario 2 in combination with activities discussed in Scenario 1 could increase the probability of exposure of whales and seals to underwater noise events, increase the footprint of the esonified area around activities that occur simultaneously in space or time, and result in a measurable change in quality or availability of sea ice habitat for seals in the region. Potential cumulative effects are expected to be similar to what was described for Scenario 1. Cumulative effects could potentially extend across the region and outside the region since beluga and bowhead whales spend part of the year outside of the BRSEA Study Area.

As discussed above, the rapid shift in marine mammal habitat quality and availability that is predicted with climate change could amplify effects and exert substantially more pressure on marine mammal populations to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change, resulting in higher magnitude effects on marine mammal populations than at present.

D.3.5.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.3.5.4.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Scenario 3 activities or infrastructure that operate year-round or specifically during the Open Water Season (i.e., seismic surveys) would overlap with marine mammal use of habitat.

Vessel activities (tankers and icebreakers) and the physical presence of the GBS and wareship would affect marine mammal habitat directly by introducing underwater noise and physically altering sea ice habitat. As noted for Scenario 2, regular transits of oil tankers during the Ice Season could create short-term openings in the pack ice during outbound and inbound transits which may attract bowhead whales (George et al. 1986) and beluga whales. This may alter movement patterns of these species and present a mortality risk (e.g., whales trapped in ice).

Vessels and icebreakers used as support to the GBS and wareship and dual action tankers used for transport of oil would be a source of underwater noise that could affect beluga and bowhead whales. Changes in sea ice habitat (e.g., ice deformation and buildup, as well as creation of open water areas) from the GBS and associated wareship, as well as ice breaking around the platform and during carrier and tanker movements during the Ice Season and the Spring and Fall Transition seasons would result in alteration of seal habitat within a limited radius around the platform and along the shipping route, potentially enhancing feeding opportunities. Seals that concentrate in the local area around the GBS to feed could be at increased potential for predation by polar bears.

Seismic surveys are assumed to be limited to the Open Water Season and would overlap with summering habitat for bowhead whale, beluga whale and seals. Underwater noise associated with offshore seismic surveys may affect animals directly by altering behaviour or causing injury, or indirectly by affecting prey source populations (e.g., plankton, fish), or by causing disturbance to marine mammals during critical periods (e.g., bowhead feeding aggregations).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The range of potential effects from vessels, icebreakers and the presence of the GBS associated with Scenario 3 are similar to those discussed above for Scenario 2 (Section D.3.5.3), but would be located in deeper water further out on the continental shelf than in Scenario 2 (i.e., 80 km offshore versus 15-20 km offshore)

Seismic surveys would be geographically limited to the area within the lease, but underwater noise produced by airguns could result in injury if whales are close to the sound source. This noise could also lead to changes in behaviour, diving and calling rates, or communication masking within a radius of up to 41 - 45 km (median distance) from the sound source (Blackwell et al. 2013). Bowhead whale, beluga whale, and seal summering habitat could overlap with seismic surveys associated with Scenario 3.

Drilling would also produce underwater noise, but noise would be continuous nature and at lower sound levels. As discussed in Section D.3.5.1.5, whales may show behavioural change up to 11 km from the sound source, but observations have indicated that whales may become accustomed to noise levels associated with drilling and the zone of influence may decrease over time (Awbrey and Stewart 1983). A similar response was noted by TLK holders in Tuktoyaktuk “if they are not abused or mistreated whales and seals are naturally curious and may move too close to the drilling area where there is an increased chance of injury or death due to collisions with boats and other machinery” (IMG Golder and Golder Associates 2011e: 13).

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

The effects of climate change on potential effects to marine mammals from activities associated with Scenario 3 are anticipated to be similar to those discussed above for Scenarios 1 and 2.

D.3.5.4.2 MITIGATION AND MANAGEMENT

Mitigation and management measures described for Scenario 1 would also be applicable to deal with similar effects described for Scenario 3. In addition, specific mitigations would be applied to seismic surveys to reduce potential effects of underwater noise on marine mammals. This would include:

- monitored safety zones around the sound source would be maintained for the duration of the survey to protect marine mammals from injury
- temporal restrictions or use of alternate monitoring technology (e.g., passive acoustic monitoring) may be required if operating within specific habitat zones (e.g., bowhead feeding aggregations)

Additional details are provided in Appendix F.

D.3.5.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Spatial and temporal overlap between Scenario 3 activities and marine mammal habitat use is expected.

Effects of ice disturbance would be limited to the local area around the GBS and the shipping routes used for tankers and support vessels. Alteration of sea ice habitat around the GBS could result in a positive effect on seals by attracting prey species to the unconsolidated ice pack surrounding the GBS but, in turn, may result in increased mortality risk due to attraction of polar bears to the area. Increased tracts created by icebreakers may result in altered movement of whales and potentially increased mortality risk if they become trapped in ice. Potential effects of icebreaking and presence of the GBS platform on seals are expected to be adverse with low magnitude since habitat alterations would change baseline conditions but are not anticipated to affect the viability of seal populations in the region. The extent of potential effects of ice disturbance on marine mammals is expected to be limited to the local area around the development and along shipping routes. Potential effects would be multiple irregular events of medium-term duration and reversible in nature.

Adverse effects of underwater noise would extend to the regional area, given the nature of the distances that underwater noise is known to travel and affect marine mammal behaviour (Southall et al. 2007). Potential effects are predicted to be low in magnitude, altering baseline conditions but not affecting the long-term resiliency or viability of marine mammal populations. Potential effects would be multiple regular events of medium-term duration and reversible in nature.

Given the unpredictable nature of how marine mammal populations might respond to impacts of climate change over the 30-year time period, the prediction and characterization of residual effects is made with low confidence. Given the offshore nature of the GBS associated with Scenario 3, climate predictions indicate that sea ice along the continental shelf may recede earlier and form later, resulting in a longer Open Water Season. This extended Open Water Season could increase the net period of time that marine mammals would remain in the area and be affected by underwater noise associated with vessels, seismic surveys and drilling.

In contrast, a shorter Ice Season could result in dietary and habitat restriction for seals in the region, or lower survival of pups if birthing lairs are disturbed or lost earlier and pups lose the protection of the lair before they are ready. This would increase stress in individual seals and reduce resiliency in the population. Seals may become attracted to offshore platforms where sea ice habitat is modified, and prey species (i.e., fish) are more abundant; if this was to occur, more seals that are nutritionally stressed would be concentrated over a smaller area for a shorter period of time, trying to maintain nutritional requirements. This shift in distribution and attraction to an artificial structure for foraging habitat could result in a higher frequency and magnitude of mortality risk resulting from polar bear predation.

CUMULATIVE EFFECTS

Oil and gas exploration, development and operations activities that become aggregated in time or by geographic location, along with activities under Scenario 1 may result in cumulative effects to marine mammals. Cumulative effects associated with Scenario 3 would largely be associated with icebreaking and shipping. Contributions of project specific shipping combined with regional shipping could have a measurable effect on marine mammal habitat in the region. Early identification of risks, and regional co-management of marine mammal populations would be key to reducing the potential that cumulative effects would result in reduced viability of marine mammal populations in the region.

The rapid shift in marine mammal habitat quality and availability that is predicted to result from climate change could amplify effects and exert substantially more pressure on the population to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change to increase the severity of effects on marine mammal populations in the region.

D.3.5.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

Potential residual effects of activities associated with Scenario 4 (e.g., seismic survey, installation of FPSO and wareships, drilling, ice-breaking and shipping) are anticipated to be similar to what was described for Scenario 3, but further offshore over the continental slope (i.e., >100 km offshore versus 80 km offshore). Tanker transits to the east through Amundsen – Queen Maude Gulf are unique to Scenario 4; tanker movements in these areas could interact with beluga and bowhead whale feeding concentrations and movements in Amundsen Gulf. Tanker and other vessel movements in areas to the west of the Beaufort Sea would have similar effects to those described for Scenarios 2 and 3.

Due to the location of Scenario 4, interactions are expected to be more frequent with bowhead whale than with beluga, which tend to utilize more shallow water habitat. Potential effects on seals are anticipated to be similar for Scenario 3 and 4 since seals are widely distributed throughout the BRSEA Study Area, and closely associated with the sea ice.

The effects of climate change on potential effects to marine mammals from activities associated with Scenario 4 are anticipated to be similar to those discussed above for Scenarios 1 to 3.

Mitigation measures for Scenario 4 would be similar to those described for Scenario 3.

The potential for Scenario 4 activities to contribute to cumulative effects on marine mammals in the region is also similar to what was described for Scenario 3.

D.3.5.6 Scenario 5: Large Oil Release Event

While the Large Oil Release Event is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels. If the fuel tanks for these vessels were affected (e.g., punctured during a collision), large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on marine mammals from such an event may differ slightly from what is described below for surface or subsea releases.

D.3.5.6.1 POTENTIAL IMPACTS AND EFFECTS OF A LARGE OIL RELEASE

DESCRIPTION OF EFFECT PATHWAY

Impacts of a large oil release event on beluga and bowhead, regardless of the event being a surface release or a subsurface release within or outside the Mackenzie River plume, would be most severe if the event were to occur during the Open Water Season. The effect pathway of most concern for whales is through inhalation of toxins that have evaporated or volatilized from the surface slick, or through ingestion of affected prey.

During the Open Water Season, bowhead whales are feeding offshore, whereas belugas are congregating within the Mackenzie estuary as well as travelling to feeding areas in deeper water. Because both species travel throughout the region to access feeding and other important habitat, they could be exposed regardless of where the spill occurs. A spill event during the Spring or Fall Transition seasons (either surface or seabed, inside or outside of the plume), when whales are migrating to or from the BRSEA Study Area, also would likely affect whales but effects might be less severe since the population would be traveling, potentially reducing the duration that animals are exposed to oil. If a large oil release was to occur during the Ice Season, whales would not be directly affected since they would not be in the region at that time. However, they may be exposed to oil, released from ice, during the following Spring Transition Season.

Seals are present and widely distributed in the BRSEA Study Area year-round and utilize many aspects of available habitat (benthos, sea ice, water column). Given this aspect of their ecology, they would be vulnerable to effects of an oil spill regardless of its origin (seabed or surface), timing or location. The effect pathway of most concern for seals is through the fouling of fur (newborn seals), inhalation of toxins that have evaporated or volatilized from the surface slick, or through ingestion of affected prey.

Impacts of an oil spill on seals would be most severe if it were a surface or seabed release that occurred during the Ice or Spring Transition seasons inside or outside plume since seals would be utilizing the sea ice as haul out habitat, for breathing holes and birthing lairs. A spill during the Spring Transition Season inside or outside the plume would be particularly severe since it would affect newborn and juvenile seals in birthing lairs. Seals would also be affected by a spill during the Open Water Season but, since they are most closely associated with ice, it is anticipated that a smaller proportion of the population would be affected during the Open Water Season.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Fur-bearing marine mammals (e.g., newborn seals) are generally considered to be at greater potential for exposure to oil than smoothed-skinned marine mammals (e.g., whales). Oil can coat the fur and disrupt its insulation capacity and lead to hypothermia (Boyd et al. 2001; St. Aubin 1990). Animals may ingest or inhale oil that has fouled fur or skin during grooming, which can lead to lethal and sublethal effects (e.g., tissue damage to stomach, intestines, kidneys, eyes, lungs; reproductive problems; and various changes in behaviour) (Boyd et al. 2001; Carpenter et al. 2008; Øritsland et al. 1981; Venn-Watson et al. 2015).

Animals that aggregate in large numbers (e.g., seals) near specific habitats can be more vulnerable to spills since a higher percentage of animals could be affected at once. This could be especially detrimental if a spill is not contained quickly (Garlich-Miller et al. 2011). Pinnipeds that use scent to establish a mother-pup bond (e.g., this has been documented in sea lions, and may apply to seals) may reject oiled pups if they are not able to recognize their scent (St. Aubin 1990). Oiled seals also have been observed to become disoriented and reluctant to re-enter the water (St. Aubin 1990).

Marine mammals may be exposed to chronic effects of contamination and toxicity associated with effects on their prey (e.g., fish, plankton). Baleen whales that are unable to move away from surface oil following a spill may be subject to acute (direct exposure) effects by fouling of baleen (hair-like projections used to filter prey from the water), eye irritation, and vapour inhalation. Whales are generally believed to avoid exposure to oil spills by moving from the area; however, there are reports of fatalities suspected from either consumption of contaminated prey, or inhalation of volatile gases (e.g., killer whales) (Fortuna et al. 2002).

Effects of Climate Change on Potential Effects

Physical stressors on marine mammals (e.g., reduced extent and quality of sea ice, altered ocean temperature, shifting species assemblages and distributions) may reduce the general resiliency of individual marine mammals. Therefore, it is likely that climate change would exacerbate potential effects from a large oil release event by contributing additional stressors on marine mammals. The effect of climate change would depend on the species of marine mammals (e.g., life history traits that might improve or reduce the ability to recover from an effect) and the associated level of resilience to withstand the combined stressors.

D.3.5.6.2 Mitigation and Management

Oil spill response planning and measures are discussed in Sections 2.13 and 3.10.5.3. Additional details are provided in Appendix F.

D.3.5.6.3 Effects Characterization

Residual Effects

Potential effects of an oil spill on marine mammals are expected to be regional or extra-regional in extent and long-term in duration. The probability of a spill occurring is very low; therefore it is characterized as a single event. Fur bearing mammals (i.e., seals) are expected to be more vulnerable to effects of oil than whales. Potential effects would be adverse and, depending on the severity of the spill, population viability could be affected, resulting in moderate to high magnitude effects.

Climate change is expected to exacerbate stresses on marine mammal populations in the region, Climate change is not anticipated to change the prediction of potential effects of oil spills on marine mammals but may influence the number of species that are affected, particularly if species composition shifts in the region to include more frequent presence of killer whales, grey whales, or different species of pinnipeds. An extended Open Water Season would increase the duration that whales would be in the region and exposed to the impacts of an oil spill.

D.3.5.7 Summary of Residual Effects

Potential residual effects of Scenarios 1 – 4 and a large oil release event on marine mammal are summarized in Table D-42 and Table D-43.

D.3.5.8 Gaps and Recommendations

Current data on the population status, distribution and habitat use of marine mammals in the BRSEA Study Area is critical to understanding how human activity and climate change is influencing marine mammal populations in the region. In particular, bowhead feeding habitat should be identified and the physical and biological variables that influence the location of these areas assessed. In addition, integration of TLK and traditional harvest data on animal distribution, abundance, behaviour and health into the management of marine mammal populations in the region will continue to be important.

D.3.5.9 Follow-up and Monitoring

Follow up and monitoring programs could include the following:

- ongoing data collection on abundance and distribution of common species and monitoring for presence of less common species (e.g., killer whales, narwhal)
- monitoring body condition of seals and whales as an indication of overall ecosystem health (e.g., prey abundance and quality)

Table D-42 Potential Residual Effects of Scenarios 1 – 4 on Marine Mammals

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Ice	• No overlap with beluga and bowhead habitat, • Potential for seal habitat disturbance (i.e., snowmobiles) and damage to birthing lairs and breathing holes	• No overlap with beluga and bowhead habitat • Icebreaking, and year-round operations could result in seal habitat disturbance (sea ice), change in behaviour, change in habitat, and change in mortality risk (polar bear predation).	• No overlap with beluga and bowhead habitat • Icebreaking, and year-round operations could result in seal habitat disturbance (sea ice), change in behaviour, change in habitat, and change in mortality risk (polar bear predation).	• No overlap with beluga and bowhead habitat • Icebreaking, and year-round operations could result in seal habitat disturbance (sea ice), change in behaviour, change in habitat, and change in mortality risk (polar bear predation).
Spring Transition	• Moderate overlap between shipping, tourism, research and marine mammal habitat use may cause disturbance or alteration to habitat • Potential effects on migrating whales and seals using sea ice habitat for birthing lairs	• Moderate overlap between tanker transits, other shipping, icebreaking, footprint of GBS and marine mammal habitat use • Potential effects on migrating whales and seals using sea ice habitat for birthing lairs	• Moderate overlap between tanker transits, other shipping icebreaking, drilling, presence of the GBS and wareship, and marine mammal habitat use • Potential effects on migrating whales and seals using sea ice habitat for birthing lairs	• Moderate overlap between tanker transits, other shipping icebreaking, drilling, presence of the FPSO and wareship, and marine mammal habitat use • Potential effects on migrating whales and seals using sea ice habitat for birthing lairs
Open Water	• Direct overlap with habitat for seals and whales • Vessel activity from shipping, tourism, research could cause marine mammal disturbance (underwater noise)	• Direct overlap with habitat for seals and whales • Vessel activity (tankers, supply) could cause marine mammal disturbance (underwater noise)	• Direct overlap with habitat for seals and whales • Vessel activity (tankers, supply), seismic surveys and drilling could cause marine mammal disturbance (underwater noise)	• Direct overlap with habitat for seals and whales • Vessel activity (tankers, supply), seismic surveys and drilling could cause marine mammal disturbance (underwater noise)

Table D-42 Potential Residual Effects of Scenarios 1 – 4 on Marine Mammals

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Fall Transition	• Moderate overlap between shipping, tourism, research and marine mammal habitat use may cause disturbance or alteration to habitat • Potential effects on migrating whales and seals using sea ice habitat	• Moderate overlap between tanker transits, other shipping, icebreaking, footprint of GBS and marine mammal habitat use • Potential effects on migrating whales and seals using sea ice habitat	• Moderate overlap between tanker transits, other shipping, icebreaking, drilling, presence of the GBS and wareship, and marine mammal habitat use • Potential effects on migrating whales and seals using sea ice habitat	• Moderate overlap between tanker transits, other shipping, icebreaking, drilling, presence of the FPSO and wareship, and marine mammal habitat use • Potential effects on migrating whales and seals using sea ice habitat
Legend				
• Least effect – No to minor effect on marine mammal habitat, behaviour, and/or mortality risk				
• Moderate effect -- Moderate effect on marine mammal habitat, behaviour, and/or mortality risk				
• High effect -- Major effect on marine mammal habitat, behaviour, and/or mortality risk				
• Greatest effect – Severe effect on marine mammal habitat, behaviour, and/or mortality risk				

Table D-43 Potential Effects of a Large Oil Release Event (Scenario 5) for Marine Mammals

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• No overlap with whale habitat, therefore no direct effects; release of oil during ice melt would result in potential exposure the following year • Oil in leads could affect seal habitat or prey species, leading to indirect effects (change in health and mortality). • Oil could be ingested through contaminated prey or self-grooming.	• No overlap with whale habitat, therefore no direct effects; release of oil during ice melt would result in potential exposure the following year • Oil in leads could affect seal habitat or prey species, leading to indirect effects (change in health and mortality). • Oil could be ingested through contaminated prey or self-grooming.	• No overlap with whale habitat, therefore no direct effects; release of oil during ice melt would result in potential exposure the following year • Oil in leads could affect seal habitat or prey species, leading to indirect effects (change in health and mortality). • Oil could be ingested through contaminated prey or self-grooming.
Spring Transition	• Limited overlap with whale habitat (migratory corridors, through ice leads) • Oil in broken ice/open water could affect sea ice habitat for seals • Change in health, and behaviour resulting from ingestion through contaminated prey or self-grooming. • Reduced survival of seal pups, or abandonment of birthing lairs prematurely	• Limited overlap with whale habitat (migratory corridors, through ice leads) • Oil in broken ice/open water could affect sea ice habitat for seals • Change in health, and behaviour resulting from ingestion through contaminated prey or self-grooming. • Reduced survival of seal pups, or abandonment of birthing lairs prematurely	• Limited overlap with whale habitat (migratory corridors, through ice leads) • Oil in broken ice/open water could affect sea ice habitat for seals • Change in health, and behaviour resulting from ingestion through contaminated prey or self-grooming. • Reduced survival of seal pups, or abandonment of birthing lairs prematurely
Open Water	• Whales may be exposed to vapours or ingest contaminated prey • Potentially severe effects on beluga if spill occurs while beluga are congregated within the Mackenzie estuary • Limited overlap with seal habitat given close association with sea ice, but moderate effect on seals could result from direct oiling and ingestion, or indirectly through ingestion of oiled prey.	• Whales may be exposed to vapours or ingest contaminated prey • Potentially severe effects on bowhead if spill occurs within feeding habitat • Limited overlap with seal habitat given close association with sea ice, but moderate effect on seals could result from direct oiling and ingestion, or indirectly through ingestion of oiled prey.	• Whales may be exposed to vapours or ingest contaminated prey • Potentially severe effects on bowhead if spill occurs within feeding habitat • Limited overlap with seal habitat given close association with sea ice, but moderate effect on seals could result from direct oiling and ingestion, or indirectly through ingestion of oiled prey.

Table D-43 Potential Effects of a Large Oil Release Event (Scenario 5) for Marine Mammals

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Fall Transition	• Limited overlap with whale habitat as most would have migrated out of the region • Oil in broken or new ice could affect seal habitat, health, and behaviour resulting from inhalation of fumes, ingestion through contaminated prey or self grooming.	• Limited overlap with whale habitat as most would have migrated out of the region • Oil in broken or new ice could affect seal habitat, health, and behaviour resulting from inhalation of fumes, ingestion through contaminated prey or self grooming.	• Limited overlap with whale habitat as most would have migrated out of the region • Oil in broken or new ice could affect seal habitat, health, and behaviour resulting from inhalation of fumes, ingestion through contaminated prey or self grooming.
Longer-term/ Multi-year	• Long- term/multi-year effects on whales are not expected • High mortality of seals could result in reduced resiliency and slow population recovery over the longer term • Prey species that are prone to chronic effects of oiling could be ingested and bioaccumulated by marine mammals	• Long- term/multi-year effects on whales are not expected • High mortality of seals could result in reduced resiliency and slow population recovery over the longer term • Prey species that are prone to chronic effects of oiling could be ingested and bioaccumulated by marine mammals	• Long- term/multi-year effects on whales are not expected • High mortality of seals could result in reduced resiliency and slow population recovery over the longer term • Prey species that are prone to chronic effects of oiling could be ingested and bioaccumulated by marine mammals
Legend			
• Least effect – No to minor effect on marine mammal habitat, behaviour, and/or mortality risk			
• Moderate effect -- Moderate effect on marine mammal habitat, behaviour, and/or mortality risk			
• High effect -- Major effect on marine mammal habitat, behaviour, and/or mortality risk			
• Greatest effect – Severe effect on marine mammal habitat, behaviour, and/or mortality risk			

D.3.6 Polar Bear

D.3.6.1 Scoping

D.3.6.1.1 IDENTIFICATION OF INDICATORS

The assessment of potential effects on polar bear focuses on this species and does not require the use of indicators. The assessment focuses on potential effects on the four polar bear populations with ranges that overlap with the BRSEA Study Area: Arctic Basin, Southern Beaufort, Northern Beaufort, and Viscount-Melville populations (Figure 7-48).

D.3.6.1.2 SPATIAL BOUNDARIES

As described in Section 7.3.7, polar bears maintain large home ranges and are present throughout the BRSEA Study Area. Given the predicted impacts of climate change on polar bear in the region, uncertainty in how climate change may alter habitat use by polar bear (i.e., sea ice habitat throughout the BRSEA Study Area could be used by polar bear throughout the year), and the anticipated increase in human use and development at higher latitudes, the spatial boundary for polar bear is defined as the entire BRSEA Study Area (i.e., the marine waters of the ISR) (see Figure 7-48). This spatial extent captures potential present and future impacts throughout the polar bear range in the BRSEA Study Area.

D.3.6.1.3 TEMPORAL BOUNDARIES

The assessment of potential effects on polar bear encompasses a 30-year period between 2020 – 2050.

D.3.6.1.4 ASSESSMENT OF POTENTIAL EFFECTS

The assessment of potential effects on polar bear considers residual effects on the population, not on individual bears. Based on the established spatial boundaries, the discussion and characterization of potential effects is assessed in the context of the Southern Beaufort Sea, Northern Beaufort Sea, Arctic Basin and Viscount-Melville populations of polar bear within the BRSEA Study Area. Qualitative characterization of potential residual effects on polar bear associated with each scenario is based on the characterization terms defined in Table D-44.

Table D-44 Characterization of Residual Environmental Effects on Polar Bear for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect on the VC	**Positive**—a net benefit to the health, mortality or habitat or behaviour **Adverse**—a reduction or influence on the health, mortality, habitat or behaviour that could result in a change in the status or resiliency of the polar bear population **Neutral**—no net change in the viability, status or resiliency of the polar bear population
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	Typically expressed qualitatively as: **Negligible**—no measurable change in health, mortality, habitat or behaviour and no measurable effect on the polar bear population **Low**—a measurable change in the status or resiliency of the polar bear population, but would not affect the long-term sustainability of the polar bear population **Moderate**—measurable change in the status or resiliency of the polar bear population, with potential to affect the long-term sustainability of the polar bear population **High**—measurable change with relative certainty of affecting the long-term sustainability of the polar bear population
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the local (immediate) area around the activity **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area) **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area)
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity **Continuous**—residual effect occurs continuously for the duration of the activity
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to one phase or season (e.g., seismic survey, exploration drilling) **Medium-term**—residual effect extends through multiple seasons or years (e.g., production phase) **Long-term**—residual effect extends beyond the life of the project (e.g., beyond closure) **Permanent**—measurable parameter unlikely to recover to existing conditions

Table D-44 Characterization of Residual Environmental Effects on Polar Bear for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.3.6.1.5 Potential Impacts and Effects of Routine Activities

Issues and concerns about effects of human activities on polar bear are primarily linked to impacts on sea ice habitat and increased human-bear interactions resulting from operations during the Ice Season and the Spring and Fall Transition seasons. The Sachs Harbour Community Working Group has identified concern that marine vessels, seismic activity and related low-level flying could result in disturbance to seal lairs and polar bear den sites in multi-year ice, and that noise from ships could affect polar bear and seal communication and social functions (SCCP 2016: 21).

During the Open Water Season, there is lower potential for interactions between polar bears and scenario activities. Although it is not uncommon for polar bear to swim in open water during the summer months, they spend the majority of their time on land or follow the sea ice as it retreats north during the Open Water Season (see Section 7.3.7). Therefore, spatial overlap between polar bears and scenario activities during the Open Water Season is limited in the nearshore and continental shelf and slope regions of the BRSEA Study Area.

While this may be the case during the Open Water Season in the southern Beaufort Sea, there is potential that channels to the east of the Beaufort Sea such as the Northwest Passage and Amundsen-Queen Maude Gulf may contain landfast ice, floe ice or even pack ice. Given this spatial variation in sea ice conditions, if suitable sea ice habitat is present in M'Clure Strait and Amundsen Gulf during the Open Water Season, there is potential for increased interaction between transiting vessels and polar bears.

Interactions with human activities (e.g., vessels and platforms) during the Open Water Season are predicted to be infrequent, limited in duration (i.e., the duration of the vessel passage or the period of time a bear remains around a platform), low magnitude (e.g., affecting a few individuals within a population), and not expected to result in residual effects on the polar bear populations in the region. Potential effects on polar bear resulting from activities that occur during the Open Water Season are not discussed further. However, potential effects of vessel transit through the Northwest Passage during the Open Water Season would be similar to those discussed for the Spring and Fall Transition seasons and these effects are addressed in the scenarios where vessel transits may occur through the Northwest Passage.

Low flying aircraft (i.e., in-air noise from helicopters) or seismic surveys (i.e., underwater noise disturbance of swimming bears) could result in noise and associated disturbance effects on polar bear. Polar bears are known to exhibit a startle response to low flying aircraft in direct proximity (Amstrup 1993). Helicopters used for crew transport would only be taking off and landing from the service and supply bases and the vessel or platform associated with the development; for the remainder of the flight, it is assumed that helicopters would follow the guidelines for minimum flight altitudes (> 300 -400 m; EIRB 2011, Appendix F). Although helicopter activity would startle polar bears in the vicinity and likely cause them to leave the area, the potential effect would be limited to a temporary stress response and abandonment of the immediate area around the vessel or platform. Deterring bears from the immediate area on a regular basis could result in a net benefit, as it could reduce the potential and frequency of bear-human conflict around the platform. Helicopters used for ice reconnaissance or other project related activity would be required to maintain appropriate elevations to reduce potential effects on wildlife inhabiting sea ice or open water habitat. While noise impacts might occur, effects on polar bear populations are expected to be negligible. As a result, potential effects of in-air noise on polar bear are not discussed further.

Noise produced by offshore seismic surveys is directed into the water column and would not result in ambient noise levels high enough to result in injury or disturbance to polar bear on sea ice, therefore the discussion of potential effects of seismic noise on polar bear is limited to underwater noise. Implementation of standard mitigation and monitoring measures during seismic surveys would consider potential effects of underwater noise on swimming and diving polar bears. A marine mammal monitoring program would provide ongoing monitoring of a radius around the seismic vessel to confirm that whales and swimming polar bears would not be exposed to underwater noise levels that could result in injury. Potential effects of underwater noise on polar bear are not discussed further.

The relationship between human activities, interactions, impacts and potential effects are summarized in Table D-45. Although activities and associated impacts are similar across the Status Quo and the three oil and gas development scenarios, potential effects of each scenario are discussed independently to identify specific interactions that may result from variations in timing, spatial extent, or geographic location assumed for each scenario. A summary of potential effects of sea ice disturbance resulting from routine activities is provided below. A summary of potential effects of an oil spill is provided in Section D.3.6.6. As discussed earlier, other potential effects, such as disturbances during the Open Water Season, and noise effects are not considered further.

Table D-45 Summary of Potential Impacts and Effects on Polar Bear

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Noise (in-air and underwater)	• vessel transits (engine, propeller, and ice-breaking activities) • seismic surveys • drilling • operational and maintenance activities to vessels, production platform, and wells • Helicopters, low flying aircraft, and snowmobiles	• injury to swimming polar bears from underwater noise produced by seismic air guns • startle response or avoidance of area subjected to ambient noise from helicopters or low-flying aircraft	• potential residual effects on individual bears are possible but with mitigation in place (e.g., wildlife monitors, use of safety radii, minimum aircraft altitudes, seasonal shipping routes), potential residual effects on behaviour, health, mortality risk, and habitat are expected to be negligible in magnitude • **further assessment of this impact is not warranted**	• NA
Artificial Light	• lighting used on nearshore infrastructure (wind turbines, marine infrastructure), offshore platforms and vessels	• attraction of polar bears to structures and subsequent mortality resulting from bear-human conflict	• potential residual effects on individual bears are possible but with mitigation in place (e.g., wildlife monitors, light management), potential residual effects on behaviour, health, mortality risk, and habitat are expected to be negligible in magnitude • **further assessment of this impact is not warranted**	• NA
Seabed Disturbance	• subsea well, manifold, and pipeline installations and repairs	• no interaction anticipated	• **further assessment of this impact is not warranted.**	• NA

Table D-45 Summary of Potential Impacts and Effects on Polar Bear

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Ice Disturbance	• icebreakers transiting through sea ice (ice management, support, transport) • presence of structures on/in sea ice or open water (drillships, platforms, wind turbines)	• habitat alteration due to physically breaking up sea ice • effects on prey source from alteration of sea ice habitat resulting in shifts in availability or quality of food for polar bears • disturbance of denning habitat for female bears and/or cubs • attraction of polar bears to human structures and subsequent mortality resulting from bear-human conflict	• change in behaviour • change in health • change in mortality risk • change in habitat	• areal extent of habitat altered or lost (m^2) relative to that available • change in population size • quality of habitat for hunting and denning • zone of influence for sensory disturbance and overlap with key habitat • estimated change in rate of mortality or injury (e.g., removal of nuisance animals) • change in Body Condition Index
Routine Discharges	• air emissions • bilge and ballast water • drilling muds and lubricating fluids • drill cuttings and disposal • sewage and food waste • cooling water and deck drainage	• effects on prey source resulting in shifts in availability or quality of food for polar bears • attraction of polar bears to human structures and subsequent mortality resulting from bear-human conflict	• potential residual effects on individual bears are possible but with mitigation in place, potential residual effects on behaviour, health, mortality risk, and habitat are expected to be negligible in magnitude • **further assessment of this impact is not warranted**	• NA

Table D-45 Summary of Potential Impacts and Effects on Polar Bear

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Oil Spill	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• effects on prey source resulting in shifts in availability or quality of food for polar bears • attraction of polar bears to human response activities and subsequent mortality resulting from bear-human conflict • ingestion of oil through oil fouled prey or self-grooming oil fouled fur • disturbance of denning habitat for female bears and/or cubs	• change in behaviour • change in health • change in mortality risk • change in habitat	• areal extent of habitat altered or lost (m^2) relative to that available • change in population size • quality of habitat for hunting and denning • estimated change in rate of mortality or injury (e.g., removal of nuisance animals) • modelled or observed estimate of change in prey quality, etc. • change in Body Condition Index • tissue and hair analysis to measure contamination levels

POTENTIAL EFFECTS OF SEA ICE DISTURBANCE

Polar bears in the BRSEA Study Area utilize sea ice habitat throughout the year but the Spring and Fall Transition seasons are particularly critical since bears intake up to 84% of their annual food during these times (Crockford 2018). Maternal dens are used during the Ice Season, generally between October to April, and are distributed along coastlines (primarily along the coast of Banks Island and along the mainland NWT and Alaska) and on the sea ice (Durner et al. 2010; Stirling and Andriashek 1992). There is potential for behavioural changes in or injury to female bears and cubs in dens during the winter months if the dens are not identified and are unknowingly disturbed. Disturbance of female bears in dens has been shown to lead to abandonment and reproductive failure (loss of cubs) (Joint Secretariat 2017). Members of the Ulukhaktok community have raised concern that additional marine traffic could destroy polar bear dens in multi-year ice and that ship tracks would pose dangers to hunters in the area.(OCCP 2016: 40). Greater consideration should be given to periods when females are entering or exiting the dens with cubs. Given what is known about the temporal and spatial use of habitat by polar bear in the BRSEA Study Area, potential effects of habitat alteration are expected to be more pronounced during the spring and fall transition seasons.

Changes in polar bear behaviour as a result of habitat alteration from icebreakers are expected to be minimal due to the wide range of polar bears and their ability to access to other suitable habitat in the region. Previous studies have indicated that polar bears do not appear to be disturbed by the presence of icebreakers or the resulting open water, although habitat fragmentation may increase energy expenditures (Mauritzen et al. 2003).

Ice-breaking and benthic habitat alterations from marine infrastructure may result in changes in prey distribution and productivity of under-ice and ice edge habitats, that may indirectly affect polar bear health. The productivity of under ice and ice edge habitats is important for arctic cod (Coad and Reist 2004), which are a key part of the diet of ice-dependent pinnipeds (e.g., ringed seal (Yurkowski et al. 2016)). The distribution of ice-dependent pinniped species and polar bear, which predate on them, are often strongly associated with the distribution of productive ice edge habitats (COSEWIC 2008; Kovacs 2016; Moore and Huntington 2008). Changes in benthic or pelagic prey distribution may lead to more energy expended searching for prey, increased stress, and poor body condition (Moore and Huntington 2008), potentially resulting in changes in foraging activity and change in health. Seals have been observed hauled out near drill rigs and artificial islands (Harwood et al. 2007; Moulton et al. 2005). The potential for leads to be formed in the lee of an offshore platform may result in increased open water habitat that may be utilized by seals (Stirling 1988), resulting in changes in behaviour and distribution of both bears and seals in the region. TLK holders stated that polar bears would be attracted to drill rigs, potentially leading to problem encounters with bears (Kavik Axys 2004b: 4-3; Kavik-Axys 2004c: 4-3). Although the presence of offshore platforms has not been linked to increased potential for aggressive behaviour by polar bears toward humans, the increased abundance in prey surrounding offshore platforms can attract bears to the area, increasing the mortality risk if a bear needs to be destroyed due to human bear conflict (Stirling 1988).

D.3.6.2 Scenario 1: Status Quo

D.3.6.2.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Activities or infrastructure that operate year-round (e.g., renewable energy, low level aircraft, snowmobiles) or during the spring or fall transition seasons (i.e., icebreaking, tourism, scientific research, military vessels and exercises) would overlap with polar bear use of habitat for foraging and denning. These activities may affect habitat directly by physically altering sea ice habitat or denning habitat, indirectly by affecting prey source populations (e.g., seals), or by causing disturbance to bears during critical periods (e.g., hunting, entering or emerging from maternal dens).

If future vessel use from the ISR into Nunavut (or vice versa) is extended into the transition seasons with support of ice-breaking vessels, or if icebreaking is considered during the Open Water Season, vessel activity may overlap with sea ice habitat in the M'Clure Strait and Amundsen Gulf during outbound or inbound transits to the Beaufort Sea and potentially affect polar bear habitat.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Disturbance resulting from human activity can result in change in behaviour. Polar bears that are disturbed while actively hunting could be scared away from prey that they are pursuing or consuming, resulting in loss of food opportunity and increased energy expenditure to replace that lost food source. These effects would be particularly detrimental to female bears with cubs.

Habitat alteration in the direct vicinity of an offshore wind turbine could attract seals that come to utilize suitable sea ice habitat, in turn attracting polar bears to a concentrated prey source. Increased presence of polar bears around the platform could lead to increased potential for bear human conflict.

Vessels (i.e., icebreakers or ice-strengthened ships) transiting through the Northwest Passage and Amundsen-Queen Maude Gulf could alter sea ice habitat, potentially resulting in shifts in seal distribution and a correlated shift in habitat use by polar bears.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Climate induced changes to polar bear habitat over the 30-year assessment period are expected to result in a longer duration and a larger geographic extent of open water (Laidre et al. 2015). This shift in the distribution of sea ice habitat is likely to affect polar bears directly (through loss and alteration of available sea ice habitat) and indirectly (through effects on ice dependent prey species). Bears that range over the convergent ice ecoregion (i.e., Arctic Basin and Northern Beaufort Sea populations; see Section 7.3.7), would likely remain on the sea ice as it recedes and become geographically separated from human activities.

Bears that range over divergent ice and archipelago ecoregions (i.e., Southern Beaufort Sea and Viscount Melville populations; see Section 7.3.7) may be forced onto land for longer periods of time during the Open Water Season. These bears would face reduced access to their primary food source (ice dependent seals) and pressure to replace that source with alternate (usually less energy rich) prey species on land. The increased abundance and duration of bears on land would also increase the geographic overlap between bears and human activity, resulting in a greater potential for bear-human interactions and mortality.

Loss of habitat could lead to increased stress in individual bears (Ferguson et al. 2017; Mauritzen et al. 2003) and geographical pressure on the population that could result in reduced viability. In a population that is already in a vulnerable state due to changing environmental conditions caused by climate change, resilience to effects from human activities is likely to be reduced. Although it is difficult to make predictions of potential effects of human activities over such a large temporal scale, recent studies have indicated that as sea ice becomes increasingly short-lived annually, polar bears are likely to experience increasingly stressful conditions, shifting habitat (e.g., increased use on land based denning habitat) and higher mortality rates (Fischbach et al. 2007; Olson et al. 2017; Pagano et al. 2018). Ongoing research and monitoring of polar bear populations in the region is recommended to support robust adaptive management strategies focused on maintaining the sustainability of polar bear populations (Bromaghin et al. 2015).

D.3.6.2.2 MITIGATION AND MANAGEMENT

General mitigation measures and standard operational procedures associated with the protection of wildlife from human impacts should be employed (Section 2.4). Measures specific to the protection of polar bears from human impacts include:

- habitat protection setbacks and timing windows to protect sensitive foraging, rearing, or denning habitat from icebreakers, snowmobiles, and low flying aircraft
- for vessels traveling through the Northwest Passage and Amundsen-Queen Maude Gulf, use of timing windows and specific routes (to avoid important habitat areas), operational procedures (e.g., consistent course with reduced vessel speeds), and wildlife monitors
- use of existing and common travel routes by vessels and icebreakers where possible and practical
- polar bear safety program to educate workers and reduce potential human-bear conflict
- wildlife monitoring program to identify bears in the area and maintain safe operating distance This could include remote observations using drones (e.g., around wind turbines)
- long term monitoring program to collect additional data on population status, habitat use, body condition and response of polar bear to human and development activities
- identification and monitoring of maternal denning habitat and development of requirements to avoid key sensitive areas during shipping and other activities (e.g., maintain safe operating distance)
- development and implementation of co-management strategies that define management goals and objectives and align standard polar bear management policy across multiple marine users in the region (i.e., ISR Polar Bear Joint Management Plan [Joint Secretariat 2017])

Details are provided in Appendix F.

D.3.6.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Although activities associated with Scenario 1 are expected to increase in frequency and seasonal extent over the next 30 years, overlap with polar bear habitat use is expected to be minimal. Given the types of mitigation and management measures that would be employed (e.g., avoidance of maternal dens, minimum aircraft altitudes, standard vessel routes, reduced ship speeds in proximity to sensitive areas, wildlife monitors), human-bear interactions and habitat disturbance during the ice and transition seasons are not expected to result in changes that would threaten the long-term viability of polar bear populations in the region. While effects on polar bear are expected to be adverse, potential effects are predicted to be negligible and limited to the footprint of the activity. Potential effects would be multiple irregular events with short-term duration, dispersed over the BRSEA Study Area, and reversible in nature.

With increasing extent and duration of the length of the Open Water Season (Laidre et al. 2015) and thinner ice, there may be less need for ice-breaking with a corresponding increase in vessel traffic and an extended period of open water. Given the unpredictable nature of how polar bear populations might respond to impacts of climate change over the 30-year time period, as well as uncertainty on how much shipping traffic in the BRSEA Study Area might increase (and likely routes), the prediction and characterization of residual effects is made with low confidence. The influence of climate change may alter the prediction of magnitude from low to high magnitude, resulting in the potential to affect the long-term sustainability of the population.

CUMULATIVE EFFECTS

Given the low probability of residual effects on the polar bear population from activities associated with Scenario 1, it is unlikely that cumulative effects from concurrent activities in the region would result in cumulative effects on the polar bear populations in the BRSEA Study Area. The greatest potential effect might be from multiple passages by different types of vessels during the Open Water Season and associated changes in remaining areas of sea ice and cumulative disturbances to polar bear (and their prey). As noted, vessel transits through the channels in the Northwest Passage and Amundsen-Queen Maude Gulf are expected to increase as the duration of the Open Water Season increases and would likely bring vessels in direct proximity to polar bears compared to offshore transits across the southern or central Beaufort Sea.

As discussed above, the rapid shift in polar bear habitat quality and availability that is predicted to result from climate change is expected to amplify effects and exert substantially more pressure on the population to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change to result in high magnitude effects on polar bear.

D.3.6.3 Scenario 2: Export of Natural Gas and Condensates

D.3.6.3.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Activities that have the potential to adversely affect polar bear populations in Scenario 2 include year-round activities or those occurring in the Fall and Spring transition seasons. Potential effects include direct changes to habitat by physically altering sea ice habitat or denning habitat, indirect changes by affecting prey source populations (e.g., seals), and disturbance to bears during critical periods (e.g., hunting, entering or emerging from maternal dens).

Installation of the GBS loading platform would be done during the Open Water Season and would result in minimal to no interaction with polar bears.

The location of the GBS loading platform and associated facilities would overlap winter landfast ice habitat for polar bear, as well as the area between sea ice and landfast ice. As a result, individual bears may be in proximity to the project throughout much of the late Fall Transition, Ice and early Spring Transition seasons.

Changes in sea ice habitat (e.g., ice deformation and buildup) from the GBS and associated loading facility for the LNG carriers and condensate tankers, as well as ice breaking around the platform and during carrier and tanker movements during the Ice Season and the Spring and Fall Transition seasons, would result in alteration of polar bear habitat within a limited radius around the platform. The modification of ice habitat could potentially enhance habitat for prey species (i.e., seals). Bears that remain in the area to hunt may be at increased mortality risk resulting from human-bear interactions.

In addition, as the GBS loading platform and associated facilities are within 20 km of shore, human activities and habitat changes around the GBS platform have potential to overlap with maternal denning habitat. As discussed in Section 7.2.7, dens are most commonly found on land. Observations of dens on sea ice have declined, potentially due to shifting sea ice conditions in the region (Durner et al. 2009).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The range of potential effects on polar bear from activities associated with Scenario 2 are similar those discussed above for Scenario 1 (Section D.3.6.2) and summarized in Table D-46.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

The effects of climate change on potential effects on polar bear from activities associated with Scenario 2 are anticipated to be similar to those discussed above for Scenario 1 (Section D.3.6.2).

D.3.6.3.2 MITIGATION AND MANAGEMENT

Mitigation and management measures described for Scenario 1 would also apply to similar effects on polar bear for Scenario 2.

D.3.6.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Spatial and temporal overlap between Scenario 2 activities and polar bear habitat use, specifically nearshore denning habitat, is expected to be higher than with other development scenarios due to the nearshore nature of the GBS loading platform and associated infrastructure, some vessel movements, and helicopter traffic. Polar bear have the potential to be affected more regularly as they transition between nearshore, onshore and offshore habitats, and would potentially be at higher potential to be affected during critical phases (i.e., entry and emergence from maternal dens). Implementation of standard mitigation and management measures would reduce the potential for potential effects on polar bears. However, these measures would not eliminate or reduce the frequency of interaction between polar bears and development activities since polar bears would continue to use important nearshore habitat features in the area. Potential effects on polar bear are expected to be adverse with low magnitude. The extent of potential effects is expected to be limited to the local area around the development. Potential effects would be multiple regular events with medium-term duration and reversible.

Given the unpredictable nature of how polar bear populations might respond to impacts of climate change over the 30-year time period, the prediction and characterization of residual effects is made with low confidence. If polar bears are forced onto land earlier and for longer periods of time, Scenario 2 activities may affect a greater proportion of the polar bear population than would be anticipated given current conditions. The magnitude of effects may be amplified if the bears in the area are already vulnerable due to dietary or habitat shifts that they are not able to adapt to. The influence of climate change may alter the prediction of magnitude from medium to high magnitude, resulting in the potential to affect the long-term sustainability of the population.

CUMULATIVE EFFECTS

Oil and gas exploration, development and operations activities that become aggregated in time or by geographic location, along with other past, present and future activities may result in cumulative effects to polar bear. Because of the remote nature of the region and the current lack of available infrastructure, future development and human activity in the region is likely to be most concentrated along coastlines and nearshore habitat to facilitate the use of existing services and facilities available in communities. In combination with this expected development pressure on nearshore regions, the development of a nearshore LNG and condensate export facility would contribute to cumulative effects on polar bear in the BRSEA region. The cumulative nature of effects on polar bear would be reflected in an increased frequency of potential interaction with activities that could result in effects, over a great spatial extent, and with moderate to high magnitude if bears are consistently affected across their range. Early identification of risks and regional co-management of polar bear populations are key to reducing the potential for cumulative effects to result in reduced viability of polar bear in the region.

The rapid shift in polar bear habitat quality and availability that is predicted to result from climate change could amplify effects and exert substantially more pressure on the population to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change, resulting in the potential to affect the long-term sustainability of the population

D.3.6.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.3.6.4.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Activities on and around the GBS and wareship, helicopter overflights, and movements of tankers and support vessels in Scenario 3 would result in similar pathways for effects as described under Scenario 2. The primary difference is the location of the infrastructure and activities in Scenario 3 further offshore (i.e., >80 km offshore versus 15-20 km offshore in Scenario 2).

Activities or infrastructure in Scenario 3 that operate year-round or during the Spring or Fall Transition seasons would overlap with polar bear use of habitat for foraging and denning. These activities may affect habitat directly by physically altering sea ice habitat or denning habitat, indirectly by affecting prey source populations (e.g., seals), or by causing disturbance to bears during critical periods (e.g., hunting, entering or emerging from maternal dens).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The range of potential effects from activities associated with Scenario 3 are similar to those discussed above for Scenarios 1 and 2 (Section D.3.6.3).

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS.

The effects of climate change on potential effects from activities associated with Scenario 3 are anticipated to be the similar to those discussed above for Scenario 1 and 2 above.

D.3.6.4.2 MITIGATION AND MANAGEMENT

Mitigation and management measures to reduce potential effects of Scenario 3 activities on Polar Bears are identical to those described for Scenario 1 (Section D.3.6.2.2).

D.3.6.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Spatial and temporal overlap between Scenario 3 activities and polar bear habitat use is expected but would be limited to the local area around the GBS and the shipping routes used for tankers and support vessels. Since the platform would be on the continental shelf, it is not expected to overlap or be within the vicinity of specific habitat that is critical to polar bears (i.e., maternal denning habitat or coastal transition areas for polar bears in convergent or archipelago ecoregions). Mitigation measures should include identification of maternal denning areas and reducing the potential for human bear conflict around the GBS; these measures are expected to reduce the frequency and magnitude of potential effects on behaviour and mortality risk. Alteration of sea ice habitat around the GBS could result in a positive effect on polar bear by attracting seals to the unconsolidated ice pack surrounding the GBS. Implementation of standard mitigation and management measures would reduce the potential for potential effects on polar bears but would not be expected to eliminate or reduce the frequency of interaction between polar bears and development activities. Overall, potential effects of icebreaking and the presence of the GBS and wareship on polar bear are expected to be adverse and low magnitude, since habitat alterations would change baseline conditions but are not anticipated to affect the viability of polar bear populations in the region. The extent of potential effects is expected to be limited to the local area around the development and along shipping routes. Potential effects would be multiple regular events with medium-term duration and reversible.

Given the unpredictable nature of how polar bear populations might respond to impacts of climate change over the 30-year time period, the prediction and characterization of residual effects is made with low confidence. Climate predictions indicate that sea ice along the continental shelf may recede earlier and form later, resulting in a longer Open Water Season. This extended Open Water Season could reduce the net period of time that polar bear would utilize habitat directly around the GBS and along the shipping route, and potentially reduce the magnitude and frequency of effects. In contrast, a shorter ice season could result in dietary and habitat restrictions on polar bear in the BRSEA Study Area, increasing stress in individual bears and reducing resiliency in the population. Bears may become attracted to offshore platforms where sea ice habitat is modified, and prey species (i.e., seals) are more abundant. More bears that are nutritionally stressed would be concentrated over a smaller area for a shorter period of time, trying to maintain nutritional requirements. This shift in distribution and attraction to artificial structures for foraging habitat could result in a higher frequency and magnitude of mortality resulting from human bear conflict.

Cumulative Effects

Cumulative effects associated with Scenario 3 would largely be associated with shipping (i.e., icebreaking). Contribution of project specific shipping combined with regional shipping during the ice and transition seasons could have a measurable effect on polar bear habitat in the region. Impacts on sea ice habitat would be multiple and regular in frequency and dispersed over the BRSEA Study Area. These impacts could potentially result in moderate to high magnitude effects on polar bear habitat and behaviour. Early identification of risks, and regional co-management of polar bear populations would be key to reducing the potential that cumulative effects would result in reduced viability of polar bear in the region.

The rapid shift in polar bear habitat quality and availability that is predicted to result from climate change could amplify effects and exert substantially more pressure on the population to a point where effects resulting from multiple human activities could act cumulatively with effects from climate change and result in effects on polar bear populations in the region.

D.3.6.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.3.6.5.1 Potential Impacts and Effects of Routine Activities

Potential effects of activities on polar bear associated with Scenario 4 (e.g., seismic survey, installation of FPSO and wareships, drilling, shipping) are anticipated to be similar to what was described for Scenario 3, with the exception that the development is further offshore in deeper water over the continental slope (i.e., >100 km offshore verses ~80 km for Scenario 3). In addition, tanker transits east of the Beaufort Sea (i.e., through the Northwest Passage and Amundsen-Queen Maude Gulf) would potentially bring vessels closer to polar bear habitat than transit routes in the offshore areas of the Southern or Central Canadian Beaufort Sea. Tanker and vessels transits in the area west of the Beaufort Sea would have similar effects to those already described for tankers and other vessels in Scenarios 1 and 2. The effect of climate change on potential effects is similar to what was discussed for Scenario 3.

D.3.6.5.2 Mitigation and Management

Mitigation and management measures to reduce potential effects of Scenario 4 activities on polar bears are identical to those described for Scenarios 1 (Section D.3.6.2.2).

D.3.6.5.3 Effects Characterization

Residual Effects

Residual effects and the potential influence of climate change on the prediction of residual effects are anticipated to be similar to those described for Scenario 3. Residual effects associated with the transit of vessels through the Northwest Passage and Amundsen-Queen Maude Gulf during the Open Water Season is anticipated to be similar to what was described in Scenario 1. Potential effects are expected to be adverse and low magnitude since habitat alteration could change baseline conditions, but is not expected to affect the long-term sustainability of the population of the polar bear population in the region. The extent of potential effects is expected to be limited to the local area around the development and along shipping routes. Potential effects would be multiple regular events with medium-term duration and reversible.

Cumulative Effects

As previously described for Scenario 3, potential cumulative effects for Scenario 4 would largely be associated with shipping (i.e., icebreaking). Contribution of project specific shipping combined with regional shipping could have a measurable effect on polar bear habitat in the region. In combination with the increased volume of vessel traffic that is expected to occur as the Northwest Passage and Amundsen-Queen Maude Gulf become ice free due to climate change, cumulative effects on polar bears in the region, and particularly in areas along shipping routes could be moderate to high in magnitude. Early identification of risks, and regional co-management of polar bear populations would be key to reducing the potential that cumulative effects would result in reduced viability of polar bear in the region.

D.3.6.6 Scenario 5: Large Oil Release Event

D.3.6.6.1 POTENTIAL IMPACTS AND EFFECTS OF A LARGE OIL RELEASE

DESCRIPTION OF EFFECT PATHWAY

Impacts of a large oil release event on polar bear would be most severe if it were a surface release onto sea ice that occurred during the Spring or Fall Transition Season while polar bears are actively hunting (important feeding phase) and female bears and cubs are entering or emerging from denning habitat. A spill during the Ice Season would still result in potential effects to polar bears that are in the area of the spill. However, effects are anticipated to be less severe since bears would have a larger area of habitat to disperse to and spilled oil on or below consolidated winter ice could be more effectively contained and removed or would be encapsulated into ice (see Sections 2.13 and 3.10.5).

Effects from a surface release onto ice would be expected to be more severe than effects from sub surface release since there is a higher probability that polar bears would come into direct contact with oil on the ice. Shoreline oiling from releases inside and outside the plume could also attract polar bears to carrion and oiled prey on shore and result in fouling of polar bears by oil (see below) and ingestion of oil through grooming or ingestion of contaminated prey.

The location of an oil spill relative to the Mackenzie plume (i.e., inside or outside the plume) is less relevant than the season during which a spill occurs. During the Open Water Season, polar bears would be largely concentrated on or in association with the receding sea ice (i.e., offshore in the northern Beaufort Sea) or have moved onto land. Given their distribution, polar bears could contact oil in areas inside or outside the area of influence of the plume during this season.

Polar bears are attracted to the smells and sounds associated with human activity (Stirling 1988) and may be drawn into an area where a spill has occurred, leading to higher possibility of coming into direct contact with oil (i.e., fouling fur), ingesting oil (i.e., through grooming or eating oil fouled prey), or coming into contact with humans involved with response and clean-up activities, leading to higher mortality risk from human bear conflicts. Adverse effects of an oil spill on the health, distribution, population size, or behaviour of important prey species (e.g., seals) would result in potential effects on health and behaviour of polar bears if availability or quality of prey species is affected. Oil spills also may result in changes in the behaviour of polar bear, habitat quality and use, health and mortality risk.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

If polar bears come in direct contact with oil, their fur becomes fouled, disrupting its insulation capacity, potentially leading to hypothermia (Boyd et al. 2001; Helm et al. 2015; St. Aubin 1990). External oiling of fur or skin may also increase the potential for ingestion and inhalation of oil, both of which can lead to potential lethal and sublethal effects (e.g., tissue damage to stomach, intestines, kidneys, eyes, lungs; reproductive problems; and various changes in behaviour) (Boyd et al. 2001; Carpenter et al. 2008; Øritsland et al. 1981; Venn-Watson et al. 2015). Polar bears that ingest oil during grooming may be subject to thermoregulatory and metabolic stresses from toxicity (Mattson 1990). Ingestion of oil by polar bears may lead to changes in behaviour (behavioural abnormalities), tissue damage, anorexia, and death by renal failure (Øritsland et al. 1981). Furthermore, polar bears may be indirectly affected by changes in the abundance of the seals they prey on, if those seal populations are negatively affected by oil. (Mattson 1990).

Effects of Climate Change on Potential Effects

As discussed for Scenarios 1 – 4, climate change is expected to alter polar bear habitat, force a shift in the geographical distribution of polar bears on sea ice and along coastlines, and place increased pressure on polar bear to access their primary food source (i.e., seals). The cumulative stress this imposes is likely to decrease the resiliency of the population and lower the ability to sustain the population at baseline levels.

D.3.6.6.2 Mitigation and Management

A spill during any season should consider mitigation measures to identify polar bears in the area and actively deter them from the area to reduce direct effects on bears and avoid human-bear conflicts during the response.

Oil spill response planning and measures are discussed in Sections 2.13 and 3.10.5.3. Additional details on mitigation are provided in Appendix F.

D.3.6.6.3 Effects Characterization

Residual Effects

Effects of oil spills that occur during the Ice or Transitional seasons could result in adverse effects on polar bear that are regional in extent and medium to long term. Given that oil spills are considered an accident or malfunction, they are predicted to be irregular in occurrence. Potential effects could be moderate to high in magnitude depending on timing and location and may affect the long-term sustainability of polar bear populations in the region.

Given the unpredictable nature of how polar bear populations might respond to impacts of climate change over the 30-year time period, the prediction and characterization of residual effects is made with low confidence. The influence of climate change may increase the magnitude of effects and affect the long-term sustainability of the population.

D.3.6.7 Summary of Residual Effects

Potential residual effects of Scenarios 1 – 4 and a large oil release event on polar bear are summarized in Table D-46 and Table D-47.

Table D-46 Potential Residual Effects of Scenarios 1 – 4 on Polar Bear

Season	Scenario 1: Status Quo	Scenario 2 Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Ice	• Few year-round activities; these would include snowmobile travel, offshore wind turbines, and aircraft overflights • Limited interaction with human activities given limited overlap with winter polar bear habitat.	• Spatial and temporal overlap with sea ice and denning habitat • Icebreaking and year-round operation could result in habitat disturbance, change in behaviour and increased mortality risk due to increased potential for human/bear conflict.	• Spatial and temporal overlap with sea ice and denning habitat • Icebreaking and year-round operation could result in habitat disturbance, change in behaviour and increased mortality risk due to increased potential for human/bear conflict.	• Spatial and temporal overlap between sea ice and denning habitat • Icebreaking, and year round production could result in habitat disturbance, change in behaviour and increased mortality risk due to increased potential for human/bear conflict.
Spring Transition	• Moderate overlap between shipping, tourism, military, and research activities and polar bear habitat use may cause disturbance or alteration to habitat	• Direct overlap with polar bear habitat could cause alteration to habitat, disturbance, and change in health or mortality risk due to change in prey species habitat and distribution or human/bear conflict. • Important feeding period • Females and cubs sensitive to impacts when emerging from dens	• Direct overlap with polar bear habitat could cause alteration to habitat, disturbance, and change in health or mortality risk due to change in prey species habitat and distribution or human/bear conflict. • Important feeding period • Females and cubs sensitive to impacts when emerging from dens	• Direct overlap with polar bear habitat could cause alteration to habitat, disturbance, and change in health or mortality risk due to change in prey species habitat and distribution (indirect effect) or human/bear conflict. • Important feeding period • Lower use of denning habitat but still potential for overlap
Open Water	• Limited interaction with human activities given limited overlap with polar bear habitat. Vessel activity would be the main source of impact.	• Minimal interaction with human activities given limited overlap with polar bear habitat. • Vessel activity would be the main source of impact.	• Minimal interaction with human activities given limited overlap with polar bear habitat. Vessel activity would be the main source of impact.	• Minimal interaction with human activities given limited overlap with polar bear habitat. Vessel activity would be the main source of impact.

Table D-46 Potential Residual Effects of Scenarios 1 – 4 on Polar Bear

Season	Scenario 1: Status Quo	Scenario 2 Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Fall Transition	• Moderate overlap between shipping, tourism, research and polar bear habitat use may cause disturbance or alteration to habitat	• Direct overlap with polar bear habitat could cause alteration to habitat, disturbance, and change in health or mortality risk due to change in prey species habitat and distribution (indirect effect) or human/bear conflict. • Important feeding period	• Direct overlap with polar bear habitat could cause alteration to habitat, disturbance, and change in health or mortality risk due to change in prey species habitat and distribution (indirect effect) or human/bear conflict. • Important feeding period	• Direct overlap with polar bear habitat could cause alteration to habitat, disturbance, and change in health or mortality risk due to change in prey species habitat and distribution (indirect effect) or human/bear conflict. • Important feeding period
Legend				
• Least effect – No to minor effect on polar bear habitat, behaviour, and/or mortality risk				
• Moderate effect -- Moderate effect on polar bear habitat, behaviour, and/or mortality risk				
• High effect -- Major effect on polar bear habitat, behaviour, and/or mortality risk				
• Greatest effect – Severe effect on polar bear habitat, behaviour, and/or mortality risk				

Table D-47 Potential Effects of a Large Oil Release Event (Scenario 5) for Polar Bear

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume) (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• Oil in leads could affect denning habitat or prey species, leading to indirect effects on polar bear (change in health and mortality). • Oil could be ingested through contaminated prey or self-grooming.	• Oil in leads could affect denning habitat or prey species, leading to indirect effects on polar bear (change in health and mortality). • Oil could be ingested through contaminated prey or self-grooming.	• Oil in leads could affect denning habitat or prey species, leading to indirect effects on polar bear (change in health and mortality). • Oil could be ingested through contaminated prey or self-grooming.
Spring Transition	• Oil in broken ice/open water could affect nearshore polar bear habitat, health, and behaviour resulting from ingestion through contaminated prey or self-grooming. harvesting. • Cleanup would be more difficult than other seasons resulting in longer exposure.	• Oil in broken ice/open water could affect polar bear habitat, health, and behaviour resulting from ingestion through contaminated prey or self-grooming. harvesting. • Cleanup would be more difficult than other seasons resulting in longer exposure.	• Oil in broken ice/open water could affect polar bear habitat, health, and behaviour resulting from ingestion through contaminated prey or self-grooming. harvesting. • Cleanup would be more difficult than other seasons resulting in longer exposure.
Open Water	• Limited overlap with polar bear habitat but moderate effect on polar bear could result from direct oiling and ingestion, or indirectly through ingestion of oiled prey.	• Limited overlap with polar bear habitat but moderate effect on polar bear could result from direct oiling and ingestion, or indirectly through ingestion of oiled prey.	• Limited overlap with polar bear habitat but moderate effect on polar bear could result from direct oiling and ingestion, or indirectly through ingestion of oiled prey.
Fall Transition	• Oil in broken ice/open water could affect nearshore polar bear habitat, health, and behaviour resulting from ingestion through contaminated prey or self-grooming. harvesting. • Cleanup would be more difficult than other seasons resulting in longer exposure.	• Oil in broken ice/open water could affect polar bear habitat, health, and behaviour resulting from ingestion through contaminated prey or self-grooming. harvesting. • Cleanup would be more difficult than other seasons resulting in longer exposure.	• Oil in broken ice/open water could affect polar bear habitat, health, and behaviour resulting from ingestion through contaminated prey or self-grooming. harvesting. • Cleanup would be more difficult than other seasons resulting in longer exposure.

Table D-47 Potential Effects of a Large Oil Release Event (Scenario 5) for Polar Bear

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume) (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Longer-term/ Multi-year	• Most residual oil removed by ongoing spill response and cleanup. • Residual oil in nearshore areas could affect prey species (e.g., seal) resulting in indirect effects on polar bear in the BRSEA Study Area. • Mortality of adult bears could result in extended recovery times for population	• Most residual oil removed by ongoing spill response and cleanup. • Residual oil in nearshore areas could affect prey species (e.g., seal) resulting in indirect effects on polar bear in the BRSEA Study Area. • Mortality of adult bears could result in extended recovery times for population.	• Most residual oil removed by ongoing spill response and cleanup. • Residual oil in nearshore areas could affect prey species (e.g., seal) resulting in indirect effects on polar bear in the BRSEA Study Area. • Mortality of adult bears could result in extended recovery times for population.
Legend			
• Least effect – No to minor effect on polar bear habitat, behaviour, and/or mortality risk			
• Moderate effect -- Moderate effect on polar bear habitat, behaviour, and/or mortality risk			
• High effect -- Major effect on polar bear habitat, behaviour, and/or mortality risk			
• Greatest effect – Severe effect on polar bear habitat, behaviour, and/or mortality risk			

D.3.6.8 Gaps and Recommendations

Polar bear populations in the BRSEA Study Area are well studied and management frameworks are in place to maintain the population at sustainable levels. However, as the apex predator in the Arctic, they have an important role in maintaining ecosystem balance, and like most Arctic species, there is great uncertainty in how polar bears would respond to climate induced changes to their habitat.

D.3.6.9 Follow-up and Monitoring

Confidence on the prediction of potential effects on polar bears is dependent on ongoing monitoring regarding body condition, prey availability, use of key habitat and availability (e.g., denning sites), population numbers and distribution. Ongoing monitoring programs that measure the viability of the population and identify drivers of potential threat to that viability would be key to an adaptive management approach targeted at limiting residual effects of human activity on polar bear and maintaining the populations ability to adapt to ecosystem changes that are predicted to occur.

D.3.7 Caribou

D.3.7.1 Scoping

D.3.7.1.1 IDENTIFICATION OF INDICATORS

Traditional harvesting of caribou is undertaken by all communities in the BRSEA Study Area (e.g., PCCP 2016:80; TCCP 2016:32). As such, communities are concerned that future resource development and exploration could have negative effects on the caribou calving grounds and summer ranges (PCCP 2016: 80; TCCP 2016:120).

Because offshore activities in the Status Quo and the three oil and gas development scenarios have limited potential to affect land-based caribou habitat and land-based effects are outside the scope of the BRSEA, the focus for the Caribou VC is on coastal habitats that are used by the majority of caribou populations that overlap the BRSEA Study Area. For this reason, the assessment of potential effects is on caribou and does not use specific caribou populations as indicators.

The assessment considers habitat use for the six caribou populations with seasonal ranges that overlap the BRSEA Study Area, including four barren-ground caribou herds (Porcupine, Tuktoyaktuk Peninsula, Cape Bathurst, and Bluenose West), one Peary caribou population (Banks/northwest Victoria Island), and the Dolphin and Union caribou population (Figure 7-53). Where there are important differences, these exceptions are noted.

Two of the caribou populations, the Peary caribou population and the Dolphin and Union caribou population, cross sea ice (i.e., inter-island movement) as follows:

- The Peary caribou population crosses sea ice to move between islands in the Arctic Archipelago. At present, inter-island movement by Peary caribou only occurs between islands in the northern half of the Archipelago (i.e., north of the Northwest Passage)[17]; these movements would be unaffected by vessel and tanker movements along the Northwest Passage and Amundsen-Queen Maude Gulf (Miller et al. 2005, Poole et al. 2010, Dumond et al. 2013, COSEWIC 2015, Jenkins et al. 2016, Johnson et al. 2016). In addition, most inter-island movements occur in Nunavut and are outside the BRSEA Study Area.
- The Dolphin and Union caribou herd calve on northwest Victoria Island within the BRSEA Study Area; however, these caribou cross sea ice in Nunavut (i.e., outside the BRSEA Study Area) when they travel back and forth from Victoria Island to the mainland during spring and fall migration (Poole et al. 2010).

Effects of vessel and tanker movements during the Open Water Season through channels to the east of the Beaufort Sea (e.g., Northwest Passage, Amundsen-Queen Maude Gulf) on inter-island movement by Peary caribou or the Dolphin and Union caribou herd are most likely to occur within Nunavut and are outside of the BRSEA Study Area; as a result, this effect not addressed further. It is acknowledged that shipping traffic during the migration season for these two populations has the potential to create barriers to caribou movement, as well as affect timing and patterns of ice formation and break up, which could delay movements or increase potential for crossing (Miller et al. 2005, Poole et al. 2010, Dumond et al. 2013, Jenkins et al. 2016, Johnson et al. 2016). If future vessel use from the ISR into Nunavut (or vice versa) is extended into the Spring or Fall Transition seasons with support of ice-breaking vessels or dual action hulls, or if icebreaking is considered during the Open Water Season[18], environmental protection measures should be implemented and monitoring conducted to confirm that icebreaking and vessel movements do not interfere with crossings of sea ice by this species. Of note, Peary caribou and the Dolphin and Union caribou herd are still considered for a large oil release event.

D.3.7.1.2 SPATIAL BOUNDARIES

As described in Section 7.2.7, the BRSEA Study Area overlaps the ranges of the six caribou populations (see Figure 7-53).

[17] Before ~1980 when abundance of Peary caribou was still relatively high, this species made seasonal movements between Banks and northwestern Victoria islands. Caribou residing on these two islands were recognized as a subpopulation by COSEWIC (2004). Notably, several aerial surveys since 1982 along with more recent satellite-tracking have failed to detect evidence of such travel. Inuvialuit hunters also reported no evidence of movement in the past decade (Paulatuk HTC 2013).

[18] During the Open Water Season in the nearshore and continental shelf and slope regions of the Beaufort Sea, there is potential that channels to the east of the Beaufort Sea such as the Northwest Passage and Amundsen-Queen Maude Gulf may contain floe ice or even pack ice. As a result, there is potential for vessel and tanker movements to interact with caribou use of sea ice.

D.3.7.1.3 TEMPORAL BOUNDARIES

The assessment of potential effects on caribou encompasses a 30-year period between 2020 – 2050.

D.3.7.1.4 ASSESSMENT OF POTENTIAL EFFECTS

The assessment of potential effects on caribou focuses on the potential for scenario activities to interact with seasonal caribou habitat use. Based on the established spatial boundaries, the discussion and characterization of effects are qualitatively assessed to estimate potential change in habitat use due to sensory disturbance or change in movement in the context of the life cycle for applicable caribou herds in the BRSEA Study Area. Effects of a large oil release event are also assessed. Qualitative characterization of potential residual effects on caribou associated with each scenario is based on the characterization terms defined in Table D-48.

Table D-48 Characterization of Residual Environmental Effects on Caribou for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect on the VC	**Positive**—a net benefit to the health, mortality, habitat or behaviour of the caribou population **Adverse**—a reduction or influence on the health, mortality, habitat or behaviour that could result in a change in the status or resiliency of the caribou population **Neutral**—no net change in the viability, status or resiliency of the caribou population
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no measurable change in health, mortality, habitat or behaviour (i.e., no change in abundance or distribution of the caribou population) **Low**—a measurable change in the distribution of the caribou population, but would not affect the long-term sustainability of the caribou population **Moderate**—measurable change in the distribution and abundance of the caribou population, with potential to affect the long-term sustainability of the caribou population **High**—measurable change with relative certainty of affecting the long-term sustainability of the caribou population
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the local area around the activity **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area) **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area)

Table D-48 Characterization of Residual Environmental Effects on Caribou for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity **Continuous**—residual effect occurs continuously for the duration of the activity
Duration	The period of time the residual effect can be measured or expected	**Short-term**—residual effect restricted to one phase or season (e.g., seismic survey, exploration drilling) **Medium-term**—residual effect extends through multiple seasons or years (e.g., production phase) **Long-term**—residual effect extends beyond the life of the project (e.g., beyond closure) **Permanent**—measurable parameter unlikely to recover to existing conditions
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.3.7.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

Interactions with the Status Quo (Scenario 1) and the three oil and gas development scenarios (Scenarios 2 to 4) are focused on physical activities in the nearshore areas that may disturb caribou using shallow coastal waters to escape insect harassment (specifically barren-ground caribou). The activities that are most likely to affect caribou are aircraft overflights and vessel movements near shore (i.e., within 2-3 km of the coastline where auditory and visual disturbances to caribou might occur depending on weather (such as onshore winds). Effects of an oil spill on caribou along coastlines are considered for a large oil release event (Scenario 5).

Anthropogenic noise has the potential to alter animal behaviour through a number of mechanisms including changes in temporal patterns (e.g., timing of movements), alterations in spatial distributions and movement (e.g., increased energetic costs), and increased vigilance and reduced foraging efficiency (Francis and Barber 2013). Caribou responses to specific noise sources such as aircraft varies depending on the season, degree of habituation, type of aircraft, altitude, airspeed, weather conditions, frequency of overflights, and the sex and age composition of caribou groups (Miller and Gunn 1979, Wolfe et al. 2000, Reimers and Colman. 2006; Stankowich 2008). Maier et al. (1998) concluded that responses of caribou to aircraft varied by season where responses were relatively weak during late winter, intermediate in the insect season, and strongest during the post-calving season. Females with young calves exhibited the most sensitive responses to aircraft overflights. Cameron et al. (2005) also reported that parturient females had stronger avoidance of oil field structures than non-parturient females in the Central Arctic herd. Although aircraft disturbance can result in short-term behavioural responses, Harrington and Veitch (1992) reported calving success for woodland caribou was reduced by exposure to low-level jets flights[19]. Caribou have also been reported to avoid human developments and infrastructure (Johnson and Russel 2014), which results in reduced habitat effectiveness.

Interactions of migratory barren-ground caribou with human activities in the BRSEA Study Area are most likely during the calving and post-calving seasons (June-July) when caribou increase their use of coastline habitats (i.e., primarily during the Open Water Season). Given their ranges during the Open Water Season (Figure 7-53), the Tuktoyaktuk, Cape Bathurst and Bluenose West populations are more likely to be in proximity to areas where vessels in various scenarios might be closest to the coastline. In contrast, the summer range of the Porcupine caribou population is largely in Alaska; while vessels could also disturb this population while on the summer range, this area is outside of the BRSEA Study Area, and is not considered further. However, effects on the Porcupine population are likely to be similar to the effects predicted for the other three caribou populations.

While caribou could be affected by sensory disturbance from vessels, interactions are expected to be uncommon. For an interaction to occur, caribou would need to be present on the shoreline or in shallow water at the same times as a vessel passes close to shore. These interactions are also likely to be short in duration (i.e., the duration of the vessel transit plus a recovery period). As noted above, few vessel movements are expected in the nearshore; most would occur 2-3 km or more offshore.

Aircraft overflights could occur along or across coastal areas in the BRSEA Study Area in all scenarios. However, it is assumed that aircraft would adhere to flight guidelines within the BRSEA Study Area (i.e., aircraft would maintain altitudes of >610 m when crossing areas in proximity to caribou (EIRB 2011, Appendix F)). As a result, aircraft overflights would not be expected to interfere with caribou use of coastal area. Policy, regulations and guidelines are expected to be followed for all aircraft uses, including industry, tourism, and community use; compliance monitoring should be used to confirm that operators are adhering to the minimum altitude restrictions and avoid flying over areas being used by caribou.

During the spring and fall migration, few if any effects from aircraft or vessels on caribou use of coastlines are expected, as most animals would not have arrived (Spring Transition Season) or would have already moved away to ranges that are further inland (Fall Transition Season) (COSEWIC 2016; SARC 2017). Since the majority of barren-ground caribou overwinter on traditional winter ranges that are away from the marine areas considered in the BRSEA (COSEWIC 2016; SARC 2017) and no vessels are likely to be operating in nearshore areas during the Ice Season, no interactions would occur during the Ice Season. Of note, some animals in the Cape Bathurst herd may use the Bathurst Peninsula during the winter; the majority move down the coast towards the south end of the Tuktoyaktuk Peninsula (COSEWIC 2016; SARC 2017).

[19] For this assessment, it is assumed that aircraft would be flying at altitudes greater than the minimum flying elevation guideline for large mammals and caribou (i.e., 300 m to 610 m depending on season; EIRB 2011, Appendix C)

Overall, potential effects of marine activities (e.g., installation and operation of infrastructure, drilling, seismic, vessel traffic) on barren-ground caribou herds are expected to be negligible as most marine vessel activities would be substantial distances offshore. Peary caribou and the Dolphin and Union caribou herd may also be affected by sensory disturbance but are in areas where vessel transits and other human activities would be less frequent. The exceptions would be local uses of snowmobiles and small boats along coastal areas, and during approaches by vessels or aircraft to service and supply bases and harbours (e.g., Tuktoyaktuk, Summers Harbour). As a result, the large majority of marine activities are expected to have minimal effects on habitat effectiveness for caribou when they are present along coastlines (i.e., irregular and short duration effects on a low to moderate number of animals in a population, with effects reversible within a short period (i.e., hours)). As a result, effects on habitat effectiveness for caribou are only discussed at a high level for the Scenarios 1 to 4.

The relationship between human activities, interactions, impacts and potential effects are summarized in Table D-49. As the activities and associated impacts are similar across the Status Quo and the three oil and gas development scenarios (2 to 4), it is assumed that there are no potential residual effects from each scenario on caribou, with the exception of Scenario 5 (large oil release event). Potential residual effects of an oil spill on caribou is discussed in Section D.3.7.6.

Table D-49 Summary of Potential Impacts and Effects on Caribou

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Air Contaminant and GHG Emissions	• vessel transits • seismic surveys • drilling • operational and maintenance activities to vessels, production platform, and wells • helicopters, low flying aircraft, and snowmobiles	• no interaction	• NA	• NA
Noise (in-air and underwater)	• vessel transits (engine, propeller, and ice-breaking activities) in channels to the east of the Beaufort Sea • seismic surveys • drilling • operational and maintenance activities to vessels, production platform, and wells • helicopters, low-flying aircraft and snowmobiles	• startle response or avoidance during spring/late summer migration in areas subjected to ambient noise from helicopters or low-flying aircraft, vessel traffic, or other nearshore activities	• potential residual effects on caribou are possible; with mitigation in place (e.g., wildlife monitors, minimum aircraft altitudes, seasonal and designated shipping routes), potential residual effects on behaviour (migration patterns and/or sensory disturbance) should be reduced • **this effect is not assessed further**	• change in number of individuals observed during migration • change in number of individuals observed using coastal areas (calving grounds, insect-relief)
Artificial Light	• lighting used on nearshore infrastructure (wind turbines, marine infrastructure), offshore platforms and vessels • lighting for offshore developments	• no interaction	• NA	• NA
Seabed Disturbance	• subsea well manifold, and pipeline installations and repairs	• no interaction	• NA	• NA

Table D-49 Summary of Potential Impacts and Effects on Caribou

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Ice Disturbance	• icebreakers transiting through sea ice (ice management, support, transport) • presence of structures on/in sea ice or open water (drillships, platforms, wind turbines)	• habitat alteration due to physically breaking up sea ice resulting in a barrier to seasonal migration/movement • depending on shipping routes, migration across sea ice could be affected • changing climate affecting sea ice extent and thickness	• potential residual effects on caribou are possible; with mitigation in place (e.g., wildlife monitors, seasonal and designated shipping routes), potential residual effects on behaviour (migration patterns and/or sensory disturbance) should be reduced • **this effect is not assessed further**	• change in number of individuals observed during migration • number of individuals stranded
Vessel Wake	• Vessel use during Open Water Season (commercial, personal use, tourism, sea lift, military, research, harvesting)	• no interaction	• NA	• NA
Routine Discharges	• air emissions • bilge and ballast water • drilling muds and lubricating fluids • drill cuttings and disposal • sewage and food waste • cooling water and deck drainage	• no interaction	• NA	• NA
Vessel Collision	• vessel transits (Shipping, tankers, icebreakers, personal watercraft)	• no interaction	• NA	• NA

Table D-49 Summary of Potential Impacts and Effects on Caribou

Potential Impact	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Oil Spill	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from a subsurface location (well head, pipeline)	• Ingestion of oil through oil contaminated coastal vegetation communities; however, likelihood of ingestion is low for caribou.	• potential residual effects on caribou are possible; with mitigation in place (e.g., spill response and clean-up protocols, exclusion of wildlife from spill area), potential residual effects on behaviour and health may be reduced but require further assessment.	• change in body condition • change in number of individuals observed using coastal areas (calving grounds, insect-relief)

D.3.7.2 Scenario 1: Status Quo

D.3.7.2.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY AND RANGE OF POTENTIAL EFFECTS

Marine activities (e.g., tourism, scientific research, military vessels and exercises) and low-level aircraft have potential to indirectly affect caribou seasonal habitat use due to sensory disturbance (i.e., noise and lights) when caribou are present in coastal areas for insect relief as well as calving and post-calving. Although noise and human activities have the potential to result in habitat avoidance and displacement, the potential effects of these activities may have relatively greater effects during calving and post-calving; caribou avoidance of human developments has been reported to be reduced during insect harassment (Pollard et al. 1996, Wolfe et al. 2000).

While sensory disturbance from human and industrial activities in the BRSEA Study Area could affect caribou use of coastal habitats, several factors would reduce the potential risk:

- given the distances from the coastline that vessel activities are likely to occur (i.e., several to many kilometres offshore) and the separation of caribou from these activities, effects of sensory disturbance on use of coastal habitats by caribou are predicted to be uncommon, of short duration and reversible
- there is a low potential for interactions between vessels and caribou during vessel approaches and use of land-based service and supply bases (e.g., Tuktoyaktuk and Summers Harbour). Given the likely amounts of human activities in and adjacent to these bases (and the community of Tuktoyaktuk), caribou would be less likely to use areas adjacent to these bases.
- aircraft are assumed to follow minimum altitude restrictions and avoid areas where caribou are present (i.e., EIRB 2011, Appendix F); as a result, effects of aircraft overflights on use of coastal habitat by caribou should be low to negligible

Effects on caribou use of coastal habitat due to activities outlined in Scenario 1 are predicted to be low to negligible (i.e., irregular and short duration effects on a low to moderate number of animals in a population, with effects reversible within a short period (i.e., hours)).

As discussed in Section D.3.7.1.1, vessel movements in major channels between the Arctic islands to the east of the Beaufort Sea (e.g., Northwest Passage, Amundsen-Queen Maude Gulf) are unlikely to interact with crossing of sea ice by Peary caribou. In addition, the seasonal timing of vessel use may not overlap a great deal with caribou use of sea ice. Peary caribou typically cross sea ice during the spring migration (e.g., April–June) and during movements in the fall (e.g., September–November) (Jenkins et al. 2016; Mallory and Boyce 2019). As discussed earlier, crossing of sea ice by Peary caribou and the Dolphin and Union caribou population largely occurs within Nunavut and is outside of the BRSEA Study Area. Given these factors, this effect is not considered further in this assessment. However, if future vessel use is extended into the Transition seasons with support of ice-breaking vessels or dual action hulls, environmental protection measures and monitoring are recommended to confirm that icebreaking and vessel movements do not interfere with crossings of sea ice by this species.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Climate change is expected to continue to affect the distribution of sea ice in the Arctic. Overall, the effects of climate change have the potential to exacerbate the potential effects of commercial shipping as declines in sea ice coverage are predicted and the shipping season lengthens (Mallory and Boyce 2019).

Changes in sea ice conditions have the potential to affect Peary caribou and the Dolphin and Union caribou populations that rely on sea ice to move seasonally between islands. More open water would create barriers to movement and reduce the ability for these caribou to move between islands or the mainland to avoid predators or seek more favorable foraging conditions. Mallory and Boyce (2019) recently reported that a longer ice-free season in the Canadian High Arctic would dramatically decrease connectivity between Peary caribou island habitats during important movement periods in both late winter and spring. Island connectivity is important to maintain genetic diversity; however, based on a connectivity analysis, these authors emphasized that maintaining connectivity, especially for smaller islands within the Bathurst complex including the West Queen Elizabeth Islands (e.g., Prince Patrick and Melville), is most important, since larger islands (e.g., Banks) currently have limited roles in connecting Peary caribou.

D.3.7.2.2 MITIGATION AND MANAGEMENT

General mitigation measures and standard operational procedures associated with the protection of wildlife from human impacts should be employed (Section 2.3). Measures specific to the protection of caribou from human impacts include:

- adhere to minimum altitudes for aircraft (>610 m or 2000 feet) that are flying close to caribou, as recommended by the EIRB (2011, Appendix F). The Tuktoyaktuk Community Conservation Plan (TCCP 2016:126), Sachs Harbour Community Conservation Plan (SCCP 2016:64) and others include similar minimum flying altitudes
- use existing and common travel routes by vessels, icebreakers and aircraft that avoid sensitive habitat where possible and practical
- avoid vessel and icebreaking traffic in channels to the east of the Beaufort Sea during the Spring Transition and late Fall Transition seasons
- manage the number and distribution of tourist operators to avoid potential effects on calving and use of winter habitat (TCCP 2016)
- undertake long-term monitoring to collect additional data on population status, habitat use, body condition and response of caribou to human and development activities
- for coastline areas identified as important for caribou seeking insect-relief, limit offshore vessel traffic within 1 to 3 km from June 20 to August 15 (after Clough et al. 1987)

Additional details are provided in Appendix F.

D.3.7.2.3 EFFECTS CHARACTERIZATION

As discussed in Section D.3.7.1.5, there is limited potential for offshore activities to affect migratory barren-ground caribou, Peary caribou or the Dolphin and Union caribou population. As such, no residual effects are expected on caribou use of coastal habitats from activities associated with Scenario 1. As there are no predicted residual effects, no assessment of cumulative effects was undertaken.

D.3.7.3 Scenario 2: Export of Natural Gas and Condensates

The effects pathways for this scenario are similar to those described for the Scenario 1; the primary activities of concern are: construction and operation of subsea pipelines, loading platforms, and offshore infrastructure, as well as increased aircraft activity (e.g., helicopter). However, due to the distance offshore of these activities (i.e., 1 km to 15-20 km), they would have negligible effects on caribou using coastal plain habitats during calving or for insect relief. As aircraft would be transiting to supply and service bases that are close to existing communities (e.g., Tuktoyaktuk) or offshore and are assumed to follow minimum altitude requirements (EIRB 2011, Appendix F), there is a low to negligible potential for these activities to result in sensory disturbance effects and associated avoidance of important coastal habitats. As such, there are no residual effects expected on caribou from activities associated with Scenario 2[20] (i.e., irregular and short duration effects on a low to moderate number of animals in a population, with effects reversible within a short period (i.e., hours)).

Effects of climate change on caribou use of coastal habitat are similar to those discussed earlier for Scenario 1 (Section D.3.7.1.1).

As described for Scenario 1, general mitigation measures and standard operational procedures for wildlife (Section 2.3) and caribou (Section D.3.7.2.2) should be employed for Scenario 2. Additional details are provided in Appendix F.

D.3.7.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

The effect pathways and potential effects of Scenario 3 are similar to those described for Scenario 2 (e.g., ship movements close to shore and aircraft movements between the service and supply centres in Tuktoyaktuk and Summers Harbour), except that the majority of activity is further offshore (>80 km). Effects on caribou use of coastal habitat due to activities outlined in Scenario 3 are predicted to be low to negligible (Section D.3.7.1.5) (i.e., irregular and short duration effects on a low to number of animals in a population, with effects reversible within a short period (i.e., hours)).

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[20] As noted in the discussion for Scenario 2 (Section 3.7.1), a major portion of the LNG development would be on land within or adjacent to the Mackenzie Delta, and involve drilling of land-based production and injection wells, service and supply bases, gathering pipelines and a facility for gas extraction processing, and liquefication. These facilities would have a much greater potential to interact with barren-ground caribou populations. However, land-based activities and effects are outside the scope of the BRSEA.

Effects of climate change on caribou use of coastal habitat are similar to those discussed earlier for Scenario 1 (Section D.3.7.1.1).

As described for Scenario 1, general mitigation measures and standard operational procedures for wildlife (Section 2.3) and caribou (Section D.3.7.2.2) should be employed for Scenario 3. Additional details are provided in Appendix F.

D.3.7.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

The effect pathways and potential effects for Scenario 4 are similar to those described in previous scenarios (Section D.3.7.2.1), except that the majority of activity is further offshore (>100 km) than the other oil and gas development scenarios. As described for Scenario 1, tanker transits major channels between the Arctic islands to the east of the Beaufort Sea (e.g., Northwest Passage, Amundsen-Queen Maude Gulf) during the Open Water Season are unlikely to interact with crossing of sea ice by Peary caribou. In addition, the seasonal timing of vessel use may not overlap a great deal with caribou use of sea ice. Effects on caribou use of coastal habitat due to activities outlined in Scenario 4 are predicted to be low to negligible (Section D.3.7.1.5) (i.e., irregular and short duration effects on a low to number of animals in a population, with effects reversible within a short period (i.e., hours)).

Effects of climate change on caribou use of coastal habitat are similar to those discussed earlier for Scenario 1 (Section D.3.7.1.1).

As described for Scenario 1, general mitigation measures and standard operational procedures for wildlife (Section 2.3) and caribou (Section D.3.7.2.2) should be employed for Scenario 4. Additional details are provided in Appendix F.

D.3.7.6 Scenario 5: Large Oil Release Event

While the Large Oil Release Event is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels. If the fuel tanks for these vessels were affected (e.g., punctured during a collision), large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on caribou from such an event may differ slightly from what is described below for surface or subsea releases.

D.3.7.6.1 Potential Impacts and Effects of a Large Oil Release

Description of Effect Pathway

Marine oil spills have the potential to adversely affect caribou as a result of direct and indirect exposure to oil. In the event of a spill, exposure may occur when caribou visit barrier islands and shallow coastal waters (i.e., along coastlines) when avoiding insect harassment (Alaska OCS Region 1998). In addition to direct contact with oil (i.e., becoming oiled), caribou may also ingest contaminated vegetation. However, there is low potential for ingestion of oil by barren-ground caribou herds when they are present in coastal areas to avoid insect harassment (WMAC-NS and AHTC 2009), since the shorelines areas that might be affected by oil (e.g., oil washed ashore) are not suitable for foraging. Upland areas (including coastal marshes/plains) where barren-ground caribou may forage are less likely or unlikely to be fouled by oil.

Unlike other wildlife species (e.g., birds), caribou that become oiled are unlikely to suffer the loss of thermo-insulation through fur contamination, although sublethal effects may be possible through direct absorption or inhalation (Alaska OCS Region 1998). Oiled hair would be shed during the summer (i.e., before caribou grow their winter fur).

Description of Range of Potential Effects

Effects on caribou from a large oil release event include changes in habitat and habitat use, behaviour, and health. Mortality risk due to inhalation and absorption of oil is possible, but unlikely. If an oil spill were to occur, caribou using coastlines for relief of insect harassment are generally considered to be at lower potential for exposure to oil than most other wildlife species (WMAC-NS and AHTC 2009).

The greatest potential for caribou contacting oil would be a large release of oil within the Mackenzie Plume during the Open Water Season. This is because caribou are most likely to be in coastal areas during the Open Water Season (i.e., avoiding insects), and the potential for shoreline oiling is greatest for oil releases within the Mackenzie Plume during the Open Water Season (Table 3-12). The potential for caribou to interact with released oil is lower in the Spring and Fall Transition seasons, since fewer or no caribou would be present on shorelines close to the highest high-water mark. During the Ice Season, the potential is negligible as most, if not all, caribou would be absent during this season. However, oil released from ice during the Spring Transition Season could expose caribou in coastal areas to oil during the following Open Water Season.

Effects of Climate Change on Potential Effects

Climate change is not anticipated to change the potential effects of oil spill on caribou.

D.3.7.6.2 Mitigation and Management

Spill planning and response measures are described in Sections 2.13 and 3.10.5.3. Additional details are provided in Appendix F.

D.3.7.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

While an oil spill in any season or location could result in transport to oil on shore, the greatest risk of a spill to caribou would be in the Open Water Season when caribou are present and using these areas for insect relief, calving and post-calving during the Open Water Season. Given that oil spills are considered an accident or malfunction, they are predicted to be irregular in occurrence. While effects of an oil spill would be adverse, based on the effect pathways, it is unlikely that the viability of caribou herds would be affected by an offshore spill. The extent of these effects would depend on the volume of oil spilled, spill response mobilization time, effectiveness of containment measures, and ecological, environmental, and oceanographic conditions, as well as the extent of temporal and spatial overlap between the spill and use of coastlines by caribou.

D.3.7.7 Summary of Residual Effects

Potential residual effects of Scenarios 1 – 4 and a large oil release event on caribou are summarized in Table D-50 and Table D-51.

D.3.7.8 Gaps and Recommendations

Although caribou migration and habitat use is well known, continued research and monitoring, including the incorporation of TLK, on population status, distribution (including seasonal distribution, migration patterns), and habitat use is highly recommended as it is critical in the understanding of how human activity and climate change are influencing caribou populations in the region.

D.3.7.9 Follow-up and Monitoring

As onshore oil and gas operations and infrastructure would be expected to have more important interactions with seasonal habitat use and movements and have greater potential to result in important effects on caribou than offshore developments, the priority for this species should be monitoring the effects of future onshore activities. As part of monitoring in coastal areas, caribou use of coastal areas and islands for insect relief, calving and post-calving could also be assessed to better understand spatial and temporal distribution and inter-annual variation.

Table D-50 Potential Residual Effects of Scenarios 1 – 4 on Caribou

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Ice	• Minimal interaction with Peary caribou migration over ice • Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas	• Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas.	• Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas.	• Minimal interaction with Peary caribou migration over ice • Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas
Spring Transition	• Vessels travelling east of the Beaufort Sea would not affect Peary caribou use of sea ice within BRSEA Study Area. • Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas.	• Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas.	• Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas.	• Tankers travelling east of the Beaufort Sea would not affect Peary caribou use of sea ice. within BRSEA Study Area. • Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas.
Open Water	• Vessels travelling east of the Beaufort Sea would not affect Peary caribou use of sea ice within BRSEA Study Area. • Given spatial use of coastlines by vessels and aircraft, sensory disturbance from these activities would have low to negligible effects on caribou using coastal areas for insect relief or on calving grounds.	• Given spatial use of coastlines by vessels and aircraft, sensory disturbance from these activities would have low to negligible effects on caribou using coastal areas for insect relief or on calving grounds	• Given spatial use of coastlines by vessels and aircraft, sensory disturbance from these activities would have low to negligible effects on caribou using coastal areas for insect relief or on calving grounds	• Tankers travelling east of the Beaufort Sea would not affect Peary caribou use of sea ice within BRSEA Study Area. • Given spatial use of coastlines by vessels and aircraft, sensory disturbance from these activities would have low to negligible effects on caribou using coastal areas for insect relief or on calving grounds

Table D-50 Potential Residual Effects of Scenarios 1 – 4 on Caribou

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4: Oil Development in Deep Water
Fall Transition	• Vessels travelling east of the Beaufort Sea would not affect Peary caribou use of sea ice within BRSEA Study Area. • Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas.	• Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas.	• Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas.	• Tankers travelling east of the Beaufort Sea would not affect Peary caribou use of sea ice within BRSEA Study Area. • Minimal interaction with human activities (e.g., vessels, aircraft) as majority of caribou would be away from coastal areas.
Legend				
• Least effect – No to minor effect on caribou behaviour (i.e., migration/movement/calving)				
• Moderate effect -- Moderate effect on caribou behaviour (migration/movement/calving)				
• High effect -- Major effect on caribou behaviour (migration/movement/calving)				
• Greatest effect – Severe effect on caribou behaviour (migration/movement/calving)				

Table D-51 Potential Effects of a Large Oil Release Event (Scenario 5) for Caribou

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume) (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• Low or negligible potential for caribou to contact oil as caribou would be on traditional wintering grounds which are far removed from coastal areas and potential onshore oiling effects.	• Low or negligible potential for caribou to contact oil as caribou would be on traditional wintering grounds which are far removed from coastal areas and potential onshore oiling effects.	• Low or negligible potential for caribou to contact oil as caribou would be on traditional wintering grounds which are far removed from coastal areas and potential onshore oiling effects.
Spring Transition	• Effects to caribou health and mortality risk. Caribou overlapping with coastal areas could be affected by oil contact and ingestion	• Effects to caribou health and mortality risk. Caribou overlapping with coastal areas could be affected by oil contact and ingestion	• Effects to caribou health and mortality risk. Caribou overlapping with coastal areas could be affected by oil contact and ingestion
Open Water	• Effects to caribou health and mortality risk. Caribou overlapping with coastal areas could be affected by oil contact and ingestion	• Effects to caribou health and mortality risk. Caribou overlapping with coastal areas could be affected by oil contact and ingestion	• Effects to caribou health and mortality risk. Caribou overlapping with coastal areas could be affected by oil contact and ingestion
Fall Transition	• Effects to caribou health and mortality risk. Caribou overlapping with coastal areas could be affected by oil contact and indirect issues such as ingestion of oil while foraging	• Effects to caribou health and mortality risk. Caribou overlapping with coastal areas could be affected by oil contact and indirect issues such as ingestion of oil while foraging	• Effects to caribou health and mortality risk. Caribou overlapping with coastal areas could be affected by oil contact and indirect issues such as ingestion of oil while foraging

Table D-51 Potential Effects of a Large Oil Release Event (Scenario 5) for Caribou

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume) (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Longer-term/ Multi-year	• If oil clean-up/recovery efforts are incomplete, lingering oil could have interactions with caribou during Spring Transition, Open Water and Fall Transition seasons. • Long-term effects from direct and indirect exposure can have wide-ranging demographic consequences on populations; including decreased survivorship due to effects on food quality and chronic health effects from lingering oil.	• If oil clean-up/recovery efforts are incomplete, lingering oil could have interactions with caribou during Spring Transition, Open Water and Fall Transition seasons. • Long-term effects from direct and indirect exposure can have wide-ranging demographic consequences on populations; including decreased survivorship due to effects on food quality and chronic health effects from lingering oil.	• If oil clean-up/recovery efforts are incomplete, lingering oil could have interactions with caribou during Spring Transition, Open Water and Fall Transition seasons. • Long-term effects from direct and indirect exposure can have wide-ranging demographic consequences on populations; including decreased survivorship due to effects on food quality and chronic health effects from lingering oil.
Legend			
• Least effect – No to minor effect on caribou habitat, behaviour, and/or mortality risk			
• Moderate effect -- Moderate effect on caribou habitat, behaviour, and/or mortality risk			
• High effect -- Major effect on caribou habitat, behaviour, and/or mortality risk			
• Greatest effect – Severe effect on caribou habitat, behaviour, and/or mortality risk			

D.4 Human Environment

D.4.1 Economy

This section of the assessment addresses potential benefits and adverse effects on economic parameters within the BRSEA Study area and, where required, effects on adjacent areas including the NWT, Yukon and beyond (e.g., Canada).

As the assessment for the BRSEA is based on hypothetical scenarios, quantitative estimates or ranges for different economic parameters were not calculated; in particular, specific information is not known for aspects such as work force size and sequencing, value and schedule for equipment and supply purchases and other expenditures, and terms of benefit agreements for Inuvialuit and other northerners. Developing defendable values for these and other parameters is not possible without detailed information on program specifics, which are beyond the purpose of the scenarios for the BRSEA. The budget scope for the Data Synthesis and Assessment report also did not permit modeling to predict potential estimates or ranges. While past projects can offer input to these parameters, none of these are adequate "surrogate" projects for Scenarios 2 or 4.

Past oil and gas activities in the BRSEA Study Area have focused on exploration activities for oil and gas resources, including land and marine seismic surveys, exploration drilling and construction and operation of infrastructure to support these activities. As a result, past economic effects and benefits reflect the types of activities completed, the location of these activities, and evolving changes and improvements in benefit agreements, the employment of Inuvialuit residents and use of Inuvialuit and other local service providers and suppliers.

For previous exploration projects in the BRSEA Study Area, the IRC has noted that onshore exploration activities have resulted in comparatively higher economic opportunities and benefits for Inuvialuit and the ISR compared to exploration activities that have occurred further offshore (Cournoyea, pers. comm. 2014). However, oil and gas development scenarios, as envisioned in Scenarios 2 – 4, are qualitatively different from exploration, because they would involve development and operation of a natural gas/condensate export facility, various types of offshore oil field development, onshore logistical support and administrative centres, and crew transfers and accommodations. The experience of Newfoundland and Labrador shows that offshore oilfield development can produce substantial regional economic benefits, when operated under a comprehensive benefits sharing agreement[15].

[15] Statistics compiled by the Canadian Association of Petroleum Producers indicate that from 1995 – 2017, the oilfield developers invested over $42 billion in Newfoundland and Labrador's offshore oil and gas sector and generated over $20 billion in provincial royalty revenue. In 2017, the sector employed more than 5,200 persons, and is supported by 600 supply and service companies (CAPP 2018: https://www.capp.ca/wp-content/uploads/2019/11/Canada_s_Offshore_Oil_and_Natural_Gas_Industry_in_Newfoundland_and_Labrador-320561.pdf).

Key elements of the IFA would play a substantial role in influencing how future projects might proceed in the BRSEA Study Area and how Inuvialuit would participate and benefit; these include:

- education of Inuvialuit individuals and the development of business capacity
- ownership and access to Inuvialuit Land, including participation agreements which include "specific terms and conditions respecting the nature and magnitude of the land use for which the access is being sought". These can include "employment, service and supply contracts".
- co-operation and benefits agreements for oil and gas developments that define the types benefits that the Inuvialuit would receive in terms of training, education, employment, contracts and other business opportunities. These agreements typically have been accepted by governments as sufficient to satisfy their approval process (e.g., northern benefit plans for CIRNAC).
- priority access for Inuvialuit businesses[16] to aid them in meaningfully participating in economic development activities in the region. Inuvialuit must have access to the opportunities as they arise. "The Inuvialuit Land Administration (ILA) can establish priority access to procurement initiatives for Inuvialuit businesses through instruments such as cooperation agreements, participation agreements, access agreements and permits (IRC 2020: https://www.irc.inuvialuit.com/ibl-policy).

These aspects of the IFA, as well as components of cooperation and benefits agreements that apply to other northerners (e.g., NWT, Yukon, and Nunavut) are important in project planning, as well as developing measures to increase potential benefits while reducing adverse effects during constriction and operations.

D.4.1.1 Scoping

D.4.1.1.1 IDENTIFICATION OF INDICATORS

The following measurable parameters are used in the assessment of the Economy VC:

- economic activity: Measures of economic activity include capital investment, GDP, and economic diversification. These relate to the size, growth, and stability of the economies of the ISR, NWT and Yukon.
- local labour indicators: The participation rate and unemployment rate measure the extent to which ISR residents are participating in the wage economy, which is also correlated to household income.
- household income: relates broadly to health and wellbeing of Inuvialuit and other residents. Changes associated with industrial projects mainly relate to wage incomes, employee benefits, and local purchases of supplies and services (and associated employment income from those supply and service companies).

[16] The criteria for being listed an Inuvialuit business include: majority Inuvialuit ownership of the business; substantive business capacity in the area for which listing is sought; significant management roles for Inuvialuit, a high degree of Inuvialuit employment and local presence (IRC 2020: https://www.irc.inuvialuit.com/ibl-policy).

- changes in the proportion of traditionally harvested versus store bought foods can also affect household income and the cost of living, as well as health and wellbeing (Section D.4.4)
- cost of living: relates to household economic well-being

D.4.1.1.2 Spatial Boundaries

Economic effects encompass spending and hiring that could occur within one or more communities within the ISR and extend beyond the ISR to other communities in NWT, Yukon and Canada. The six communities within the ISR are: Aklavik, Inuvik, Paulatuk, Sachs Harbour, Tuktoyaktuk, and Ulukhaktok.

D.4.1.1.3 Temporal Boundaries

The assessment of potential effects on the economy encompasses a 30-year period between 2020 – 2050.

D.4.1.1.4 Assessment of Potential Effects

A qualitative characterization of potential residual effects on the economy associated with each scenario is based on the characterization terms defined in Table D-52.

Table D-52 Characterization of Residual Environmental Effects on Economy for the time period 2020 – 2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Positive**—an increase in economic indicators **Adverse**—a decrease in economic indicators **Neutral**—no net change in economic indicators
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no measurable change in economy **Low**— effect cannot be distinguished from baseline condition; within normal range of variability **Moderate**—measurable change but unlikely to pose a serious risk or substantial benefit to the economy **High**—measurable change that, if adverse, is likely to pose a serious risk to the economy. If positive, it would be a substantial economic benefit.
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity. **Local**—residual effects extend into the local area around the activity. **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area). **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area).

Table D-52 Characterization of Residual Environmental Effects on Economy for the time period 2020 – 2050

Characterization	Description	Definition of Qualitative Categories
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once. **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity. **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity. **Continuous—**residual effect occurs continuously for the duration of the activity.
Duration	The period of time the residual effect can be measured or expected	**Short-term**—the residual effect is restricted to short-term events or activities such as discrete component completion during construction, maintenance, or rehabilitation activities (i.e., a timeframe of several months up to 1 year) **Medium-term**—the residual effect extends through the completion of construction and rehabilitation activities (i.e., a timeframe of 1 year to 5 years) **Long-term**—the residual effect extends beyond the completion of construction and rehabilitation activities into the operations and maintenance phase of a project (i.e., a timeframe of greater than 5 years) **Permanent**—the measurable parameter is unlikely to recover to existing conditions
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Socio-economic context	Existing condition and trends in the area where residual effects occur	**Average condition**—Economic condition within area, measured by unemployment rate, per capital income, or other indicators, is comparable with territorial average **Below average condition**—Economic condition within area, measured by unemployment rate, per capital income, or other indicators, is demonstrably below territorial average

D.4.1.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

All activities that result in spending within and financial inflows into the ISR would have an economic impact. This could include:

- activities involving the transfer of equipment, materials, and personnel via air or vessels through port or airport facilities, including local resupply of offshore facilities by ship or helicopter
- purchase of goods and services from local suppliers
- employment of residents from ISR communities

These expenditures will vary among the scenarios that are considered in the BRSEA, reflecting the relative levels of onshore expenditures and employment, verses likely offshore activities and supply. Scenarios which rely more heavily on offshore activities and supply are expected to provide fewer benefits to the ISR economy than those with high levels of onshore expenditures and employment. However, it is assumed in the Status Quo and the three oil and gas development scenarios that provisions would be made through the benefits agreements with the Inuvialuit to provide opportunities for employment of Inuvialuit, use of Inuvialuit businesses for local supplies and services, and land-based logistic and administrative centres within the ISR. Financial inflows related to government services and transfers would remain an important component of the economy.

Activities that interact adversely with traditional harvesting would also affect household economics because a decrease in traditional harvesting would necessitate increased expenditure on store-bought foods. Potential effects on traditional harvesting are addressed in Section D.4.4.

The total magnitude of capital inflows within the region would depend on, the range of available services, contracting capacity and value-added within ISR. During the 2006 to 2011 oil and gas exploration period in the Beaufort Sea, Inuvialuit companies directly participating in exploration activities obtained contracts with a combined total of up to $100 million per year, while sub-contractors obtained contracts with a combined total of up to $35 million (Impact Economics 2014). However, a large proportion of the value of these contracts would have been the value of equipment, materials, and energy products (e.g., fuel) that would have been manufactured outside of the ISR (Impact Economics 2014).

Large scale oil or gas activity within the BRSEA Study Area would likely require labour forces in the order of magnitude of hundreds to thousands during project site preparation, installation and operation. While it would be expected that skilled labour from outside ISR would be required, there would be substantial employment opportunities for ISR residents. Inuvialuit beneficiaries would be preferentially hired under Subsection 16 of the IFA, Section 5.2 of, COGOA and Section 21 of CPRA (see Section 2.11). During the 2006 to 2011 oil and gas exploration period in the ISR, Inuvialuit accounted for approximately 26% of the total direct oil and gas exploration workforce of up to 335 persons; with NWT non-Inuvialuit accounting for 9% of the direct workforce; Gwich'in First Nation 2%; non ISR resident Inuvialuit 1%, and southern non-Inuvialuit 63% (Impact Economics 2014).

The economic impacts would multiply as dollars are recycled through the local economy. For example, higher levels of household spending on goods and services would induce further economic activity, including employment, GDP generation, and increased government revenue. Positive economic effects would also result from the additional generation of government revenues from personal and corporate taxes and resource royalties.

Activities within the ISR with no or little interaction with ISR communities would have no or minimal economic impact; these include offshore ship resupply from ports outside of the ISR and activities that are logistically supported or provided from outside the ISR (e.g., manufacture of GBS platforms or the FPSO; construction or rental of wareships from foreign sources, contracting of tow ships and resupply vessels from locations outside the ISR). Table D-53 summarizes potential impacts and effects for the Economy VC that could be associated with various development scenarios, as well as the large oil release event. Environmental effects that result in changes in traditional harvesting also would affect the incomes, health and wellbeing of households in the ISR (Section D.4.4).

Table D-53 Summary of Potential Impacts and Effects on Economy

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 1 (Status Quo)	• marine vessels – commercial shipping, cruise ship tourism, scientific research, military • ship-based or barge resupply of ISR coastal communities • renewable energy project (e.g., offshore wind turbine) • traditional harvesting – regional boat traffic and snowmobile use • scientific research and associated activities, including collection of TEK	• purchasing of goods and services results in capital inflows into ISR and elsewhere in NWT and Yukon • hiring and employment of labour from ISR communities • change in traditional harvesting activities (see Section D.4.4) could affect household expenditures on market foods	• change in regional economy • change in labour force • change in household • change in cost of living	• regional economy: GDP change, capital investment • labour force: total labour requirements, % Inuvialuit in workforce, labour participation rate, unemployment rate • household income: Average household income, average monthly cost of food
Scenario 2 (Export of Natural Gas and Condensates)[17]	**Construction** • towing and installation of GBS loading platform at project site • installation of dual pipelines **Operations** • LNG carrier and condensate tanker loading • LNG carrier and condensate tanker transits westward	• purchasing of goods and services results in capital inflows into ISR and elsewhere in NWT and Yukon • Hiring and employment of workers from ISR communities • change in traditional harvesting activities (see Section D.4.4) could affect household expenditures on market foods	• change in regional economy • change in labour force • change in household income] • change in cost of living	• regional economy: GDP change, capital investment • labour force: total labour requirements, % Inuvialuit in workforce, labour participation rate, unemployment rate • household income: Average household income, average monthly cost of food

[17] Only economic benefits and effects from the marine operations are considered here; economic benefits from development of gas fields, pipelines gas processing facilities onshore are not considered.

Table D-53 Summary of Potential Impacts and Effects on Economy

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 2 **(Export of Natural Gas and Condensates) (cont'd)**	• icebreaker management around GBS facility and possibly as carrier/tanker escort • annual sealift • local resupply of GBS loading facility by vessel • helicopter transfer of crews • Tuktoyaktuk logistical support base • crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik **Decommissioning** • removal of GBS loading facility • capping and filing of undersea pipelines			

Table D-53 Summary of Potential Impacts and Effects on Economy

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf)	**Exploration/Development** • 3D seismic surveys to delineate field • site preparation for GBS • GBS platform and wareship towed into position and installed • field development • first production and injection wells directionally drilled from GBS **Operations** • additional production wells directionally drilled from GBS • loading and westward transits of ice strengthened oil tankers • icebreaking around GBS facility and as tanker escort • wareship provides logistical support • annual sealift • local resupply from Tuktoyaktuk and Summers Harbour (ship and air) • helicopter transfer of crews	• purchasing of goods and services results in capital inflows into ISR and elsewhere in NWT and Yukon • hiring and employment of workers from ISR communities • change in traditional harvesting activities (see Section D.4.4) could affect expenditures on market foods, health and well-being of households in ISR	• change in regional economy • change in labour force • change in household income • change in cost of living	• regional economy: GDP change, capital investment • labour force: total labour requirements, % Inuvialuit in workforce, labour participation rate, unemployment rate • household income: Average household income, average monthly cost of food (note: effects on traditional harvesting considered in Section D.4.4)

Table D-53 Summary of Potential Impacts and Effects on Economy

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf) (cont'd)	• crew changes airflights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik • Tuktoyaktuk and Summers Harbour used as service and supply bases **Decommissioning** • removal of GBS platform and wareship • well capping			
Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope)	**Exploration/Development** • drillship transit to/from Beaufort Sea • exploration and delineation drilling **Operations** • transit of FPSO to Beaufort Sea, anchoring at production site • production and injection wells drilled from drillship • loading and eastward and westward transits of ice-strengthened oil tankers (Ice Season transits westward only)	• purchasing of goods and services results in capital inflows into ISR and elsewhere in NWT and Yukon • hiring and employment of workers from ISR communities • change in traditional harvesting activities (see Section D.4.4) could affect household expenditures on market foods	• change in regional economy • change in labour force • change in household income/ • change in cost of living	• regional economy: GDP change, capital investment • labour force: total labour requirements, % Inuvialuit in workforce, labour participation rate, unemployment rate • household income: Average household income, average monthly cost of food

Table D-53 Summary of Potential Impacts and Effects on Economy

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope) (cont'd)	• wareship logistical support • annual sealift • local resupply from Tuktoyaktuk and Summers Harbour (ship and air) • helicopter transfer of crews • crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik • Tuktoyaktuk and Summers Harbour service and supply bases **Decommissioning** • removal of FPSO and wareship • well capping			

Table D-53 Summary of Potential Impacts and Effects on Economy

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 5 (Large Oil Release Event)	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• oil spill response would involve expenditure of funds and labour, especially nearshore • response likely to involve substantial numbers of personnel from outside the ISR; would require accommodations, air travel, services and support • oil spills could affect species targeted for traditional harvesting and/or access to harvesting locations (Section D.4.4). Change in traditional harvesting could affect household expenditures on market foods. • other uses such as tourism adversely affected	• effects would depend on the location and magnitude of spill, and the cost and logistical effort required to clean it up	• regional economy: GDP change, capital investment • labour force: total labour requirements, % Inuvialuit in workforce, labour participation rate, unemployment rate • household income: Average household income, average monthly cost of food

TLK holders have identified equitable access to economic opportunities associated with project development as an issue (among communities within the ISR). One TLK holder felt that “Inuvik always seems to get the work and Tuktoyaktuk is left out even though the work is occurring here” (KAVIK-AXYS Inc. 2009: 10-9 to 10-11). Sachs Harbour TLK holders similarly observed that with past development projects, few people from Sachs Harbour got jobs, and while some people benefited from oil and gas activities, others were worse off (IMG Golder and Golder Associates 2011c: 20). Of note, the more remote communities (e.g., Aklavik, Sachs Harbour, Paulatuk and Uluhaktok) in the ISR have a higher cost of living than Inuvik and Tuktoyaktuk. Individuals from these four remote communities also would likely need to work remotely either in the offshore or in land-based facilities in Tuktoyaktuk and Inuvik. Measures recommended by TLK holders to address economic effects included partnerships/contracts with communities in the region, working with the Inuvialuit business list, and engagement with communities, including youth and elders (KAVIK -Axys Inc. 2009: 10-9 to 10-11; IMG Golder and Golder Associates 2011e: 20).

D.4.1.2 Scenario 1: Status Quo

D.4.1.2.1 Potential Impacts and Effects of Routine Activities

Description of Effect Pathway

Effects pathways for Scenario 1 include capital inflows and hiring associated with Status Quo activities within the BRSEA Study Area. Economic activities identified in Scenario 1 that could result in capital inflow include commercial tourism, sealifts, and port calls by scientific research or military vessels, as well as site preparation, installation and operation of a wind energy facility. These activities could result in additional spending in the region through the procurement of services and supplies and spending on accommodations, meals, recreation/cultural activities, and souvenirs, as well as employment of ISR residents. Operation of the wind energy facility would be expected to result in a decrease in fuel consumption within the ISR and could lead to lower energy costs.

Description of Range of Potential Effects

The Status Quo scenario would result in modest changes in economic conditions in ISR. With the exception of commercial tourism, it is anticipated that public and private sector economic activities, related employment opportunities, and median household income would remain similar to baseline conditions. Ongoing government (i.e., GNWT, YG, federal) and Inuvialuit programs to improve socio-economic conditions and cultural (e.g., tourism) activities would help increase benefits to local communities and businesses.

The Status Quo anticipates 10 cruise ship visits per annum to the ISR, with one or two stops per transit during the Open Water Season. This would represent an increase in cruise ship activity compared to the 2017 season, which experienced five visits to the area (GNWT 2017). Cruise ship tourism would create employment and other economic benefits to those ISR communities that host such visits. Historically, cruise ships have visited Ulukhaktok, Paulatuk, Tuktoyaktuk and, less frequently, Sachs Harbour. While each visit represents an important economic opportunity to the host community, cruise ship tourism would generally make only a modest economic contribution to the overall economy of the ISR due to the infrequency and short duration of such visits.

Construction of the offshore wind energy facility would have short term economic effects from hiring of construction workers from ISR communities, procurement of goods and services from local vendors, and spending within the ISR by non-local workers. An offshore wind energy facility of 3 MW capacity (sufficient for approximately 1500 households) could likely be constructed with a workforce of approximately 50 persons (Lantz and Tegen 2009); assuming ~ 50 persons for this workforce and additional persons for service and supply businesses, the total workforce is assumed to be less than 100 persons. During operations, there would be local employment for facility operators and maintenance personnel, with annual employment estimated at five persons (Lantz and Tegen 2009). A wind energy facility also would likely generate royalties, land fees and revenues for the Inuvialuit. It is assumed that the facility would operate year-round. Long-term economic benefit would result from reduced diesel fuel consumption, potentially lower electric energy costs for some ISR consumers.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Climate change could result in both positive and negative economic effects to the ISR. While commercial shipping activities are predicted to increase, this would only have a marginal benefit because most commercial ships would not stop at ISR communities. Commercial tourism may be both positively and adversely affected: with more ice-free days, there would be a longer tourist season resulting in more opportunities for visiting cruise ships. However, due to its remoteness and high cost to access the area, cruise ship tourism to the ISR would likely remain a niche market activity. Moreover, cruise ship tourism potential could be adversely affected by climate change due to a likelihood of increased fog and extreme storm events, associated access to cultural experiences (i.e., greater difficulty accessing communities from the cruise ships) and changes in wildlife viewing opportunities (as a result of weather and changing distributions and abundance).

Climate change is a driver for ongoing development of renewable energy generation and storage (IRENA 2017). Such development has resulted in a lowering of costs of offshore wind-based energy generation and other renewable energy sources (Dudley 2019), which could make the installation of such facilities within the ISR more economically attractive. Climate change-induced weather changes (see Section 6.4 and Section D.2.2) could also affect the amount of power that can be generated, and thus the economic feasibility of offshore wind energy generation.

Climate change would necessitate new and upgraded infrastructure and resiliency works (e.g., coastal protection works such as used in Tuktoyaktuk) which would result in jobs and other economic benefits, such as goods and service contract opportunities. A substantial workforce may be needed to undertake such maintenance and resiliency works.

D.4.1.2.2 MITIGATION AND MANAGEMENT

In accordance with Subsection 16(1) of the IFA, the wind energy project proponent would be required to develop benefit plans with the IRC, including commitments for employment, training, and education of Inuvialuit. Inuvialuit businesses would benefit from supplier development initiatives (e.g., advance notice of specific requirements of supplies and services) and have fair access to opportunities to provide supplies and services. Other management measures that could reduce or avoid adverse economic effects and increase benefits include:

- early discussions with stakeholders to alert them to and discuss employment and business opportunities that may arise from the wind energy project
- supplier development initiatives to help local businesses prepare to support potential oil and gas activity
- opportunities for ownership investment by Inuvialuit, including the ownership of the wind energy project, as well as infrastructure or equipment (ships, ice breakers, etc.)
- communication with relevant Inuvialuit communities and representative organizations, through established and/or informal engagement processes, as required and requested
- conducting public consultation in potentially interested communities in the BRSEA Study Area by providing clear, non-technical information and an opportunity for additional mitigation measures to be developed to address public or stakeholder concerns related to the economy, including availability of jobs and other economic opportunities
- develop and implement a socio-economic agreement that contains commitments and actions to address socio-economic impacts, review of project performance, construction and operational monitoring, cumulative effects monitoring and adaptive management

D.4.1.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

The Status Quo scenario is predicted to have a low to moderate magnitude positive effect on the regional economy and labour force within the ISR. This scenario could result in limited additional capital investment within ISR communities. While there is predicted to be an increase in employment and economic opportunities associated with tourism, such activities would be infrequent, of short duration, and only experienced by coastal ISR communities. The construction of the wind energy facility would result in a short term and moderate increase in construction related employment (estimated at ~50 persons), with ten or less additional permanent jobs created for operations and maintenance. Assuming that the wind energy project lowers energy costs within communities that it supplies, this could result in a reduction in the average cost of living within those communities. Absent specific information on scenario procurement and hiring, the prediction and characterization of residual effects is made with medium confidence.

Climate change could result in increased opportunities for cruise ship-based tourism because of the increased number of ice-free days.

CUMULATIVE EFFECTS

Cumulative economic effects for Scenario 1 would be the same as the residual effects since the economic impacts and benefits are based on the same suite of concurrent activities in the ISR.

D.4.1.3 Scenario 2: Export of Natural Gas and Condensates

D.4.1.3.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Scenario 2 would see substantial economic activity within the ISR. During the site preparation and installation of the dual pipelines and GBS loading platform, and the operation of the GBS loading platform and wareship, Tuktoyaktuk would serve as the service and supply base, while Inuvik would serve as a regional administrative and commercial hub. It is anticipated that the region would experience a substantial increase in capital investment; during construction and/or upgrading of service and supply bases, workforce accommodations, marine and airport infrastructure and infrastructure (e.g., improvement of roads) to support site preparation and operation of the GBS.

Construction and operation phases would provide numerous local employment opportunities through employment of workers by the project proponents and major contractors, as well as supporting goods, equipment, and services providers. The natural gas and condensate export facility and pipelines would likely be built and operated primarily via a Fly-In Fly-Out (FIFO) workforce, with the majority of the workers transported by air to and from Tuktoyaktuk or Inuvik. The remainder of the workforce would be Inuvialuit, potentially from all communities and residents of the NWT and Yukon. Additional information on the assumed logistical support for the offshore natural gas and condensate export facility is provided in Section 3.7.

As discussed in Section 3.7.1, the on-land components of this development and effects on economy are expected to be substantial; however, these effects are outside the geographic scope of the BRSEA. As a result, the development, construction and operation of the anchor fields, associated field infrastructure, gathering pipelines and the gas processing facility is not considered in this assessment. Given the size and complexities of these facilities compared to the offshore pipelines and GBS loading facility, economic effects from on-land activities are expected to be larger than effects from the offshore activities.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The natural gas and condensate export project would have a substantial economic impact on the regional economy and labour force due to capital inflows and local employment. Capital investment in infrastructure needed to support export of natural gas and condensate would provide business opportunities for local companies, as would contracts to provide equipment, supplies, and services to the various entities involved in site preparation, installation and operation of the GBS loading platform[18]. It is assumed that most construction related effects would occur during the Open Water Season. Once operational, the GBS loading platform would operate year-round.

Installation of pipelines and the GBS loading platform would likely require a workforce in the order of magnitude of hundreds of persons, inclusive of offshore construction workers, and on-shore administration, logistics, maintenance and other personnel. Operation of the GBS loading facility, inclusive of ice-breaking crews, GBS loading platform crew, and onshore logistics, administration, transportation, and maintenance support would likely require a workforce of up to several hundred persons.

There would be a substantial increase in year-round local employment in Tuktoyaktuk because of its location as the logistics centre for the natural gas and condensate export facility, as well as in Inuvik, given its position as the ISR's government and administrative centre. Employment benefits would likely extend to other ISR communities and other NWT and Yukon residents if project proponents and major contractors implement multiple points of hire.

Employment within the ISR and elsewhere in the NWT and Yukon, which is associated with the natural gas and condensate export facility, would result in an increase in average family income, and positively affect the standard of living in many households. Increased participation in wage employment by ISR residents could affect traditional harvesting in several ways. It could result in decreased participation in traditional harvesting activities (due to less time available for these activities). This could result in increased household expenditures on market foods, thus increasing the cost of living for some households. However, it also could allow these individuals to better equipped for harvesting through purchase of equipment and supplies. Section D.4.4 addresses effects on traditional harvesting.

EFFECTS OF CLIMATE CHANGE

Climate change considerations would be factored into the site preparation, installation and operation of the natural gas and condensate export facility. For example, the GBS and new and/or upgraded port, airport, and other logistics infrastructure, would be designed to accommodate predicted changes in sea level, extreme weather events, and permafrost degradation. It could also involve coastal resilience measures to remediate or manage coastal erosion and permafrost degradation and relocation of infrastructure and buildings.

The increase in number of ice-free days associated with climate change could reasonably be expected to improve the financial viability of the natural gas and condensate export facility due to lowered operating costs associated with ice-breaking activities, less risk of ice-related infrastructure damage, and extended ice-free shipping season. Given an increased need for resilient infrastructure to support the development activities detailed under this scenario, this could spur additional economic investment into increasingly

[18] As discussed in Section 3.7.1, there would be additional economic opportunities and benefits associated with the land-based components of this project; however, land areas are outside the scope of the geographic scope of the BRSEA and are not considered here.

vulnerable infrastructure that already exists in the ISR. Such a benefit might not occur in the absence of this development. While predicted increases in ocean waves, wind, and storm surges associated with climate change could pose risks to natural gas and condensate export facility and result in shipping delays, the oil and gas industry has extensive experience operating in offshore environments that can experience extreme weather (e.g., Gulf of Mexico, North Sea, and Newfoundland and Labrador).

D.4.1.3.2 MITIGATION AND MANAGEMENT

In accordance with Subsection 16(1) of the IFA, Section 5.2 of COGA (Section 5.2), and Section 21 of CPRA (Section 2.11) the project proponents would be required to develop benefit plans with the IRC, including commitments for employment, training, and education of Inuvialuit. Inuvialuit businesses would benefit from supplier development initiatives and have fair access to opportunities to provide supplies and services. As described for Scenario 1, other management measures to reduce or avoid adverse economic effects and increase benefits include early discussion with stakeholders; supplier development initiatives for local businesses; ownership investment by Inuvialuit; regular communication with relevant Inuvialuit communities and representative organizations; ongoing public consultation to identify additional mitigation measures; and multiple points of hire in the ISR, NWT and Yukon.

D.4.1.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Scenario 2 would have a moderate to high magnitude positive economic impact on the NWT and Yukon in general, and the ISR in particular, which would benefit from capital inflows associated with site preparation, installation and operations activities, increased GDP, and increased employment, increased government revenue associated with taxation of corporate and personal income, and resource royalties sharing.

Positive economic effects would occur during construction, operation, and decommissioning of the natural gas and condensate export facility. As a logistics and administration / business hubs, Tuktoyaktuk and Inuvik would be expected to experience the greatest economic benefits, but other communities would benefit economically from the employment opportunities that would be made available to their residents. Most construction and installation related effects would occur during the Open Water Season, when most offshore site preparation and installation activities would occur. Operation and maintenance related effects would occur continually throughout the year.

The workforce required for developing and operating a natural gas and condensate export facility would be large compared to the available workforce in the ISR (Section 7.4.2). Because of limited labour availability within ISR, and specialized skill requirements, it is expected that a large proportion of the work would be undertaken by non-resident labour (e.g., other areas of the NWT, Yukon and perhaps Nunavut, as well as southern Canada and perhaps internationally) retained on a FIFO basis. However, the implementation of benefits plans would result in access to education, training, and opportunities for Inuvialuit employment and business opportunities for Inuvialuit companies, both directly with project proponents and with supporting contractors. Therefore, it could be expected that the proportion of Inuvialuit represented in the workforce would increase over time. The relatively high pay and benefits offered by construction companies and natural gas producers could result in some job switching, and current employers could experience some competition for local labour.

Should ISR residents who take up project employment have less time for traditional harvesting, they may have to purchase more store-bought foods, resulting in a higher cost of living. However, this higher cost of living would be offset by higher income levels. Higher income levels also may allow harvesters to invest in better equipment to support harvesting activities.

The presence of the natural gas and condensate export facility could have legacy effects that would persist after the eventual closure and decommissioning of the operating infrastructure. This includes the continued availability of an upgraded airport, port and other infrastructure and increased local labour force and business experience and capabilities. Some of the resource royalties paid during the production phase could be retained for the future and ongoing economic benefits for NWT and Yukon residents in general and ISR residents in particular.

In summary, activities associated with Scenario 2 are predicted to have a moderate to high magnitude positive effect on the economy within the ISR. With application of effects management measures, such effects should extend throughout the ISR and to communities elsewhere in NWT and Yukon. Current negotiations and agreement on off-shore and self-government revenue sharing would help to clarify future economic benefits. With decommissioning and closure of the facility, beneficial effects related to capital inflows and direct project employment would cease. However, the ISR, NWT and Yukon should continue to benefit economically from the retention of royalty and tax revenue earned throughout the operations period. Previous oil and gas development in the BRSEA Study Area was linked with a positive increase in GDP and local employment (Section D.4.1.1.5). However, absent specific information on project procurement and hiring, the prediction and characterization of residual effects is made with medium confidence.

Climate change may make the development of a natural gas and condensate export facility economically more viable by reducing operational costs such as ice-breaking and shipping. However, if climate change results in decreased traditional harvesting, it could adversely affect the cost of living by forcing households to increase the amount of store-bought foods they purchase. The economic effects of climate change would be partially mitigated by the higher average household income in Scenario 2, resulting from higher levels of employment by Inuvialuit residents.

Cumulative Effects

The natural gas and condensate export facility described in Scenario 2, combined with activities of Scenario 1, would result in a beneficial cumulative effect to the economies of the ISR, NWT and Yukon economies. In the ISR, the degree of change would depend on terms of the benefit agreements and the capacity of the Inuvialuit and Inuvialuit businesses. In the cumulative scenario there would be more diversification of employment opportunities and increase in the GDP of ISR, NWT and Yukon.

Climate change may result in both direct and indirect cumulative economic effects. On the one hand, the extended ice free season may lower certain operating costs and thus increase feasibility of certain activities such as shipping. Climate change, in combination with a gas and condensate project, could also indirectly support spending for new and upgraded infrastructure and resiliency works in the ISR.

D.4.1.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.4.1.4.1 Potential Impacts and Effects of Routine Activities

Description of Effect Pathway

Economic impacts in Scenario 3 would be qualitatively similar to those described for Scenario 2; however, it is anticipated that the construction and operational workforce required for Scenario 3 would exceed that for Scenario 2. Tuktoyaktuk and Summers Harbour (or equivalent) would serve as logistics bases (Section 3.4), while Inuvik would serve as a regional administrative centre. It is anticipated that the region would experience a substantial increase in capital investment during construction and/or upgrading service and supply bases, workforce accommodations, marine infrastructure and airport facilities, and community infrastructure (e.g., roads) to support site preparation and installation of the GBS (Table D-53). There would be substantial local employment opportunities, working for project proponents, major contractors, and providers of goods, equipment, and services.

Description of Range of Potential Effects

Scenario 3 would have a substantial economic impact within the ISR due to capital inflows and employment opportunities. Capital investment in infrastructure needed to support oil industry activity would provide business opportunities for local companies, as would contracts to provide equipment, supplies, and services to the various entities involved in site preparation for and installation of the GBS and operation of the GBS and wareship. It is assumed that most exploration and development related effects would occur during the Open Water Season. Once operational, the GBS oil production facility would operate year-round

During field development and construction, the seismic data acquisition program, installation of the GBS loading and production platform, and drilling of production wells would likely require a workforce ranging from hundreds to over a thousand persons, inclusive of offshore construction workers, wareship crew, and onshore administration, logistics, maintenance and other personnel (see Section 3.8.2 for Scenario 3 details). Operation of the GBS loading and production platform, wareship, icebreakers, helicopter crews, and onshore staff would likely involve a workforce of several hundred persons.

There would be a substantial increase in local employment opportunities in Tuktoyaktuk because of its role as the logistics centre for the production platform and related activity, as well as in Inuvik, because of its position as the ISR's administration and business hub. Employment also would be provided in a service and supply base at Summers Harbour (or equivalent). Employment opportunities would likely extend to other ISR communities, as well as to other NWT and Yukon residents, particularly if project proponents and major contractors implement multiple points of hire.

The employment opportunities within ISR, and elsewhere in the NWT and Yukon, associated with the development of an oil production industry, would result in an increase in average family incomes, and positively affect the standard of living in many households. However, the increased participation in wage employment by ISR residents could result in decreased participation in traditional harvesting activities.

This could result in increased household expenditures on market foods, thus increasing the cost of living for some households. Section D.4.4 addresses effects on traditional harvesting.

EFFECTS OF CLIMATE CHANGE

Climate change considerations would be factored into the design, site preparation, installation and operation of the GBS. For example, it and any new and/or upgraded port, airport, and other logistics infrastructure would be designed to accommodate predicted changes in sea level, extreme weather events, and permafrost levels. Given an increased need for resilient infrastructure to support the development activities detailed under this scenario, additional economic investment is likely to modify increasingly vulnerable existing infrastructure in the ISR. Such a benefit might not occur in the absence of this development.

The increase in number of ice-free days associated with climate change could reasonably be expected to improve the financial viability of oil production in the Beaufort Sea due to lowered operating costs associated with ice-breaking activities, less risk of ice-related infrastructure damage, and an extended ice-free shipping season. While predicted increases in ocean waves, wind, and storm surges, associated with climate change could pose risks to infrastructure and result in shipping delays, the oil and gas industry has extensive experience operating in offshore environments that can experience extreme weather (e.g., Gulf of Mexico, North Sea, and Newfoundland and Labrador).

D.4.1.4.2 MITIGATION AND MANAGEMENT

In accordance with Subsection 16 of the IFA, Section 5.2 of, COGOA and Section 21 of CPRA (see Section 2.11), the project proponents would be required to develop benefit plans with the IRC, including commitments for employment, training, and education of Inuvialuit. Inuvialuit businesses would benefit from supplier development initiatives and have access to opportunities to provide supplies and services. The additional management measures described for Scenario 1 would also help reduce or avoid adverse economic effects and increase benefits in Scenario 3.

D.4.1.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Scenario 3 would have a high magnitude positive economic impact on the NWT and Yukon in general, and the ISR in particular, which would benefit from capital inflows associated with site preparation and installation activities, increased GDP, increased employment, as well as increased government revenue associated with taxation of corporate and personal income, and resource royalties sharing.

Positive economic effects would occur continually throughout construction, operation, and decommissioning of the offshore oil industry project. As logistics and administration / business hubs, Tuktoyaktuk and Inuvik could be expected to experience the largest economic impacts, but other communities would benefit economically from the employment opportunities that would be made available to their residents. Most development related economic effects would occur during the Open Water Season, when most development activities would occur. Operation related effects would occur throughout the year.

The personnel requirements (skilled and unskilled) for site preparation and installation and operation of an offshore oil production facility in the Beaufort Sea would exceed the available labour force in the ISR (Section 7.4.2). As a result, it is expected that a large proportion of project employment would be undertaken by a skilled non-resident workforce from the NWT, Yukon and perhaps Nunavut, as well as southern Canada, the United States and internationally, retained on a FIFO basis. However, the implementation of benefits plans would result in access to education, training, and opportunities for Inuvialuit employees, both directly with project proponents and with supporting contractors. Therefore, it could be expected that the proportion of Inuvialuit represented in the workforce would increase over time. The relatively high pay and benefits offered by construction and operating companies could result in some job switching, and current employers would likely experience some competition for local labour.

Should ISR residents who take up project employment have less time for traditional harvesting, they may have to purchase more store-bought foods, resulting in a higher cost of living. However, this higher cost of living would be offset by higher income levels.

In summary, activities associated with Scenario 3 are predicted to have a high magnitude positive effect on the economy within the ISR. With application of effects management measures, such effects should extend throughout the ISR and to communities elsewhere in NWT and Yukon. Current negotiations and agreement on off-shore and self-government revenue sharing would help to clarify future economic benefits. While beneficial effects related to capital inflows and direct project employment would cease with decommissioning and closure of the offshore oil production facility, the ISR, NWT and Yukon should continue to benefit economically from the retention of royalty and tax revenue earned throughout the operations period. However, absent specific information on project procurement and hiring, the prediction and characterization of residual effects is made with medium confidence.

Climate change may make offshore oil development within the Beaufort economically more viable by reducing operational costs such as ice-breaking and shipping. However, if climate change results in decreased traditional harvesting, it could adversely affect cost of living by forcing households to increase the amount of store-bought foods they purchase.

Offshore oil production could have legacy effects that would persist after the eventual decommissioning and closure of operating infrastructure and as a result of increased local labour force and business experience and capabilities. Some of the resource royalties paid during the production phase could be retained for the future and ongoing economic benefit of NWT and Yukon residents in general and ISR residents in particular.

Cumulative Effects

The offshore oil field development described in Scenario 3, combined with activities of Scenario 1, would result in a beneficial cumulative effect to the ISR, NWT and Yukon economies. In the ISR, the degree of change would depend on the terms of the benefit agreements and the capacity of the Inuvialuit and Inuvialuit businesses. In the cumulative scenario there would be more diversification of employment opportunities and increase in GDP of ISR, NWT and Yukon.

Climate change may result in other cumulative economic effects. The extended ice free season may lower certain operating costs and thus increase the feasibility of certain activities, such as shipping. Climate change, in combination with an offshore oil development project could also indirectly support spending for new and upgraded infrastructure and resiliency works in the ISR.

D.4.1.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.4.1.5.1 Potential Impact and Effects of Routine Activities

Description of Effect Pathway

The effects pathways for economic impacts in Scenario 4 would be similar to that for Scenario 3. Tuktoyaktuk and Summer Harbour (or equivalent) would serve as logistics bases (see Section 3.4), while Inuvik would serve as a regional administration / business hub. It is anticipated that the region would experience a substantial increase in capital investment during construction and/or upgrading service and supply bases, workforce accommodations, and marine and airport infrastructure to support oil exploration activities, the drilling of production wells by drillships or semi-submersible rigs, operation of the floating production storage and offloading (FPSO) production vessel, and the shipping oil.

Description of Range of Potential Effects

Effects pathways for economic impacts in in Scenario 4 would be qualitatively similar to those in Scenario 3. Tuktoyaktuk and Summers Harbour (or equivalent) would serve as logistics bases (see Section 3.4), while Inuvik would serve as a regional administration and business hub. It is anticipated that the region would experience a substantial increase in capital investment, for example during construction and/or upgrading service and supply bases, workforce accommodations, and marine and airport infrastructure to support development and operation of the project.

The 3D seismic program (one season), exploration drilling, and delineation drilling would occur during the Open Water Season only, with a total workforce (assuming two shifts) of several hundred persons. Field development drilling, construction of subsea infrastructure, and connection to FPSO, would likely involve a workforce of several hundred to over a thousand persons, inclusive of offshore construction workers, drill ship crews, wareship crew, and onshore administration, logistics, maintenance and other personnel (see Section 3.8 for Scenario 3 details). Operation of the FPSO production platform, wareship, icebreakers, helicopter crews, and onshore staff would likely involve a workforce of several hundred persons.

There would be substantial local employment opportunities with project proponents and major contractors, as well as supporting goods, equipment, and services providers. Once operational, the FPSO oil production facility would operate year-round.

Effects of Climate Change

Climate change considerations would be factored into the installation and operation of the FPSO, production drilling and related infrastructure. For example, it and new and/or upgraded port, airport, and other logistics infrastructure would be designed to accommodate predicted changes in sea level, extreme weather events, and permafrost levels.

The increase in number of ice-free days associated with climate change could reasonably be expected to improve the financial viability of oil production in the Beaufort Sea due to lowered operating costs associated with drilling, ice-breaking activities, less risk of ice-related infrastructure damage, and an extended ice-free shipping season. Given an increased need for resilient infrastructure to support the development activities detailed under this scenario, this could spur additional economic investment into other increasingly vulnerable infrastructure. Such a benefit might not occur in the absence of this development.

While predicted increases in ocean waves, wind, and storm surges, associated with climate change could pose risks to the FPSO and drilling rigs and result in shipping delays, the oil and gas industry has extensive experience operating in offshore environments that can experience extreme weather (e.g., Gulf of Mexico, North Sea, and Newfoundland and Labrador).

D.4.1.5.2 Mitigation and Management

In accordance with Subsection 16 of the IFA, Section 5.2 of, COGOA and Section 21 of CPRA (see Section 2.11), the project proponents would be required to develop benefit plans with the IRC, including commitments for employment, training, and education of Inuvialuit. Inuvialuit businesses would benefit from supplier development initiatives and have fair access to opportunities to provide supplies and services. The additional management measures described for Scenario 1 would also help reduce or avoid adverse economic effects and increase benefits in Scenario 4.

D.4.1.5.3 Effects Characterization

Residual Effects

As described for Scenario 3, Scenario 4 would have a high magnitude positive economic impact on the NWT and Yukon in general, and the ISR in particular, including benefits from capital inflows associated with site preparation and installation activities, increased GDP, increased employment, increased government revenue associated with taxation of corporate and personal income, and resource royalties sharing. Current negotiations and agreement on off-shore and self-government revenue sharing would help to clarify future economic benefits. However, absent specific information on project procurement and hiring, the prediction and characterization of residual effects and benefits is made with medium confidence.

Positive economic effects would occur continually throughout construction, operation, and decommissioning of the project. Advance education and training and well as rotational work arrangements can help improve benefits all of the six ISR communities.

The personnel requirements for installing and operating an FPSO in the Beaufort Sea (inclusive of supporting personnel) and operating drilling rigs and support vessels would be considerably larger than the entire available labour force in the ISR (see Table 7-23), and as a result it is expected that a large proportion of project employment would be undertaken by a skilled non-resident workforce, retained on a FIFO basis. The implementation of benefits plans would provide access to education, training, and opportunities for Inuvialuit employees both directly with project proponents and with supporting contracting companies. As noted for Scenario 3, increased participation in wage employment by ISR residents could have adverse and positive effects on traditional harvesting (Section D.4.4).

While beneficial effects related to capital inflows and direct project employment would cease at the end of the project, the ISR, NWT and Yukon is expected to continue to benefit economically from the retention of royalty and tax revenue.

Climate change may make offshore oil development within the Beaufort economically more viable by reducing operational costs such as ice-breaking and shipping. However, if climate change results in decreased traditional harvesting, it could adversely affect cost of living by forcing households to increase the amount of store-bought foods they purchase.

CUMULATIVE EFFECTS

The offshore oil field development described in Scenario 4, combined with activities of Scenario 1, would result in a beneficial cumulative effect to the ISR, NWT and Yukon economies. In the ISR, the degree of change would depend on terms of the benefit agreements and the capacity of the Inuvialuit and Inuvialuit businesses. In the cumulative scenario there would be more diversification of employment opportunities and increase in GDP of ISR, NWT and Yukon.

Climate change may result in other cumulative economic effects. The extended ice free season may lower certain operating costs and thus increase feasibility of certain activities, such as shipping. Climate change, in combination with the offshore development project could also indirectly support spending for new and upgraded infrastructure and resiliency works in the ISR.

D.4.1.6 Scenario 5: Large Oil Release Event

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface spill from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on the economy from such an event may differ slightly from what is described below for surface or subsea releases.

D.4.1.6.1 ASSESSMENT OF EFFECTS OF AN OIL SPILL

DESCRIPTION OF EFFECT PATHWAY

An oil spill in the BRSEA Study Area would have economic impacts through a number of mechanisms, including:

- expenditures required for spill response and clean-up
- reduction in oil production activities
- measurable or perceived changes in environmental values affecting tourism and related industries
- reduction in harvesting of traditional foods, resulting in increased purchasing of market foods
- payment of compensation

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The nature and magnitude of economic effects of an oil spill would vary depending on the season that it occurred, its location, the conditions at the time of the spill (e.g., wind, sea state), the type of release (surface verses subsea) and oil spill type (Table D-55). Direct economic effects of a surface release, sub-surface release, or tanker incident would be similar during most seasons as an effective spill response would require large numbers of people and volumes of equipment, as well as logistical support (e.g., aircraft, vehicles, accommodation, health and safety). While oil releases during the Ice Season and part of the Spring and Fall Transition seasons, may not spread as rapidly (due to containment by ice) as releases during the Open Water Season, logistical challenges of cold temperatures and dark or shorter days would affect response costs. Because a large oil release might be contained by the ice during the Ice Season, there may be a lower likelihood of spatial overlap with traditional harvesting activities, as well as a lower potential to affect harvested species or their habitats since some species would be absent (e.g., migratory birds). Subsurface discharges, regardless of season could affect fisheries resources because of potential degradation of fish habitat, as well as physiological and mortality effects on fish species (see Section D.3.2). Reductions in traditional harvesting could adversely affect household economics within the ISR due to increased expenditures on market foods.

A large surface or sub-surface oil release in the BRSEA Study Area during the Open Water Season could have a major to severe economic effect on the ISR. The magnitude of effect would be proportional to the amount of oil released, the extent of dispersion, the effectiveness of containment and clean-up efforts, and whether there was shoreline oil contamination. A surface release within the Mackenzie River plume during the Open Water Season would likely have the most severe economic effects because of the greater risk of shoreline oiling and consequent higher clean-up costs and higher magnitude impacts on economically valuable environmental resources (including tourism values). The degradation of environmental VCs resulting from a large surface oil release in the BRSEA Study Area would likely directly affect tourism interest and activity in the region.

A large surface release of oil could result in widespread mortality and/or contamination of traditionally harvested species, including fish, birds, seals, and beluga whales. The degree of such effects would depend on the nature of the spill and seasonality. Generally, a spill occurring during the Open Water Season would have the most severe effects on traditionally harvested species (see Section D.2) and the harvest activities. A reduction in the availability and quality of country foods would result in households needing to increase expenditures on market foods, which would adversely affect household economics.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Economic effects of an oil spill could be adversely and positively affected by climate change through several mechanisms including: a longer Open Water Season which could affect the extent of the spill and increase the intensity of cleanup activities, costs, and the level of expenditures for equipment and the workforce; and more severe weather which would complicate spill response and also increase clean-up activities, costs and expenditures. Effects of an oil spill on traditionally-harvested species and traditional harvesting activities (e.g., travel, coastal camps, ability or desire to harvest) would affect traditional uses and could increase purchase of market foods.

D.4.1.6.2 MITIGATION AND MANAGEMENT

Spill response planning and measures are described in Sections 2.13 and 3.10.5.3. Additional mitigation and management measures for the economy include:

- early engagement of Inuvialuit communities in the planning and preparation of spill response plans, establishment of equipment stores, and training and readiness of Inuvialuit and other responders
- creation of an Inuvialuit owned and operated oil spill response organization, potentially through a joint venture with an established spill response company
- regular (e.g., annually) drills to simulate command and execution approaches for first response and larger spill response measures. Inuvialuit should be involved in the management and response aspects, along with government and response organizations
- engagement of Inuvialuit community leaders in the unified command for a spill response to represent community concerns and knowledge
- completion of comprehensive oil spill response planning and capability prior to commencement of oil exploration, production and transport
- if a release event were to occur, effective and transparent communications with Inuvialuit communities on oil spill progress and success, as well as input from communities on the response (e.g., use of TLK to plan and implement the response)
- clearly defined compensation procedures that can be quickly implemented to provide financial and other support to affected individuals, businesses, and organizations

Producers and shippers of oil would be required to pay for all costs associated with responding to spills, environmental clean-up, and compensation to affected parties, as discussed in Section 2.13.8. The predicted effectiveness of oil spill response measures is summarized in Table 3-14.

D.4.1.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Regardless of season, the effects of a large oil release event on the economy would be high.

The response to a major oil spill would involve a large amount of equipment, personnel, and logistics support. While these activities might generate economic benefits over the short-term, these would be outweighed by the longer-term adverse economic effects on the region, including effects on traditional harvesting, cultural vitality, tourism and other activities. Compensation of affected parties would help offset economic loss associated with an oil spill but would not fully replace all losses (e.g., loss or impairment of use of traditional or cultural sites). There also would be substantial adverse economic effects on the responsible party.

Residual effects of an oil spill on the ISR economy would depend on the location, season, type of spill, and the effectiveness of oil spill response. A spill occurring closer to shore (i.e., within the Mackenzie River plume) has a higher potential for causing economic impacts due to reduced traditional harvesting and reduced tourism. Spills that affect traditional harvesting activities would adversely affect the cost of living of many ISR households because they would need to increase the amount of spending on market foods. Spills occurring during the Open Water Season, particularly if they result in shoreline fouling, have the highest potential for affecting tourism activities in ISR.

Overall effects of a large oil release event on the economy are predicted to be adverse, moderate to high in magnitude with effects at a regional and intra-regional level. Effects on the economy would persist for the moderate- to long-term (i.e., effects would persist through the spill response and clean-up, as well as the recovery period for the physical, biological, and human environment). With recovery of the environment and human uses, as well as resumption of the offshore hydrocarbon development (or shipping), effects would reversible.

D.4.1.7 Summary of Residual Effects

Potential residual effects on the economy of Scenarios 1 – 4 and a large oil release are summarized in Table D-54 and Table D-55. While there could be some seasonal differences in economic benefits and adverse effect among seasons for the Status Quo, the three oil and gas development scenarios and the large oil release event, there is insufficient information to provide seasonally-specific effects characterizations for the economy. As a result, an effects characterization is provided for an annual cycle for each of the five scenarios. A long-term effects characterization is provided for a large oil release event.

Table D-54 Potential Residual Effects of Scenarios 1 – 4 on the Economy for All Seasons[19]

	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4 Oil Development in Deep Water
Potential Effects	• Low to moderate economic benefits, with more benefits occurring during construction of the wind energy facility.	• Moderate to high economic benefits associated with increased investment and expenditures in region, increased employment, and higher average household income.	• Major economic effects associated with substantial increase in investment and expenditures in region, increased employment, and higher average household income	• Major economic effects associated with substantial increase in investment and expenditures in region, increased employment, and higher average household income
Legend				
• Least effect – No economic effect				
• Moderate effect -- Moderate economic effect				
• High effect -- Major economic effect				
• Greatest effect – Severe economic effects				

[19] While there could be some differences in economic benefits and adverse effect among seasons for the Status Quo and the three oil and gas development scenarios, there is insufficient information to provide seasonally-specific effects characterizations for the economy. Instead, effects characterizations are provided for an annual cycle for the Status Quo and the three oil and gas development scenarios.

Table D-55 Potential Effects of a Large Oil Release Event (Scenario 5) on the Economy for All Seasons and the Longer Term[20]

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
All seasons	• Major economic effects associated with oil-spill clean-up. Potential for high magnitude effects on household expenditures associated with reduction in traditional foods consumption, particularly if spill results in shoreline fouling. Tourism impact may occur if coastlines affected and oil not cleaned up by summer.	• Major economic effect associated with oil spill cleanup. Moderate to high magnitude effects on household expenditures associated with reduction in traditional foods consumption due to contamination concerns. Tourism impact likely less because of lower potential for shoreline fouling.	• Major economic effect associated with oil spill cleanup. Moderate to high magnitude effects on household expenditures associated with reduction in traditional foods consumption due to contamination concerns. Tourism impact likely less because of lower potential for shoreline fouling.
Longer-term/ Multi-year	• Multi-year effect potential dependent on seasonality of release. Could be long-term effects on traditionally harvested foods because of chronic health effects on target species, bioaccumulation slow population recovery.	• Multi-year effect potential dependent on seasonality of release. Could be long-term effects on traditionally harvested foods because of chronic health effects on target species, bioaccumulation slow population recovery.	• Multi-year effect potential dependent on seasonality of release. Could be long-term effects on traditionally harvested foods because of chronic health effects on target species, bioaccumulation slow population recovery.

Legend
• Least effect – No to minor economic effect
• Moderate effect -- Moderate economic effect
• High effect -- Major economic effect
• Greatest effect – Severe economic effect

20 While there could be some differences in economic benefits and adverse effect among seasons for the large oil release scenario, there is insufficient information to provide seasonally-specific effects characterizations for economy. Instead, effects characterizations are provided for all seasons and the longer term.

D.4.1.8 Gaps and Recommendations

While there is considerable information available on the economy of NWT, Yukon and ISR, additional specific information would inform a detailed economic assessment for future projects within the ISR.

- information on capital and operational spending and labour requirements over the duration of potential future developments to supplement information provided in this assessment
- more specific knowledge of the labour availability within the ISR, including skills inventory, training requirements, and perspective on employment preferences (e.g., hiring locations, shift structure) would inform a project specific economic assessment. Similar information for the NWT and Yukon also would be useful.
- future socio-economic assessments for projects should include the collection of information related to gender, sexual identity, and other relevant identity factors, to support an assessment of socio-economic impacts on vulnerable population groups that may be disproportionately affected by industrial development (note: the new Canada Impact Assessment Act requires this type of assessment)
- more detailed understanding of the cost and timeline for upgrading infrastructure for climate change resiliency is needed to inform a comprehensive economic impact assessment of the ISR (see also Section D.4.3)

D.4.1.9 Follow-up and Monitoring

It is recommended that a labour force analysis be undertaken to better understand the capabilities, interests, and requirements of ISR communities to participate in various future projects. Similar information for the NWT and Yukon also would be useful. It is also recommended that a detailed inventory of new and upgraded infrastructure for climate change resiliency, including cost estimates and timing, be undertaken. Lastly, there should be ongoing socio-economic monitoring based on the indicators used in socio-economic monitoring undertaken by the IRC, and modified, where appropriate to take in account indicators related to gender and other identify factors.

D.4.2 Demographics

D.4.2.1 Scoping

D.4.2.1.1 IDENTIFICATION OF INDICATORS

The assessment of the Demographics VC focuses on changes to the population of ISR communities as a result of project and other employment that could result in each scenario and the large oil release event. Effects of population changes on the economy, infrastructure, cultural vitality and other aspects are addressed elsewhere in Section D.4.

The following indicators are used in the assessment of the Demographics VC:

- total population within ISR
- Inuvialuit population within ISR communities

D.4.2.1.2 *SPATIAL BOUNDARIES*

Demographic effects would result from individuals relocating to the ISR due to scenario-related employment and visiting the ISR as a result of Fly in Fly out (FIFO) employment. Demographic changes within ISR communities can also occur when individuals move from one community to another in search of employment. The six communities within the ISR are: Aklavik, Inuvik, Paulatuk, Sachs Harbour, Tuktoyaktuk, and Ulukhaktok.

D.4.2.1.3 *TEMPORAL BOUNDARIES*

The assessment of potential effects on demographics encompasses a 30-year period between 2020 – 2050.

D.4.2.1.4 *ASSESSMENT OF POTENTIAL EFFECTS*

The assessment of demographics considers the residual effects on the population of ISR communities; expressed as a change in the population of ISR communities.

A qualitative characterization of potential residual effects on demographics associated with each scenario is based on the characterization terms defined in Table D-56.

Table D-56 Characterization of Residual Environmental Effects on Demographics for the time period 2020 – 2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Positive**—an increase in the population of ISR communities **Adverse**—a decrease in the population of ISR communities **Neutral**—no net change in population of ISR communities
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no measurable change in the population **Low**— effect within normal range of variability **Moderate**—measurable change resulting in a moderate change in the population **High**—measurable change resulting in a large change in the population
Geographic Extent	The geographic area in which a residual effect occurs	**Single event**—residual effect occurs once. **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity. **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity. **Continuous**—residual effect occurs continuously for the duration of the activity.
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Short-term**—residual effect restricted to one phase or season (e.g., seismic survey, exploration drilling). **Medium-term**—residual effect extends through multiple seasons or years (e.g., production phase). **Long-term**—residual effect extends beyond the life of the project (e.g., beyond closure). **Permanent**—measurable parameter unlikely to recover to existing conditions.

Table D-56 Characterization of Residual Environmental Effects on Demographics for the time period 2020 – 2050

Characterization	Description	Definition of Qualitative Categories
Duration	The period of time the residual effect can be measured or expected	**Short-term**—the residual effect is restricted to short-term events or activities such as discrete component completion during construction, maintenance, or rehabilitation activities (i.e., a timeframe of several months up to 1 year) **Medium-term**—the residual effect extends through the completion of construction and rehabilitation activities (i.e., a timeframe of 1 year to 5 years) **Long-term**—the residual effect extends beyond the completion of construction and rehabilitation activities into the operations and maintenance phase of a project (i.e., a timeframe of greater than 5 years)
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to existing conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Stable**—Populations in ISR communities are stable **Unstable**—Populations in ISR communities are not stable

D.4.2.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

The creation of job opportunities related to the different activities in the described scenarios would draw people to the ISR for employment. Effects on demographics are those that would result from a population increase as non-Inuvialuit move into Tuktoyaktuk, Inuvik and possibly the other Inuvialuit communities. Because most new jobs would likely be available in Tuktoyaktuk, Inuvik, in logistics bases (e.g., Tuktoyaktuk and Summers Harbour) or offshore (with crew transfers originating from Tuktoyaktuk or Summers Harbour), job seekers from other ISR communities may re-locate there in hopes of securing employment. Some residents of other ISR communities who are hired may also subsequently decide to relocate to Tuktoyaktuk and Inuvik to reduce travel time and costs to/from work and avail themselves of the range of services and infrastructure available in these larger communities. The potential completion of development projects by 2050 (or some future date for decommissioning of a development) may result in an out-migration of workers who originated from outside the ISR, as well as some Inuvialuit. Table D-57 summarizes potential impacts and effects of the Status Quo, the three oil and gas development scenarios and the large oil release event for the Demographics VC.

Table D-57 Summary of Potential Impacts and Effects on Demographics

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 1 (Status Quo)	• marine vessels – commercial shipping, cruise ship tourism, scientific research, military • ship-based or barge resupply of ISR coastal communities • renewable energy project (e.g., offshore wind turbine) • traditional harvesting – regional boat traffic and snowmobile use	• labour force required to perform activities would temporarily increase the total population of the ISR	• change in population of ISR communities	• total population within ISR • Inuvialuit population within ISR communities
Scenario 2 (Export of Natural Gas and Condensates)[21]	**Construction** • towing and installation of GBS loading platform at project site • installation of dual pipelines **Operations** • LNG carrier and condensate tanker loading • LNG carrier and condensate tanker transits westward • icebreaker management around GBS facility and possibly as carrier/tanker escort • annual sealift • local resupply of GBS loading facility by vessel	• labour force required to construct infrastructure would temporarily increase the total population of the ISR	• change in population of ISR communities	• total population within ISR • Inuvialuit population within ISR communities

[21] Only economic benefits and effects from the marine operations are considered here; economic benefits from development of gas fields, pipelines gas processing facilities onshore are not considered.

Table D-57 Summary of Potential Impacts and Effects on Demographics

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 2 (Export of Natural Gas and Condensates) (cont'd)	• helicopter transfer of crews • Tuktoyaktuk logistical support base • crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik **Decommissioning** • removal of GBS loading facility • capping and filing of undersea pipelines			
Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf)	**Exploration/Development** • 3D seismic surveys to delineate field • site preparation for GBS • GBS platform and wareship towed into position and installed • field development • first production and injection wells directionally drilled from GBS	• labour force required to complete installations would temporarily increase the total population of the ISR.	• change in population of ISR communities	• total population within ISR • Inuvialuit population within ISR communities

Table D-57 Summary of Potential Impacts and Effects on Demographics

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf) (cont'd)	**Operations** • additional production wells directionally drilled from GBS • loading and westward transits of ice strengthened oil tankers • icebreaking around GBS facility and as tanker escort • wareship provides logistical support • annual sealift • local resupply from Tuktoyaktuk and Summers Harbour (ship and air) • helicopter transfer of crews • crew changes airflights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik • Tuktoyaktuk and Summers Harbour used as service and supply bases **Decommissioning** • removal of GBS platform and wareship • well capping			

Table D-57 Summary of Potential Impacts and Effects on Demographics

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope)	**Exploration/Development** • drillship transit to/from Beaufort Sea • exploration and delineation drilling **Operations** • transit of FPSO to Beaufort Sea, anchoring at production site • production and injection wells drilled from drillship • loading and eastward and westward transits of ice-strengthened oil tankers (Ice Season transits westward only) • wareship logistical support • annual sealift • local resupply from Tuktoyaktuk and Summers Harbour (ship and air) • helicopter transfer of crews • crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik • Tuktoyaktuk and Summers Harbour service and supply bases	• labour force required to perform activities would temporarily increase the total population of the ISR	• change in population of ISR communities	• total population within ISR • Inuvialuit population within ISR communities

Table D-57 Summary of Potential Impacts and Effects on Demographics

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope) (cont'd)	**Decommissioning** • removal of FPSO and wareship • well capping			
Scenario 5 (Large Oil Release Event)	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• non-resident labour force may be required to clean up spill would temporarily increase the total population of the ISR.	• change in population of ISR communities	• total population within ISR • Inuvialuit population within ISR communities

D.4.2.2 Scenario 1: Status Quo

D.4.2.2.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

While there is predicted to be an increase in employment and economic opportunities associated with tourism in the Status Quo scenario (see Section D.4.1), such activities would be infrequent, seasonal, and of short duration. These employment opportunities are not expected to be of a magnitude to draw workers to the ISR communities on a permanent basis. The wind energy project included in Scenario 1 would require a relatively small labour force during four months of construction (some of whom would come from outside the ISR due to the specialized nature of the work for installation and initial operations) and a small permanent operations crew. Of note, while the wind energy project would replace some of the electrical needs now supplied by the existing power generation plant in Inuvik (propane-fired with diesel back-up) or the diesel-fired power plants in the other five communities, the existing power plants would still be required for base and peaking power generation. Effects of the wind energy project on the workforce at the existing power plants are not known.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Scenario 1 could experience an Open Water Season workforce of up to 100 persons. While a proportion of these workers would be hired from within the ISR, it is anticipated that the majority would work on a FIFO basis and only be in the ISR temporarily. The offshore wind generation facility is anticipated to operate with a crew of approximately 10 persons. At the start of operations it would be expected that most or some operational staff would be from outside the ISR, and work on a FIFO basis; however, with skills training for Inuvialuit, it is assumed that more of the operating jobs would be held by ISR residents.

Under Scenario 1, demographics would be affected by natural birth and death rates and the rates of in- and out-migration. Between 2013 and 2018, the population of the ISR was relatively stable, increasing by only 1.3%. As described in Section 7.4.2.1, the ISR has been experiencing a net out-migration in ISR communities as young people move to find post-secondary education and jobs elsewhere. Population projections indicate this trend will continue, forecasting that the Inuvialuit population of the ISR will decrease by 7.5% from nearly 6,000 in 2018 to 5,549 in 2035 (GNWT 2018e). The net permanent jobs created in Scenario 1 are not likely sufficient to reverse the trend. Absent specific information on worker requirements and hiring associated with Scenario 1, the prediction and characterization of residual effects is made with medium confidence.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Sea level rise, increases in storm surge frequency and strength, waves, sea ice extent and location, and permafrost degradation is predicted to affect coastal infrastructure. Tuktoyaktuk, for instance, has been and is experiencing coastal erosion from climate change-related sea level rise and the people there are taking steps to protect their community, such as moving homes and buildings away from the areas that are seeing the greatest erosion (Zingel 2019). Therefore, climate change may exacerbate the current demographic decline and displacement of coastal communities, potentially resulting in more people moving out of the ISR.

A substantial workforce may be needed to undertake maintenance and resiliency works to address climate change effects. Depending on the location of projects and labour requirements there could be migration of workers both between ISR communities, and by workers from outside the ISR into the region. While the prospects of employment may motivate some individuals to move into the ISR permanently, other individuals may be employed temporarily on a FIFO basis.

D.4.2.2.2 MITIGATION AND MANAGEMENT

The GNWT recognizes the importance of supporting population growth as a key component of developing a strong and prosperous NWT economy (GNWT 2015). It is recognized that resource development would be the primary driver of the economy, but that economic growth is constrained by the limited availability of a skilled workforce. Measures identified in GNWT (2015) to support population growth in NWT include:

- providing quality government programs and services that would encourage people to live and work in the NWT
- marketing the NWT as a great place to live and work
- improving actions to recruit and retain employees in the GNWT workforce

The successful implementation of such measures may help stabilize the population in ISR and reduce the rate of the population decline. Addressing housing shortages in the ISR communities may also help address demographic changes, including out-migration.

Actions to design, build, and maintain climate resilient communities are identified in GNWT's 2020 NWT *Climate Change Strategic Framework, 2019-2023 Action Plan* (GNWT 2019b). By improving climate change resilience, these actions may limit demographic changes in ISR communities that are influenced by climate change.

D.4.2.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

The new jobs created under Scenario 1 and implementation of management plans to counter population decline, outlined in Section D.4.2.2.2, may slow population decline in the ISR. However, under Scenario 1, the population within the region is predicted to continue to decline, and residual adverse effects on demographics are expected to be neutral to negative in direction, low magnitude, regional, continuous, and long-term. Coastal erosion associated with climate-change could result in shifts in residents within the ISR (e.g., people moving away from coastal to inland communities such as Inuvik) or ISR residents moving from the region; both have a potential to affect demographics.

CUMULATIVE EFFECTS

Concurrent activities into the region are embodied in Scenario 1, so the cumulative effects are the same as the residual effects.

D.4.2.3 Scenario 2: Export of Natural Gas and Condensates

D.4.2.3.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

All activities that result in spending within the ISR could have an effect on demographics because they would result in employment of residents from ISR communities and elsewhere in the NWT and Yukon. The proponent for the development would be expected to include training and employment of Inuvialuit, as per requirements of the Subsection 16 of the IFA, Section 5.2 of, COGOA and Section 21 of CPRA (see Section 2.11). However, the majority of the workforce for site preparation and installation of the dual pipeline system and the GBS loading platform is expected to be non-local FIFO individuals with specialized engineering and construction skills. Many of the FIFO workers would likely work on rotations with workers transported by air to and from Inuvik, Tuktoyaktuk or logistics bases from other parts of Canada and, possibly, the United States and internationally.

While some individuals from outside the ISR may permanently relocate to Tuktoyaktuk and Inuvik, consistent with previous experience with oil exploration activity in the BRSEA Study Area, it is expected that the majority of the non-resident workforce would be employed on a FIFO basis, and they would not affect the population of the ISR, NWT or Yukon. However, in support of Scenario 2 activities, there would be new local employment opportunities for Inuvialuit and other northern residents through the project proponents and major contractors, supporting commercial providers of goods, equipment, and services, and through community infrastructure and services providers. A number of government positions may also increase. This may result in Inuvialuit job seekers from ISR communities and non-Inuvialuit from elsewhere in NWT, Yukon and Canada moving to Tuktoyaktuk or Inuvik in hopes of securing employment.

As discussed in Section 3.7.1, while the on-land components of this development and effects on demography are expected to be substantial, these effects are outside the geographic scope of the BRSEA. As a result, the development, construction and operation of the anchor fields, associated field infrastructure, gathering pipelines and the gas processing facility is not considered in this assessment. Given the size and complexities of these facilities compared to the offshore pipelines and GBS loading facility, demographic effects from on-land activities are expected to be larger than effects from the offshore activities.

EFFECTS OF CLIMATE CHANGE

Assuming that climate change does not adversely affect the viability of the export facility and associated infrastructure over its operational life, it is not expected to affect demographic changes associated with Scenario 2. If climate change affects the functioning viability of some ISR communities, then it could contribute to inter-regional migration within ISR, and out-migration from ISR.

D.4.2.3.2 MITIGATION AND MANAGEMENT

The following management measures would help manage adverse effects and increase positive effects of Scenario 2 on demographics within the ISR:

- in accordance with Subsection 16(1) of the IFA, COGOA (Section 5.2) and CPRA (Section 21) (Section 2.11 this report), the project proponents would be required to develop benefit plans with the IRC, including commitments for employment, training, and education of Inuvialuit, as well as use of local services and suppliers
- restrict or focus hiring within the north to Inuvialuit, other Indigenous persons and other northern residents, including those permanently residing in NWT, Yukon and possibly Nunavut
- designate all communities within ISR, as well as other NWT communities in the Mackenzie Delta, as points of hire
- provide transportation to and from points of hire
- provide gender training, cultural sensitivity training, and cross-cultural awareness training to all project workers
- develop and implement a socio-economic agreement and management plan that contains commitments and actions to address socio-economic impacts, review of project performance, construction and operational monitoring, cumulative effects monitoring and adaptive management
- monitor effects of industrial and other activities on population and demographics, as part of broader socio-economic monitoring, and use information to support decision-making systems for existing mitigation measures, future projects and co-management processes

D.4.2.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

With the implementation of plans to encourage the training and hiring of residents of ISR communities and point of hire policies, Inuvialuit may be encouraged to remain in their home communities, and inter-regional migration to Tuktoyaktuk and Inuvik by jobseekers might be reduced. The presence of employment opportunities may encourage some previous ISR residents to return, thus reducing or reversing net out-migration from ISR communities. Possible migration of non-Inuvialuit into the region would be consistent with GNWT's objectives to stimulate population increases to help grow the economy (GNWT 2015).

Residual effects of Scenario 2 on demographics are expected to be positive, of low to moderate magnitude, with higher magnitude effects occurring during construction associated with the influx of the FIFO workforce. There is predicted to be a smaller permanent population increase in the ISR during operations, which would be present over the life of the project, and reversible upon decommissioning. During site preparation and installation of infrastructure, most population effects would occur during the Open Water Season. Operations related population effects would occur throughout the year.

As long as climate change does not affect the viability of the offshore export facility it would not substantially affect demographics in the ISR.

Previous oil and gas development in the BRSEA Study Area showed that the majority of workers for oil and gas projects would come from outside the ISR (Section D.4.1.1.5). However, absent specific information on worker requirements, hiring, and extent of Inuvialuit participation in project employment for the scenarios, the prediction and characterization of residual effects is made with medium confidence.

CUMULATIVE EFFECTS

The modest declines in population within ISR that are predicted for Scenario 1, would be offset by the large temporary FIFO population influxes and smaller permanent population changes associated with Scenario 2. Therefore, the cumulative effect on demographics is predicted to be neutral to positive, low to moderate magnitude, long-term, and reversible. If climate change affects the functioning viability of some ISR communities, then it could contribute to inter-regional migration within ISR, and out-migration from ISR.

D.4.2.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.4.2.4.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Effects pathways of Scenario 3 on demographics are similar to those for Scenario 2 described in Section D.4.2.3. As in Scenario 2, it is expected that the majority of the workforce needed to construct and operate a GBS oil production platform and run logistics bases (e.g., Tuktoyaktuk and Summers Harbour or equivalent) would be hired from outside the ISR and be employed on a FIFO basis. Non-local workers would transit via Tuktoyaktuk and, because of limited interaction within ISR communities, are not expected to affect the demographics of the ISR.

During construction and operation of the GBS platform and the operation of supply and service bases, there also would be numerous local employment opportunities for Inuvialuit and other northern residents to work for project proponents and major contractors, as well as supporting goods, equipment, and service providers. Inuvialuit job seekers from ISR communities and non-Inuvialuit from elsewhere in the NWT and Yukon could move to Tuktoyaktuk or Inuvik in hopes of, or subsequent to, securing employment.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Throughout site preparation, installation and operation for the GBS oil platform, there would be a large population of non-resident workers transiting through Tuktoyaktuk, Inuvik or the supply and service bases. While not in transit, it is assumed that these individuals would be lodged in self-contained workforce accommodation within these bases that would be separate from the towns' permanent populations. Unless managed, it could be expected that some Inuvialuit and non-Inuvialuit would relocate to Tuktoyaktuk and Inuvik from other ISR communities and elsewhere in NWT and Yukon in search of, or subsequent to, employment. This would increase the rate of population decline in the other communities but increase the population in Tuktoyaktuk and Inuvik.

EFFECTS OF CLIMATE CHANGE

As long as climate change does not adversely affect the viability of the offshore oil industry within the BRSEA Study Area over its operational life, it is not expected to affect demographic changes associated with Scenario 3. If climate change affects the functioning viability of some ISR communities, then it could contribute to inter-regional migration within ISR, and out-migration from ISR.

D.4.2.4.2 MITIGATION AND MANAGEMENT

Measures to manage adverse and increase positive effects on the total and Inuvialuit populations in Scenario 3 would be similar to those described for Scenario 2 (Section D.4.2.3.2).

D.4.2.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

As in the case of Scenario 2, with the implementation of plans to encourage hiring of ISR residents, Inuvialuit may remain in their home communities, and inter-regional migration to Tuktoyaktuk and Inuvik might be limited. Employment opportunities, in addition to current initiatives by government and Inuvialuit to increase education and skills may encourage some previous ISR residents to return, reducing or reversing net out-migration from most ISR communities. Any in-migration of non-Inuvialuit to the region would be consistent with GNWT's objectives of stimulating population and economic growth. Residual effects of Scenario 3 on demographics are considered to be positive, moderate magnitude, long-term and reversible. During site preparation and installation, most population effects would occur during the Open Water Season. Operations related population effects would occur throughout the year.

Previous oil and gas development in the BRSEA Study Area showed that the majority of workers for oil and gas projects would come from outside the ISR region (Section D.4.1.1.5). However, absent specific information on worker requirements and hiring, the prediction and characterization of residual effects is made with medium confidence.

CUMULATIVE EFFECTS

The modest decline in population within the ISR that is predicted for Scenario 1, would be offset by the large temporary FIFO population influxes and smaller permanent population changes associated with Scenario 3. Therefore, the cumulative effect on demographics is predicted to be neutral to positive, low to moderate magnitude, long-term, and reversible. If climate change affects the functioning viability of some ISR communities, then it could contribute to inter-regional migration within ISR, and out-migration from ISR.

D.4.2.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.4.2.5.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Effects pathways on demographics for Scenario 4 would be similar to those for Scenario 3 (Section D.4.2.3). It is expected that the majority of the workforce needed to install and operate the FPSO and supporting infrastructure, logistics bases (e.g., Tuktoyaktuk and Summers Harbour or equivalent) and crew the drilling rigs for exploration, delineation and production wells, would come from outside the ISR and be employed on a FIFO basis via Tuktoyaktuk and possibly Inuvik. Because of limited interaction within ISR communities, they are not expected to affect the demographics of the ISR.

Project development and operation also would provide numerous local employment opportunities. Inuvialuit job seekers from ISR communities and non-Inuvialuit from elsewhere in the NWT and Yukon could move to Tuktoyaktuk and Inuvik in hopes of securing employment thereby increasing the local population.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The potential demographic effects associated with Scenario 4 are expected to be similar to the effects described for Scenario 3 (Section D.4.2.4.1).

EFFECTS OF CLIMATE CHANGE

As long as climate change does not adversely affect the viability of the offshore oil industry within the BRSEA Study Area over its operational life, it is not expected to affect demographic changes associated with Scenario 4. If climate change affects the functioning viability of some ISR communities, then it could contribute to inter-regional migration within ISR, and out-migration from ISR.

D.4.2.5.2 MITIGATION AND MANAGEMENT

Mitigation and management measures to limit adverse effects and increase positive effects on demographics for Scenario 4 would be similar to those described for Scenario 2 (Section D.4.2.2.2).

D.4.2.5.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

The residual effects of Scenario 4 on demographics are similar to Scenario 3. Residual effects on demographics are considered to be positive, moderate magnitude, long-term and reversible. During site preparation and installation, most population effects would occur during the Open Water Season. Operations related population effects would occur throughout the year.

Previous oil and gas development in the BRSEA Study Area showed that the majority of workers for oil and gas projects would come from outside the ISR region (Section D.4.1.1.5). However, absent specific information on worker requirements and hiring, the prediction and characterization of residual effects is made with medium confidence.

CUMULATIVE EFFECTS

The modest changes in population within ISR, predicted for Scenario 1, would be offset by the population changes associated with Scenario 4, including a large increase in the temporary population due to the FIFO workforce during all phases, and a smaller permanent population increase in Inuvik and Tuktoyaktuk. Therefore, the cumulative effect on demographics is predicted to be neutral to positive, moderate magnitude, long-term, and reversible. If climate change affects the functioning viability of some ISR communities, then it could contribute to inter-regional migration within ISR, and out-migration from ISR.

D.4.2.6 Scenario 5: Large Oil Release Event

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface spill from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on demography from such an event may differ slightly from what is described below for surface or subsea releases.

D.4.2.6.1 ASSESSMENT OF EFFECTS OF AN OIL SPILL

DESCRIPTION OF EFFECT PATHWAY

Depending on the magnitude of the spill, additional personnel may need to be brought in from outside the ISR to help with containment and clean-up. It would be anticipated that most of these workers would mobilize from and be lodged in Tuktoyaktuk or one of logistics bases (Tuktoyaktuk and Summers Harbour or equivalent). Additional command personnel (e.g., proponent, government, response organization) and support personnel may move through or be located in Inuvik. It is also anticipated that this workforce would leave gradually as the spill response and site clean-up is completed. The effect of the spill itself, could include loss of traditional activities, and employment related to tourism. This could result in some out-migration due to measurable or perceived degradation in lifestyle, food security, or economic opportunities.

Description of Range of Potential Effects

Table D-58 summarizes potential effects of a large-scale oil release on demographics. Depending on its severity and requirements for clean-up personnel, an oil spill could result in a temporary increase in the non-resident population of the ISR. Inuvialuit and non-Inuvialuit from other ISR communities, and from other areas may also temporarily move to Tuktoyaktuk, Inuvik or logistics bases to assist with the oil spill response.

The workforce required to manage and conduct a spill response and cleanup would likely be similar regardless of the season. While a spill in the late Fall Transition and Ice seasons might be contained to some degree by the ice, cold temperatures and long night conditions would make the response more complex and require additional logistical support and people (e.g., shorter outdoor work periods and rotations of workers due to cold temperatures). By contrast, a spill occurring during the Open Water Season might require additional equipment and people to cover a wider area, while temperatures and long daylight conditions would require less support and fewer or longer crew rotations. Regardless, few, if any, of the workforce would result in a change to permanent demographics.

If traditionally-harvested species, habitats and species valuable for tourism are adversely affected over the long-term, traditional harvesting, cultural vitality (Sections D.4.4 and D.4.5) and tourism may also be adversely affected, potentially resulting in some out-migration from the region.

Effects of Climate Change on Potential Effects

Environmental changes associated with climate change may affect spill characteristics, including spill extent (i.e., the movement or trajectory of released oil), shoreline oiling and oil dispersion in the water column. The nature of the spill would determine the size of the response teams and the infrastructure required to clean up the spill.

D.4.2.6.2 Mitigation and Management

Comprehensive oil spill response planning and capabilities would be developed and implemented prior to commencement of oil production and transport, as discussed in Sections 2.13 and 3.10.5.3. Use of supply and service bases as the primary location for command and spill response personnel would reduce effects of temporary population increases on communities. Development of first response capabilities in the Inuvialuit communities (e.g., training and ongoing readiness drills for first responders, equipment caches) would directly engage community residents and reduce the need for responders from outside of the communities.

D.4.2.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

A spill response for a large oil release would require mobilization of large numbers of non-resident FIFO personnel to manage and conduct the spill response and clean-up activities; this would result in a short-term increase in the ISR population. Ongoing cleanup and restoration would require a smaller workforce, likely drawn mainly from ISR residents, and supplemented by non-resident FIFO personnel. However, a large oil spill that results in severe environmental contamination and shoreline fouling could have a long-term adverse impact on ISR demographics, particularly if residents were to leave the region as a result of real or perceived degradation of lifestyle and reduced food security.

D.4.2.7 Summary of Residual Effects

Potential residual effects of Scenarios 1 – 4 and a large oil release on demography are summarized in Table D-58 and Table D-59. While there could be some seasonal differences in demographic changes and adverse effect among seasons for the Status Quo, the three oil and gas development scenarios and the large oil release event, there is insufficient information to provide seasonally-specific effects characterizations for potential demographic changes. As a result, an effects characterization is provided for an annual cycle for each of the scenarios. A long-term effects characterization for demography is provided for a large oil release event.

D.4.2.8 Gaps and Recommendations

Project specific socio-economic assessments should include the collection of information related to gender, sexual identity, and other relevant identity factors, to support an assessment of socio-economic impacts on vulnerable population groups that may be disproportionately affected by industrial development.

Table D-58 Potential Residual Effects of Scenarios 1 – 4 on Demographics for All Seasons[22].

	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4 Oil Development in Deep Water
Potential Effects	• Potential temporary change in population of ISR communities resulting from wind development project employment • Continued slow population decline	• FIFO workforce for site preparation and installation of the dual pipeline and GBS loading platform • Employment in project development and support services, would result in net immigration leading to a possible stabilization of the population in the ISR	• FIFO workforce for Project site preparation and installation activities, including GBS installation • Employment in project development and support services, would result in net immigration leading to a possible stabilization of the population in the ISR	• FIFO workforce for Project drilling site preparation and installation activities, including the FPSO and wareship • Employment in the development and support services, would result in net immigration leading to a possible stabilization or increase of the population in the ISR
Legend				
• Least effect – No to minor effect on demographic stability				
• Moderate effect -- Moderate effect on demographic stability				
• High effect -- Major effect on demographic stability				
• Greatest effect – Severe effect on demographic stability				

22 While there could be some differences in demographic benefits and adverse effects among seasons for the Status Quo and the three oil and gas development scenarios, there is insufficient information to provide seasonally-specific effects characterizations for demography. Instead, effects characterizations are provided for an annual cycle for the Status Quo and the three oil and gas development scenarios.

Table D-59 Potential Effects of a Large Oil Release Event (Scenario 5) for Demographics for All Seasons and the Longer Term[23].

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
All seasons	• Workforce to manage and mobilize spill response and shoreline cleanup. • Temporary influx of large numbers of FIFO responders and personnel; greater numbers required due to shoreline effects and cleanup • Would involve trained responders and other workers from Inuvialuit communities	• Workforce to manage and mobilize spill response and shoreline cleanup. • Temporary influx of large numbers of FIFO responders and personnel • Would involve trained responders and other workers from Inuvialuit communities	• Workforce to manage and mobilize spill response and shoreline cleanup. • Temporary influx of large numbers of FIFO responders and personnel • Would involve trained responders and other workers from Inuvialuit communities
Longer-term/ Multi-year	• Ongoing shoreline cleanup and restoration would require a smaller workforce than main response • With training, this work force could be predominantly Inuvialuit with FIFO responders for specialized skills	• Ongoing cleanup and restoration would require a smaller workforce than main response; fewer shorelines effects predicted for this type of release • With training, this work force could be predominantly Inuvialuit with FIFO responders for specialized skills	• Ongoing cleanup and restoration would require a smaller workforce than main response; fewer shorelines effects predicted for this type of release • With training, this work force could be predominantly Inuvialuit with FIFO responders for specialized skills
Legend			
• Least effect – No to minor effect on population and demographic stability			
• Moderate effect -- Moderate effect on population and demographic stability			
• High effect -- Major effect on population and demographic stability			
• Greatest effect – Severe effect on population and demographic stability			

[23] While there could be some differences in demographic benefits and adverse effect among seasons for the large oil release scenario, there is insufficient information to provide seasonally-specific effects characterizations for demography. Instead, effects characterizations are provided for all seasons and the longer term.

D.4.3 Infrastructure

D.4.3.1 Scoping

D.4.3.1.1 Identification of Indicators

The functioning of communities within the ISR involves a range of infrastructure and services including utilities (electricity, telephone, internet, water supply, sewage, solid waste disposal), roadways, hospitals, emergency services, clinics, schools, government buildings and services, recreational facilities, grocery and other stores, etc. The capacity of infrastructure and these services is often based on the population size of the communities, with additional facilities and services for commercial and industrial activities, as well as tourism (e.g., hotels, transportation services, food supply). The latter depend on reliable functioning of community infrastructure and services. The following indicators are used in the assessment of the Infrastructure VC:

- capacity of accommodations, including permanent housing and temporary accommodations
- municipal utilities capacity, including water supply, and waste treatment and disposal
- transportation infrastructure capacity, including roads, air fields, and port facilities
- energy and communications infrastructure capacity, including power generation and distribution, cellular and other telecommunications services
- medical services capacity, including hospitals and clinics
- emergency services capacity, including fire, ambulance, and police services

Effects on infrastructure associated with industrial activity can be both adverse and positive. Increased demands on infrastructure by industry can strain community resources and reduce the level of services or quality of services for community residents. However, building of new infrastructure or upgrading existing infrastructure by industry can benefit communities and provide long-term legacy benefits.

D.4.3.1.2 Spatial Boundaries

Infrastructure and services within the six communities in the ISR (Aklavik, Inuvik, Paulatuk, Sachs Harbour, Tuktoyaktuk, and Ulukhaktok) could be affected by industrial development or a large oil release event. Infrastructure outside of communities, such as roadways (e.g., Tuktoyaktuk and Dempster highways), could also be affected by industrial development activities and/or effects from climate change.

D.4.3.1.3 Temporal boundaries

The assessment of potential effects on infrastructure encompasses a 30-year period between 2020 – 2050.

D.4.3.1.4 ASSESSMENT OF POTENTIAL EFFECTS

The assessment of potential effects on infrastructure considers the adverse and positive residual effects on infrastructure in the ISR communities. Qualitative characterization of potential residual effects on infrastructure associated with each scenario is based on the characterization terms defined in Table D-60.

Table D-60 Characterization of Residual Environmental Effects on Infrastructure for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Positive**—increase in demand for local infrastructure relative to baseline. **Adverse**—a decline in demand for local infrastructure relative to baseline. **Neutral**—no net change in demand for local infrastructure relative to baseline.
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no measurable change in demand on infrastructure **Low**—a measurable change but on a scale that is within current infrastructure capacity **Moderate**—a measurable change that nears current infrastructure capacity **High**—a measurable change that exceeds the capacity of current infrastructure
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity. **Local**—residual effects extend into the local area around the activity. **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area). **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area).
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once. **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity. **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity. **Continuous—**residual effect occurs continuously for the duration of the activity.
Duration	The period of time the residual effect can be measured or expected	**Short-term**—the residual effect is restricted to short-term events or activities such as discrete component completion during construction, maintenance, or rehabilitation activities (i.e., a timeframe of several months up to 1 year) **Medium-term**—the residual effect extends through the completion of construction and rehabilitation activities (i.e., a timeframe of 1 year to 5 years) **Long-term**—the residual effect extends beyond the completion of construction and rehabilitation activities into the operations and maintenance phase of a project (i.e., a timeframe of greater than 5 years)

Table D-60 Characterization of Residual Environmental Effects on Infrastructure for the time period 2020-2050

Characterization	Description	Definition of Qualitative Categories
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Resilient**—infrastructure has capacity to accommodate increased demand **Not Resilient**—infrastructure has limited capacity to accommodate increased demand

D.4.3.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

Effects on infrastructure are related to their ability/capacity to support development activities and communities and their effects in the region. This includes, but is not limited to:

- infrastructure used to service activities, such as ports for servicing supply vessels and drilling rigs, and airports to transport workers between their home communities and offshore locations
- use of services such as scheduled flights, charters, helicopters and roads
- the ability of community infrastructure to support the workers drawn to the region by, or affected by, development activities

A temporary or permanent influx of workers can strain a community's capacity to offer services to its residents. This can include services such as healthcare, policing, fire and emergency services, education, housing, water and wastewater treatment, and waste management. Infrastructure that can be affected includes:

- permanent and temporary accommodations
- retail facilities such as grocery stores
- recreation centres
- meeting facilities
- schools and training facilities
- hospitals and emergency services
- roads, airports, and other transportation infrastructure
- fuel storage and sales
- energy generation and distribution infrastructure
- telecommunications equipment and networks
- water pumping stations
- sewage treatment facilities
- solid waste disposal

Past industry projects in the BRSEA Study area have provided legacy benefits that have persisted after the eventual closure and decommissioning of various projects. Examples include upgrading of airports (e.g., Inuvik, Tuktoyaktuk), port facilities and harbours (e.g., Tuktoyaktuk), logistical supply bases (e.g., multiple logistical bases and camps in Tuktoyaktuk) and other infrastructure (e.g., roads). Oil and gas projects also have helped support the development of supply and service businesses (e.g., airlines, oil field supply services, food distributors, catering, hotels). In addition to industry spending, municipal tax revenue and other economic benefits associated with economic development can be used to support infrastructure improvements or be retained for the future and ongoing economic benefits for ISR residents, as well as residents of the NWT and Yukon.

Effects on infrastructure may also result from climate change and interventions to reduce climate change effects by building new infrastructure designed to better withstand the effects of climate change.

Table D-61 summarizes potential impacts and effects on infrastructure of the Status Quo, the three oil and gas development scenarios and the large oil release event.

Table D-61 Summary of Potential Impacts and Effects on Infrastructure

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters

Scenario 1 (Status Quo)	• marine vessels – commercial shipping, cruise ship tourism, scientific research, military
	• ship-based or barge resupply of ISR coastal communities
	• renewable energy project (e.g., offshore wind turbine)
	• traditional harvesting – regional boat traffic and snowmobile use
		• new and upgraded infrastructure and services would be required to support activities
		• labour force required to perform activities would place additional demands on infrastructure
		• effects from climate change would necessitate infrastructure resiliency measures and infrastructure upgrades
			• change in infrastructure requirements/capacity
			• change in demand for local infrastructure
				• capacity of infrastructure
				  • accommodations
				  • municipal utilities
				  • transportation
				  • medical services
				  • emergency services
				• population

Scenario 2 (Export of Natural Gas and Condensates)[24]	• local resupply of GBS loading facility by vessel
	• helicopter transfer of crews
	• Tuktoyaktuk logistical support base
	• crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk
	• administrative base in Inuvik
	Decommissioning
	• removal of GBS loading facility
	• capping and filing of undersea pipelines
		• new and upgraded infrastructure and services would be required to support activities, especially in regard to marine infrastructure (e.g., harbours, docks), search and rescue, and spill response
		• labour force required to perform activities would place additional demands on infrastructure
		• effects from climate change would necessitate infrastructure resiliency measures and new and upgraded infrastructure
			• change in infrastructure requirements/capacity
			• Change in demand on local infrastructure
				• capacity of infrastructure
				  • accommodations
				  • municipal utilities
				  • transportation
				  • medical services
				  • emergency services
				• upgrading of existing or building of new infrastructure
				• population

[24] Only economic benefits and effects from the marine operations are considered here; economic benefits from development of gas fields, pipelines gas processing facilities onshore are not considered.

Table D-61 Summary of Potential Impacts and Effects on Infrastructure

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters

Scenario 3
(Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf)
	Exploration/Development
	• 3D seismic surveys to delineate field
	• site preparation for GBS
	• GBS platform and wareship towed into position and installed
	• field development
	• first production and injection wells directionally drilled from GBS
	Operations
	• additional production wells directionally drilled from GBS
	• loading and westward transits of ice strengthened oil tankers
	• icebreaking around GBS facility and as tanker escort
	• wareship provides logistical support
	• annual sealift
	• local resupply from Tuktoyaktuk and Summers Harbour (ship and air)
	• helicopter transfer of crews
	• crew changes airflights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk
		• new and upgraded infrastructure and services would be required to support activities, especially in regard to marine infrastructure (e.g., harbours, docks), search and rescue, and spill response
		• labour force required to perform activities would place additional demands on infrastructure
		• effects from climate change would necessitate infrastructure resiliency measures and new and upgraded infrastructure
			• change in infrastructure requirements/capacity
			• change in demand on local infrastructure
				• capacity of infrastructure
				  • accommodations
				  • municipal utilities
				  • transportation
				  • medical services
				  • emergency services
				• upgrading of existing or building of new infrastructure
				• population

Table D-61 Summary of Potential Impacts and Effects on Infrastructure

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 3 **(Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf) (cont'd)**	• administrative base in Inuvik • Tuktoyaktuk and Summers Harbour used as service and supply bases **Decommissioning** • removal of GBS platform and wareship • well capping			

Scenario 4
(Large Scale Oil Development within Exploration Licenses on the Continental Slope)
	Exploration/Development
	• drillship transit to/from Beaufort Sea
	• exploration and delineation drilling
	Operations
	• transit of FPSO to Beaufort Sea, anchoring at production site
	• production and injection wells drilled from drillship
	• loading and eastward and westward transits of ice-strengthened oil tankers (Ice Season transits westward only)
	• wareship logistical support
	• annual sealift
	• local resupply from Tuktoyaktuk and Summers Harbour (ship and air)
		• new and upgraded infrastructure and services would be required to support activities, especially in regard to marine infrastructure (e.g., harbours, docks), search and rescue, and spill response
		• labour force required to perform activities would place additional demands on infrastructure
		• effects from climate change would necessitate infrastructure resiliency measures and new and upgraded infrastructure
			• change in infrastructure requirements/capacity
			• change in demand on local infrastructure
				• capacity of infrastructure
				  • accommodations
				  • municipal utilities
				  • transportation
				  • medical services
				  • emergency services
				• upgrading of existing or building of new infrastructure
				• population

Table D-61 Summary of Potential Impacts and Effects on Infrastructure

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 4 **(Large Scale Oil Development within Exploration Licenses on the Continental Slope) (cont'd)**	• helicopter transfer of crews • crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik • Tuktoyaktuk and Summers Harbour service and supply bases **Decommissioning** • removal of FPSO and wareship • well capping			

Scenario 5
(Large Oil Release Event)
	• oil released from above the sea or ice surface (e.g., GBS platform)
	• oil released from a moving tanker or vessel
	• oil released from subsurface location (well head, pipeline)
		• labour force required to clean up spill would temporarily place additional demands on infrastructure	• change in demand on local infrastructure	• capacity of infrastructure
				  • accommodations
				  • municipal utilities
				  • transportation
				  • medical services
				  • emergency services

D.4.3.2 Scenario 1: Status Quo

D.4.3.2.1 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

A change in demand for infrastructure can come from activities directly related to a project or activity, be associated with the presence of a temporary workforce, and result from a change in permanent population. Examples of direct interaction between an activity and infrastructure is the movement of equipment, materials, and personnel on roads, air strips, and through port facilities. People, either in the region temporarily or permanently, may be direct consumers for a wide range of infrastructure and services, including accommodations, health care, emergency services, municipal utilities, power services, and telecommunications services.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

In Scenario 1, the population of the ISR is predicted to decline over the long-term (see Section 7.4.1.1); therefore, certain demands for new infrastructure may decline if the ISR population does not increase. However, aging or non-functioning pieces of infrastructure would need to be continually replaced, regardless of population loss. The presence of commercial ships, scientific research vessels and military vessels in the ISR would have little potential effect on infrastructure, as the vessels would generally be located at sea and crews may only go ashore during aerial transfer between the vessel and the mainland. Likewise, cruise ship passengers would generally be lodged on-board, only going ashore for short excursions, and thus placing minimal demands on infrastructure. It is assumed that ship-based resupply sealifts would be a continuation of existing practices and, therefore, would not result in additional infrastructure demands.

The construction of a renewable infrastructure project would likely require the use of transportation infrastructure, such as air fields, port facilities, and roads. Construction of the renewable energy project could involve a temporary workforce of < 100 persons, which could place demands on accommodations and other infrastructure within nearby ISR communities.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Changes in permafrost, ice conditions, precipitation, drainage patterns, temperatures, and extreme weather events can have adverse effects on infrastructure. Changing permafrost conditions, for instance, can alter the strength and integrity of the ground and cause building, road and other foundations to shift and become weak. While engineering and construction practices are being developed to build on changing permafrost, older facilities may be more vulnerable to the effects of climate change (GNWT 2018f).

Climate change may also affect transportation infrastructure. If warming trends continue in the north, more open water would increase marine traffic, including cruise ship activity, and create demands on local harbours in the coastal ISR communities. Climate change is also expected to adversely affect infrastructure. For example, degrading permafrost and changing freeze-thaw cycles have visibly shifted and cracked the surface of airport runways in northern communities (GNWT 2018f).

In addition, changes in wind direction can influence storm surge, waves, and precipitation; and increases in ambient temperature variability and thermal range, sea ice extent and location, are expected to have direct effects on coastal (and inland) infrastructure. Sea level rise also can have implications for coastal communities and infrastructure. Tuktoyaktuk is already experiencing coastal erosion from climate change-related coastal erosion and residents have taken steps to protect their community, such as moving buildings from the areas that are seeing the greatest erosion (Zingel 2019).

Addressing climate change challenges in ISR could involve substantial investment in equipment and materials, plus considerable labour both to address infrastructure deterioration (such as from melting of permafrost) and address other environmental changes, such as rising sea level. A substantial workforce may be needed to undertake such maintenance and resiliency works. This workforce would also need to be accommodated and transported and would place other demands on infrastructure within the ISR.

D.4.3.2.2 MITIGATION AND MANAGEMENT

Mitigation measures for infrastructure under Scenario 1 are likely similar to those anticipated for the ISR at present. The GNWT recognizes the importance of supporting population growth as a key component of developing a strong and prosperous NWT economy (GNWT 2015); a key aspect of retaining residents is to provide quality infrastructure and services to individuals and families and improve infrastructure.

The proponent for the renewable energy project might construct a self-contained logistics facility or lease an existing facility, including workforce accommodation and a supply and service base. This project could be expected to implement appropriate measures for the handling, transportation, and onshore disposal of solid and hazardous wastes. If it is feasible to use municipal utilities (potable water, sewage disposal, solid waste disposal) it would be expected that access to such services would be purchased through usage fees.

Actions to design, build, and maintain climate resilient communities have been identified in GNWT’s 2020 NWT Climate Change Strategic Framework, 2019-2023 Action Plan (GNWT 2019b). By improving climate change resilience, these actions may reduce climate change influenced demographic changes and either maintain or increase infrastructure demands in the ISR communities.

D.4.3.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Scenario 1 activities would result in only a small, short-term increase in population, primarily related to the construction of the renewable energy project. The movement of personnel, materials, and equipment associated with this project would require the use of transportation infrastructure within the ISR. However, by lodging crews in self-contained accommodations, the temporary population change occurring as a result of construction activities would have minimal, short-term adverse effects on infrastructure within the ISR. The operation of the renewable energy facility would involve a permanent crew. It is possible that such individuals would be hired from within the ISR, resulting in no population change. If the operations workforce is from outside the ISR, because of the low number of additional persons, the effect on infrastructure would be negligible. The overall population of the ISR is predicted to decline over the long term in Scenario 1, consistent with current forecasts. Therefore, the long-term demand for infrastructure by the permanent population is anticipated to be similar or less than today.

Climate change is predicted to have high magnitude adverse effects on infrastructure within ISR communities, with such effects anticipated to be larger than those caused by Scenario 1 activities. Such effects would be continuous, long-term, and occur throughout the ISR, particularly in ISR communities.

The extent to which climate change effects would be irreversible would depend on the extent of investment in resiliency works and projects. The labour force needed to implement such resiliency works would itself place demands on infrastructure and services within the ISR, and may necessitate additional infrastructure investments, such as workforce housing.

Detailed information on infrastructure within the ISR, such as capacity, current utilization, and sustaining maintenance requirements (i.e., maintenance needed to sustain current capacity) was not available for this analysis. Absent specific information on proponent provided infrastructure, such as worker accommodation facilities, the prediction and characterization of residual effects is made with medium confidence.

Cumulative Effects

Concurrent activities in ISR are embodied in Scenario 1, so the cumulative effects are the same as the residual effects.

D.4.3.3 Scenario 2: Export of Natural Gas and Condensates

D.4.3.3.1 Assessment of Effects of Routine Activities

Description of Effect Pathway

Scenario 2 considers effects associated with development of subsea pipelines and a GBS-based loading facility for the export of natural gas and condensates. Effects on infrastructure from Scenario 2 are expected to be a mixture of adverse effects on community infrastructure and positive effects through upgrading of existing infrastructure or building of new infrastructure. Adverse effects would be more likely to occur early on the development, whereas positive effects would more likely occur from late construction, throughout operation, to decommissioning.

The export project would require a logistical base to provide services and supplies for offshore activities, as well as facilities for crew changes. Tuktoyaktuk would likely be used as the primary logistical support and supply base. Supplies and services for offshore development would largely be provided through annual sealifts and a combination of wareships and offshore supply bases. The supply and service base would include additional onshore logistical support infrastructure such as marine access and docking facilities, storage warehouses, fuel tanks, maintenance shops, administrative offices, airport facilities (i.e., runways, heliports, hangers, fuel and buildings for passengers and cargo), and water treatment and waste management facilities (Section 3.7). Administrative and business support also would be required in Inuvik (e.g., office space, accommodation for employees).

In Scenario 2, site preparation and installation of components for the export facility would require the short-term presence of a non-local workforce that could increase demand on infrastructure in the ISR, including housing, healthcare, policing, fire and emergency services, education, water and wastewater, and waste management. Once the logistical support bases and project work camps are complete (e.g., within the first year of the construction period), construction crews for the remainder of the project development would be expected to use those facilities, thereby reducing demand on community and regional infrastructure. The capacity of local infrastructure within the ISR may increase if improvements are made to marine and air transport infrastructure to support project activities. It is assumed that most construction related effects (i.e., site preparation and installation) would occur during the Open Water Season. Once operational, the natural gas and condensate export facility would operate year-round.; While the infrastructure demands would be continual, the workforce to operate the offshore facility would be smaller than during construction and demands on infrastructure would be reduced. During operations, upgrades of infrastructure or building of new infrastructure for the export project would be in use and would help reduce demands on community infrastructure.

Description of Range of Potential Effects

In Scenario 2, up to several hundred non-resident FIFO workers would be transiting through Tuktoyaktuk and Inuvik. Most would be lodged at self-contained workforce accommodations within the service and supply base at Tuktoyaktuk, while transiting to development sites. It is also assumed that Inuvialuit residents working on the project who are not resident of Tuktoyaktuk also would be lodged at the workforce accommodations. Since most construction workers are expected to move through and be accommodated within the service and supply base, they would be separated from adjacent communities; as a result, they would have limited impact on local infrastructure. However there could be use of municipal utilities (potable water, sewage disposal), solid waste disposal, and municipal roadways. Contractors not directly associated with the development proponent or associated major engineering contractors may arrive on commercial flights and would require accommodations and other services; most of these individuals would be expected to arrive in Inuvik and use accommodations there.

Project hiring of ISR residents may result in increased demand for government-supported services that had previously been provided by household members, including child care and Elder care. This would occur during both construction and operations (MGP-JRP 2009).

During operations there may be a small increase in the population of Tuktoyaktuk and Inuvik due to relocation of some households within the ISR for employment, and possibly some migration into the region from other parts of Canada. However, it would be expected that the majority of the operations workforce would be engaged on a FIFO basis, and would be accommodated at self-contained worker housing at the Tuktoyaktuk base (or equivalent), prior to being transported to the GBS loading platform.

During operations, project activities such as annual sealifts, crew changes and ship and air resupply may place additional demands on existing marine infrastructure and airports, particularly in Tuktoyaktuk, which could serve as a main logistics hub and workforce staging area. However, as noted in Section 3.4, a number of improvements would be expected to be completed at the existing base in Tuktoyaktuk to bring them up to the requirements of a major development such as in Scenario 2 (as well as Scenarios 3 and 4). This would likely include upgrades to the airport, accommodations, offices, warehousing, docks and other harbour facilities. These upgraded and new development are expected to benefit the community over the medium to long-term. In the long term, infrastructure that is upgraded to support Scenario 2 activities could be beneficial to ISR communities and support future industrial projects.

The disposal of solid waste created during project activities may place additional demands on the capacity of waste management infrastructure. Hazardous waste is expected to be containerized and shipped to appropriate treatment facilities in southern Canada.

EFFECTS OF CLIMATE CHANGE

The increased number of ice-free days may result in some changes in the operations and logistics support of the natural gas and condensate export facility. For example, there would be less requirement for ice-breaking, and a potential increase in shipping support activities. Such operational changes may have implications for port and logistics infrastructure in Tuktoyaktuk.

Climate change processes may adversely affect the integrity of critical onshore transportation, logistics, and other infrastructure required to support Scenario 2 activities. Investments in new and upgraded infrastructure and other resiliency works would likely be required to ensure long term functioning of infrastructure needed to support industrial development within the ISR.

D.4.3.3.2 MITIGATION AND MANAGEMENT

The following measures should be considered to manage effects on infrastructure for Scenario 2:

- use of self-contained service and supply bases, including workforce accommodations, at the supply and service base, as well as on the GBS Loading platform (once operational)
- appropriate handling, storage, transportation and onshore disposal of solid and hazardous waste
- regular communications with Inuvialuit communities and representative organizations, through established and/or informal engagement processes, as required and requested
- undertake regular update meetings in each of the Inuvialuit communities in the ISR to address public concerns prior to commencement of the project
- normal and extreme weather and oceanographic conditions should be included in project design, materials selection, planning, and maintenance
- provide funding for addressing the indirect effects of a project on community services, including increased demand for childcare and Elder care that result from the increased employment of ISR residents
- implement measures to discourage non-NWT and Yukon project workers from entering other NWT and Yukon communities during their transit between the project sites and their home communities
- develop and implement a socio-economic agreement and management plan that contains commitments and actions to address socio-economic impacts, review of project performance, construction and operational monitoring, cumulative effects monitoring and adaptive management
- monitor effects of industrial and other activities on infrastructure and services, as part of broader socio-economic monitoring, and use information to support decision-making systems for existing mitigation measures, future projects and co-management processes

D.4.3.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

The natural gas and condensate export facility (Scenario 2) would be expected to result a mixture of adverse effects and benefits to infrastructure. Heavier use of existing infrastructure within the BRSEA Study Area would result from increased number of workers and demands for supplies and services. However, upgrades and new infrastructure from the project (e.g., an upgraded service and supply base, new worker accommodations, new emergency support capabilities) would reduce additional demands on local infrastructure.

The residual effects on infrastructure within the ISR for the export facility are expected be neutral to adverse (i.e., some increased demands would be felt in Inuvik, Tuktoyaktuk and possibly other communities early during construction and perhaps into operations). Effects are predicted to affect a low to moderate magnitude of local infrastructure outside of the service and supply base, be localized to specific communities, be continuous over the life of the project and be long-term (30 years or more). However, upgrades to existing infrastructure and building of new infrastructure would eventually help to reduce effects on local infrastructure and may benefit local communities over the medium- to long-term (e.g., improved airports, better accommodations, improved supplies and services businesses).

It is assumed that climate change considerations would be factored into the design specifications and operating parameters of the natural gas and condensate export facility and supporting activities. Climate change resiliency also would be factored into new and upgraded infrastructure needed to support scenario activities, such as the airstrip, roads, buildings, and logistics support areas. Such investments may not have been undertaken absent the project, so these upgrades can be considered as having a beneficial effect on infrastructure within the ISR (i.e., a low to moderate magnitude improvement in local infrastructure in specific communities with benefits be continuous over the life of the project and long-term (30 years or more)). New or upgraded facilities such as airports and expanded supply and service companies also could benefit local communities.

Detailed information on infrastructure within the ISR, such as capacity, current utilization, and sustaining maintenance requirements (i.e., maintenance needed to sustain current capacity) was not available for this analysis. Absent specific information on proponent provided infrastructure, such as worker accommodation facilities, the prediction and characterization of residual effects is made with medium confidence.

CUMULATIVE EFFECTS

Increases in vessel activity, tourism, and wind power in Scenario 1 along with oil and gas activities in Scenario 2 may act cumulatively to place additional demands on infrastructure within the ISR communities. Marine and air transport infrastructure would likely be upgraded or rebuilt to accommodate these industries.

Community infrastructure could be affected cumulatively should construction and installation of components for oil and gas projects involve some workers staying in local communities (e.g., smaller contractors might arrive into Inuvik and require accommodations and other services there). An influx of workers has the potential to affect the capacity of hotels and temporary accommodations, grocery stores and service centres, healthcare services, and fire and emergency services.

Climate change is predicted to adversely affect existing built infrastructure within ISR communities, which is not currently resilient to effects such as sea level rise and melting permafrost. Because such infrastructure would be needed to support industrial development activities in the BRSEA Study Area, it is likely that, under Scenario 2, climate change resilience investments would be made in Tuktoyaktuk because of its position as a service and supply base and shipping centre. However, other ISR communities would continue to face potential high magnitude effects on infrastructure, related to climate change, which would extend over the long-term. The extent to which climate change effects would be avoidable would depend on the amount of investment in resiliency works and projects. The labour force needed to implement such resiliency works would itself place demands on infrastructure and services within the ISR, and may necessitate additional infrastructure investments, such as workforce housing.

D.4.3.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.4.3.4.1 Assessment of Effects of Routine Activities

Description of Effect Pathway

Effects on infrastructure from Scenario 3 are expected to be a mixture of adverse effects on community infrastructure and positive effects through upgrading of existing infrastructure, building of new infrastructure or improving the resiliency of infrastructure to climate change. Adverse effects would be more likely to occur early on the development, whereas positive effects would more likely occur during late construction through to decommissioning.

Effects pathways of Scenario 3 would be similar to those described for the natural gas and condensate export facility (Scenario 2) but would be located ~80 km offshore (versus 15-20 km for the export facility. Scenario 3 also includes a 3D seismic program and drilling activity from the GBS, the mooring of a wareship beside the GBS and weekly inbound and outbound transits by oil tankers along the routes to the west. Weekly transits would occur year-round with icebreaking and possibly icebreaker escorts during the late Fall Transition, Ice and early Spring Transition seasons. Due to the size of the development, at least two supply and service bases are likely to be required; this scenario assumes one base in Tuktoyaktuk and one in Summer Harbour (or an equivalent location).

While development activities would largely be supported from the offshore wareship and resupply and logistics bases (e.g., Tuktoyaktuk and Summer Harbour, or equivalent), some activities are likely to require support from specific locations or communities in the ISR. Seismic activities, site preparation and installation of the GBS platform, drilling of production wells, oil production, and tanker transport of oil through routes west of the development would require a labour force and project requirements that would have some impact on infrastructure and services in the ISR communities, thereby creating additional demands. For example, some contract and management personnel would arrive and depart from Inuvik and require accommodations and other services there. Administrative and business functions for the development are also likely to require office and meeting space and services in Inuvik or Tuktoyaktuk. If non-hazardous waste materials produced by project activities are disposed in local facilities, this may increase pressure on local landfills,. Hazardous waste would need to be containerized and shipped to appropriate treatment facilities in southern Canada. However, positive effects may result from the building of new infrastructure required to support the project.

As in Scenario 2, project activities, such as the annual sealift, crew changes and ship and air resupply may place additional demands on existing marine infrastructure and airports. It is assumed that most construction related effects on infrastructure would occur during the Open Water Season when site preparation and installation activities are most likely to occur. Once operational, the GBS production platform would operate year-round and infrastructure demands would be continual.

Once upgrades to existing infrastructure and the building of new infrastructure is complete, these facilities would eventually help to reduce effects on local infrastructure and may benefit local communities over the medium- to long-term (e.g., improved airports, better accommodations, improved supplies and services businesses).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Scenario 3 would see a large population of non-resident FIFO workers transiting through Tuktoyaktuk, Inuvik and logistics bases. Once they are in the ISR, it is assumed that they may spend a night in self-contained workforce accommodations within one or both of logistics bases (e.g., Tuktoyaktuk, Summers Harbour) before they are taken out to the development site. Weather delays could extend the stays for several days. Since these individuals would be isolated from adjacent communities, they would not place additional demands on local infrastructure, such as housing and temporary accommodations. However, contractors not directly associated with the development proponent or associated major engineering contractors may arrive on commercial flights and would require accommodations and other services; most of these individuals would be expected to arrive in Inuvik and use accommodations there.

Project activities, such as annual sealifts, crew changes and ship and air resupply may place additional demands on existing marine infrastructure and airports. The creation of non-hazardous waste by the development may also increase pressure on local waste management infrastructure.

Unless managed, it would be expected that some Inuvialuit and non-Inuvialuit would relocate to Tuktoyaktuk and Inuvik from other ISR communities and elsewhere in NWT and Yukon in search of, or as a result of, employment. An increase in the populations of Inuvik and Tuktoyaktuk may lead to additional demands on the infrastructure of those communities.

Production operations would create the largest potential for interaction with infrastructure, since production systems and related requirements have a much longer duration (10–30 years or more) than other phases of activity. With such a long lifespan, there is a higher potential for some non-local workers, along with their families, to move to the region and live in local communities. They may place increased pressure on community infrastructure and services but, as described above, there would be lead-time to respond to this. New infrastructure that is built in response to this demand may remain as a positive legacy after the end of oil and gas activity; it may be beneficial to ISR communities and support future industrial projects.

EFFECTS OF CLIMATE CHANGE

Climate change may have an effect on marine shipping and servicing infrastructure if warming trends in the north continue. With increased open water and access to areas of the ISR, there could be increased traffic in and out of available ports. Oil and gas activity has the potential to further increase such activity, which may put a strain on marine infrastructure, and the ability to service all vessels effectively.

Climate change processes may adversely affect the integrity of critical onshore transportation, logistics, and other infrastructure required to support Scenario 3 activities. Investments in new and upgraded infrastructure and other resiliency works by the Town of Inuvik, the GNWT and possibly other Inuvialuit communities, would likely be required to provide long term functioning of infrastructure needed to support industrial development and growth in residential populations and business visitors within the ISR. For example the utilidor system in Inuvik requires an $80 million upgrade because permafrost has weakened the foundation of the utlildor (B. Simpson 2020, pers. comm.)

D.4.3.4.2 MITIGATION AND MANAGEMENT

The mitigation and management measures described in Section D.4.3.3 for Scenario 2 also would be implemented to manage effects on infrastructure for Scenario 3.

D.4.3.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Scenario 3 (large scale oil development within significant discovery licenses on the continental shelf) would be expected to result in a mixture of adverse effects and benefits to infrastructure. Heavier use of existing infrastructure within the BRSEA Study Area would result from increased number of workers and demands for supplies and services. However, upgrades and new infrastructure from the project (e.g., an upgraded service and supply base, new worker accommodations, new emergency support capabilities) would eventually reduce additional demands on local infrastructure.

Residual effects on infrastructure are expected to be adverse, of moderate magnitude, affecting a local area around the supply and service bases, continuous throughout the life of the project, and long-term (i.e., for the life of the project through to the end of decommissioning). However, to the extent that this hypothetical offshore oil development (Scenario 3) facilitates new and upgraded infrastructure within the ISR, there also would be positive benefits (i.e., low to moderate amounts of improvements in local infrastructure with benefits continuous throughout the life of the project and long-term).

It is assumed that climate change considerations would be factored into the design specifications and operating parameters of the GBS platform and supporting activities, including logistics bases. Climate change resiliency requirements also would be factored into new and upgraded onshore infrastructure needed to support development activities, such as the airstrip, local and regional roads, buildings, and logistics support areas.

Detailed information on infrastructure within the ISR, such as capacity, current utilization, and sustaining maintenance requirements (i.e., maintenance needed to sustain current capacity) was not available for this analysis. Absent specific information on proponent provided infrastructure, such as worker accommodation facilities, the prediction and characterization of residual effects is made with medium confidence.

Cumulative Effects

The construction and operation of the renewable energy project and increases in cruise ship tourism in Scenario 1 along with oil and gas activities in Scenario 3 may act cumulatively to affect infrastructure within ISR communities. For example, it is likely that new or upgraded marine and air transport infrastructure, as well as accommodations and associated services, office space and industrial areas would be required to accommodate these industries.

Community infrastructure could be affected cumulatively if some of the construction and installation of components for oil and gas projects involves workers staying in local communities. An influx of such workers has the potential to affect the capacity of hotels and temporary accommodations, grocery stores and service centres, healthcare services, and fire and emergency services. These effects are expected to be focused on Inuvik with smaller demand in Tuktoyaktuk. Few or no changes are expected in the remaining four Inuvialuit communities.

Climate change is predicted to adversely affect existing built infrastructure within ISR communities, which is not currently resilient to effects such as sea level rise and melting permafrost. Because such infrastructure would be needed to support industrial development activities in the BRSEA Study Area, it is likely that under Scenario 3, climate change resilience investments would be made in Tuktoyaktuk because of its position as a logistics and shipping centre and Inuvik as the business and administration centre. However, other ISR communities would continue to face potential high magnitude effects on infrastructure, related to climate change, which would extend over the long-term. The extent to which climate change effects would be avoidable would depend on the amount of investment in resiliency works and projects. The labour force needed implement such resiliency works would itself place demands on infrastructure and services within the ISR, and may necessitate additional infrastructure investments, such as workforce housing.

D.4.3.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.4.3.5.1 Assessment of Effects of Routine Activities

Description of Effect Pathway

Scenario 4 assesses effects resulting from exploration and hydrocarbon development within ELs in deep water. Effect pathways would be similar to those described for Scenario 3 and are expected to result in both adverse and benefits to infrastructure.

The exploration drilling program for this scenario would be considerably longer (four years) since each well would require two years to complete. Following the exploration drilling program, two delineation wells would be drilled (i.e., another four years). Following installation of an FPSO for processing oil and loading onto tankers, up to 50 production and injection wells are expected to be drilled over the life of the development. All drilling of wells would be done from a dynamically-positioned drill ship. Tankers would transit at weekly intervals to the west year-round and to the east on a monthly basis during the Open Water Season. At least two service and supply bases would be required to support offshore operations; this scenario assumes one base in Tuktoyaktuk and one in Summers Harbour (or an equivalent location).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Scenario 4 could involve a larger population of non-resident workers transiting through Tuktoyaktuk and Inuvik compared to Scenario 3. However, the majority of these workers would be lodged in self-contained workforce accommodations within the supply and service bases (e.g., Tuktoyaktuk and Summers Harbour) and, thus, place few additional demands on local infrastructure, such as housing and temporary accommodations. Project activities may place additional demands on existing marine infrastructure and airports, as well as waste management infrastructure for non-hazardous solid waste and hazardous waste (the latter are located in Alberta or British Columbia, but could be developed in the ISR, NWT or Yukon). An increase in the populations of Inuvik and Tuktoyaktuk by Inuvialuit and non-Inuvialuit in search of, or subsequent to, employment may place additional demands on the infrastructure of those communities.

Activities associated with this scenario would result in increased traffic in ports and associated service areas for offshore supply vessels. Exploration, delineation and production drilling would require a larger workforce than would be needed for development activities in Scenarios 2 or 3. Most workers are expected to be working on a FIFO basis with rotational shifts. This would involve a mix of workers from the ISR and adjacent territories (NWT, Yukon and possibly Nunavut) as well as workers from southern Canada. Some specialized workers could be required from the United States and internationally. This would result in increased activity at local airports with scheduled or charter flights bringing workers in and out of Tuktoyaktuk, Inuvik or logistics bases, and helicopters taking them to and from drilling rigs.

Production operations would create the largest potential for interaction with infrastructure, since production systems and related requirements have a much longer duration (10–30 years or more) than other phases of activity. With such a long lifespan, there is a higher potential for some non-local workers, along with their families, to move to the region and live in local communities. They may place increased pressure on community infrastructure and services but, as described above, there would be lead-time to respond to this. New infrastructure that is built in response to this demand may remain as a positive legacy after the end of oil and gas activity.

In the medium- to long term, infrastructure that was upgraded to support Scenario 4 activities could be beneficial to ISR communities and support future industrial projects.

EFFECTS OF CLIMATE CHANGE

Climate change may have an effect on marine shipping and servicing infrastructure if warming trends in the north continue. With increased open water and access to areas of the ISR, there could be increased traffic in and out of available ports. Oil and gas activity has the potential to further increase the number of vessel activity out of these ports, which may put a strain on the quality of marine infrastructure, and the ability to service all vessels effectively.

Climate change processes may adversely affect the integrity of critical onshore transportation, logistics, and other infrastructure required to support Scenario 4 activities. Investments in new and upgraded infrastructure and other resiliency works would likely be required to ensure long term functioning of infrastructure needed to support industrial development within the ISR.

D.4.3.5.2 MITIGATION AND MANAGEMENT

The mitigation and management measures for Scenario 2 and 3 also would be implemented to manage effects on infrastructure for Scenario 4.

D.4.3.5.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

With mitigation and management measures, the residual adverse effects of Scenario 4 on infrastructure are expected to be similar to those described for Scenarios 3 (Section D.4.3.4.3). Adverse effects are predicted to be of moderate magnitude, local, and continuous, and long—term (reflecting the longer production period and likely extension beyond 2050; Section 3.9). Infrastructure upgrades, new infrastructure and improved resiliency of existing infrastructure would provide positive benefits to local communities and the region that are expected to be continuous throughout most of the life of the project and long-term.

CUMULATIVE EFFECTS

The cumulative effects of Scenario 1 (e.g., construction and operation of the renewable energy project and increases in cruise ship tourism) in combination with offshore oil and gas activities in Scenario 4 are similar to the cumulative effects described earlier for Scenario 3 (Section D.4.3.4.3). Effects of climate change on cumulative effects in Scenario 4 are also similar to those described for Scenario 3.

D.4.3.6 Scenario 5: Large Oil Release Event

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface spill from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on infrastructure from such an event may differ slightly from what is described below for surface or subsea releases.

D.4.3.6.1 ASSESSMENT OF EFFECTS OF AN OIL SPILL

DESCRIPTION OF EFFECT PATHWAY

Increased demands on infrastructure would result from the non-resident response personnel and equipment moving temporarily into the ISR to assist with spill response. Local emergency infrastructure and marine and air transport infrastructure would also see increased use during the spill response and clean-up. While oil spill response crews located within the ISR, including Inuvialuit responders, would deploy the initial containment and spill response, large numbers of temporary personnel would be expected to mobilize to the ISR to support the management and execution of the spill response (Sections 2.13.2 and 2.13.4).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Table D-62 summarizes potential effects of a large oil release event on infrastructure by spill type. Regardless of the season, it could be expected that a large oil release in the BRSEA Study Area would prompt a large-scale response. While locally based responders and workers might be sufficient to address small spills, a large spill would most certainly require that additional response personnel and support teams be brought from outside the ISR to execute the spill containment and clean-up program. It is expected that many off these workers would mobilize and be lodged in self-contained accommodations within logistics bases (e.g., Tuktoyaktuk and Summers Harbour). However, depending on the number of additional personnel brought into the region, some may need to be housed in commercial accommodations, and require the use of civic infrastructure and services while in the region.

The use of emergency services and equipment, harbour and air transport infrastructure, and storage facilities, would place additional demands on local infrastructure in the short-term. However, the capacity of such infrastructure may have been upgraded to support hydrocarbon development and as part of oil spill planning and preparation.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Climate change would not affect infrastructure requirements needed to prepare for or address a major oil spill, as it is likely that such infrastructure would already have been upgraded to support hydrocarbon development and as part of oil spill planning and preparation.

D.4.3.6.2 MITIGATION AND MANAGEMENT

Mitigation and management measures would be followed to reduce effects on infrastructure in the event of an oil spill are described in Sections 2.13 and 3.10.5.

D.4.3.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Oil spills that require large numbers non-resident response personnel and support teams would increase demands on emergency, storage, and transportation infrastructure; this is expected to have an adverse effect on infrastructure. Depending on the size and location of the oil release and the effects of weather and sea states of the oil release, a single oil release event would be expected to have a low to moderate magnitude effect on infrastructure that would be local (i.e., focused on specific communities or service and supply bases), medium-term in duration (i.e., > 5 years) and, once spill cleanup and restoration is complete, reversible.

Detailed information on infrastructure within the ISR, such as capacity, current utilization, and sustaining maintenance requirements (i.e., maintenance needed to sustain current capacity) was not available for this analysis. Absent specific information on proponent provided infrastructure, such as worker accommodation facilities, the prediction and characterization of residual effects is made with medium confidence.

D.4.3.7 Summary of Residual Effects

Potential residual effects of Scenarios 1 – 4 and a large oil release on infrastructure are summarized in Table D-62 and Table D-63.

D.4.3.8 Gaps and Recommendations

Gaps associated with the assessment of effects on infrastructure are related to limitations of available demographic and infrastructure statistics and other information that may be out of date. The most recent Statistics Canada data is from 2016 (Statistics Canada. 2017a). The most recent available information and studies on infrastructure are one to two years old.

There is limited publicly available information on infrastructure status within communities in the ISR. More specific knowledge of existing infrastructure, including capacity, utilization, maintenance and upgrade requirements would better inform a project specific assessment of infrastructure impacts. Finally, more detailed understanding of the cost and timeline for upgrading infrastructure for climate change resiliency is needed to inform a comprehensive infrastructure assessment.

D.4.3.9 Follow-up and Monitoring

It is recommended that an infrastructure inventory survey be undertaken in all ISR communities to better understand capacities, utilization, and upgrade/maintenance requirements. It is also recommended that the survey identify required new and upgraded infrastructure for climate change resiliency, including cost estimates and timing, be undertaken. This survey could be undertaken by the IRC and the GNWT and repeated at regular intervals to track changes in use, status and resiliency.

Table D-62 Potential Residual Effects of Scenarios 1 – 4 on Infrastructure for All Seasons[25].

	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4 Oil Development in Deep Water
Potential Effects	• Potential small and temporary increase in population resulting from increased wind power and tourism employment would place minor additional demands on regional infrastructure	• FIFO workforce for Project construction activities, including site preparation and installation of the dual pipelines and GBS would temporarily increase the population of ISR increasing demands on infrastructure. Small increase in workforce and demands on infrastructure during operations.	• FIFO workforce for the seismic program and construction activities, including site preparation and installation of the GBS platform, would temporarily increase the population of ISR increasing demands on infrastructure. Moderate increase in workforce (more so than Scenario 2) and demands on infrastructure during operations	• FIFO workforce for the seismic program and construction activities, including installation of the FPSO and subsea infrastructure, would temporarily increase the population of ISR (more so than Scenario 3) increasing demands on infrastructure.
Legend				
• Least effect – No to minor effect on infrastructure				
• Moderate effect -- Moderate effect on infrastructure				
• High effect -- Major effect on infrastructure				
• Greatest effect – Severe effect on infrastructure				

25 While there could be some differences in infrastructure benefits and adverse effect among seasons for the Status Quo and the three oil and gas development scenarios, there is insufficient information to provide seasonally-specific effects characterizations for infrastructure. Instead, effects characterizations are provided for an annual cycle for the Status Quo and the three oil and gas development scenarios.

Table D-63 Potential Effects of a Large Oil Release Event (Scenario 5) for Infrastructure for All Seasons and the Longer Term[26].

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
All seasons	• Moderate effect on infrastructure due to use of infrastructure such as port facilities, roads, airport, and waste disposal facilities during spill response. Large temporary workforce may be needed for spill clean-up, and some may require commercial accommodations and place demands on civic infrastructure and services.	• Moderate effect on infrastructure due to use of infrastructure such as port facilities, roads, airport, and waste disposal facilities during spill response. Large temporary workforce may be needed for spill clean-up, and some may require commercial accommodations and place demands on civic infrastructure and services.	• Moderate effect on infrastructure due to use of infrastructure such as port facilities, roads, airport, and waste disposal facilities during spill response. Large temporary workforce may be needed for spill clean-up, and some may require commercial accommodations and place demands on civic infrastructure and services.
Longer-term/ Multi-year	• Multi-year effect potential dependent on seasonality of release. If in Open Water Season may require a longer-term spill response because of larger geographic extend of spill, and potential for shoreline fouling.	• Multi-year effect potential dependent on seasonality of release. If in Open Water Season may require e of larger geographic extend of spill,	• Multi-year effect potential dependent on seasonality of release. If in Open Water Season may require a longer-term spill response because of larger geographic extend of spill, and potential for shoreline fouling
Legend			
• Least effect – No to minor effect on infrastructure			
• Moderate effect -- Moderate effect on infrastructure			
• High effect -- Major effect on infrastructure			
• Greatest effect – Severe effect on infrastructure			

26 While there could be some differences in infrastructure benefits and adverse effect among seasons for the large oil release scenario, there is insufficient information to provide seasonally-specific effects characterizations for infrastructure. Instead, effects characterizations are provided for an all-seasons and the longer term.

D.4.4 Traditional Activities

D.4.4.1 Scoping

Traditional harvesting activities, which can include hunting, trapping, fishing, camping, and gathering, are important components of traditional activities and are strongly linked to the cultural values of the Inuvialuit. A key element to participation in traditional harvesting activities is the opportunity for transfer of Inuvialuit knowledge from those that hold it (Elders) to younger people. For example, hunting for polar bear on ice floes or whaling for beluga in coastal waters joins traditional harvesting practices with cultural components, serving nutritional needs and meaningfully enriching the lives of Inuvialuit through the sharing of traditional practices. Effects on cultural vitality are assessed in Section D.4.5.

Information on traditional harvesting activities is derived largely from the sources included in the TLK Inventory (Appendix B) and published sources (citations are provided throughout this report). The TLK Inventory included information on traditional harvesting activities and cultural uses from the Inuvialuit Harvest Study (a 10-year study of Inuvialuit harvesting based on monthly interviews with harvesters more than 16 years of age; it provides detailed information on harvested species by community by month), as well as more recent work by the IRC/IGC. While information on the location of specific harvesting activities was collected, this spatial information is not readily available to parties outside of the Inuvialuit and was not included in the Data Synthesis and Assessment Report.

D.4.4.1.1 IDENTIFICATION OF INDICATORS

The following measurable parameters are used in the assessment of the Traditional Activities VC:

- harvest and quality of harvested species
- area available for harvesting and access to harvesting sites
- rate of participation in traditional harvesting

Indicators include the practice and proliferation of traditional harvesting activities by Inuvialuit, as well as how participation in wage employment in a development may change an individual's availability to participate in traditional harvesting. These indicators were selected because they incorporate quantitative parameters such as harvest number, pounds of traditional foods, or hectares of harvesting area, as well as qualitative parameters such as the value and perceived quality of traditional foods and experience of harvesters while engaging in traditional harvesting activities.

Potential impacts and effects of routine activities can take the form of changes to the practice of traditional harvesting activities, including hunting and fishing. Routine effects would extend to effects on species harvested by the Inuvialuit within the BRSEA Study Area, location and timing of harvests, and the modes of access of harvested species and harvest locations.

D.4.4.1.2 SPATIAL BOUNDARIES

The Inuvialuit communities are considered in this SEA are: Aklavik, Inuvik, Paulatuk, Sachs Harbour, Tuktoyaktuk, and Ulukhaktok. The spatial boundaries include these Inuvialuit communities as well as the coastlines and coastal waters within the BRSEA Study Area where people from these communities may engage in traditional harvesting activities.

D.4.4.1.3 TEMPORAL BOUNDARIES

The temporal boundary for the SEA is a 30-year period between 2020-2050.

D.4.4.1.4 ASSESSMENT OF POTENTIAL EFFECTS

A qualitative characterization of potential residual effects on the economy associated with each scenario is based on the characterization terms defined in Table D-64.

Table D-64 Characterization of Residual Environmental Effects on Traditional Activities for the time period 2020 – 2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Positive**—an increase in traditional activities **Adverse**—a decrease in traditional activities **Neutral**—no net change in traditional activities
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	Typically expressed qualitatively as: • **Negligible**—no measurable change from the Status Quo and traditional activities can continue at current levels • **Low**—a measurable change but minor, and traditional activities can continue at current levels • **Moderate**—measurable change but current use can continue at a reduced level or with some restrictions on traditional harvesting practices • **High**—measurable change such that current use cannot continue or cannot continue without substantial changes to current practices or substantial restrictions to current practices, including in preferred ways and at preferred use locations
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the local area **Regional**—residual effects extend into the regional area **Extra-regional**—residual effects extend beyond the regional area

Table D-64 Characterization of Residual Environmental Effects on Traditional Activities for the time period 2020 – 2050

Characterization	Description	Definition of Qualitative Categories
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—the potential effect occurs once during the life of a project **Multiple irregular event (no set schedule)**—the potential effect occurs only occasionally, and without any predictable pattern during the life of a project **Multiple regular event**—the potential effect occurs at regular and frequent intervals during the project phase in which they occur, over the life of a project **Continuous**—residual effect occurs continuously
Duration	The period of time the residual effect can be measured or expected	**Short-term**—the residual effect is restricted to short-term events or activities such as discrete component completion during construction, maintenance, or rehabilitation activities (i.e., a timeframe of several months up to 1 year) **Medium-term**—the residual effect extends through the completion of construction and rehabilitation activities (i.e., a timeframe of 1 year to 5 years) **Long-term**—the residual effect extends beyond the completion of construction and rehabilitation activities into the operations and maintenance phase of a project (i.e., a timeframe of greater than 5 years) **Permanent**—the measurable parameter is unlikely to recover to existing conditions
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the potential effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—project-specific potential effects are permanent and irreversible
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.4.4.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

Traditional harvesting activities are of high importance to Inuvialuit in the ISR and are strongly linked to valuable harvested species. While effects on harvested species are a consideration for traditional harvesting activities, the assessment here focuses on aspects directly linked to traditional harvesting: harvest success and quality of harvested species, access to harvesting sites and ability to use areas for harvesting, and the rate of participation in traditional harvesting (Section D.4.4.1.1). Effects of disturbance of habitat and disruption of migration routes for harvested species as a result of increased shipping and air traffic, human presence, and noise are assessed in Section D.2.

Increased industrial and human activities in the different scenarios have the potential to affect Inuvialuit modes of access to traditional harvesting activities. An increase in ice-breaking could inhibit Inuvialuit travel across sea ice to access hunting and fishing locations. Offshore construction, including pipeline systems and GBS facilities, could necessitate a change of Inuvialuit travel routes to access species and harvest locations. In the past, industrial ice roads or tracks have been used by harvesters for some parts of their travel and some offshore structures may be used as a marker during travel on ice. Offshore platforms also can create small open water areas that attract seals and polar bears (Section D.3.5.2.1) which may be of interest to harvesters.

Changes to traditional harvesting activities also can result from project-related effects on the timing and locations of harvested species and access to harvesting areas. Increased shipping traffic, offshore construction, and increased human presence on the ocean and sea ice could result in changes to movement pattern or result in avoidance of preferred habitat by harvested species (e.g., beluga, polar bear, seals or other harvested species) (Section D.3 for details).

All of the scenarios have the potential to change the quality and availability of species harvested for traditional purposes, the success of the traditional food harvest, and participation rates in traditional harvesting (Table D-65). Monitoring of traditional harvesting would be required prior to and during proposed development to track these potential effects.

Table D-65 Summary of Potential Impacts and Effects on Traditional Activities

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 1 (Status Quo)	• marine vessels – commercial shipping, cruise ship tourism, scientific research, military • ship-based or barge resupply of ISR coastal communities • renewable energy project (e.g., offshore wind turbine) • traditional harvesting – regional boat traffic and snowmobile use	• scenario activities changing the distribution, abundance or behavior of species harvested for traditional harvesting purposes • scenario activities, infrastructure and associated sensory disturbances (e.g., light, noise, odour) may restrict access to harvesting areas or lead to avoidance of harvesting areas	• change in quality and availability of species harvested for traditional harvesting purposes • change in success of traditional harvesting • change in participation in traditional harvesting	• availability of habitat (ha) for harvested species • use of preferred sites and areas and travel routes by Inuvialuit • harvesting time periods (duration, frequency, seasonality) • value and perceived quality of harvested foods identified by Inuvialuit • harvesting effort and harvesting success reported by Inuvialuit • type and number of animals harvested for food per household • type and number of animals harvested for sports hunts and fur
Scenario 2 (Export of Natural Gas and Condensates) [27]	**Construction** • towing and installation of GBS loading platform at project site • installation of dual pipelines	• scenario activities changing the distribution, abundance or behaviour of species harvested for traditional harvesting purposes	• change in quality and availability of species harvested for traditional harvesting purposes • change in success of traditional harvesting	• availability of habitat (ha) for harvested species • use of preferred sites and areas and travel routes by Inuvialuit • harvesting time periods (duration, frequency, seasonality)

[27] Only economic benefits and effects from the marine operations are considered here; economic benefits from development of gas fields, pipelines gas processing facilities onshore are not considered.

Table D-65 Summary of Potential Impacts and Effects on Traditional Activities

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 2 (Export of Natural Gas and Condensates) (cont'd)	**Operations** • LNG carrier and condensate tanker loading • LNG carrier and condensate tanker transits westward • icebreaker management around GBS facility and possibly as carrier/tanker escort • annual sealift • local resupply of GBS loading facility by vessel • helicopter transfer of crews • Tuktoyaktuk logistical support base • crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik **Decommissioning** • removal of GBS loading facility • capping and filing of undersea pipelines	• scenario activities, infrastructure and associated sensory disturbances (e.g., light, noise, odour) may restrict access to harvesting areas or lead to avoidance of harvesting areas	• change in participation in traditional harvesting	• value and perceived quality of harvested foods identified by Inuvialuit • harvesting effort and harvesting success reported by Inuvialuit • type and number of animals harvested for food per household • type and number of animals harvested for sports hunts and fur • purchase of equipment and supplies to support harvesting activities and associated travel

Table D-65 Summary of Potential Impacts and Effects on Traditional Activities

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf)	**Exploration/Development** • 3D seismic surveys to delineate field • site preparation for GBS • GBS platform and wareship towed into position and installed • field development • first production and injection wells directionally drilled from GBS **Operations** • additional production wells directionally drilled from GBS • loading and westward transits of ice strengthened oil tankers • icebreaking around GBS facility and as tanker escort • wareship provides logistical support • annual sealift • local resupply from Tuktoyaktuk and Summers Harbour (ship and air) • helicopter transfer of crews • crew changes airflights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk	• scenario activities changing the distribution, abundance or behavior of species harvested for traditional harvesting purposes • scenario activities, infrastructure and associated sensory disturbances (e.g., light, noise, odour) may restrict access to harvesting areas or lead to avoidance of harvesting areas	• change in quality and availability of species harvested for traditional harvesting purposes • change in success of traditional harvesting • change in participation in traditional harvesting	• area (ha) with access restrictions • availability of habitat (ha) for harvested species • value and perceived quality of harvested foods identified by Inuvialuit • use of preferred sites and areas and travel routes by Inuvialuit • harvesting time periods (duration, frequency, seasonality) • harvesting effort and harvesting success reported by Inuvialuit • type and number of animals harvested for food per household • type and number of animals harvested for sports hunts and fur • purchase of equipment and supplies to support harvesting activities and associated travel

Table D-65 Summary of Potential Impacts and Effects on Traditional Activities

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf) (cont'd)	• Administrative base in Inuvik • Tuktoyaktuk and Summers Harbour used as service and supply bases **Decommissioning** • removal of GBS platform and wareship • well capping			
Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope)	**Exploration/Development** • drillship transit to/from Beaufort Sea • exploration and delineation drilling **Operations** • transit of FPSO to Beaufort Sea, anchoring at production site • production and injection wells drilled from drillship • loading and eastward and westward transits of ice-strengthened oil tankers (Ice Season transits westward only) • wareship logistical support	• scenario activities changing the distribution, abundance or behaviour of species harvested for traditional harvesting purposes • scenario activities, infrastructure and associated sensory disturbances (e.g., light, noise, odour) may restrict access to harvesting areas or lead to avoidance of harvesting areas	• change in quality and availability of species harvested for traditional harvesting purposes • change in success of traditional food harvest • change in participation in traditional harvesting	• area (ha) with access restrictions • availability of habitat (ha) for harvested species • value and perceived quality of harvested food identified by Inuvialuit • use of preferred sites and areas and travel routes by Inuvialuit • harvesting time periods (duration, frequency, seasonality) • harvesting effort and harvesting success reported by Inuvialuit • type and number of animals harvested for food per household • type and number of animals harvested for sports hunts and fur

Table D-65 Summary of Potential Impacts and Effects on Traditional Activities

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope) (cont'd)	• annual sealift • local resupply from Tuktoyaktuk and Summers Harbour (ship and air) • helicopter transfer of crews • crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik • Tuktoyaktuk and Summers Harbour service and supply bases **Decommissioning** • removal of FPSO and wareship • well capping			• purchase of equipment and supplies to support harvesting activities and associated travel
Scenario 5 (Large Oil Release Event)	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• species harvested by Inuvialuit in the ISR may come in contact with, ingest, inhale or be contaminated by oil • oil spill changes the health, distribution, abundance or behaviour of species harvested for traditional harvesting purposes	• change in quality and availability of species harvested for traditional harvesting purposes • change in success of traditional harvesting • change in participation in traditional harvesting • changes or perceived changes in nutritional or toxicological composition of harvested food.	• safety, value and perceived quality of traditional food identified by Inuvialuit • area (ha) with access restrictions • availability of habitat (ha) for harvested species • use of preferred sites and areas and travel routes by Inuvialuit

Table D-65 Summary of Potential Impacts and Effects on Traditional Activities

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 5 (Large Oil Release Event) (cont'd)		• oil spill may restrict or detracts from use of harvesting areas or leads to avoidance of harvesting areas	• change in the harvesting pressures on areas and Inuvialuit communities not affected by the oil spill	• harvesting time periods (duration, frequency, seasonality) • harvesting effort and harvesting success reported by Inuvialuit • type and number of animals harvested for food per household

D.4.4.2 Scenario 1: Status Quo

D.4.4.2.1 POTENTIAL EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Effects pathways for Scenario 1 include changes in the quality and availability of species harvested for traditional harvesting purposes; restriction or avoidance by Inuvialuit of harvesting areas as a result of scenario activities, change in success of traditional food harvest, and change in participation in traditional food harvesting. These latter two effects could occur as a result of the presence of infrastructure, and associated sensory disturbances (e.g., light, noise, odour); and avoidance of areas by the Inuvialuit or inability of harvesters to access sites affected by development activities.

In Scenario 1, the region would experience regular marine vessel activity, including commercial, tourism, sea lift, military, research, and personal use. This activity would occur primarily in the Open Water Season, with some extensions into the Spring and Fall Transition seasons with ice-strengthened vessels or icebreakers. Coastal communities in the ISR would receive resupply by ships, and overall marine vessel activity could result in effects to species harvested and restriction of access by Inuvialuit harvesters. Offshore renewable energy projects (e.g., wind turbines) may lead to restricted access or avoidance of harvesting areas. Low-level aircraft overflights could disturb wildlife and marine species, reducing or affecting access and availability; however, as noted previously, there are seasonal and locational restrictions on minimum aircraft altitudes that are intended to reduce effects on specific species and sensitive areas (EIRB 2011, Appendix F; EISC 2004, Appendix 1).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Potential effects to traditional harvesting activities in Scenario 1 include changes to the quality and availability of species harvested for traditional harvesting purposes, the success of traditional food harvests, and participation in traditional food harvesting.

Inuvialuit harvest a range of marine species, including polar bears, seals, fish, and whales, and have reported changes to traditional activities as a result of Status Quo activities related to shipping and aircraft passage. A TLK holder from Ulukhaktok indicated that marine wildlife may be affected by the development by smells from the equipment and the potential for accidental releases in the water (IMG Golder and Golder Associates 2011d:16). Wildlife can be disturbed by aircraft passing overhead, and many TLK holders said that aircraft and boats can affect the belugas and use should be avoided during the whaling season (KAVIK-AXYS Inc. 2004a:4-2 – 4-3). Aklavik harvesters indicated concerns that increased aircraft traffic over the area could result from development activities in the BRSEA Study Area and on the Tuktoyaktuk Peninsula (ACCP 2016:29).

Inuvialuit hunt and fish year-round, throughout the Ice, Open Water, and Transition seasons, and the timing and location of the harvest is dependent on factors such as species and weather. For example, beluga whales are commonly harvested in July, in open water, with adjustments made for weather and other factors as needed. The current level of shipping traffic under Scenario 1 could affect the location and timing of harvests through disruption of animal migration routes (such as those of beluga whales).

For example, Paulatuk TLK holders have an annual beluga whale hunt during the summer months to coincide with the beluga migration (IMG Golder and Golder Associates 2011b:8). Any disruption to that hunt would pose a substantial effect to the harvesting of a valued traditional food. Sachs Harbour residents hunt seals along the coast and out in the ocean; they noted that there are many seals when ice is present, (IMG Golder and Golder Associates 2011d:10), so regular shipping activity in the BRSEA Study Area could affect seal hunts. Inuvialuit TLK holders indicated that Tuktoyaktuk Harbour is an important location for loons and ducks, and white fronted geese are popular species harvested in the spring, and to a lesser extent, in the fall (IMG Golder and Golder Associates 2014:5-6).

The installation and operation of offshore wind turbines might affect the local distributions of harvested species (e.g., migratory birds) and the deflection of sea ice by the GBS turbine platforms could create small open water areas that attract seals and polar bears (the primary predator of seals) (Section D.3.5.2.1) which may be of interest to harvesters. Both activities are predicted to have negligible to low effects on access to harvesting areas or travel by Inuvialuit. As a result, this effect is not considered further for this scenario.

Effects of Climate Change on Potential Effects

Climate change has, and is continuing to affect, traditional harvesting in a number of ways, with the most important changes being increases in the duration and extent of open water and a decline in the duration and extent of sea ice cover.

Changes in the duration and extent of open water and ice in the BRSEA Study Area are affecting how and where Inuvialuit travel to harvesting areas and harvest. Inuvialuit hunters and fishers must contend with longer periods of open water, which necessitates greater use of watercraft for traditional harvesting activities. Pursuing seals and polar bears often requires access to harbours and areas around islands. TLK experts from Ulukhaktok noted that ice break up now happens earlier and freeze up occurs later, compared to previous years, with one TLK holder indicating the ice break up in April 2010 was the "earliest yet" and that they have never seen it like that before (IMG Golder and Golder Associates 2011d:15). Reductions in the duration and areal extent of sea ice is affecting the ability of the Inuvialuit to pursue traditional activities (Sections 7.4.5 and D.4.2.2). Pathways for this effect include changes in access to and availability of hunting locations, changes in the seasonal timing of and success of harvests, and declines in the frequency and amount that species are consumed.

TLK Holders from all the Inuvialuit communities interviewed for the 2015 Polar Bear Traditional Knowledge Study spoke of profound changes in climate and sea ice conditions starting in the late 1980s (Joint Secretariat 2015:162-163). Polar bears and seals are intimately connected to sea ice, and Inuvialuit harvesters indicated that polar bears require specific ice conditions: the ice cannot be too thick, as there would be no breathing holes for seals. One Inuvialuit TLK expert noted that “If there’s really good ice, if there’s pressure ridges, that’s where they’re [polar bears] going to stay… Nobody harvests here anymore [because] it [ice] keeps opening” (Joint Secretariat 2015:165-166). However, if there is too much open water, polar bears cannot easily hunt seals (Slavik 2010:46). Reductions in ice cover may also cause species to relocate, affecting the ability of the Inuvialuit to access them, and forcing harvesters to search in other areas.

These effects on traditional harvesting are already presenting challenges to Inuvialuit harvesters. While small increases in shipping are expected under the Status Quo scenario (e.g., cruise ships, cargo vessels), increases in the duration and extent of open water may accelerate rises in vessel traffic in the BRSEA Study Area. This increase, combined with increased vessel and aircraft traffic in Scenario 1, is likely to exacerbate the effects of climate change on traditional harvesting.

D.4.4.2.2 MITIGATION AND MANAGEMENT

Under all Scenarios, effective mitigation and management would be tied to fostering good working relationships with the Inuvialuit communities in the ISR. Mitigation measures that can be used to reduce potential effects of Scenario 1 on traditional harvesting include:

- discussion between vessel and project operators and harvesters regarding potential effects and mitigation measures to reduce effects of ship transits and ice breaking on traditional harvesting and travel over ice
- adherence to and enforcement of minimum aircraft altitudes during specific seasons and over specific areas (EIRB 2011, Appendix F)
- development of specific vessel transit corridors and aircraft flight lines to reduce disturbances to wildlife and harvesters.
- development of specific times of day during particular months for vessel travel and aircraft flights to reduce disturbances to wildlife and harvesters.
- development and implementation of environmental management plans for the construction and operation of offshore wind farm(s)
- development and implementation of co-management strategies for beluga whale, polar bear and other species (e.g., Beaufort Sea Beluga Management Plan [FJMC 2013])
- flexible work rotations for Inuvialuit employees (e.g., wind energy project, tourism) to allow participation in traditional activities such as hunting, fishing, and whaling in their appropriate seasons

Past and more recent work on the Inuvialuit Harvest Study would be useful in predicting, planning mitigation for and monitoring effects of projects on traditional harvesting.

A variety of mitigation measures to reduce effects of human and industrial activities and infrastructure on fish, migratory birds, seabirds, marine mammals, and polar bear (Section D.3) also would benefit traditional harvesting.

D.4.4.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

The Status Quo scenario is predicted to have a neutral magnitude effect on traditional activities in the ISR; while some effects to traditional harvesting would be adverse, there also could be benefits. The balance between adverse effects and benefits on traditional harvesting will depend on how Inuvialuit manage their participation in wage incomes (e.g., wind energy project, tourism) and how such involvement is used to benefit participation in traditional harvesting, use and share traditional foods, and continue other traditional activities (see Section D.4.5 Cultural Vitality).

Few if any changes are expected regarding quality and availability of species harvested for traditional harvesting purposes, success of traditional food harvests, or participation in traditional food harvesting. Wage employment also could help some individuals to purchase equipment and supplies to support traditional activities (Section D.4.1.3.1). Inuvialuit traditional harvesting practices are expected to continue with little change, and with the application of Inuvialuit-appropriate mitigation plans, residual effects are anticipated to be local to negligible in geographic extent, affect little of the current harvesting activity, be irregular in frequency, and short-term in duration (i.e., individual interactions between other human activities and traditional harvesting would be in the range of hours).

Effects of ongoing climate change, including the reduction of sea ice in the region, could affect harvesting locations and techniques, the ability of Inuvialuit to successfully pursue traditional harvesting, consumption of harvested food, and the cultural and language links between Inuvialuit and traditional activities.

Information on traditional harvesting practices was available from a variety of TLK sources, harvest reports, and government databases. Based on this, and considering the potential effects of climate change, the prediction and characterization of residual effects is made with medium confidence.

CUMULATIVE EFFECTS

Under a Status Quo scenario, and without the potential influence of specific projects, cumulative effects are expected to be similar to residual effects.

D.4.4.3 Scenario 2: Export of Natural Gas and Condensates

D.4.4.3.1 ASSESSMENT OF EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

While the GBS loading platform is 15-20 km offshore, there is some potential for sensory disturbance and the visual impact of the facility to directly and indirectly affect travel by boat or skidoo and potentially change access to harvesting areas. Of note, mapping of harvesting activities and location show that while some harvesters may travel far offshore, most harvesters stay within 20 km from shore to hunt for marine mammals (FJMC and IRC 2019b). As a result, the GBS and pipeline, as well as logistic support between the mainland and the GBS would overlap traditional harvesting areas and travel routes. The initial portion of the LNG carrier and condensate tankers movements in the vicinity of the GBS would also overlap these same areas, while the remaining movements to the west would be farther offshore and less likely to overlap with traditional harvesting activities.

Beluga harvesting is concentrated in shallow waters (less than 2 m) where beluga concentrate during the summer. These areas include coastal harvesting camps in Shallow Bay, east Mackenzie Bay and Kugmallit Bay (Beluga Zone 1a). Beluga Zone 2 (waters <20m, not included in Zone 1a) are an important beluga travel corridor and an area that beluga are widely distributed in during July and August (ACCP 2016:33, 44, 49, 50, 53, 56, 58, 59, 61; ICCP 2016:41, 50, 51, 56, 57, 60, 63, 65, 66,6 8; TCCP 2016: 90, 91, 96, 97, 100, 101, 103, 105, 106, 107). Paulatuk hunters harvest beluga whales in the nearshore waters off Darnley and Franklin Bays (PCCP 2016:43, 59, 84, 86). Beluga are occasionally harvested by Ulukhaktok and Sachs Harbour harvesters in the nearshore waters of Minto Inlet, Prince Albert Sound, Walker Bay, De Salis and Jesse Bay (SCCP 2016:36; OCCP 2016:42,78). Amundsen Gulf and the tip of Darnley Bay provides a main migration route for beluga whales (PCCP 2016:63). Inuvialuit communities harvest fish and seals at the same time as beluga in these areas. While the potential for tanker transits to and from the GBS to interfere with beluga hunting in the ISR is minimal, these transits would overlap beluga migration areas further out into the Beaufort Sea (e.g., Beluga Zone 2).

An increase in vessel and aircraft transits between the service and supply base and the export facility also could interfere with or disturb traditional harvesting activities; these activities also could change the seasonal distribution, abundance, or behaviour of species relied upon by Inuvialuit for traditional harvesting activities. Some aspects of the export operations, which include loading of LNG carriers and condensate tankers and the initial transits away from the GBS (as well as ice management around the GBS loading platform) could change access to harvesting areas, influence the availability of species for harvest, and ultimately affect the success of traditional harvesting.

Changes in Inuvialuit employment due to industry related activities could adversely and positively affect the ability of individuals to undertake traditional harvesting activities; this includes less time to participate in hunting due to employment, but also improved ability to purchase equipment and supplies to support harvesting activities (Section D.4.6.1.4).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Potential effects on traditional harvesting in Scenario 2 are similar to potential effects in Scenario 1; these include changes to the quality and availability of species harvested for traditional purposes, success of traditional food harvest, and participation in traditional food harvesting. During the Ice Season, weekly inbound and outbound transits of dual action LNG carriers and condensate tankers and possibly ice breaker escorts could affect ability of Inuvialuit harvesters to safely access hunting and fishing areas that require ice crossing.

EFFECTS OF CLIMATE CHANGE

As discussed for Scenario 1, Inuvialuit are reliant on sea ice and open water for the practice of traditional harvesting and cultural activities. An increase of ice-free days, associated with climate warming, could affect Inuvialuit ability to access and harvest key species. The abundance of key species may also be affected by decreased ice presence in the region. Reduced ice in the ISR could lead to an increase in shipping traffic and greater use of icebreakers (as in Scenario 1) that could further decrease access to harvesting areas, and potentially change the timing and location of harvest, travel routes, and access to harvest areas. Increased vessel and aircraft traffic, as well as increased human activity and noise, is likely to exacerbate the effects of climate change on traditional harvesting.

D.4.4.3.2 MITIGATION AND MANAGEMENT

Mitigation measures under Scenario 2 that would benefit Inuvialuit traditional harvesting activities include:

- flexible work rotations for Inuvialuit employees, such that participation in traditional harvesting activities such as hunting, fishing, and whaling could continue in their appropriate seasons
- provision of country food in project work camps, including allowing Indigenous workers to bring their own country foods and kitchens for preparation of country foods (Baffinland and QIA 2019)
- ongoing engagement with Inuvialuit groups and communities regarding project-related effects of the use of tankers and icebreakers on traditional harvesting (e.g., timing and routes for travel, avoidance of harvest locations during specific periods), and harvested species. For example, consultation with harvesters by proponents about potential effects and mitigation measures to reduce the effect of ice breaking on traditional harvesting and travel over ice.
- ongoing engagement to keep Inuvialuit groups and communities informed on project activities and schedules and develop collaborative approaches for environmental protection. For example, project activities could be scheduled to avoid or limit interference with harvesting or traditional land use activities. Conversely, if a specific project activity had to occur at a specific time or a specific place, hunters may be able to slightly shift the timing or location of harvesting to accommodate that specific activity.
- exclusion zones or restricted activity periods which are co-created with Inuvialuit groups and communities and used to avoid disturbance from vessels and aircraft on specific harvesting areas. This could include identification of preferred routes for LNG and condensate tanker, other vessels and aircraft that reduce or avoid impacts either through activity timing and/or location (e.g., avoidance of bowhead whale aggregation areas).
- development of specific vessel transit corridors and aircraft flight lines to minimize disturbance to wildlife and harvesters
- development of specific times of day during particular months for vessel travel and aircraft flights to minimize disturbance to wildlife and harvesters
- operators to inform communities on the timing and location of LNG carrier and condensate tanker movements, as well as ship transits between the service and supply base to the GBS loading platform
- undertake monitoring studies on key species movements and harvester activities in advance of offshore activities and compare with changes during activities. This could be done by expanding the work of the Inuvialuit Community Based Monitoring program.

D.4.4.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

While effects on traditional harvesting within the BRSEA Study Area in Scenario 2 are anticipated to be adverse and result in moderate magnitude changes to these activities, some effects could be beneficial. The balance between adverse effects and benefits on traditional harvesting will depend on how Inuvialuit manage their participation in wage incomes and how such involvement is used to benefit participation in traditional harvesting, use and share traditional foods, and continue other traditional activities (see Section D.4.5 Cultural Vitality).

The presence of facility infrastructure and operational activities (e.g., increased ship and aircraft transits, installation of pipelines) associated with Scenario 2 may restrict access to harvesting areas or lead to avoidance of harvesting areas. Additional information from Inuvialuit harvesters would be needed to better understand residual effects on use, access, and avoidance for development in a specific location.

Inuvialuit are anticipated to increasingly be part of the workforce required for project development. Participation in the wage economy is likely to adversely affect overall time available for hunting and fishing activities but may provide a beneficial effect through more money being available for financing hunting and fishing equipment (Martin 2015; Natcher 2009). A modest increase in shipping is anticipated, which may have effects to key species harvested by Inuvialuit (Section D.3.5). Construction noise and human activity related to the pipeline system may affect the abundance and distribution of other harvested species (Sections D.3.2 to D.3.7).

Assuming application of proposed mitigation and management measures, overall residual effects on traditional activities under Scenario 2 are anticipated to be moderate and adverse, regional in context (i.e., while some effects are localized changes in access or species distributions could be over large regional areas), irregular or continuous in frequency (depending on the occurrence and regularity of activities), and of long-term duration (infrastructure and ice transits as well as employment of Inuvialuit would continue over the life of the project). There also could be benefits such as the improved ability to purchase equipment and supplies to support harvesting activities and associated travel using income from wage employment (Section D.4.6.1.4).

Information on traditional harvesting practices was available from a variety of TLK sources, harvest reports, and government databases. Based on this, and considering the potential effects of climate change, the prediction and characterization of residual effects is made with medium confidence.

CUMULATIVE EFFECTS

Construction activity and increased tanker traffic associated with oil and gas projects under Scenario 2 in combination with increased vessel movements in Scenario 1, could have cumulative effects on traditional harvesting activities, including limiting Inuvialuit access to some hunting and fishing areas (e.g., in proximity to icebreaking and in areas affected by vessel and aircraft movements in nearshore areas and close to communities).These cumulative effects are anticipated to be additive.

The cumulative effects of the industrial and other human activities and infrastructure in Scenarios 1 and 2 are likely to exacerbate effects of climate change on Inuvialuit traditional harvesting activities (e.g., effects on sea ice and travel; access to harvesting areas). As a result, traditional harvesting may decrease, or Inuvialuit may need to change patterns of access or harvesting locations to accommodate these changes. In turn, this could affect the success of traditional harvesting and participation rates in these activities (e.g., less success may lead some individuals to reduce harvesting activities). Climate change and disturbances from vessels and aircraft associated with Scenario 2 are also anticipated to increase effects on harvested species, such as marine mammals, (Section D.3.5). These residual cumulative effects may act synergistically to reduce the amount of traditional food per household, and the opportunities to transmit harvesting knowledge between generations; in turn, this can weaken the important cultural link between Inuvialuit and traditional harvesting activities (Section D.4.5).

D.4.4.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.4.4.4.1 Assessment of Effects of Routine Activities

Description of Effect Pathway

The majority of the offshore oil development in Scenario 3 is located 80 km offshore; as a result, it is likely that the GBS platform, wareship, and tanker transits on routes to the west of the development would interact much less with traditional harvesting and associated travel than Scenario 2. However, some of these activities, including a single 3D seismic program over an area of about 60,000 ha during a single Open Water Season, may temporarily affect the availability of species for traditional harvesting through changes in distribution, abundance, or behaviour of species with associated changes in the success of traditional harvestings. These effects would be limited to the duration of the seismic program and a short recovery period for marine species.

Aircraft and vessel transits between the supply and service bases and the GBS platform for drilling and oil production could cross areas that are used by Inuvialuit for harvesting, as well as travel routes to and from harvesting areas and communities (e.g., by boat in the Open Water Season and skidoo in the Ice Season). This could result reduced use or avoidance of harvesting areas by Inuvialuit as a result of sensory disturbances, changes in the success of traditional food harvest, and possibly changes in participation in traditional food harvesting.

As noted for Scenario 2, changes in Inuvialuit employment due to industry related activities could adversely and positively affect the ability of individuals to undertake traditional harvesting activities; this includes less time to participate in hunting due to employment, but also improved ability to purchase equipment and supplies to support harvesting activities (Section D.4.6.1.4). Potential increased use of drugs and alcohol in the region could also affect Inuvialuit participation in traditional harvesting.

Description of Range of Potential Effects

Potential effects to traditional harvesting under Scenario 3 include changes to the quality and availability of species harvested for traditional harvesting purposes, participation in traditional food harvesting, and success of traditional food harvesting.

Inuvialuit people have a long-standing and intimate relationship with water and ice, both as sources of traditional resources (such as key species) and as an indicator of the overall health of animals, waterways, and Inuvialuit culture. Activities such as 3D seismic surveys can result in short-term and localized effects on whales, seals, and fish (Sections D.3.2 to D.3.7). Aklavik TLK holders expressed concern regarding past seismic work in the area; one TLK holder expressed concern regarding past seismic activity offshore from Tuktoyaktuk in 1998 because there were many ocean fish that could be harmed by the explosions (KAVIK-AXYS Inc. 2004a:4-11-4-12).

The increased use of ice breakers, especially for access to coastal areas such as the logistics supply bases at Tuktoyaktuk or Summers Harbour, could affect Inuvialuit ability to access harvesting areas and preferred species. A Tuktoyaktuk TLK holder noted that in late fall when the ice is freezing in the harbour, ship traffic in and out of the harbour would create channels so skidoos cannot travel across (KAVIK-AXYS Inc. 2009:10-5). The Ulukhaktok, Sachs Harbour and Paulatuk Community Conservation Plan Working Groups were concerned that marine traffic (tankers, ice breakers, seismic vessels) and associated low flying aircraft would have negative impacts on wildlife and traditional use. Specific concerns included impacts on seal lairs and polar bear denning sites from noise disturbance, disruption of ice; ship track hazards to traditional harvesting, including the safety of harvesters traveling on the ice; and the potential for oil spills if tanker traffic was allowed (PCCP 2016: 52, 62; SCCP 2016: 22, 55, 58; UCCP: 41, 43, 81, 84). Further, warming conditions or wind and water currents can prevent or delay the channels created by ice breakers from freezing over, which may lead to huge ice flows breaking off from land fast ice (PCCP 2016:62).

Inuvialuit representation in the project workforce could have effects on their ability to participate in traditional harvesting activities such as hunting and fishing, and impair abilities to participate in the related cultural knowledge transfer associated with traditional harvesting practices. One TLK holder noted that “once you get lots of jobs and money it's gonna cause more problems, like people are going to be fighting over land, going to be fighting over everything... the outcome leads to worse things, or maybe better. There's advantages [and] disadvantages" (IMG Golder and Golder Associates 2011d:20). Employment of Inuvialuit in different parts of the development or supporting jobs could have social effects on Inuvialuit (including potential for introduction of alcohol and drugs, informal economies, wage labour opportunities), which may affect traditional harvesting activities. Participation in the wage economy can result in less time to participate in hunting due to employment, but can also improve the ability of some harvesters to purchase equipment and supplies to support traditional activities (Martin 2015; Natcher 2009).

EFFECTS OF CLIMATE CHANGE

Reduction in ice coverage is a key outcome of climate change for Inuvialuit and could affect Inuvialuit ability to undertake successful traditional harvesting practices. Decreased ice in the region is also likely to lead to an increase in shipping traffic and greater use of icebreakers (as in Scenario 2), which could affect access, availability, abundance, and success of harvests, particularly if vessel movements are in nearshore areas or close to communities. Increased human activity associated with Scenario 3 is expected to increase the effects of climate change on traditional harvesting.

D.4.4.4.2 MITIGATION AND MANAGEMENT

Mitigation measures for traditional harvesting activities under Scenario 3 are similar to those of Scenario 2, with the addition of mitigations aimed at the effects of seismic programs. Proponents undertaking seismic program should with Inuvialuit groups (e.g., IGC, FJMC, HTCs) and communities regarding project-related effects of seismic programs on marine species, the use of ice breakers, potential interruption of species migrations, and the incorporation of Inuvialuit knowledge in mitigation design and environmental management plans. Ongoing monitoring of harvesting activities and consultation with

HTC's also could help in identifying measures to reduce potential conflicts with development (e.g., establishing timing windows for industrial activities close to Marine Protected Areas).

D.4.4.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

While effects on traditional harvesting within the BRSEA Study Area in Scenario 3 (as in Scenario 2) are anticipated to be adverse and result in low magnitude changes to these activities, some effects could be beneficial. The balance between adverse effects and benefits for traditional harvesting will depend on how Inuvialuit how Inuvialuit manage their participation in wage incomes and how such involvement is used to benefit participation in traditional harvesting, use and share traditional foods, and continue other traditional activities (see Section D.4.5 Cultural Vitality).

Scenario 3 is expected to have low-magnitude adverse effects to traditional harvesting activities in the ISR. Effects are most likely to be associated with vessel and aircraft activity along or across nearshore and coastal areas, especially in areas close to Inuvialuit communities or nearby coastal camps. Additional information from Inuvialuit harvesters is needed to better understand residual effects on use and access to harvesting areas by Inuvialuit harvesters.

Inuvialuit are expected to make up a portion of the large workforce required for year-round oil production. Participation in the wage economy may reduce the time that some individuals have for such activities, thereby adversely affecting their availability to undertake or participate in traditional harvesting practices for themselves and family members. A potential benefit of participating in the wage economy is that Inuvialuit workers may have more discretionary income to spend on hunting and fishing equipment, supplies and trips.

Year-round oil production and associated shipping could have effects on key species harvested by Inuvialuit (Section D.3.5). Activities related to site preparation, installation and operations of the GBS platform and wareship, as well as year-round tanker transits may locally affect the abundance and distribution of other harvested species (Sections D.3.2 to D.3.7).

While effects of 3D seismic on marine species, including beluga whales, seals, and fish, are of high concern for Inuvialuit communities, the seismic program would only occur during one Open Water Season in an area ~80 km offshore. With mitigation (e.g., use of seasonal timing windows, slow ramp-up of air guns, use of safety radii for marine mammals, use of marine mammal monitors, shut down of airguns if marine mammals are sighted within safety radii), effects of a single seismic survey on traditional harvesting are predicted to be adverse. As individuals or small groups of animals may avoid the area and little, if any, mortality would be expected to occur, a small proportion of the species which are important to traditional harvesting might be affected in a localized area around the seismic program for a short duration. Effects would be reversible within hours to days of the end of the seismic activity.

With the application of proposed mitigation and management measures, including ongoing engagement with affected Inuvialuit communities, residual effects on traditional harvesting activities under Scenario 3 are expected to affect a small proportion of traditional harvesting in the region (given the location of most activities ~80 km or more offshore), on an irregular basis over the life of the development (i.e., long-term).

There also could be benefits such as the improved ability to purchase equipment and supplies to support traditional harvest and associated travel using income from wage employment (Section D.4.6.1.4).

The effects of climate change under Scenario 3 are anticipated to act in combination and further alter Inuvialuit traditional harvesting activities.

Information on traditional harvesting practices was available from a variety of TLK sources, harvest reports, and government databases. Based on this, and considering the potential effects of climate change, the prediction and characterization of residual effects is made with medium confidence.

CUMULATIVE EFFECTS

Cumulative effects of Scenario 3 in combination with Scenario 1 are most likely to be associated with vessel and aircraft activity along or across nearshore and coastal areas, especially in areas close to Inuvialuit communities. Sensory disturbance and physical effects (e.g., changes in sea ice) could reduce access to harvesting areas and make access to harvesting areas more difficult, thereby reducing opportunities for Inuvialuit to participate in traditional harvesting activities such as hunting and fishing.

Similar to the cumulative effect's discussion for Scenario 2 (see Section D.4.4.3 above), the effects of climate change on Inuvialuit traditional harvesting activities are anticipated to act in conjunction with the cumulative effects from offshore developments (Scenario 3) and other human activities. Human-associated effects in combination with climate change could incrementally change the distribution and abundance of species harvested for traditional purposes and access to the traditional harvesting areas. These residual cumulative effects may act synergistically to reduce the availability of traditional food, as well as the opportunities to transmit harvesting knowledge, and may also affect components of cultural vitality (Section D.4.5).

D.4.4.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.4.4.5.1 ASSESSMENT OF EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Effects pathways for Scenario 4 would be similar to those described for Scenario 3. Most offshore infrastructure and activities would be ~100 km or more offshore and are unlikely to overlap or interact with traditional harvesting areas or travel routes to these areas (Elliot 2019a, 2019b). As noted for Scenario 3, the exceptions would be aircraft and vessel transits between the supply and service bases and the drill ship or FPSO/wareship that could cross areas that are used by Inuvialuit for harvesting, as well as travel routes to and from harvesting areas and communities (e.g., by boat in the Open Water Season and skidoo in the Ice Season). Tanker traffic to the east (monthly during Open Water Season) through the Northwest Passage or Amundsen – Queen Maude Gulf also would bring vessels closer to Sachs Harbour, Ulukhaktok and Paulatuk. Sensory disturbances from offshore and nearshore activities, including icebreaking and ice management, could result in effects on harvested species (e.g., changes in the distribution, migration routes, abundance, or behaviour of species harvested for traditional purposes) that, in turn, may affect harvesting success and harvesting locations and travel.

Participation of Inuvialuit in the workforce for the development or support services could affect the amount of time and availability for individuals to undertake or participate in traditional harvesting. However, based on experiences with oil and gas developments over the past 40 years, industry has been able to work collaboratively with Inuvialuit employees to schedule job rotations and various types of leave to allow for a continued participation in harvesting activities. In addition, while participation in the wage economy would result in less time to participate in hunting due to employment, it can also improve the ability of some harvesters to purchase equipment and supplies to support traditional activities (Martin 2015; Natcher 2009). As noted in Scenario 3, adverse effects of the wage economy such as access to drugs and alcohol, could also reduce participation rates in traditional harvesting.

Description of Range of Potential Effects

Potential effects to Inuvialuit under Scenario 4 are similar to those under Scenario 3 and include changes to the quality and availability of species harvested for traditional purposes, participation in traditional food harvesting, and success of traditional food harvesting.

The ISR, including land, waters, and ocean, is so important that the Inuvialuit consider the Delta and the coast as a “bank”, and are concerned about water quality (KAVIK-AXYS Inc. 2004b:4-8). In relation to tanker transits, TLK holders have noted that tanker ships emit various emissions, and can potentially leak oil, fuel, and any other stored material, and may take on and discharge ballast water during a voyage. Inuvialuit TLK holders asked, “who monitors ballast and bilge water” (KAVIK-AXYS Inc. 2009:10-7)[28].

Increased Inuvialuit representation in the local workforce could have effects on Inuvialuit ability to participate in traditional harvesting activities such as hunting and fishing and reduce abilities to participate in the related cultural knowledge transfer associated with such practices. However, there also could be benefits such as the improved ability to purchase equipment and supplies to support traditional harvesting and associated travel using income from wage employment.

Effects of Climate Change

Inuvialuit are reliant on sea ice in the ISR for the practice of traditional harvesting activities and for travel. Climate-linked reduction of sea ice has and is continuing to reduce the ability of the Inuvialuit to successfully pursue traditional harvesting, especially for species such as seals and polar bears which are typically hunted on ice. Reductions in the duration and extent of sea ice can affect hunting locations and harvest timing. Reduced sea ice is also likely to coincide with an increase in shipping traffic, which could exacerbate the effects of climate change through disruption of access or changes to abundance of species harvested.

[28] While discharge of bilge and ballast water is a concern to communities and is acknowledged, tankers are not permitted to discharge ballast within the territorial waters of Canada. International standards do not permit discharge of ballast and, if required, bilge discharges must meet minimum thresholds for oil content and be discharged away from coastal areas (Section 2.5).

D.4.4.5.2 MITIGATION AND MANAGEMENT

Mitigation measures for traditional harvesting Scenario 4 are similar to those for Scenario 2 and 3, with the addition mitigation measures as follows:

- ongoing engagement with Inuvialuit groups (e.g., IGC, FJMC, HTCs) and communities regarding project-related effects of:
  - 3D seismic programs
  - offshore activities
  - increased tanker traffic to the west (year-round) and east (monthly during Open Water Season)
  - effects to marine-based species of value to Inuvialuit
  - incorporation of Inuvialuit knowledge of water, ice, animals, and areas into mitigation planning

D.4.4.5.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

While effects on traditional harvesting within the BRSEA Study Area in Scenario 4 (as in Scenarios 2 and 3) are anticipated to be adverse and result in low magnitude changes to these activities, some effects could be beneficial. The balance between adverse effects and benefits for traditional harvesting will depend on how Inuvialuit manage how Inuvialuit manage their participation in wage incomes and how such involvement is used to benefit participation in traditional harvesting, use and share traditional foods, and continue other traditional activities (see Section D.4.5 Cultural Vitality).

Scenario 4 is expected to have low-magnitude adverse effects to traditional harvesting activities in the ISR. Effects are most likely to be associated with vessel and aircraft activity along or across nearshore and coastal areas, especially in areas close to Inuvialuit communities, as well as during tankers transits through the Northwest Passage and Amundsen – Queen Maude Gulf. Additional information from Inuvialuit harvesters is needed to better understand residual effects on use and access to harvesting areas by Inuvialuit harvesters.

Effects of 3D seismic on marine species, including beluga whales, seals, and fish, are of high concern for Inuvialuit communities. While the 3D seismic program would cover an area of 80,000 to 120,000 ha versus 60,000 ha in Scenario 3, given mitigation measures for seismic surveys, effects on the distribution, abundance and movements of harvested marine species (Sections D.3.2 to D.3.7) are not expected to have a measurable effect on traditional harvesting.

Inuvialuit are expected to make up a portion of the large workforce required for year-round oil production. While some Inuvialuit would benefit monetarily from participating in the wage economy, others would not, and those engaged in oil and gas-related employment would have less time available for traditional harvesting activities. However, based on past projects in the BRSEA Study Area, work rotations for Inuvialuit employees can be adjusted to allow them to participate in important seasonal harvesting activities. A potential benefit of participating in the wage economy is that Inuvialuit workers may have more discretionary income to spend on hunting and fishing equipment, supplies and trips.

There may be some minimal adverse effects on the integrity of the sea ice surface as a transportation medium where icebreaking or ice management activities take place; however, these are expected to be confined to the footprint of icebreaking activities and be short-lived in duration. Given that the ship transit routes to the west and ice management areas for Scenario 4 are far offshore (> 100 km), there would be no or limited interaction with Inuvialuit use of the sea ice for hunting or transportation. If ice persists in the Northwest Passage and icebreaking is required, the eastward tanker movements during the Open Water Season could affect local travel across an area where icebreaking occurs.

With the application of proposed mitigation and management measures, including ongoing engagement with affected Inuvialuit communities, HTCs, and individual harvesters regarding timing and location of proposed activities and associated mitigation measures, residual effects on traditional harvesting activities under Scenario 4 are expected to affect a low proportion of traditional harvesting in the region (given that the location of most activities ~100 km or more offshore), on an irregular basis over the life of the development (i.e., long-term). there also could be benefits such as the improved ability to purchase equipment and supplies to support traditional harvesting and associated travel using income from wage employment.

The effects of climate change under Scenario 4 are anticipated to act in combination and further alter Inuvialuit traditional harvesting activities.

Information on traditional harvesting practices was available from a variety of TLK sources, harvest reports, and government databases. Based on this, and considering the potential effects of climate change, the prediction and characterization of residual effects is made with medium confidence. Ongoing monitoring of harvesting activities and consultation with HTC's also would help in reducing potential conflicts with development (e.g., establishing timing windows for industrial activities close to Marine Protected Areas).

CUMULATIVE EFFECTS

Cumulative effects of Scenario 4 and Scenario 1 would be similar to those described for Scenario 3. The effects of climate change on Inuvialuit traditional harvesting activities are anticipated to be exacerbated by cumulative effects arising from industrial and human activities in Scenario 4 and Scenario 1. The residual cumulative effects of these scenarios in combination with effects of climate change may act synergistically to reduce the availability of traditional food, as well as the opportunities to transmit harvesting knowledge, and may also affect components of cultural vitality (Section D.4.5).

D.4.4.6 Scenario 5: Large Oil Release Event

While the Large Oil Release Event is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface release from an oil tanker, large oil releases could also occur as a result of a collision or accidents involving other vessels such as cruise ships, cargo vessels, military vessels, or research vessels. If the fuel tanks for these vessels were affected (e.g., punctured during a collision), large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on traditional harvesting from such an event may differ slightly from what is described below for surface or subsea releases from an offshore oil development. A compensation plan designed to offset effects to traditional harvesting may also be in place.

D.4.4.6.1 ASSESSMENT OF EFFECTS OF AN OIL SPILL

DESCRIPTION OF EFFECT PATHWAY

In the event of a large oil release, Inuvialuit are likely to avoid hunting or fishing activities in or close to the affected area due to concerns about contamination of harvested food and sea water, sensory disturbance from the spills and response activities (e.g., smell, visual effects and noise), and damage or fouling of equipment and gear (e.g., boats, skidoos, nets). The response organization may also close an area to human use to protect human safety and address potential contaminant issue. Oil spills on the sea ice or in the ocean also have the potential to affect the health, distribution, abundance, or behaviour of harvested species harvested and harvesting areas. Any one of these factors or several in combination may change harvesting success and the willingness of individuals to undertake or participate in harvesting. While there is some sharing of harvested food between communities, avoidance of harvesting areas may also place additional harvesting pressures on areas and Inuvialuit communities which are not affected by the oil spill.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Oil spills are of great concern to the Inuvialuit, as a high degree of reliance is placed on marine species, ecology, sea ice, and the ocean itself to support traditional harvesting and other traditional activities (Section D.4.5). The nature and magnitude of effects of an oil release on traditional harvesting would vary dependent on the season when a release occurs, the location of a spill, weather conditions at the time of the spill (e.g., sea state, wind), the type of release (e.g., surface vs. subsea) and type of oil (Table D-66). Direct effects include changes in the success of traditional food harvesting, contamination of harvested food and nutritional value, and the rate of participation in traditional food harvesting, as well as potential shifts in harvesting pressures in areas and Inuvialuit communities not affected by the oil spill. Changes in the quality and availability of species harvested for traditional purposes would also affect traditional harvesting.

Oil spills have the potential to adversely affect marine wildlife; as Inuvialuit rely on marine animals for food, an oil release could have a large effect on communities due to ocean currents and the effects on the animals harvested (IMG Golder and Golder Associates 2011c:13). Inuvialuit are generally concerned with development, including the effects of oil and gas exploration. An Sachs Harbour TLK holder said that the spill in the Gulf of Mexico has caused her to think about a similar incident in the north (IMG Golder and Golder Associates 2011d:13). An Ulukhaktok TLK holder indicated that if there were an oil spill, the wildlife would move away to a cleaner area (IMG Golder and Golder Associates 2011f:16). An Inuvialuit harvester said, “If you have an oil spill out there, I think it's going to be a catastrophe for the bears. They rely on sea ice to survive” (Slavik 2010:57).

Releases of oil are likely to result in contamination of traditional food sources, and reduction in opportunity for Inuvialuit to practice traditional harvesting. Inuvialuit from Paulatuk expressed concern regarding the effects of a well blowout or oil spill on marine animals relied upon as food sources (IMG Golder and Golder Associates 2011c:13). The Ulukhaktok Community Working Group also expressed concerns about potential effects that an oil spill could have on the renewable resources base in the Beaufort region (OCCP 2016:42). Inuvialuit from Inuvik indicated that an oil spill could "affect the whole, especially the ocean; it's our food, the ocean is where we get our food from" (ICC et al. 2006:13-5-13-6).

The Inuvialuit consider food provided by traditional harvesting to be healthier than food procured from a store. For example, in the Tuktoyaktuk Harbour and area, there is a general consensus that traditional food is healthier than store-bought foods and that people are encouraged by Health Canada to eat as much country food as possible (IMG Golder and Golder Associates 2014:12). Reduced consumption of country foods due to contamination of harvested food from an area or fears of such contamination could trigger a change in Inuvialuit food procurement, including higher reliance on store-bought pre-prepared food stuffs, affecting the traditional harvesting activities.

Inuvialuit in the ISR may avoid an area where a spill has taken place for fear that valued hunting and fishing equipment may become damaged, thereby affecting access. A large spill on ice or in open water may also affect access in terms of preventing Inuvialuit hunters from traveling to a preferred harvesting area. Similarly, a large spill in open water or on ice may also cause marine species to change their habitation or migration patterns, thereby affecting Inuvialuit ability to access these species.

Effects of Climate Change on Potential Effects

Inuvialuit are reliant on sea ice in the ISR for numerous reasons, including traditional harvesting activities. Continued reduction in the duration and extent of sea ice in the ISR is eroding the ability of Inuvialuit to undertake or participate in traditional harvesting including effects on harvested species, harvesting locations, and harvest timing. Effects of a large oil release (Scenario 5) in combination with climate change have the potential to be substantial.

Changes in sea ice from climate change could affect the distribution of an oil release, as well as spill response methods and success. Effects of an oil release on traditional harvesting activities (e.g., exclusion or avoidance of harvest locations, effects on travel to these areas) as well as changes in the distribution, abundance, and health of harvested species would exacerbate effects of climate change that are being experienced by Inuvialuit and by marine life.

D.4.4.6.2 Mitigation and Management

Mitigation measures, including spill planning and response are discussed in Sections 2.13 and 3.10.5.3. Development of comprehensive oil spill response plans would be required as part of environmental and approvals for specific projects. Projects also would be required to develop spill response capabilities and stockpile equipment in local areas (e.g., Inuvialuit coastal communities), prior to commencement of drilling and oil production and transport. Additional mitigation measures include:

- Engage Inuvialuit groups within the ISR (e.g., IGC, FJMC, HTCs) in open discussion regarding spill planning and response in the region

- In advance of offshore activity, develop first response capabilities in the Inuvialuit communities (e.g., training and ongoing readiness drills for first responders, equipment caches)
- In the unlikely event of an oil spill, undertake a collaborative approach to oil spill cleanup, including shorelines, incorporating Inuvialuit concerns, feedback, and suggestions into the process and response. Involve trained Inuvialuit responders in the initial response, as well as throughout the spill response and cleanup
- Continue engagement of communities throughout the spill response and clean-up activities to provide updated information on progress with the response and cleanup; effects on the environment and human use, and mitigation measures. Input from the communities should also be used to modify response actions and identify new measures to mitigate the release.

D.4.4.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

A large oil release event could have a range of adverse effects to traditional harvesting activities in the ISR that range from severe to lower consequences. The specific effects are highly dependent on the season in which the spill occurs, its location, local conditions at the time of the spill, the type of oil and overlap with important seasonal harvesting sites and areas.

Inuvialuit are highly concerned with the potential for any type of release. Ice-based oil spills adversely affect marine species that are reliant on ice for habitat, including polar bears and seals (Sections D.3.5 to D.3.6). These same species are affected by oil spills occurring in Open Water Season, as are fish and whales (Sections D.3.2 to D.3.5). Effects to these species also are likely to affect traditional harvesting activities within the BRSEA Study Area and perhaps beyond, so Inuvialuit concern extends to oil spills in any water or terrestrial environment that they utilize.

Inuvialuit are not likely to undertake traditional harvesting activities in areas affected by or located near an oil spill, due to potential area closures, concerns about contamination of harvested species; changes in the safety and nutritional value of harvested species, sensory disturbances to harvesters (e.g., smell, noise, and visual), and damage or fouling of equipment and gear. These effects are expected to directly affect harvesting success, and the willingness of individual harvesters to undertake or participate in harvesting, thereby reducing participation rates. Shifts in harvesting locations and timing could also place additional harvesting pressures on areas and Inuvialuit communities which are not affected by the oil spill.

A large surface or subsurface oil release during Open Water Season could have severe effects on Inuvialuit traditional harvesting activities. However, the severity of the effects could vary substantially depending on the size of a release, the weathering and behaviour of an oil release relative to harvesting locations and seasons, the type of oil, and the success of spill response and cleanup measures. Traditional harvesting activities could be directly impeded, or harvesters might avoid the spill area and adjacent area. Real and perceived contamination of harvested species would also affect the willingness of harvesters to undertake or participate in harvesting.

The magnitude of effects of a large oil release on traditional harvesting activities could be severe or lower, and affect an area ranging from local to regional. Effects would be continuous and persist for the duration of the spill event, including the spill response and cleanup activities. Depending on the success of the response and cleanup, effects could continue for one to several years. Effects to Inuvialuit traditional harvesting activities are expected to be medium to long-term. Effects on harvested species would be reversible over time, but perceived concerns of contamination of harvested food by some Inuvialuit could extend effects on traditional harvesting. Some individuals may consider the effects of an oil spill on harvesting to be irreversible. A robust monitoring system would be required to gather current information on the status of the marine environmental and harvesting to improve the confidence in the spill response and predictions for recovery of the marine environment.

The effects of climate change, including the reduction of sea ice in the BRSEA Study Area, may influence the effects predictions. Effects of an oil spill are likely to exacerbate effects of climate change on existing Inuvialuit harvesting activities, as well as effects on harvested species.

Information on traditional harvesting practices was available from a variety of TLK sources, harvest reports, and government databases. Based on this, and considering the potential effects of climate change, the prediction and characterization of residual effects is made with medium confidence.

D.4.4.7 Summary of Residual Effects

Potential residual effects of Scenarios 1 – 4 on Traditional Activities are summarized in Table D-66. The potential effects of a large oil release are considered separately in Table D-67.

It should be noted that Table D-66 provides a high-level overview of effects based on the respective scenarios and the seasons in which they may occur. Seasonal effects, and the particular species they could act upon, are considered in the above narrative sections of this appendix.

Table D-66 Potential Residual Effects of Scenarios 1 – 4 on Traditional Activities.

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4 Oil Development in Deep Water
Ice	• Limited effects to traditional harvesting activities as a result of Status Quo	• Moderate effects on traditional activities associated with export facility, increased employment opportunities for Inuvialuit, non-local FIFO workforce, increased shipping traffic, and increased human activity in the ISR	• Low effects on traditional activities associated with increased employment of Inuvialuit, year-round oil production, increased shipping traffic, 3D surveys, and non-local workforce	• Low effects on traditional activities, including increased employment of Inuvialuit, year-round oil production, 3D surveys, use of FPSO and drilling rigs, and non-local FIFO workforce
Spring Transition	• Limited effects to traditional harvesting activities as a result of Status Quo	• Moderate traditional activities effects associated with oil and gas projects, increased employment opportunities for Inuvialuit, non-local FIFO workforce, increased shipping traffic, and increased human activity in the ISR	• Low effects on traditional activities associated with increased employment of Inuvialuit, year-round oil production, increased shipping traffic, 3D surveys, and non-local FIFO workforce	• Low effects on traditional activities associated with increased employment of Inuvialuit, year-round oil production, 3D surveys, use of FPSO and drilling rigs, and non-local FIFO workforce
Open Water	• Limited effects to traditional harvesting activities as a result of Status Quo	• Moderate traditional activities effects associated with oil and gas projects, increased employment opportunities for Inuvialuit, non-local FIFO workforce, increased shipping traffic, and increased human activity in the ISR	• Low effects on traditional activities associated with increased employment of Inuvialuit, year-round oil production, increased shipping traffic, 3D surveys, and non-local FIFO workforces	• Low effects on traditional activities associated with increased employment of Inuvialuit, year-round oil production, 3D surveys, use of FPSO and drilling rigs, and non-local FIFO workforce

Table D-66 Potential Residual Effects of Scenarios 1 – 4 on Traditional Activities.

Season	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4 Oil Development in Deep Water
Fall Transition	• Limited effects to traditional harvesting activities as a result of Status Quo	• Moderate traditional activities effects associated with oil and gas projects, increased employment opportunities for Inuvialuit, non-local FIFO workforce, increased shipping traffic, and increased human activity in the ISR	• Low effects on traditional activities associated with increased employment of Inuvialuit, year-round oil production, increased shipping traffic, 3D surveys, and non-local FIFO workforce	• Low effects on traditional activities associated with increased employment of Inuvialuit, year-round oil production, 3D surveys, use of FPSO and drilling rigs, and non-local FIFO workforce
Legend				
• Least effect – No to minor effect on traditional activities				
• Moderate effect -- Moderate effect on traditional activities				
• High effect -- Major effect on traditional activities				
• Greatest effect – Severe effect on traditional activities				

Table D-67 Potential Effects of a Large Oil Release Event (Scenario 5) for Traditional Activities

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• Major effects to traditional activities, including to key species and their habitat, such as polar bears and seals. Contamination of country foods. Impediments to access of traditionally harvested species. Potential effects to ocean ecology. Species ingestion of oil	• Major effects to traditional activities, including to key species and their habitat, such as polar bears and seals. Contamination of country foods. Impediments to access of traditionally harvested species. Potential effects to ocean ecology. Species ingestion of oil	• Major effects to traditional activities, including to key species and their habitat, such as polar bears and seals. Contamination of country foods. Impediments to access of traditionally harvested species. Potential effects to ocean ecology. Species ingestion of oil
Spring Transition	• Major effects to traditional activities, including to valued species habitat, to country foods, to hunting and fishing equipment, and to access	• Major effects to traditional activities, including to valued species habitat, to country foods, to hunting and fishing equipment, and to access	• Major effects to traditional activities, including to valued species habitat, to country foods, to hunting and fishing equipment, and to access
Open Water	• Severe effects to traditional activities, including contamination of country foods; access to harvesting areas; and impacts to harvested species, species habitat; shorelines, marine water quality and marine ecology	• Severe effects to traditional activities, including contamination of country foods; access to harvesting areas; and impacts to harvested species, species habitat; marine water quality and marine ecology	• Severe effects to traditional activities, including contamination of country foods; access to harvesting areas; and impacts to harvested species, species habitat; marine water quality and marine ecology
Fall Transition	• Major effects to traditional activities, including to valued species habitat, to country foods, to hunting and fishing equipment, and to access	• Major effects to traditional activities, including to valued species habitat, to country foods, to hunting and fishing equipment, and to access	• Major effects to traditional activities, including to valued species habitat, to country foods, to hunting and fishing equipment, and to access

Table D-67 Potential Effects of a Large Oil Release Event (Scenario 5) for Traditional Activities

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Longer-term/ Multi-year	• Multi-year effect potential is dependent on seasonality of release. Open water release has highest potential for multi-year effects to traditional activities, including shoreline oiling. Effects to country foods and access to traditional harvesting sites	• Multi-year effect potential is dependent on seasonality of release. Open water release has highest potential for multi-year effects to traditional activities, including shoreline oiling. Effects to country foods and access to traditional harvesting sites	• Multi-year effect potential is dependent on seasonality of release. Open water release has highest potential for multi-year effects to traditional activities, including shoreline oiling. Effects to country foods and traditional activities
Legend			
• Least effect – No to minor effect on traditional activities			
• Moderate effect -- Moderate effect on traditional activities			
• High effect -- Major effect on traditional activities			
• Greatest effect – Severe effect on traditional activities			

D.4.4.8 Gaps and Recommendations

Potential gaps for assessing traditional activities include the need for further detailed quantitative information regarding Inuvialuit traditional activities in the ISR. The current Community Based Monitoring program for the Inuvialuit harvest could be expanded to engage local beneficiaries to the same level as did the Inuvialuit Harvest Study (Joint Secretariat 2003). In this study, Inuvialuit reported on what species were harvested, when harvested, where harvested (mapped data) and numbers of wildlife harvested.

The 10-year Inuvialuit harvest study (1988-1997) had harvesters mark detailed harvest locations on 1:250000 scale maps. Due to GIS technological limitations at the time, this information was not digitized. These maps could now be properly digitized and analyzed with an existing data set to provide a very detailed view of Inuvialuit harvesting by species, location and season.

The ongoing assessment would benefit greatly with the digitizing and analysis of the harvest levels and locations reported by this earlier study; this analysis could be expanded to include the collection of travel routes and a measure of effort and cost involved in traditional harvesting activities. This would largely fill a historical gap, as it includes data from interviewed Inuvialuit beneficiaries greater than 16 years of age, on a monthly basis, over a 10-year period (1988-1997). Information from an ongoing Inuvialuit Harvest Study could be used to inform decision making for future offshore projects (e.g., as part of future offshore management agreements).

D.4.4.9 Follow-up and Monitoring

A harvest monitoring program should include all species harvested by Inuvialuit (fish, birds, mammals), and collect mapped information on key categories such as the number of animals harvested, what species harvested, when the species were harvested, and where this harvesting took place.

The ISR Community-Based Monitoring Program already provides a basis for ongoing monitoring of effects on traditional harvesting, “The ISR-CBMP is a partnership that includes the six ISR Hunters and Trappers Committees (HTCs), the Inuvialuit Settlement Region wildlife co-management boards (EIRB, EISC, FJMC, WMAC-NWT, and WMAC- NS), the Inuvialuit Game Council (IGC), the Inuvialuit Regional Corporation (IRC), and the Joint Secretariat (JS). The program builds and increases local capacity to monitor current environmental conditions and trends through the training of Community Resource Technicians and the participation of local harvesters. The Community Based Monitoring Program includes and uses local expert Inuvialuit knowledge to inform the decisions and priorities of Inuvialuit organizations, wildlife co-management boards and territorial and federal resource management authorities.” (IRC 2020; https://www.irc.inuvialuit.com/innovation-science-climate-change-staff).

Community-based monitoring programs for species could collect specific metrics. As an example, the Paulatuk Community Conservation Plan (2016) concerns itself with the disturbance of Marine Protected Areas (MPAs) and prohibiting activity in the MPA that is likely to result in the disturbance, damage, destruction, or removal of a living marine organism or any part of its habitat. Additional metrics that the Working Group could collect include measurements of ice thickness, months of open water, numbers of polar bears visible at ice leads and in open water, number of vessels passing through or nearby to known polar bear gathering/hunting areas, and numbers for air traffic passing over known or established areas that polar bears are known to frequent.

Additionally, the CBM program in each of the six Inuvialuit communities could collect information on habitat and climate changes, wildlife movement patterns, and species condition. Information could be collected in the communities or out on the land at the coastal fishing and whaling camps in the summer, waterfowl hunting camps in the spring, and with furbearer harvesters in the winter.

Continuation of the beluga monitoring program is recommended, as it collects whale metrics, including condition.

D.4.5 Cultural Vitality

D.4.5.1 Scoping

For Inuvialuit, strong cultural links exist between perceptions of person and group worth, history, and participation in traditional activities. Underpinning participation in traditional activities, whether harvesting-related or creative, is a desire for the transfer of Inuvialuit knowledge from those that hold it (commonly, elders) to younger people. Integrating cultural components with traditional harvesting practices serves nutritional needs and enriches the lives of Inuvialuit through the reinforcement of cultural practices.

As noted by TLK holders from Tuktoyaktuk, opportunities to spend time on the land and to transfer cultural knowledge among community members, including through the use of Inuvialuktun, is very important (IMG Golder and Golder Associates 2014:10). Support for Inuvialuit ability to transmit cultural knowledge and values was expressed by hunters, trappers, and elders: “We've been brought up to teach the young people about that - that our culture and traditions are important! And when you take that away from the people, we take a lot of pride from them" (Slavik 2010: 7). Harvesters from Aklavik also recognized the need for mentoring younger people as a crucial part of knowledge transfer (Joint Secretariat 2015: 10; Slavik 2010: 7).

The Inuvialuit Game Council (IGC) (2020) noted that one of the three main goals of the IFA is to preserve Inuvialuit cultural identity and values within a changing northern society. In the context of this assessment, the IGC indicated that Inuvialuit “are evolving to our new way of living, within the context of being harvesters and knowledge holders, as Inuvialuit Canadians.” …..”We are truly destined to adapt, and we all signed on to it with the land claim” (IGC 2020).

Activities commonly associated with cultural vitality include hunting, trapping, fishing, gathering and traditional sports (e.g., Inuvialuit Games). Participation in creative expression is also an important aspect of cultural vitality and can take many forms, including carving, drawing, painting, sewing, needlecraft, weaving, basketmaking, jewelry making, performing arts, books, plays, and music.

D.4.5.1.1 IDENTIFICATION OF INDICATORS

The following indicators have been chosen for the assessment of the Cultural Vitality VC:

- use of Inuvialuktun and other Indigenous languages - Indigenous language was chosen as an indicator because it provides a cultural link between Inuvialuit and traditional practices, including creative expression such as painting, carving, needlepoint, and sewing, as well as hunting and fishing. Non-Indigenous languages, such as English, have become languages of choice for many people in the ISR during working, socializing, and educational pursuits, and based on past trends, it could reasonably be expected that the use of Inuvialuktun and other Indigenous languages would continue to decrease in the ISR (Petrov 2018:181-182). A decline in use of Inuvialuktun and other Indigenous languages can then be understood to be related to a decline in cultural vitality.
- participation in traditional activities - Participation in traditional activities was chosen as an indicator because it is a large part of cultural vitality; a category that includes hunting, fishing, gathering, camping, as well forms of creative expression, including dancing, sewing, cooking, and aesthetic enjoyment of the land. Traditional activities are integral to Inuvialuit culture, and community engagement in these activities supports cultural vibrancy and resilience.

D.4.5.1.2 SPATIAL BOUNDARIES

Effects to cultural vitality could occur within all communities within the ISR and extend beyond the ISR to other communities in NWT, Yukon and Canada. The six communities within the ISR are Aklavik, Inuvik, Paulatuk, Sachs Harbour, Tuktoyaktuk, and Ulukhaktok.

D.4.5.1.3 TEMPORAL BOUNDARIES

The temporal boundary for the assessment of effects on cultural vitality is a 30-year period between 2020-2050.

D.4.5.1.4 ASSESSMENT OF POTENTIAL EFFECTS

Potential effects to cultural vitality include changes to use of Inuvialuktun and other Indigenous languages, changes in traditional activities that support traditional harvesting (e.g., hunting, trapping, fishing), traditional use and cultural sites, and creative expression. Measurable changes to use of Inuvialuktun and other Indigenous languages include increases or decreases in language use by year and community (Section 7.3.2). Measurable changes to traditional activities include increases and decreases in the number of Inuvialuit participating in traditional harvesting, use of traditional and cultural sites and travel routes, and creative expression (Section 7.3.2).

A qualitative characterization of potential residual effects on cultural vitality associated with each scenario is based on the characterization terms defined in Table D-68.

Table D-68 Characterization of Residual Environmental Effects on Cultural Vitality for the time period 2020 – 2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Positive**—an increase in use of Inuvialuktun and other Indigenous languages and participation in traditional activities **Adverse**—a decrease in use of Inuvialuktun and other Indigenous languages and participation in traditional activities **Neutral**—no net change in use of Inuvialuktun and other Indigenous languages and participation in traditional activities
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no measurable change from the Status Quo and Inuvialuktun and other Indigenous language use and participation in traditional activities are able to continue at current levels **Low**—a measurable change but minor, and Inuvialuktun and other Indigenous language use and participation in traditional activities are able to continue at current levels **Moderate**—measurable change but Inuvialuktun and other Indigenous language use and participation in traditional activities are able to continue at a reduced level or with some restrictions **High**—measurable change such that Inuvialuktun and other Indigenous language use and participation in traditional activities cannot continue or cannot continue without substantial changes or substantial restrictions
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity **Local**—residual effects extend into the local area **Regional**—residual effects extend into the regional area **Extra-regional**—residual effects extend beyond the regional area
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—the potential effects occur once during the life of a project **Multiple irregular event (no set schedule)** —the potential effects occurs only occasionally, and without any predictable pattern during the life of a project **Multiple regular event**—the potential effect occurs at regular and frequent intervals during the project phase in which they occur, over the life of a project **Continuous**—residual effect occurs continuously
Duration	The period of time the residual effect can be measured or expected	**Short-term**—the residual effect is restricted to short-term events or activities such as discrete component completion during construction, maintenance, or rehabilitation activities (i.e., a timeframe of several months up to 1 year) **Medium-term**—the residual effect extends through the completion of construction and rehabilitation activities (i.e., a timeframe of 1 year to 5 years) **Long-term**—the residual effect extends beyond the completion of construction and rehabilitation activities into the operations and maintenance phase of a project (i.e., a timeframe of greater than 5 years) **Permanent**—the measurable parameter is unlikely to recover to existing conditions

Table D-68 Characterization of Residual Environmental Effects on Cultural Vitality for the time period 2020 – 2050

Characterization	Description	Definition of Qualitative Categories
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible** – project-specific potential effects are permanent and irreversible
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Undisturbed**—area is currently undisturbed or not adversely affected by human activity **Disturbed**—area has been previously disturbed by human activity to a substantial degree (i.e., substantially modified from natural conditions) or such human activity is still occurring

D.4.5.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

Potential impacts and effects of routine activities can take the form of changes in the regular of use of Inuvialuktun and other Indigenous languages due to increasing reliance on English in working, social, and educational pursuits and changes in the rate of participation in traditional activities.

Potential effects are summarized in Table D-69 below.

Table D-69 Summary of Potential Impacts and Effects on Cultural Vitality

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 1 (Status Quo)	• marine vessels – commercial shipping, cruise ship tourism, scientific research, military • ship-based or barge resupply of ISR coastal communities • renewable energy project (e.g., offshore wind turbine) • traditional harvesting – regional boat traffic and snowmobile use	• changes to Inuvialuit cultural vitality, including participation in traditional activities such as traditional harvesting • activities, infrastructure, and associated sensory disturbances (e.g., light, noise, odour) that may affect Inuvialuit desire to access or participate in cultural practices	• changes to the use of Inuvialuktun and other Indigenous languages • changes in the rate of participation in traditional activities	• number of fluent and partial Inuvialuktun and other Indigenous language speakers • number of Inuvialuit learning Inuvialuktun and other Indigenous languages • project-related employment opportunities that support the use of Inuvialuktun and other Indigenous languages • number of Inuvialuit participating in traditional activities • use of and access to culturally important sites • harvesting effort and harvesting success reported by ISR residents
Scenario 2 (Export of Natural Gas and Condensates)[29]	**Construction** • towing and installation of GBS loading platform at project site • installation of dual pipelines	• activities that modify use of language and participation in traditional activities (e.g., offshore work rotations or work in service and supply bases)	• changes to the use of Inuvialuktun and other Indigenous languages • changes in the rate of participation in traditional activities	• number of fluent and partial Inuvialuktun and other Indigenous language speakers • number of Inuvialuit learning Inuvialuktun and other Indigenous languages

[29] Only economic benefits and effects from the marine operations are considered here; economic benefits from development of gas fields, pipelines gas processing facilities onshore are not considered.

Table D-69 Summary of Potential Impacts and Effects on Cultural Vitality

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 2 (Export of Natural Gas and Condensates)[30] (cont'd)	**Operations** • LNG carrier and condensate tanker loading • LNG carrier and condensate tanker transits westward • icebreaker management around GBS facility and possibly as carrier/tanker escort • annual sealift • local resupply of GBS loading facility by vessel • helicopter transfer of crews • Tuktoyaktuk logistical support base • crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik **Decommissioning** • removal of GBS loading facility • capping and filing of undersea pipelines	• infrastructure and associated sensory disturbances (e.g., light, noise, odour) that may affect Inuvialuit desire to access or participate in cultural practices or use traditional or cultural sites		• project-related employment opportunities which support the use of Inuvialuktun and other Indigenous languages • number of Inuvialuit participating in traditional activities • use of and access to culturally important sites • harvesting effort and harvesting success reported by ISR residents

[30] Only economic benefits and effects from the marine operations are considered here; economic benefits from development of gas fields, pipelines gas processing facilities onshore are not considered.

Table D-69 Summary of Potential Impacts and Effects on Cultural Vitality

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf)	**Exploration/Development** • 3D seismic surveys to delineate field • site preparation for GBS • GBS platform and wareship towed into position and installed • field development • first production and injection wells directionally drilled from GBS **Operations** • additional production wells directionally drilled from GBS • loading and westward transits of ice strengthened oil tankers • icebreaking around GBS facility and as tanker escort • wareship provides logistical support • annual sealift • local resupply from Tuktoyaktuk and Summers Harbour (ship and air) • helicopter transfer of crews • crew changes airflights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik	• activities that modify use of language and participation in traditional activities (e.g., offshore work rotations or work in service and supply bases) • infrastructure and associated sensory disturbances (e.g., light, noise, odour) that may affect Inuvialuit desire to access or participate in cultural practices or use traditional or cultural sites	• changes to the use of Inuvialuktun and other Indigenous languages • changes in the rate of participation in traditional activities	• number of fluent and partial Inuvialuktun and other Indigenous language speakers • number of Inuvialuit learning Inuvialuktun and other Indigenous languages • project-related employment opportunities which support the use of Inuvialuktun and other Indigenous languages • number of Inuvialuit participating in traditional activities • use of and access to culturally important sites • Harvesting effort and harvesting success reported by ISR residents

Table D-69 Summary of Potential Impacts and Effects on Cultural Vitality

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf) (cont'd)	• Tuktoyaktuk and Summers Harbour used as service and supply bases **Decommissioning** • removal of GBS platform and wareship • well capping			
Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope)	**Exploration/Development** • drillship transit to/from Beaufort Sea • exploration and delineation drilling **Operations** • transit of FPSO to Beaufort Sea, anchoring at production site • production and injection wells drilled from drillship • loading and eastward and westward transits of ice-strengthened oil tankers (Ice Season transits westward only) • wareship logistical support • annual sealift	• activities that modify use of language and participation in traditional activities (e.g., offshore work rotations or work in service and supply bases) • infrastructure and associated sensory disturbances (e.g., light, noise, odour) that may affect Inuvialuit desire to access or participate in cultural practices or use traditional or cultural sites	• changes to the use of Inuvialuktun and other Indigenous languages • changes in the rate of participation in traditional activities	• number of fluent and partial Inuvialuktun and other Indigenous language speakers • number of Inuvialuit learning Inuvialuktun and other Indigenous languages • project-related employment opportunities which support the use of Inuvialuktun and other Indigenous languages • number of Inuvialuit participating in traditional activities • use of and access to culturally important sites • harvesting effort and harvesting success reported by ISR residents

Table D-69 Summary of Potential Impacts and Effects on Cultural Vitality

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope) (cont'd)	• local resupply from Tuktoyaktuk and Summers Harbour (ship and air) • helicopter transfer of crews • crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik • Tuktoyaktuk and Summers Harbour service and supply bases **Decommissioning** • removal of FPSO and wareship • well capping			
Scenario 5 (Large Oil Release Event)	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• traditionally harvested species may come into contact with, ingest, inhale, or be contaminated by exposure to oil • oil spill changes the intangible value of sites areas, or places that Inuvialuit consider important • oil spill reduces opportunities for traditional practices affecting Inuvialuit cultural transfer, including Indigenous language	• changes to the use of Inuvialuktun and other Indigenous languages • changes in the rate of participation in traditional activities	• number of fluent and partial Inuvialuktun and other Indigenous language speakers • number of Inuvialuit learning Inuvialuktun and other Indigenous languages • number of Inuvialuit participating in traditional activities • Use of and access to culturally important sites • harvesting effort and harvesting success reported by ISR residents

D.4.5.2 Scenario 1: Status Quo

D.4.5.2.1 POTENTIAL EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Activities in Scenario 1 that could result in effects on cultural vitality include changes to the use of Inuvialuktun and other Indigenous languages, and changes in the rate of participation in traditional activities.

Currently, the BRSEA Study Area experiences regular vessel activity, including commercial, tourism, sea lift, military, research, harvesting, and personal use. This activity largely occurs during the Open Water Season, with some extensions into the Spring and Fall Transition seasons. The area also experiences daily occurrences of low-level aircraft overflights.

Activities such as nearshore ship transits (i.e., within 20 km of shore), aircraft overflights in coastal and nearshore areas, and installation and use of offshore wind turbines which may affect the ability of the Inuvialuit to access and use sites for traditional activities, as well as the quality of the experience for traditional activities. Activities further offshore (e.g., ship transits) would not directly interact with traditional activities but could affect traditional activities through effects on species of macro-benthos, fish, birds, and marine mammals that are harvested by the Inuvialuit.

Changes in the use of marine areas could result in effects not only on traditional harvesting but also in opportunities for observations and inspiration for creative expression (e.g., artistic expression, performing arts) or opportunities for to engage in traditional sports. Effects on traditional harvesting activities and creative expression could also change opportunities for cultural exchange and affect the frequency of use and scope of use of Inuvialuktun and other Indigenous languages.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Potential effects to cultural vitality under Scenario 1 include changes to use of Inuvialuktun and other indigenous languages and participation in traditional activities, including creative expression.

The use of Inuvialuktun (the predominant Inuvialuit language in the ISR) is declining (Section 7.3.2). Inuvialuit TLK holders report that speaking and understanding Inuvialuktun and other Indigenous languages can occur more readily out on the land, among community members, whereas in towns and cities (especially outside the ISR), adults and young people regularly communicate in English. Inuvialuit communities transfer knowledge orally, and stories about species, places, and people are retold and passed between generations (Riedlinger 2001). Inuvialuit indicated that spending time on the land with children and young people was very important for the maintenance of TEK and culture (IMG Golder and Golder Associates 2014:10).

Changes to traditional activities have been reported by Inuvialuit in the ISR as a result of Status Quo activities related to shipping and aircraft passage. Icebreaking activities are most likely to occur in the late Fall and early Spring Transition seasons in this scenario; movements of ice-strengthened vessels and icebreakers in and out of harbours and in nearshore areas that are close to communities can make it more difficult for Inuvialuit to safely travel on ice or block travel corridors. For example, a Tuktoyaktuk TLK holder noted that in late fall when the ice is freezing in the harbour, ship traffic would create channels so skidoos cannot travel across (KAVIK-AXYS Inc. 2009:10-5).

Many Inuvialuit depend heavily on traditional or country foods for much of their annual food supply. People have voiced concerns about increased traffic in the air, water, and on the land, in relation to past proposals for pipelines (ICC et al. 2006:14-6). Other concerns include pollution to ocean water from leaking ships and barges during past programs. Inuvialuit asked if ballast and bilge water was being monitored, and if environmental monitors would be used on vessels (KAVIK-AXYS Inc. 2009:10-7).

The ISR is a popular fishing and hunting destination for non-Indigenous peoples, and Inuvialuit expressed concerns about the potential effects of tourism on the region. TLK holders from Paulatuk expressed concerns regarding unregulated tourism and potential effects to community harvesting (PCCP 2016:84). TLK holders of the Olokhaktomiut Community Conservation Plan noted that fly-in fishing and sport fishing is common in the ISR and expressed concerns about the effects of commercial tourism on traditional sites and areas (OCCP 2016:46). TLK holders in the Aklavik Community Conservation Plan also expressed concerns related to tourism, specifically about effects that tourism and associated air traffic may have on traditional lifestyles (ACCP 2016:55).

TLK holders from Ulukhaktok expressed concern regarding effects to marine mammals and wildlife, indicating that marine wildlife may be affected by smells from the equipment (IMG Golder and Golder Associates 2011f:16). TLK holders from Aklavik indicted that aircraft and boats can affect the belugas and use should be avoided during the whaling season (KAVIK-AXYS Inc. 2004a:4-2 – 4-3). Information gathered in the Aklavik Community Conservation Plan indicated that increased aircraft traffic over the area could result from development activities in the Beaufort Sea and on the Tuktoyaktuk Peninsula (Aklavik Community Conservation Plan 2016:29). It can be reasonably expected that similar changes would continue to be experienced.

Effects of Climate Change on Potential Effects

Inuvialuit are reliant on sea ice in the ISR, both for practicing traditional activities and for transfer of cultural knowledge. Continued reductions in the duration and spatial extent of sea ice in the ISR is expected to erode Inuvialuit ability to pursue traditional activities. For example, Inuvialuit harvesters noted that the Clinton Point area, formerly a reliable source for polar bears, is in disuse because the ice is unstable (Joint Secretariat 2015:165-166). A decrease in ice also can mean a decrease in the availability of an animal species. Inuvialuit note that since the mid-1980s, no one has been able to travel and hunt polar bears as far offshore as they had previously. Ice conditions and the location of the floe edge continue to vary widely each year (Joint Secretariat 2015:164). Inuvialuit from Paulatuk indicated that the ice buckles more, making it much harder for people to travel on, and that a multi-year ice has not been seen in about 10 years (prior to 2011); (IMG Golder and Golder Associates 2011c:13). These changes have a corresponding effect on Inuvialuit culture vitality; less sea ice and reduced opportunities for activities on the ice can also change or reduce the number of opportunities for families and communities to be on the land and, in turn, affect cultural expression and the language link between Inuvialuit and traditional activities.

A longer Open Water Season, associated with climate change, could have positive and adverse effects on cultural vitality. The longer duration of the Open Water Season may provide additional opportunities for travel in open water. This longer Open Water Season could also be utilized by tourism enterprises, and potentially interfere with Inuvialuit traditional activities. Conversely, increased occurrences of severe storms, increased wave heights, and fog could make travel more difficult and hazardous (Table 6-2).

D.4.5.2.2 MITIGATION AND MANAGEMENT

Proposed mitigation measures for cultural vitality for Status Quo conditions include:

- coordinate shipping times and routes, especially for nearshore transits, to avoid or reduce effects on Inuvialuit use of coastal camps and sites and travel to and from these sites
- limit the use of ice breakers and ice-strengthened vessels during the late Fall and early Spring Transition seasons to avoid disrupting Inuvialuit travel across sea ice. If possible, coordinate ice breaker routes to avoid or reduce spatial and temporal overlap with Inuvialuit use
- manage the number and type (i.e., fixed wing vs. helicopter) of low-level overhead flights along the coastlines and in nearshore areas to reduce effects to Inuvialuit hunters and fishers, coastal camps and wildlife. Of note, aircraft must maintain a minimum flight altitude of 300 m to 400 m above ground depending on the flight location and time of year (EIRB 2011, Appendix F).
- use the existing co-management processes with Inuvialuit groups to help protect traditional activities and cultural sites during specific time periods through measures such as restricting uses of vessels and aircraft in and near exclusion zones or seasonal activity periods
- continue engagement with potentially affected Inuvialuit residents and communities to provide up-to-date information on traditional activities to support project planning and timing
- monitor effects of industrial and other activities on cultural vitality as part of broader socio-economic monitoring and use information to support decision-making systems for existing mitigation measures, future projects and co-management processes.

D.4.5.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

The Status Quo scenario is predicted to have a neutral effect on cultural vitality in the ISR (e.g., use of Inuvialuktun and other indigenous languages and participation in traditional activities). Changes to cultural vitality under this scenario are anticipated to be negligible. Assuming ongoing engagement of Inuvialuit residents in the ISR with regard to project planning and operation, residual effects under a Status Quo Scenario are characterized as local (i.e., the immediate area around the activity), irregular in occurrence, and short-term in duration.

Information relating to cultural vitality was available from TLK sources and government databases, but mostly focused on harvesting aspects of traditional practices. Absent further detailed information on components of cultural vitality, such as creative expression, prediction and characterization of residual effects is made with medium-to-low confidence.

CUMULATIVE EFFECTS

Under a Status Quo scenario, and without the potential influence of specific projects, cumulative effects are expected to be the same as residual effects.

D.4.5.3 Scenario 2: Export of Natural Gas and Condensates

D.4.5.3.1 ASSESSMENT OF EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

The development and operation of an export facility for natural gas and condensates in Scenario 2 would result in seasonal industrial and human activities close to shore (i.e., during site preparation and installation of the dual pipelines), year-round activities in the vicinity of the GBS loading platform (~ 15-20 km offshore) and transits by LNG carriers and condensate tankers using the route to the west past Alaska. These activities could interact with traditional and cultural activities associated with nearshore travel, use of coastal camps and other activities. Effects are most likely to be associated with vessel and aircraft activity along or across nearshore and coastal areas, especially in areas close to Inuvialuit communities. Changes in traditional activities in coastal camps and in marine areas can affect social gatherings and associated cultural activities and associated use of Inuvialuktun and other Indigenous languages. Participation of individual in traditional activities may be reduced as result of these effects.

Activities in Scenario 2 which can affect cultural vitality include Inuvialuit employment with the development proponents or major contractors (and reduced opportunities to participate in traditional and cultural activities), increased vessel traffic (e.g., weekly tanker transits in and out of the development areas; supply vessels), icebreaking and ice management, and use of helicopters for crew changes and some resupply. During employment, the use of English in the workplace and employment of non-local workers who do not speak Inuvialuktun as the primary language, could add to the declining trend in use of Inuvialuktun in the region. An increase in vessel transits, icebreaker use, and aircraft could affect the amount of time that individual Inuvialuit spend on the coast and in marine areas, with associated effects on traditional activities, use of coastal camps and sites and travel between home communities and these sites or other traditional use sites.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Potential effects to Inuvialuit under Scenario 2 include changes in the type, extent and timing of traditional activities and effects on use of Inuvialuktun and other Indigenous languages as a result of participation in wage economies and the presence of non-local workers; interference with travel to or use of traditional and cultural sites (e.g., disturbance of ice by ice-strengthened vessels and icebreakers); and reduced use of traditional and cultural sites due to sensory disturbance (e.g., noise, smells, and visual disturbances by vessels, aircraft and offshore facilities).

Inuvialuit who are employed wage labour opportunities in land-based service and supply bases (e.g., Tuktoyaktuk) or the offshore GBS loading platform could experience social effects (including alcohol and drugs, and informal economies). Inuvialuit from Ulukhaktok expressed concerns about the potential for increased drug and alcohol use in the community (IMG Golder and Golder Associates 2011f:15).

Inuvialuit from Tuktoyaktuk indicated concern that potential job opportunities and perceived ease and access to money may lead to increased alcohol and drug problems (IMG Golder and Golder Associates 2011e:13). A Sachs Harbour TLK holder acknowledged that work would be good for the people, but also expressed concerns about drugs and alcohol; she does not want that to come to Banks Island (IMG Golder and Golder Associates 2011d:19).

Participation in project-related employment introduces job responsibilities that could erode participation in traditional activities such as hunting or fishing. However, based on past oil and gas projects in the BRSEA Study Area, work rotations for Inuvialuit employees can be adjusted to allow Inuvialuit employees to participate in important seasonal harvesting activities. Further, while participation in the wage economy can result in less time to participate in traditional activities, a wage economy can also improve the ability of some traditional users to purchase equipment and supplies to support traditional activities and travel (Martin 2015; Natcher 2009).

The construction and operation of the supply and service base and the export facility is likely to employ large numbers of workers whose primary language is English. As employment activities are likely to be conducted in English, the social and work environment would not encourage Inuvialuktun and other Indigenous language use, which could affect the use of Inuvialuktun in the ISR.

As discussed in Section D.4.5, increased vessel activity and transits can directly affect use of coastal camps, cultural sites and access routes, and ultimately traditional and cultural activities by affecting travel to and access to sites as a result of ice-breaking and changes to sea ice that block or affect the safety of on-ice travel by the Inuvialuit. Changes to sea ice also may affect harvesting (an important component of traditional activities through effects on harvested species), as well as access to harvested species and harvesting areas or changes in the timing of these activities.

Because Inuvialuit value time spent on land, water, and ice and use these activities for knowledge transfer across generations, these effects can change traditional and cultural activities and use of Inuvialuktun. For example, spending time on the land with children and young people is very important for the maintenance of TLK and culture (IMG Golder and Golder Associates 2014:10). Inuvialuit also indicated that hunting and guiding for polar bear is a source of culturally relevant employment that provides a sense of pride and cultural identity (Slavik 2010: 7).

Sensory disturbances could result in Inuvialuit spending less time at certain traditional or cultural sites or avoiding these specific areas during peak disturbance periods. This could result in similar effects as just discussed for interference with travel or access to coastal camps, cultural sites and access routes (reduced opportunities for traditional activities, reduced participation in these activities and associated effects on language).

Effects of Climate Change

The effects of climate change on cultural vitality under Scenario 2 are anticipated to be similar to those under a Status Quo scenario, with the addition of a likely rise in shipping activity as a result of decreasing sea ice. Longer Open water seasons and greater extent of open water could lead to increased vessel activity in nearshore areas and in and out of harbours that, in turn, can affect travel by Inuvialuit, as well as the use of some traditional and cultural sites (due to increased disturbances or interference). Species harvested by the Inuvialuit (e.g., potential changes in whale migration routes and timing, changing polar bear and seal habitat, change in species composition) may also occur as a result of these activities and climate change.

D.4.5.3.2 MITIGATION AND MANAGEMENT

Mitigation and management measures under Scenario 2 for cultural vitality are aimed at addressing potential issues regarding Inuvialuit employment and engagement. These measures include:

- increasing the number of opportunities to use Inuvialuktun and other Indigenous language in the workplace (e.g., use of Inuvialuktun on signage and in training materials and courses; cross-cultural training for non-local workers). For example, while English is the work language for the Mary River Mine, job applications can be made in Inuktitut or English, lack of proficiency in English is not a barrier to employment. at Baffinland, and company policies include Inuktitut in the workplace and communications (Baffinland and QIA 2019).
- promoting use of Inuvialuktun and other Indigenous languages through language preservation and terminology workshops, development of technical dictionaries, and ongoing initiatives to identify needs for Inuvialuktun words or phrases for new technical terms.
- flexible working shifts for Inuvialuit employees, such that participation in culturally-valued traditional and cultural activities can continue (e.g., Inuvialuit Games, cultural celebrations, trips to seasonal harvesting camps)
- provision of country food in project work camps, including allowing Indigenous employees to bring their own traditional foods to project facilities and camps, and providing appropriate storage and cooking facilities in the project camp to prepare traditional foods for Indigenous workers (e.g., Baffinland and QIA 2019)
- use of cultural advisers to provide support Inuvialuit employees (this approach is being used for the Mary River Project (Baffinland and QIA 2019)
- cross-cultural training of non-local workers and contractors to reduce or avoid interference with traditional and cultural activities. This can include demonstrations of cultural activities and traditional uses (Baffinland and QIA 2019).
- management of non-local workers while on work rotations in the north. For most past projects in the ISR, non-local workers have not been allowed or have been discouraged from recreational pursuits on the land (e.g., hunting and fishing) both through restrictions on allowable activities during their work rotations, and management of these individuals during transfer in and out of the ISR. For example, most non-local workers would arrive through logistics bases and would be accommodated on site (if required), before being transferred out to the development site and vice-versa. Of note, regulatory requirements would also limit harvesting by non-Inuvialuit. The Inuvialuit have exclusive harvesting rights to a number of large game species, migratory birds and fishing (other than with a road and reel); non-Inuvialuit have to be a resident for two years to be able to obtain a recreational hunting license.
- engaging in discussions with Inuvialuit communities, the GNWT and YG concerning the limiting of non-local hunting, trapping, and fishing practices

- allocate money from the financial benefits of development to fund Inuvialuit culture and language programs in communities and schools (e.g., language preservation and terminology workshops, development of technical dictionaries, and ongoing initiatives to identify needs for Inuvialuktun words or phrases for new technical terms).
- provide financial support to cultural initiatives put forward by community groups such as women, elders, and youth
- ongoing engagement with Inuvialuit groups and communities regarding potential project-related effects from the use of ice breakers and increased vessel and aircraft traffic on traditional activities, sites and travel routes, as well as effects on harvested species. For example, sensory disturbance and direct effects on travel and site access could be managed by use of seasonally-specific routes for vessels and aircraft to avoid important traditional and cultural sites. Flight restrictions such as minimum flying altitudes near or over traditional and cultural sites would also reduce aircraft impacts.
- use of TLK in design, planning, construction, and operations of buildings and other project components
- develop and implement a socio-economic agreement and management plan that contains commitments and actions to address socio-economic impacts, review of project performance, construction and operational monitoring, cumulative effects monitoring and adaptive management
- monitor effects of industrial and other activities on cultural vitality, as part of broader socio-economic monitoring, and use information to support decision-making systems for existing mitigation measures, future projects and co-management processes

D.4.5.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

The majority of the residual environmental effects of Scenario 2 on cultural vitality within the BRSEA Study Area are expected to be adverse and low magnitude. Some effects could be beneficial.

Project-related site preparation, installation and operations would require a substantial workforce, and much of it would be filled by non-local, non-Indigenous workers. Inuvialuit in the ISR may experience competition for some traditional resources (e.g., fish, snow geese) from members of the non-local workforce or unintentional interference with traditional activities by these workers (e.g., recreational activities by non-local workers might interrupt traditional activities) but these effects are expected to be largely managed by management of non-local workers during shift rotations. Increased vessel traffic, use of icebreakers and aircraft traffic could directly affect traditional activities, sites and travel, as well as indirectly affect these activities through increased effects to harvested species.

With application of proposed mitigation and management measures, including the hiring of Inuvialuit into project-related positions, flexible work rotations, recognition of Inuvialuit culture and practices by projects and in project facilities, and ongoing engagement with affected Inuvialuit communities, the majority of the residual effects on cultural vitality under Scenario 2 are anticipated to be adverse in direction, affect a low proportion of traditional and cultural activities in coastal areas (given the proximity of the export facility and associated vessel and aircraft transits to coastal sites), regional in context, continuous in frequency, and of long-term duration (i.e., Inuvialuit would be employed and non-local workers would be present over the life of the project). Some benefits to cultural vitality could occur through an improved ability of Inuvialuit employees to purchase equipment and supplies for traditional activities and travel; support of cultural and communities initiatives and events and language retention programs by project proponents, and direct involvement of Inuvialuit in the work force and improved cultural awareness by non-Inuvialuit employees.

The effects of climate change on cultural vitality under Scenario 2 are similar to those under Scenario 1, and not expected to change the effects characterization.

Information relating to cultural vitality was available from TLK sources and government databases, but mostly focused on harvesting aspects of traditional practices. Absent further detailed information on components of cultural vitality, such as creative expression, prediction and characterization of residual effects is made with medium-to-low confidence.

Cumulative Effects

Increased employment and increases in vessel and aircraft activity in Scenarios 1 and 2 could have cumulative effects on Inuvialuit cultural vitality. This could occur by limiting opportunities to participate in traditional activities (e.g., as a result of employment in offshore wind energy, tourism operations, and the export facility), as well as sensory disturbance close to important traditional use or cultural sites (e.g., from combined effects of nearshore vessels and aircraft, offshore wind energy turbines and the export facility). An influx of non-local workers for development projects and tourism could also have effects on use Inuvialuktun and other Indigenous in the region and increase interference with traditional activities.

D.4.5.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.4.5.4.1 Assessment of Effects of Routine Activities

Description of Effect Pathway

The majority of the activities in Scenario 3 are further offshore than in Scenario 2 (80 km versus 15-20 km); as a result, there is less potential for offshore activities and vessel movements to interact with traditional activities. Direct interference with traditional activities are most likely to be associated with vessel and aircraft activity along or across nearshore and coastal areas, especially in areas close to Inuvialuit communities. There also is potential for wage employment and increases in the non-Inuvialuit population to affect participation in traditional activities, as well as erode the use of Inuvialuktun and other Indigenous languages.

Some effect pathways are similar to those discussed for Scenario 2 (e.g., year-round tanker transits, use of icebreakers for ice management and support of tanker transits, regular vessel and aircraft transits between the mainland and the offshore GBS for crew rotations and resupply; participation of Inuvialuit in the local workforce; non-local workers). Several effects pathways for Scenario 3 differ from Scenario 2; specifically: seasonal 3D seismic survey surveys and use of service and supply bases not only in Tuktoyaktuk but also Summers Harbour.

Seismic surveys are not likely to directly affect traditional and cultural activities because the surveys would be conducted in only one year in an area of ~ 60,000 ha located 80 km offshore. However, seismic surveys could temporarily affect some harvested species (e.g., marine mammals and fish could avoid the immediate area of the surveys and alter habitat use and movement patterns) (Section D.4.5).

Description of Range of Potential Effects

Potential effects to Inuvialuit under Scenario 3 include: short-term impacts to marine life from the seismic survey and associated effects on traditional activities; access to traditional and cultural sites and associated travel; effects of employment of Inuvialuit on language and rates of participation in traditional activities; and social and economic implications as a result of an increase in non-local employees in the workforce. While vessel and aircraft transits between the supply and service bases and the offshore structures would interact with traditional activities, most other activities would occur in areas where few or no traditional activities occur (i.e., 80 km offshore versus within 10 km of the coastline of the mainland and islands).

Seismic surveys can negatively affect whales, seals, and fish (Section D.3). These are key species to Inuvialuit for traditional activities, and Inuvialuit people have a long-standing and intimate relationship with water and ice, both a source of traditional resources and intimately linked to Inuvialuit culture. TLK holders from Aklavik expressed concern regarding past seismic work in the area, and noted that if companies or workers do not understand the lifestyle, values and dependence of local people on the land, they cannot assess fairly and accurately the impact they have made (KAVIK-AXYS Inc. 2004a:4-11-4-12).

The increased use of ice breakers during the late Fall Transition, Ice, and early Spring Transition seasons could affect the ability of the Inuvialuit to access sites of importance to traditional activities and cultural use. The working group from Paulatuk expressed concern that future tanker and ice breaker traffic and oil and gas development activities would have a negative impact on the wildlife in the area and on the Inuvialuit way of life (PCCP 2016:63).

As noted for Scenario 2, increased Inuvialuit representation in the local workforce could have effects on their ability to participate in traditional activities such as hunting and fishing, and impair abilities to participate in the related cultural knowledge transfer associated with traditional activities (Social, Cultural and Economic Working Group 2008:86-91). However, work rotations for Inuvialuit employees can be adjusted to allow Inuvialuit employees to participate in important seasonal harvesting activities, and a wage economy can also improve the ability of some traditional users to purchase equipment and supplies to support traditional activities and travel.

In absence of mitigation and management measures (Section D.4.5.4.2), individually or in combination, these potential effects could erode the use of Inuvialuktun and other Indigenous languages and affect the degree to which individual Inuvialuit participate in traditional and cultural activities. The non-local workforce size can be expected to increase under Scenario 3, bringing additional non-Indigenous language speakers into the region.

Effects of Climate Change

Climate-change effects on cultural vitality in Scenario 3 are anticipated to be similar to those discussed in Scenario 2, including effects of ice reduction on the ability of the Inuvialuit to engage in traditional activities, the connection between availability of sea ice and Inuvialuit cultural knowledge transfer, and increased shipping affecting the location and availability of marine species.

D.4.5.4.2 Mitigation and Management

Mitigation and management measures for considering cultural vitality under Scenario 3 are similar to those of Scenario 2, with the addition of mitigation measures aimed at the effects of seismic programs. Inuvialuit groups and communities should be engaged regarding project-related effects of the seismic program, use of ice breakers, and the land-based service and supply bases. TLK should also be used to better manage potential effects of seismic surveys on species harvested by the Inuvialuit, as well as indirect effects (e.g., effects on prey or habitat). As noted in Section D.3.5.4, wildlife monitoring program should be implemented on vessels, icebreakers, and platforms to identify marine mammals and marine birds in the area and maintain safe operating distance, as well as to monitor safety zones during seismic surveys to protect marine mammals from injury. These wildlife monitoring programs typically would involve teams of Inuvialuit monitors and marine mammal biologists.

Effects of industrial and other activities on cultural vitality and use should be monitored to support decision-making systems for existing mitigation measures, future projects and co-management processes.

D.4.5.4.3 Effects Characterization

Residual Effects

The majority of the residual environmental effects of Scenario 3 on cultural vitality within the BRSEA Study Area are expected to be adverse and of negligible to low magnitude. Some effects could be beneficial.

Concerns of communities in the ISR about effects of seismic surveys on marine species of value for traditional activities are acknowledged; however, mitigation measures such as slow ramp-up, use of safety radii and marine mammal monitors would help to effectively manage these effects. In addition, the program would only occur in one Open Water Season and would be far offshore (i.e., ~80 km). As a result, effects on traditional activities and cultural activities are predicted to be negligible to low.

Non-local workers would make up much of the required workforce. Use of English as a common language would reduce opportunities for use of Inuvialuktun. Funding of language and cultural programs in the workplace and in the Inuvialuit communities, as well as allowance for Inuvialuit workers to schedule work rotations to participate in traditional and cultural activities would reduce effects on cultural vitality to negligible or possibly low (i.e., a low magnitude of the entire Inuvialuit population that would be in the workforce) over the life of the project (long-term). Effects would be continuous. Employment income also may allow some Inuvialuit employees to purchase equipment and supplies and fund trips for traditional and cultural activities.

Recreation uses by the non-local workforce and potential competition or interference with traditional and cultural activities can be managed through company policies on recreational activities of employees during rotations and management of non-local workers during rotations (i.e., keep employees in the supply and service centre during transits in or out of the region). Effects on cultural vitality would be negligible.

Year-round oil production and associated shipping could affect nearshore travel and use of traditional and cultural sites, as well as species used for traditional activities. While mitigation measures should help reduce these effects, sensory disturbance and interference with local travel (e.g., boat or skidoo) could occur; with mitigation, effects are predicted to affect a low portion of traditional and cultural activities (e.g., avoidance of high use traditional and cultural; sites and associated travel routes), be localized to the immediate area of the vessel or aircraft activity (and occur primarily in areas close to supply and service bases), persist for only hours (i.e., short-term), and be reversible with time.

With application of proposed mitigation and management measures, including the hiring of Inuvialuit into project-related positions, flexible work rotations, recognition of Inuvialuit culture and practices by projects and in project facilities, and ongoing engagement with affected Inuvialuit communities, the majority of the residual effects on cultural vitality under Scenario 3 are anticipated to be adverse in direction, localized to specific areas of vessel and aircraft activity, occur irregularly, and be long-term in duration (i.e., Inuvialuit would be employed and non-local workers would be present over the life of the project). Some benefits to cultural vitality could occur through an improved ability of Inuvialuit employees to purchase equipment and supplies for traditional activities and travel; support of cultural and communities initiatives and events and language retention programs by project proponents, and direct involvement of Inuvialuit in the work force and improved cultural awareness by non-Inuvialuit employees.

The effects of climate change under Scenario 3 are similar to those under a Status Quo scenario and are not expected to change the effects characterization.

Information relating to cultural vitality was available from TLK sources and government databases, but mostly focused on harvesting aspects of traditional practices. Absent further detailed information on components of cultural vitality, such as creative expression, prediction and characterization of residual effects is made with medium-to-low confidence.

Cumulative Effects

Cumulative effects for Scenario 3 in combination with Scenario 1 include increases in shipping traffic, icebreakers and aircraft traffic and increased direct and indirect employment associated with offshore development and other activities (e.g., offshore wind energy, tourism, offshore oil development). Increases in vessel and aircraft activity could affect traditional activities, associated sites and travel routes. Increases in direct and indirect employment for Inuvialuit could take individuals away from their home community (e.g., work rotations, travel on vessels) and limit opportunities for Inuvialuit to participate in traditional activities such as hunting and fishing. The intake of large numbers of non-local workers to support projects could have effects on the use of Inuvialuktun and other Indigenous language in the ISR and introduce competition for traditional resources and interfere with traditional activities.

D.4.5.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.4.5.5.1 ASSESSMENT OF EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Effects pathways for Scenario 4 are similar to those discussed under Scenario 3; these include a seasonal but slightly larger 3D seismic survey program; longer transits of tankers (to the east and west of the development area); participation of Inuvialuit in the local workforce; and increased non-local workforce presence in the region. The majority of offshore infrastructure and activities and the west transit of tankers and other vessels would be ~100 km offshore (versus 80 km in Scenario 3 and 15-20 km in Scenario 2). The east transit of tankers during the Open Water Season (once per month) would bring vessels in proximity to Sachs Harbour, Ulukhaktok and Paulatuk and could interfere with or disturb local travel and activities.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Potential effects to cultural vitality under Scenario 4 are similar to those under Scenario 3. Most activities in Scenario 4 are far offshore (>100 km), including the 3D seismic program. The seismic program would cover a larger area (100,000 ha over the continental slope) than in Scenario 3 (60,000 ha over the continental shelf). While the scenario also involves an extended drilling program and the operation of a FPSO vessel and wareship, as well as subsea infrastructure (e.g., manifolds, pipe bundles), these activities are well away from areas used by the Inuvialuit for traditional and cultural activities, except for nearshore and coastal movements of vessels and aircraft between the logistics bases on the mainland and the FPSO and wareship. Without mitigation, these nearshore and coastal activities could disturb traditional activities and travel. Tanker transits through the Northwest Passage and Amundsen – Queen Maude Gulf during the Open Water Season could be visible to traditional activities along the coast or interfere with boat travel between the Arctic Islands or in these waterways. However, as there would only be two transits each month (one eastward and returning transit westward), effects would be infrequent and likely of low magnitude. Offshore activities around the FPSO as well s the tanker transits and other activities could add to sensory disturbance and other effects to harvested marine species (see Section D.3). In summary, primary effects include:

- short-term impacts to marine life from the seismic survey and associated effects on traditional activities
- access to traditional and cultural sites and associated travel
- effects of employment of Inuvialuit on language and rates of participation in traditional activities
- social and economic implications as a result of an increase in local and non-local employees in the workforce

EFFECTS OF CLIMATE CHANGE

Effects of climate are predicted to be similar to those of Scenario 3. Reduced ice cover and a shorter duration of ice cover is expected to affect the ability of the Inuvialuit to travel safely over ice, reach traditional or cultural sites, and engage in traditional activities during the late Fall Transition, Ice and early Spring Transition seasons. In turn, this could affect Inuvialuit cultural knowledge transfer and use of Inuvialuktun and other Indigenous languages. A longer Open Water Season could also lead to increased shipping and effects on harvested marine species.

D.4.5.5.2 MITIGATION AND MANAGEMENT

Mitigation and management measures for cultural vitality in Scenario 4 are similar for those for Scenarios 2 and 3, with the addition of mitigation measures for potential effects associated with Scenario 4 on Inuvialuit traditional activities and language. Additional mitigation measures include ongoing engagement with Inuvialuit groups and communities regarding project-related effects on cultural vitality and marine-based species of value to Inuvialuit in relation to 3D seismic programs, the FPSO and production drilling rigs, and tanker transits east and west of the development area.

D.4.5.5.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

The majority of the effects in Scenario 4, like Scenario 3, are anticipated to be adverse and have low magnitude adverse effects to cultural vitality in the ISR. Some effects would be beneficial.

As indicated for Scenario 3, communities in the ISR are concerned with seismic survey effects on harvested marine species, including beluga whales, seals, and fish. Deep water oil production, and the use of an FPSO and drilling rigs, have the potential to introduce effects to valued species, such as whales, fish, and seals, through increased noise, concentrated human activity in the area, and disruption of migration routes. Project labour requirements could draw on Inuvialuit and non-local workers; the latter could affect use of Inuvialuktun and other Indigenous language in the workplace.

With application of proposed mitigation and management measures, including the hiring of Inuvialuit into project-related positions, flexible work rotations, recognition of Inuvialuit culture and practices by projects and in project facilities, and ongoing engagement with affected Inuvialuit communities, the majority of the residual effects on cultural vitality under Scenario 4 are anticipated to be adverse in direction, localized to specific areas of vessel and aircraft activity, occur irregularly, and be long-term in duration (i.e., Inuvialuit would be employed and non-local workers would be present over the life of the project). Some benefits to cultural vitality could occur through an improved ability of Inuvialuit employees to purchase equipment and supplies for traditional activities and travel; support of cultural and communities initiatives and events and language retention programs by project proponents, and direct involvement of Inuvialuit in the work force and improved cultural awareness by non-Inuvialuit employees.

The effects of climate change under Scenario 4 are similar to those under a Status Quo scenario and are not expected to change the effects characterization.

Information relating to cultural vitality was available from TLK sources and government databases, but mostly focused on harvesting aspects of traditional practices. Absent further detailed information on components of cultural vitality, such as creative expression, prediction and characterization of residual effects is made with medium-to-low confidence.

CUMULATIVE EFFECTS

Cumulative effects under Scenario 4 in combination with Scenario 1 include increases in shipping traffic, icebreakers and aircraft and increased direct and indirect employment associated with offshore development and other activities (e.g., offshore wind energy, tourism, and oil development). Increases in vessels and aircraft could interfere with traditional activities, sites, and travel. Increased employment for Inuvialuit could limit opportunities for Inuvialuit to participate in traditional activities and use Inuvialuktun and other Indigenous language. The large number of non-local workers required to support oil and gas projects could have effects on the use of Inuvialuktun and other Indigenous language and result in competition for or interference with traditional activities.

D.4.5.6 Scenario 5: Large Oil Release Event

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface spill from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on cultural vitality from such an event may differ slightly from what is described below for surface or subsea releases.

D.4.5.6.1 ASSESSMENT OF EFFECTS OF AN OIL SPILL

DESCRIPTION OF EFFECT PATHWAY

Oil spills on the sea ice or in the ocean have the potential to affect Inuvialuit traditional food sources and associated traditional activities. In the event of a spill, traditional harvesting activities, as well as travel (e.g., by boat along the coastline or over ice by skidoo) are expected to be impaired or cease as a result of area closures, fears of contamination of food and water, and potential for damage to equipment and gear. Cultural knowledge transfer might also be affected by an oil spill on the ice or in open water if the ability to participate in traditional activities is affected. Any event that inhibits or prevents traditional activities also affects cultural transfer, which includes opportunities for use of Inuvialuktun and other Indigenous languages.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Potential effects of a large oil release event on cultural vitality differ from the Status Quo and the three oil and gas development scenarios in that effects are tied to an accidental and unplanned major event, rather than on a range of routine activities associated with different types of development and use. The potential effects of a large oil release event are of high concern to Inuvialuit; potential effects to marine species, water, and ice would lead to effects on traditional and cultural activities.

Members of Sachs Harbour indicated that that a spill would affect their food supplies (IMG Golder and Golder Associates 2011d:20). The Ulukhaktok Community Working Group was concerned about the impact that an oil spill would have on the renewable resource base in the region (OCCP 2016:42). Inuvialuit indicated that in the event of an oil spill, “Our main diet with the fish and whale, seals, might get affected, and the waterfowl, too" (ICC et al. 2006:13-5-13-6). Inuvialuit understand country foods to be of higher quality than store-bought foods, and that an oil spill could trigger a change in cultural practices based around traditional harvesting.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Climate change is expected to lengthen the duration of the Open Water Season and shorten the Ice Season, with variable effects on the timing and duration of the Spring and Fall Transition seasons. These changes in open water and ice conditions are expected to change traditional activities, uses of traditional and cultural sites and travel, which would be exacerbated a large oil release. In particular, as a result of an oil release, access to specific sites or harvesting areas might be limited or prevented due to closures, fear of contamination, or potential to foul equipment and gear. These effects could compound effects on cultural vitality caused by climate change.

D.4.5.6.2 MITIGATION AND MANAGEMENT

Mitigation measures for large oil releases are described in Sections 2.13 and 3.10.5.3. While these measures do not directly apply to cultural vitality, they would indirectly affect species harvested by the Inuvialuit, as well as traditional and cultural sites and travel routes.

Additional mitigation measures for cultural vitality include:

- engage and involve Inuvialuit groups in discussions regarding spill planning and response in the region
- development of first response capabilities in the Inuvialuit communities (e.g., training and ongoing readiness drills for first responders, equipment caches)
- in the unlikely event of an oil spill, undertake a collaborative approach to oil spill cleanup, including shorelines, incorporating Inuvialuit concerns, feedback, and suggestions into the process and response

D.4.5.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

A large oil release event is anticipated to have a range of adverse effects on cultural vitality in the ISR. These effects are highly dependent on the season in which the spill might occur, its location, weather conditions at the time of the release, the type of spill (surface versus subsea) and the type of oil. While effects can be managed and mitigated to some extent through a variety of measures, the Inuvialuit are concerned about any type of release. Paulatuk residents indicated that if there were a spill, it would have a large impact on their community due to ocean currents and the effects on the animals they harvest (IMG Golder and Golder Associates 2011c:13). An Ulukhaktok community member indicated that if there were an oil spill, the wildlife would move away to a cleaner area (IMG Golder and Golder Associates 2011d:16). Inuvialuit cultural vitality is closely tied to traditional activities such as hunting and fishing, and in being 'on the land', out on the water, and on the sea ice, interacting with species and environments. Any potential impediment to these practices, and especially one that affects both marine habitat and species simultaneously, is of concern to cultural vitality.

A large surface or subsurface oil release during the Open Water Season would have a severe effect on Inuvialuit cultural vitality, similar to that described for traditional harvesting (Section D.4.4.6). Access to specific traditional and cultural sites, as well as the desire to harvest would be adversely affected by a large oil release, especially if coastal and nearshore areas, the areas where traditional activities are most common (i.e., within 20 km of shore; Elliot 2019a, 2019b) are affected. Area closures, as well as contamination concerns and potential for fouling or damage to gear or equipment would likely affect travel to sites, as well as the desire and ability to safely access and use specific sites. These combined effects would reduce opportunities for Inuvialuit to engage in traditional and cultural activities, especially during time on the land. Adverse effects to the Inuvialuit sense of wellbeing and of enjoyment of the land and its resources would also occur.

In the unlikely event of a large oil release event, the magnitude of effects on cultural vitality could range from moderate to severe, and affect an area ranging from local to regional. Effects would be continuous and persist for the duration of the spill event, including the spill response and cleanup activities. Depending on the success of the response and cleanup, effects on cultural vitality could continue for one to several years. Effects to cultural vitality are expected to be medium to long-term. While effects on harvested species and habitats would be reversible over time, perceived concerns by some Inuvialuit about contamination of traditional cultural sites, harvested food, and water could extend effects on traditional harvesting. Some individuals may consider the effects of an oil spill on cultural vitality to be irreversible.

The effects of climate change, including the reduction of sea ice in the Beaufort Region, may influence the effects predictions. As described in Table 3-15, an oil spill on sea ice may be less difficult to contain and cleanup than one occurring in open water, so continued reduction of sea ice and increase in the length of the Open Water Season could increase the adverse effects of spills.

Information relating to cultural vitality was available from TLK sources and government databases, but mostly focused on harvesting aspects of traditional practices. Absent further detailed information on components of cultural vitality, such as creative expression, prediction and characterization of residual effects is made with medium-to-low confidence.

CUMULATIVE EFFECTS

Traditional activities such as traditional harvesting, already affected by oil and gas activity in the BRSEA Study Area, could be further affected if an oil spill also interacted with them, reducing both opportunities to consume country foods and to transmit language and knowledge.

D.4.5.7 Summary of Residual Effects

Potential effects of Scenarios 1-4 on Cultural Vitality are summarized in Table D-70. Potential effects of a large release of oil are summarized in Table D-71.

D.4.5.8 Gaps and Recommendations

Potential gaps for cultural vitality include Inuvialuit feedback to determine the appropriateness of the proposed effects pathways and mitigation. Potential effects on cultural vitality can be synergistic with both adverse and positive effects that can be perceived differently by individuals or groups in the community. There also is potential for mitigation measures for cultural vitality and other VCs have unintended effects. Validation by the Inuvialuit communities would strengthen the assessment. With this in mind, it is recommended that Inuvialuit communities lead a review of traditional and cultural practices in the ISR to better identify the status of baseline knowledge and identify gaps.

Project specific socio-economic assessments should include the collection of information related to gender, sexual identity, and other relevant identity factors, to support an assessment of socio-economic impacts on vulnerable population groups that may be disproportionately affected by industrial development.

D.4.5.9 Follow-up and Monitoring

As with the ‘Gaps and Recommendations’ sub-section, it is recommended that key indicators of cultural vitality be identified by Inuvialuit communities, including areas of creative expression such as dancing, singing, painting, or carving. Community-led reviews of traditional practices would be more likely to provide meaningful data, which could be used to monitor changes and identify trends.

Table D-70 Potential Residual Effects of Scenarios 1 – 4 on Cultural Vitality for All Seasons[31].

	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4 Oil Development in Deep Water
Potential Effects	• Limited effects to Inuvialuit cultural vitality (language and traditional activities) as a result of Status Quo activities	• Low to moderate effects on cultural vitality due to location 15-20 km from shore • Effects associated with increased employment opportunities for Inuvialuit, increases in vessel and aircraft traffic, human activity, and increased non-local workforce and potential for competition for or interference with traditional activities	• Low effects on cultural vitality due to location ~80 km from shore • Effects associated with increased employment opportunities for Inuvialuit, year-round oil production, 3D surveys, increases in vessel and aircraft traffic, human activity, and increased non-local workforce and potential for competition for or interference with traditional activities	• Low effects on cultural vitality due to location ~100 km from shore • Effects associated with increased employment opportunities for Inuvialuit, year-round oil production, 3D surveys, FPSO and drilling rigs, increases in vessel and aircraft traffic, human activity, increased non-local workforce, and potential for competition for or interference with traditional activities
Legend				
• Least effect – No to minor effect on cultural vitality				
• Moderate effect -- Moderate effect on cultural vitality				
• High effect -- Major effect on cultural vitality				
• Greatest effect – Severe effect on cultural vitality				

[31] While there could be some differences in benefits and adverse effect for cultural vitality among seasons for the Status Quo and the three oil and gas development scenarios, there is insufficient information to provide seasonally-specific effects characterizations for cultural vitality. Instead, effects characterizations are provided for an annual cycle for the Status Quo and the three oil and gas development scenarios.

Table D-71 Potential Effects of a Large Oil Release Event (Scenario 5) for Cultural Vitality

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Ice	• Major effects to cultural vitality and Inuvialuit sense of well-being, including: • Restriction or avoidance of traditional and cultural sites and travel routes (e.g., area closures, damage to equipment) • Actual and perceived contamination of country foods • Effects on harvested species and their habitats	• Major effects to cultural vitality and Inuvialuit sense of well-being, including: • Restriction or avoidance of traditional and cultural sites and travel routes (e.g., area closures, damage to equipment) • Actual and perceived contamination of country foods • Effects on harvested species and their habitats	• Major effects to cultural vitality and Inuvialuit sense of well-being, including: • Restriction or avoidance of traditional and cultural sites and travel routes (e.g., area closures, damage to equipment) • Actual and perceived contamination of country foods • Effects on harvested species and their habitats
Spring Transition	• Major effects to cultural vitality and Inuvialuit sense of well-being (see Ice Season)	• Major effects to cultural vitality and Inuvialuit sense of well-being (see Ice Season)	• Major effects to cultural vitality and Inuvialuit sense of well-being (see Ice Season)
Open Water	• Shoreline and nearshore oiling would overlap areas most used for traditional activities • Severe effects to cultural vitality and Inuvialuit sense of well-being, including: • Restriction or avoidance of traditional and cultural sites and travel routes (e.g., area closures, damage to equipment) • Actual and perceived contamination of country foods • Effects on harvested species and their habitats	• Shoreline and nearshore oiling would overlap areas most used for traditional activities • Severe effects to cultural vitality and Inuvialuit sense of well-being, including: • Restriction or avoidance of traditional and cultural sites and travel routes (e.g., area closures, damage to equipment) • Actual and perceived contamination of country foods • Effects on harvested species and their habitats	• Shoreline and nearshore oiling would overlap areas most used for traditional activities • Severe effects to cultural vitality and Inuvialuit sense of well-being, including: • Restriction or avoidance of traditional and cultural sites and travel routes (e.g., area closures, damage to equipment) • Actual and perceived contamination of country foods • Effects on harvested species and their habitats
Fall Transition	• Major effects to cultural vitality and Inuvialuit sense of well-being (see Ice Season)	• Major effects to cultural vitality and Inuvialuit sense of well-being (see Ice Season)	• Major effects to cultural vitality and Inuvialuit sense of well-being (see Ice Season)

Table D-71 Potential Effects of a Large Oil Release Event (Scenario 5) for Cultural Vitality

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Longer-term/ Multi-year	• Multi-year effect potential is dependent on location and season of release, success of spill response and cleanup, and overlap of surface and shoreline oiling and associated effects with traditional activities, sites and travel routes	• Multi-year effect potential is dependent on location and season of release, success of spill response and cleanup, and overlap of surface and shoreline oiling and associated effects with traditional activities, sites and travel routes	• Multi-year effect potential is dependent on location and season of release, success of spill response and cleanup, and overlap of surface and shoreline oiling and associated effects with traditional activities, sites and travel routes
Legend			
• Least effect – No to minor effect on cultural vitality			
• Moderate effect -- Moderate effect on cultural vitality			
• High effect -- Major effect on cultural vitality			
• Greatest effect – Severe effect on cultural vitality			

D.4.6 Public Health

D.4.6.1 Scoping

Aspects of public health that are relevant in this assessment include: physical and mental health outcomes, personal health, community and family health, social determinants of health, and health risk behaviours. Public health conditions arise from an interaction of many factors including social determinants (e.g., education levels, income levels, quality of housing), cultural factors (e.g., consumption of traditional foodstuffs, physical activity on the land), quality and availability of health and medical services, personal behaviours, and environmental conditions.

D.4.6.1.1 Identification of Indicators

The following indicators are used in the assessment of the Public Health VC:

- health outcomes – prevalence of and change in incidence of chronic health conditions
- health behaviours – prevalence of and/or change in incidence rate of adverse health behaviours, such as smoking, drinking, and drug use
- family and community stability – related to demographic change in the community and presence of large numbers of temporary workers
- education and training – ability to participate in the labour force and benefit from economic opportunities
- food security – availability and affordability of traditional harvested and market foods
- human health risk (measurable and perceived) – risk of exposure to contaminants

D.4.6.1.2 Spatial Boundaries

Public health effects can occur wherever people are located within the ISR. Effects on health outcomes, health behaviours, and family and community stability would be manifested where people are living. While effects related to the availability of traditionally harvested foods may occur where the food is harvested, much of the food would be consumed within home communities. Therefore, the spatial boundaries for this assessment are defined as the six communities within the ISR: Aklavik, Inuvik, Paulatuk, Sachs Harbour, Tuktoyaktuk, and Ulukhaktok.

D.4.6.1.3 Temporal Boundaries

The assessment of potential effects on public health encompasses a 30-year period between 2020 – 2050.

D.4.6.1.4 ASSESSMENT OF POTENTIAL EFFECTS

Health behaviours can be influenced both positively and negatively by changes in household income that would result from increased participation in wage employment. Family and community stability can be affected by demographic changes within communities, including the temporary presence of large numbers of FIFO construction or operational workers in service and supply bases, as well as smaller number of FIFO workers in communities such as Inuvik or Tuktoyaktuk. Education and training levels are related to a person's employment prospects, and ability to generate household income. Food security relates to availability, affordability, and quality of food within households. Increased household incomes associated with wage employment improves the ability of households to purchase market foods. Participation in wage-based employment could result in less time spent on traditional harvesting; however, greater disposable household income could also be used for the purchase of equipment and supplies needed to support harvesting activities and associated travel. Human health risk results from exposure to contaminants, including direct exposure to airborne or waterborne contaminants, and exposure via the consumption of contaminated foods. The fear (or perception) that foods may be subject to contamination can also have health-related consequences, such as avoidance behaviours or mental stress.

A qualitative characterization of potential residual effects on public health associated with each scenario is based on the characterization terms defined in Table D-72.

Table D-72 Characterization of Residual Environmental Effects on Public Health for the time period 2020 – 2050

Characterization	Description	Definition of Qualitative Categories
Direction	The long-term trend of the residual effect	**Positive**—an increase in public health indicators **Adverse**—a decrease in public health indicators **Neutral**—no net change in public health indicators
Magnitude	The amount of change in measurable parameters or the VC relative to existing conditions	**Negligible**—no measurable change in public health **Low**—a slight measurable change in public health **Moderate**—measurable change in public health but less than high **High**—measurable change in public health resulting in
Geographic Extent	The geographic area in which a residual effect occurs	**Footprint**—residual effects are restricted to the footprint of the activity. **Local**—residual effects extend into the local area around the activity. **Regional**—residual effects extend into the regional area (i.e., within the BRSEA Study Area). **Extra-regional**—residual effects extend beyond the regional area (i.e., beyond the BRSEA Study Area).
Frequency	Identifies when the residual effect occurs and how often during a specific phase for each scenario	**Single event**—residual effect occurs once. **Multiple irregular event** (no set schedule)—residual effect occurs at irregular intervals for the duration of the activity. **Multiple regular event**—residual effect occurs at regular intervals for the duration of the activity. **Continuous—**residual effect occurs continuously for the duration of the activity.

Table D-72 Characterization of Residual Environmental Effects on Public Health for the time period 2020 – 2050

Characterization	Description	Definition of Qualitative Categories
Duration	The period of time the residual effect can be measured or expected	**Short-term**—the residual effect is restricted to short-term events or activities such as discrete component completion during construction, maintenance, or rehabilitation activities (i.e., a timeframe of several months up to 1 year) **Medium-term**—the residual effect extends through the completion of construction and rehabilitation activities (i.e., a timeframe of 1 year to 5 years) **Long-term**—the residual effect extends beyond the completion of construction and rehabilitation activities into the operations and maintenance phase of a project (i.e., a timeframe of greater than 5 years)
Reversibility	Pertains to whether a VC can return to its natural condition after the duration of the residual effect ceases	**Reversible**—the effect is likely to be reversed and become comparable to natural conditions over the same time period after activity completion and reclamation **Irreversible**—the effect is unlikely to be reversed
Ecological and Socio-economic Context	Existing condition and trends in the area where residual effects occur	**Average**—Public health conditions, including health behaviours and outcomes are similar to those experienced elsewhere in NWT and Yukon and Canada **Below average**—Public health conditions are on average worse than those experienced elsewhere in NWT, Yukon and Canada

D.4.6.1.5 POTENTIAL IMPACTS AND EFFECTS OF ROUTINE ACTIVITIES

There are a number of mechanisms that can lead to potential adverse effect and benefits to public health effects in the ISR (Table D-73).

Public health conditions in ISR communities are influenced by many factors. Lifestyles in ISR communities have been changing, with less time or effort spent in traditional cultural activities (Section 7.4.3). This can result in a number of health effects ranging from diet-related health outcomes (e.g., incidence of diabetes) to changes in the social fabric of households and communities. The health conditions within households is influenced by employment and income; participation in wage employment and increased wage income can result in both improved and adverse health determinants and outcomes.

Positive effects on health conditions include increased opportunities for skills training, which could improvement employment prospects, resulting in higher household income; higher household incomes could result in improved housing and living conditions, better food security, and mental well-being associated with financial stability. Higher disposable income may also facilitate participation in traditional harvesting activities by providing the means of purchasing equipment, ammunition, fuel, and other supplies needed to support traditional harvesting and associated travel. Sharing of traditionally-harvested foods may also help reduce the effects if wage employment (Baffinland and QIA 2019).

Adverse effects of higher levels of disposable income include participation in adverse health behaviours, including smoking, drinking, and drug use. TLK holders from Sachs Harbour, Tuktoyaktuk, and Ulukhaktok all expressed concern about potential increase in drug use in their communities associated with higher levels of earnings by community residents working on industrial development projects (IMG

Golder and Golder Associates 2011c: 19,21; IMG Golder and Golder Associates 2011e: 13; IMG Golder and Golder Associates 2011d: 15). Individuals that participate in shift work can experience prolonged absences from family and friends, which could affect family and community stability. These individuals also may find that there is less time available for participating in traditional harvesting, necessitating purchasing of more store-bought foods. A shift toward increased consumption of store-bought processed foods has been linked to higher incidences of some chronic health conditions in the ISR and elsewhere in the NWT and Yukon (see Section 7.4.6.2).

The movement of large numbers of individuals from outside the ISR back to the ISR can increase the potential for the introduction and transmission of communicable disease, including respiratory diseases, gastrointestinal infections, and sexually transmitted infections.

Workers from the ISR hired to work on industrial construction and operations projects may be exposed to occupational safety hazards unfamiliar to them, particularly if they have not been previously employed in construction or industrial operations. Tuktoyaktuk TLK holders identified safety around the drilling platforms as a major concern. They indicated that safety measures implemented should take into account not only employees, but also hunters and trappers who might be in the area (KAVIK-AXYS Inc. 2004b: 4-8). Risks from such hazards can be limited with proper implementation of such measures as engineering and management controls, comprehensive safety planning and protocols, and worker safety training.

A variety of contaminants may be released as combustion by-products from ships, aircraft, or other motor vehicles; or as discharges, spills, or other accidental releases. ISR residents may be exposed to such these contaminants through direct environmental contact or through consumption of foods that have been exposed to such substances, contributing to adverse health outcomes. Inuvik TLK holders expressed concern that an accidental spill could contaminate or kill wildlife and jeopardize the Inuvialuit traditional diet, a large part of which comes from the sea. Concern also stems from the possibility of contamination from pollutants intentionally dumped in the ocean (KAVIK-AXYS Inc. 2004a: 4-8). For example, Tuktoyaktuk TLK holders identified contamination of ocean water as a serious concern because of the potential effects it might have on the beluga and fish. They also were concerned that contaminant spills would adversely affect Tuktoyaktuk because of the community’s reliance on the whale harvest (KAVIK-AXYS Inc. 2004b).

Table D-73 Summary of Potential Impacts and Effects on Public Health

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 1 (Status Quo)	• marine vessels – commercial shipping, cruise ship tourism, scientific research, military • ship-based or barge resupply of ISR coastal communities • renewable energy project (e.g., offshore wind turbine) • traditional harvesting – regional boat traffic and snowmobile use	• participation in wage employment & shift work. • demographic changes in communities • exposure to contaminants	• change in health outcomes • change in health behaviours • change in family and community stability • change in food security • change in environmental toxin exposure	• incidence/rate of chronic health conditions • incidence/ rate of detrimental health behaviours (e.g., smoking, alcohol consumption, drug use) • consumption of traditional foods as % of total food consumption
Scenario 2 (Export of Natural Gas and Condensates)[32]	**Construction** • towing and installation of GBS loading platform at project site • installation of dual pipelines **Operations** • LNG carrier and condensate tanker loading • LNG carrier and condensate tanker transits westward • icebreaker management around GBS facility and possibly as carrier/tanker escort • annual sealift	• participation in wage employment & shift work. • demographic changes in communities • exposure to contaminants	• change in health outcomes • change in health behaviours • change in family and community stability • change in food security • change in environmental toxin exposure	• incidence/rate of chronic health conditions • incidence/ rate of detrimental health behaviours (e.g., smoking, alcohol consumption, drug use) • consumption of traditional foods as % of total food consumption

[32] Only economic benefits and effects from the marine operations are considered here; economic benefits from development of gas fields, pipelines gas processing facilities onshore are not considered.

Table D-73 Summary of Potential Impacts and Effects on Public Health

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 2 (Export of Natural Gas and Condensates) (cont'd)	• local resupply of GBS loading facility by vessel • helicopter transfer of crews • Tuktoyaktuk logistical support base • crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik **Decommissioning** • removal of GBS loading facility • capping and filing of undersea pipelines			
Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf)	**Exploration/Development** • 3D seismic surveys to delineate field • site preparation for GBS • GBS platform and wareship towed into position and installed • field development • first production and injection wells directionally drilled from GBS	• participation in wage employment & shift work. • demographic changes in communities • exposure to contaminants.	• change in health outcomes • change in health behaviours • change in family and community stability • change in food security • change in environmental toxin exposure	• incidence/rate of chronic health conditions • incidence/ rate of detrimental health behaviours (e.g., smoking, alcohol consumption, drug use) • consumption of traditional foods as % of total food consumption

Table D-73 Summary of Potential Impacts and Effects on Public Health

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 3 (Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf) (cont'd)	**Operations** • additional production wells directionally drilled from GBS • loading and westward transits of ice strengthened oil tankers • icebreaking around GBS facility and as tanker escort • wareship provides logistical support • annual sealift • local resupply from Tuktoyaktuk and Summers Harbour (ship and air) • helicopter transfer of crews • crew changes airflights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik • Tuktoyaktuk and Summers Harbour used as service and supply bases **Decommissioning** • removal of GBS platform and wareship • well capping			

Table D-73 Summary of Potential Impacts and Effects on Public Health

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope)	**Exploration/Development** • drillship transit to/from Beaufort Sea • exploration and delineation drilling **Operations** • transit of FPSO to Beaufort Sea, anchoring at production site • production and injection wells drilled from drillship • loading and eastward and westward transits of ice-strengthened oil tankers (Ice Season transits westward only) • wareship logistical support • annual sealift • local resupply from Tuktoyaktuk and Summers Harbour (ship and air) • helicopter transfer of crews • crew changes flights from Inuvialuit communities and the south into Inuvik and Tuktoyaktuk • administrative base in Inuvik • Tuktoyaktuk and Summers Harbour service and supply bases	• participation in wage employment & shift work. • demographic changes in communities • exposure to contaminants	• change in health outcomes • change in health behaviours • change in family and community stability • change in food security • change in environmental toxin exposure	• incidence/rate of chronic health conditions • incidence/ rate of detrimental health behaviours (e.g., smoking, alcohol consumption, drug use) • consumption of traditional foods as % of total food consumption

Table D-73 Summary of Potential Impacts and Effects on Public Health

Scenarios	Scenario Activities Associated with the Impact	Potential Interaction between VC/indicator and Impact	Potential Effects	Recommended Measurable Parameters
Scenario 4 (Large Scale Oil Development within Exploration Licenses on the Continental Slope) (cont'd)	**Decommissioning** • removal of FPSO and wareship • well capping			
Scenario 5 (Large Oil Release Event)	• oil released from above the sea or ice surface (e.g., GBS platform) • oil released from a moving tanker or vessel • oil released from subsurface location (well head, pipeline)	• exposure to contaminants • consumption of traditionally harvested foods	• change in environmental toxin exposure • change in food security	• incidence/rate of chronic health conditions • consumption of traditional foods as % of total food consumption

D.4.6.2 Scenario 1: Status Quo

D.4.6.2.1 POTENTIAL EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

The Status Quo scenario is expected to result in a negligible changes on social determinants of health related to economic development (e.g., employment rates and household income) because only slight economic changes are expected in Scenario and effects would be a mixture of adverse and positive on public health. Health effects related to lifestyle choices and behaviours would likely continue to reflect current trends. The much higher rates of smoking and heavy drinking reported in NWT and Yukon would likely be reflected in growing incidence rates of related chronic conditions, such as asthma and heart disease. While the rate of traditionally harvested food consumption has remained high in ISR communities over the long term, the rate of consumption of such foods has been declining (Section 7.4.6.2).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

Public health conditions at the population level could improve, decline, or remain similar to current conditions over the forecast period, depending on a number of factors including overall socio-economic development within ISR, and public investment in health and social infrastructure and services. If current rates of adverse health behaviours such as smoking and heavy drinking persist, there could be increased rates of related health conditions, such as asthma and heart disease (Section 7.4.6.1). A continuation of the trend toward consumption of more market food than traditionally harvested foods could result in increased obesity and diabetes, as has been documented in several Inuit communities (Sharma 2010, Robinson and Filice 2018). This trend would be exacerbated by potential decreases in traditional harvesting activities (Section D.4.4.2). However, wage incomes through opportunities such as the wind energy project or tourism activities could support purchases of equipment and supplies to support traditional harvesting and associated travel and help sustain traditional harvesting.

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

Predicted changes in the temporal and physical extent and characteristics of sea ice, increases in the number of ice-free days, and other physical environmental changes are predicted to alter the habitat, health, abundance and distribution of some species that Inuvialuit traditionally harvest (see discussions of potential effects of climate change on marine fish in Section D.3.2, and marine mammals in Section D.3.5), Such alterations would likely affect not only the diet and food security of the Inuvialuit, but also, as discussed in Section D.4.4, cultural vitality, an important component of household and community health of the Inuvialuit.

D.4.6.2.2 MITIGATION AND MANAGEMENT

It is anticipated that programs and services provided by the Inuvialuit Regional Corporation (Health and Wellness Division), GNWT Department of Health and Social Services, Yukon Department of Health and Social Services, and Indigenous Services Canada and would help manage public health effects related to Scenario 1.

The GNWT Department of Health and Social Services and the Yukon Department of Health and Social Services provide a broad suite of health and social services to NWT and Yukon residents. The Department of Indigenous Services Canada (ISC) provides eligible Inuvialuit with additional health services not otherwise provided through territorial programs, including prescription medications, medical supplies and equipment, medical health counselling, dental and vision care, and medical transportation (IRC 2019).

The Inuvialuit Regional Corporation provides additional health and wellness initiatives for ISR residents. The Nutrition North program involves community workers hosting cooking sessions and food demonstrations in ISR communities outside of Inuvik (IRC 2019). Related wellness initiatives include programs to reduce diabetes risk, school breakfast programs, and funding for community members to travel to Inuvik to attend a Country Food Processing Methods course (IRC 2019). Supported by Cultural Support Workers located in each ISR community, the Resolution Health Support Program provides mental and emotional support to residential school survivors and their families through a variety of services and programs (IRC 2019). Project Jewel is an on-the-land mental wellness program designed to help participants manage stress, grief, trauma, and emotions (IRC 2019). The IRC also coordinates a number of health and wellness initiatives targeting youth (IRC 2019).

D.4.6.2.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

With the application of health management measures and adherence to applicable GNWT and YG occupational health and safety and public health regulations, residual effects on public health in Scenario 1 are predicted to be neutral to adverse, and of low magnitude, with effects likely higher in consideration of climate change-related effects. Positive benefits could also occur such as increased wage incomes (e.g., wind energy project, tourism development) and the ability to purchase equipment and supplies to support traditional activities and associated travel; such positive effects would help reduce or balance adverse effects. Residual effects would persist indefinitely, but could reverse with positive changes in health behaviours, improvements in food security and other social health determinants. Because public health outcomes result from numerous factors, some of which may be related to scenario activities, and others independent, the prediction and characterization of residual effects is made with low confidence.

CUMULATIVE EFFECTS

As concurrent activities in the region are considered in Scenario 1, the cumulative effects for public health are the same as the residual effects.

D.4.6.3 Scenario 2: Export of Natural Gas and Condensates

D.4.6.3.1 Assessment of Effects of Routine Activities

Description of Effect Pathway

Employment associated with site preparation, installation and operation of the natural gas and condensate export facility would increase average household income within ISR communities, which can have both positive and adverse public health consequences.

ISR communities could be exposed to communicable diseases transmitted by individuals from outside the region who are working in the ISR on a FIFO basis. Non-residents could come into contact with ISR residents at worksites, as well as public places, such as airports, hotels, and restaurants.

Workers on the GBS loading platform and involved in other activities could be exposed to occupational health and safety hazards, including potential exposure to toxic substances, working with heavy equipment, and working in challenging environmental conditions. Health and safety training would help to reduce of work place accidents and could improve health and safety for other work or personal activities.

Although 15-20 km offshore, the site preparation, installation and operation of the GBS, and in particular some ice-breaking activities, could affect access to some harvesting locations, as well as the availability of harvested species, particularly when these industrial activities are in proximity to coastal communities and coastal camps (Sections D.4.4 and D.4.5). Inuvialuit residents may also be concerned about measurable and perceived health effects of a change in quality of traditional foods due to increased industrial activity in the region.

Description of Range of Potential Effects

A number of health effects could be associated with Scenario 2. The export facility would result in training opportunities, and bring jobs and investment into the region, raising average household incomes. Such increased income could have both beneficial and adverse health effects. Increased household income can beneficially increase food security, enable households to improve housing choices, and allow purchase of equipment and supplies to support traditional harvesting and cultural activities and associated travel. However, increased disposable income could also enable adverse health behaviours, such as drug and alcohol consumption.

Increased participation by Inuvialuit in FIFO employment could have adverse effects on family and household stability due to stress associated with prolonged absences. Family and household stability could also be adversely affected by the presence of a transient workforce, though this would occur mainly in Tuktoyaktuk, which would be the staging area for transportation of workers to and from the GBS and Inuvik (the business and administration centre and location of the main airport).

Increased participation in wage employment could also result in less time being available for traditional harvesting, a reduction in traditional foods consumption and increased reliance on less nutritious market foods.

Increased exposure of ISR residents to non-residents could occur at work sites and at public places, and result in higher incidences of communicable infections within the ISR. ISR resident workers exposed to such infections could potentially transmit them back to their home communities.

Vessel and aircraft transits between logistics bases (e.g., Tuktoyaktuk and Summers Harbour) and the GBS loading platform could also directly affect harvested species (see Section D.4.5.3) or interfere with access to harvesting areas (see Section D.4.4.3), contributing to reduced traditional foods harvesting and consumption. Other activities for the export facility may add to these effects, including the site preparation, installation and operation of the GBS and pipelines, and year-round transits by the LNG carriers and condensate tankers.

Effects of Climate Change

Climate change is anticipated to adversely affect traditional harvesting due to changes in access and availability of harvested species (Section D.4.4). These would contribute to a reduction in traditionally harvested foods consumed by ISR households, and increase reliance on market foods, potentially contributing to adverse health effects associated with dietary changes.

D.4.6.3.2 Mitigation and Management

Mitigation and management measures to limit adverse changes in public health associated with Scenario 2 include:

- provide health and counselling services to workers within project work camps, this can include cultural advisers to provide support Inuvialuit employees (this approach is being used for the Mary River Project (Baffinland and QIA 2019).
- provide lifestyle and money management counselling to workers and their families (preferably offered in both Inuvialuktun and English)
- ongoing provision of public education regarding diet and lifestyle (preferably offered in both Inuvialuktun and English)
- project proponents should implement health and medical response plans that would include, but not be limited to: prevention, control, and management of communicable disease outbreaks; provision of medical services and infrastructure; and medical evacuation protocols
- project proponents should develop and implement workplace occupational health and safety plans and procedures in compliance with GNWT and Yukon Occupational Health and Safety Regulations, and other applicable standards
- plan for likely increases in stress and family conflicts associated with employee absences and provide training and/or funding to health service providers so that they can address such demands
- flexible working shifts for Inuvialuit employees, such that participation in culturally-valued traditional and cultural activities can continue

- provide country food in project work camps, including allowing Indigenous employees to bring their own traditional foods to project facilities and camps, and providing appropriate storage and cooking facilities in the project camp to prepare traditional foods for Indigenous workers (e.g., Baffinland and QIA 2019)
- communicate with relevant Inuvialuit communities and representative organizations, through established and/or informal engagement processes, as required and requested
- conduct public consultation in potentially interested communities in the BRSEA Study Area by providing clear, non-technical information and an opportunity for additional mitigation measures to be developed to address public concerns on public health prior to commencement of projects
- schedule project activities based on information acquired from consultation with local residents to limit interference with harvesting or traditional land use activities
- project proponents should inform communities on the timing and location of LNG carrier and condensate tanker movements, as well as ship transits between the service and supply base to the GBS loading platform
- require operators to consult with harvesters about potential effects and mitigation measures to reduce the effect of ice breaking on traditional harvesting and travel over ice
- develop and implement a socio-economic agreement and management plan that contains commitments and actions to address socio-economic impacts, review of project performance, construction and operational monitoring, cumulative effects monitoring and adaptive management
- monitor effects of industrial and other activities on public health, as part of broader socio-economic monitoring, and use information to support decision-making systems for existing mitigation measures, future projects and co-management processes
- health and wellness programs provided by IRC, GNWT, YG and ISC outlined in Section D.4.6.2 would be provided to ISR residents in addition to proponent-provided health medical programs. Mitigation measures to limit adverse effects on traditional harvesting activities (Section D.4.4) and cultural vitality (Section D.4.5) also should be implemented.

D.4.6.3.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Changes in public health associated with Scenario 2 are primarily related to increased average household income within ISR communities; these changes are anticipated to be both positive and adverse, of moderate magnitude, and persist throughout construction, operation, and decommissioning of the natural gas and condensate export facility. Change in public health due to food security and dietary changes may also be both positive and adverse, with adverse effects reduced with successful implementation of public health education programs.

The human health risk associated with site preparation, installation and operation of the natural gas and condensate export facility and related shipping is likely low with successful implementation of mitigation measures to manage environmental discharges (Section 2.5), limit airborne emissions, and avoid accidents or malfunctions. Implementation of workplace occupational health and safety plans and training should reduce the potential of workplace safety incidents requiring medical response. Health and safety training may also influence worker behaviour in other their personal lives or in other work place situations.

Effects are expected to persist for the duration of the development through to decommissioning (i.e., long-term). While some effects may be reversible once development pressures are gone, effects such as adverse personal behaviour could persist unless counselling is effective in altering such behaviour. Because public health outcomes result from numerous factors, some of which may be related to scenario activities, and others independent, the prediction and characterization of residual effects is made with low confidence.

CUMULATIVE EFFECTS

Changes in baseline health indicators described in the Status Quo scenario could compound with effects related to changes in household income and rates of harvesting and consumption of traditional foods described in Scenario 2. Climate change could influence the cumulative effects by reducing on-ice harvesting time. As discussed in Section 7.4.7, climate change may contribute to additional human health risks due to mechanisms that include food spoilage and northward migration of insect and mammal disease vectors.

D.4.6.4 Scenario 3: Large Scale Oil Development within Significant Discovery Licenses on the Continental Shelf

D.4.6.4.1 ASSESSMENT OF EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Effects of Scenario 3 on public health are likely to be can have both positive and adverse consequences, and would be primarily related to changes in employment and household income in ISR communities. Because there would be more employment opportunities in Scenario 3 compared to Scenario 2, it is assumed that there would be more opportunities for Inuvialuit employment, and thus potential effects on average household income would be higher. The footprint of GBS facilities, shipping activities, and re-supply are also similar between Scenario 2, with the exception that the GBS platform in Scenario 3 is approximately 80 km offshore. As a result, it is unlikely that the offshore infrastructure would have a direct effect on traditional harvesting activities and travel, except for vessel and aircraft movements between logistics bases, especially when such movements are proximity to communities and coastal camps. Scenario 3 would pose qualitatively different human health risks compared to Scenario 2 because of differences between oil production and shipping verses natural gas and condensate export (i.e., Scenario 5).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The health effects that could be associated with Scenario 3 are similar to those for Scenario 2. A large oil project would bring jobs and investment into the region, raising average household incomes. This could have beneficial and adverse effects: increased incomes can increase food security, improve housing choices, and enable the purchase of equipment and supplies to support traditional activities and associated travel. Conversely, increased income could enable adverse health behaviours such as drug and alcohol consumption or consumption of processed foods.

Family and household stability could be adversely affected by FIFO employment for Inuvialuit workers and its characteristic extended absences. Increased wage employment could reduce the time available for traditional harvesting, leading to a reduction in traditional foods consumption and an increased reliance on market foods.

Family and household stability could also be adversely affected by the presence of a transient workforce, though this would occur mainly in Tuktoyaktuk, which would be the staging area for transportation of workers to and from the GBS and Inuvik (the business and administration centre and location of the main airport). The increased exposure of ISR residents to non-residents that could occur at work sites and at public places, could result in higher incidences of communicable infections within the ISR. ISR resident workers exposed to such infections could potentially transmit them back to their home communities.

The vessel and aircraft movements between logistics bases could directly interfere with harvesting, contributing to reduced traditional foods consumption. The GBS production platform and tanker movements would be far enough offshore to not directly affect traditional harvesting and travel.

EFFECTS OF CLIMATE CHANGE

Effects of climate change on public health due to routine activities in Scenario 3 are anticipated to be similar to those in Scenario 2.

D.4.6.4.2 MITIGATION AND MANAGEMENT

Mitigation and management measures for Scenario 3 that would limit adverse effects on public health would be similar to Scenario 2, with the addition of the following measures:

Establishment of a safety zone around the GBS to limit collision risk between small craft and vessels, and other threats to human safety (e.g., offloading of goods, noise).

Adherence to and enforcement of regulations and standards for treatment, disposal and handling of waste, including synthetic and oil-based muds, hazardous waste, and solid waste (Section 2.5).

Air emissions from vessels and aircraft would be managed through regular maintenance and fuel type (for vessels). Emissions from the GBS production platform would not affect coastal locations (Section D.2.1).

D.4.6.4.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

With the application of mitigation and management measures, residual effects of Scenario 3 on public health are predicted to be similar to those for Scenario 2. Changes in public health related to increased average household income within ISR communities are anticipated to be both positive and adverse and persist throughout construction, operation, and decommissioning of a large-scale oil development on the continental shelf. Changes in public health due to food security and dietary changes may also be both positive and adverse, with adverse effects reduced with successful implementation of public health education programs. Both effects would be continuous for the life of the project (i.e., long-term). While some effects may be reversible once development pressures are gone, effects such as adverse personal behaviour could persist unless counselling is effective in altering such behaviour.

The risk of communicable disease transmission into the ISR is greater in Scenario 3 compared to Scenario 2 because of the larger workforces involved in development and operation of Scenario 3 facilities. However, exposure by the ISR population to communicable diseases would be limited by having FIFO workers lodged at self-contained accommodations facilities at logistics bases or on the GBS.

Human health risk associated with site preparation, installation and production on the GBS platform is likely a negligible to low effect during routine operations given operating standards and mitigation measures to manage environmental discharges, limit airborne emissions, protect worker safety, and reduce the potential for accidents or malfunctions.

Because public health outcomes result from numerous factors, some of which may be related to scenario activities, and others independent, the prediction and characterization of residual effects is made with low confidence.

CUMULATIVE EFFECTS

Changes in baseline health indicators described in the Status Quo scenario could compound with effects related to changes in household income and rates of harvesting and consumption of traditional foods, described in Scenario 2. Climate change could influence the cumulative effects by reducing on-ice harvesting time. As discussed in Section 7.4.7 climate change may contribute to additional human health risks due to mechanisms that include food spoilage and northward migration of insect and mammal disease vectors.

D.4.6.5 Scenario 4: Large Scale Oil Development within Exploration Licenses on the Continental Slope

D.4.6.5.1 ASSESSMENT OF EFFECTS OF ROUTINE ACTIVITIES

DESCRIPTION OF EFFECT PATHWAY

Effects of Scenario 4 on public health are likely to be can have both positive and adverse consequences, and, as in Scenarios 2 and 3, would be primarily related to changes in household income and FIFO employment. It is assumed that Inuvialuit employment opportunities would be similar among the three scenarios. Because the FPSO used in Scenario 4 would be moored farther offshore (>100 km) than the GBS platforms used in Scenarios 2 (15-20 km) or 3 (~80 km), it is unlikely that activities around the FPSO and drill site would interact with traditional harvesting activities; most harvesting and travel activities take place closer to shore (i.e., within 20 km, Elliot 2019a, 2019b). However, vessel and aircraft movements between logistics bases could overlap with harvesting areas and travel routes, especially when such industry movements are in proximity to communities and coastal camps. Scenario 4 would pose different human health risks compared to Scenario 2 due to the nature of the product (i.e., oil vs. gas and condensate).

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

The public health effects associated with Scenario 4 are similar to those described for Scenarios 2 and 3. An FPSO-based offshore oil project in ISR would raise average household incomes, which could increase food security, improve housing choices, and allow the purchase of equipment and supplies to support traditional activities and associated travel. However, increased disposable income could result in an increase in adverse health behaviours such as drug and alcohol consumption. Family and household stability could be adversely affected by FIFO employment and its characteristic extended absences, and by the presence of a transient workforce (mainly in Tuktoyaktuk, Inuvik and the supply and service bases). Increased wage employment could reduce traditional harvesting, leading to reduced consumption of traditional foods and an increased reliance on market foods, but also could provide benefits through the ability to purchase equipment and supplies to support traditional activities and travel. Flexible work rotations would also help Inuvialuit employees participate in traditional activities. Vessel and aircraft movements between logistics bases (e.g., Tuktoyaktuk and Summers Harbour) and the FPSO and wareship could also directly interfere with traditional activities, particularly when these industry activities are in proximity to communities and coastal camps. These vessel and aircraft activities could also affect the distribution and availability of harvested species to hunters.

There is potential for increased incidence of communicable diseases in the ISR due to the presence of a large non-local workforce. In addition, ISR residents working on the FPSO, drill ship, and at other facilities may be exposed to occupational hazards that could lead to injuries and other adverse health outcomes.

EFFECTS OF CLIMATE CHANGE

The effects of climate change on public health due to Scenario 4 are anticipated to be similar to those described for Scenarios 2 and 3.

D.4.6.5.2 MITIGATION AND MANAGEMENT

Mitigation measures for Scenario 4 to manage public health effects would be similar to those described for Scenarios 2 and 3.

D.4.6.5.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

With the application of mitigation and management measures, residual effects of Scenario 4 on public health are predicted to be a mixture of adverse and positive effects. Changes related to increased average household income within ISR communities are anticipated to be both positive and adverse and persist throughout construction, operation, and decommissioning of the offshore oil development. Change in public health due to food security and dietary changes may also be both positive and adverse, with adverse effects reduced with successful implementation of public health education programs, as well as increased income and education. Both effects would persist for at least the duration of the project (i.e., long-term), and perhaps beyond. While some effects may be reversible once development pressures are gone, effects such as adverse personal behaviours could persist unless counselling is effective in altering such behaviours.

The risk of communicable disease transmission into the ISR is greater in Scenario 4 compared to Scenario 2 because of the larger workforces involved in Scenario 4 activities. However, exposure of the ISR population to communicable diseases would be limited by having FIFO workers lodged at self-contained accommodations facilities either at the logistics base or on the FPSO.

The public health risk associated with construction and routine operation of the FPSO and operation of drilling rigs are likely low given a successful implementation of mitigation measures to prevent environmental discharges, limit airborne emissions, protect worker safety, and avoid accidents or malfunctions.

Because public health outcomes result from numerous factors, some of which may be related to scenario activities, and others independent, the prediction and characterization of residual effects is made with low confidence.

CUMULATIVE EFFECTS

Changes in baseline health indicators described in the Status Quo scenario could compound with effects related to changes in household income and rates of harvesting and consumption of traditional foods, described in Scenario 4. Climate change could influence the cumulative effects by reducing on-ice harvesting time. As discussed in Section 7.4.7 climate change may contribute to additional human health risks due to mechanisms that include food spoilage and northward migration of insect and mammal disease vectors.

D.4.6.6 Scenario 5: Large Oil Release Event

While the Large Oil Release event described here is focused on a subsea or surface release of oil from a production platform (e.g., GBS or FPSO) or a surface spill from an oil tanker, large oil releases could also occur as a result of a collision or accidents with other vessels such as cruise ships, cargo vessels, military vessels or research vessels, as described in Scenario 1. If the fuel tanks for these vessels were compromised, large volumes (i.e., ~ 10,000 cubic metres) of bunker C fuel or diesel could be released. Effects on public health from such an event may differ slightly from what is described below for surface or subsea releases.

D.4.6.6.1 ASSESSMENT OF EFFECTS OF AN OIL SPILL

DESCRIPTION OF EFFECT PATHWAY

A large oil release could result in direct and/or indirect effects on public health. Direct effects could include effects on worker health, demand on medical services, and contamination of traditionally harvested food. Indirect effects include change in employment and associated effects on income, purchase of food and other household items, and stress and anxiety. Effects on harvesting sites and travel routes could also lead to indirect changes in public health by affecting traditional harvesting and other traditional activities.

In the event of a major spill, oil production workers, oil cleanup response workers, and others in the vicinity of the spill could be subject to prolonged exposure to crude oil. Crude oil contains a number of hazardous chemicals, including aromatic hydrocarbons, paraphenol and benzene. Ingestion or inhalation of these compounds can result in a number of acute and chronic human health conditions (D'Andrea and Reddy 2014). However, human health risks to spill responders would be carefully managed through exclusion zones, safe work practices and safety equipment standards for spill response workers. A major oil spill can also have mental health effects due to stress and anxiety from spill-related income loss (D'Andrea and Reddy 2014) and disruption of lifestyle (Ovall 2019).

A large oil spill that results in a temporary or permanent closure of an oil production platform could result in layoffs that would adversely affect the household income of ISR residents employed in the oil industry. However, it is expected that many of these workers would be involved in some fashion in the spill response and cleanup; so layoffs could be small and there is potential that additional personnel from the ISR and elsewhere could be hired to assist with the spill response. An oil spill could also adversely affect other industries, including arctic tourism, which market the pristine environmental qualities within the region to attract visitors.

An oil spill could affect access to harvesting areas, traditionally harvested species and their habitats (Section D.3) due to contaminant concerns or fouling or damage to equipment and gear.

DESCRIPTION OF RANGE OF POTENTIAL EFFECTS

A large oil release within the BRSEA Study Area could have several effects on public health, including effects related to reduction in traditional foods consumption, psychosocial effects over actual or perceived loss of traditional lifestyle values, and socio-economic effects associated with changes in wage incomes and job security.

The nature and degree of public health impacts would depend on the location, type, and season of the oil release. Surface releases occurring during the Fall Transition and Ice seasons would have lower potential for affecting traditionally harvested species because some species would not be present during those times. Ice formation may also assist in containment and removal of oil and cleanup (Table 3-15). By contrast, a spill during the mid- to late Spring Transition and Open Water seasons could increase the magnitude of adverse public health effects due the presence of traditionally-harvested species, the potential for much broader oil spreading, potential for shoreline oiling (and effects on traditional and cultural sites) and difficulty in containment (Table 3-15). A sub-surface release could result in concerns over contamination of harvested traditional foods regardless of season.

Direct effects on public health from exposure to a large oil release are unlikely. If a large release of oil was to occur, one of the first priorities is the evacuation of workers and people from the immediate area of the spill and subsequent closure of the area until the spill has been contained and spill response and cleanup measures addressed potential health issues (e.g., air and water quality meets ambient standards). As noted, spill responders would also follow Safe Work Practices and be required to use safety equipment (e.g., protective clothing, masks and ventilators).

EFFECTS OF CLIMATE CHANGE ON POTENTIAL EFFECTS

An increase in the number of ice-free days and more stormy weather, predicted as a consequence of higher average temperatures with climate change, would increase the probability that an oil release would spread over a larger area and perhaps result in shoreline oiling. This would increase the risk of an oil spill adversely affecting public health, use of traditional and cultural sites (e.g., camps) and traditionally harvested species.

D.4.6.6.2 MITIGATION AND MANAGEMENT

Comprehensive oil spill response planning and capabilities would be developed and implemented prior commencement of oil production and transport (Sections 2.13 and 3.10.5.3).

Producers and shippers of oil would be required to pay for all costs associated with responding to spills, environmental clean-up, and compensation to affected parties, as discussed in Section 2.13.8.

Compensation for impacts of oil spills on harvested species and harvesting activities would help to mitigate losses of traditional foods but would not fully compensate for these losses (e.g., effects on food consumption, personal well-being, cultural and spiritual values).

D.4.6.6.3 EFFECTS CHARACTERIZATION

RESIDUAL EFFECTS

Residual effects of an oil spill on public health would be adverse and vary widely depending on the location, season, and type of spill, as well as effectiveness of oil spill response and the amount of overlap with traditional harvesting activities and areas. A spill occurring within the late Fall Transition, Ice or early Spring Transition seasons could have moderate magnitude effects on public health since many traditionally-harvested species would not be present and ice might aid in containing oil for removal. (Table D-75). However, because of concerns over potential contamination, traditional harvesting may be reduced after a major oil spill, regardless of the season.

A large surface oil release occurring during the Open Water Season could have moderate to high magnitude effect on public health with the magnitude of effect proportional to the amount of oil released, the extent of dispersion, the amount of overlap with traditional activities, whether there was shoreline oil contamination, and the success of containment and clean-up efforts. Surface releases within the Mackenzie River plume during the Open Water Season would likely have the most severe risk due to the potential for adversely affecting coastal and nearshore marine habitats for traditionally important species. Such a large surface release could result in widespread mortality, contamination, and adverse habitat effects on traditionally harvested species, including fish (Section D.3.2.6.3) and beluga wales (Section D.3.5.6.3). A reduction in the availability and quality of such foods could result in households needing to increase consumption of less nutritious market foods.

CUMULATIVE EFFECTS

Depending on its severity, an oil spill could cumulatively interact with other public health effects mechanisms. For example, traditional harvesting activities already affected by other activities and/or oil industry activity could be further affected if an oil spill also interacted with such activities. This could result in a combined reduction in the consumption of traditionally harvested foods and increased consumption of less nutritious store-bought foods.

D.4.6.7 Summary of Residual Effects

Potential residual effects of Scenarios 1 – 4 and a large oil release on the Public Health are summarized in Table D-74 and Table D-75.

Table D-74 Potential Residual Effects of Scenarios 1 – 4 on Public Health for All Seasons[33].

	Scenario 1: Status Quo	Scenario 2: Export of Natural Gas and Condensate	Scenario 3: Oil Development in Mid-Water	Scenario 4 Oil Development in Deep Water
Potential Effects	• Adverse change in public health associated with decline in traditional food consumption/lifestyle	• Adverse change in public health associated with decline in traditional food consumption/lifestyle. • Increased household income could have beneficial (improved food security) and adverse (negative health behaviours) effects. • Shift work could affect family and community stability. • Increased exposure of ISR communities to communicable disease	• Adverse change in public health associated with decline in traditional food consumption/lifestyle. • Increased household income could have beneficial (improved food security) and adverse (negative health behaviours) effects. • Shift work could affect family and community stability. • Increased exposure of ISR communities to communicable disease (greater potential than Scenario 2 due to larger transient workforce)	• Adverse change in public health associated with decline in traditional food consumption/lifestyle. • Increased household income could have beneficial (improved food security) and adverse (negative health behaviours) effects. • Shift work could affect family and community stability. • Increased exposure of ISR communities to communicable disease (greater potential than Scenario 4 due to larger transient workforce)
Legend				
• Least effect – No to minor effect on public health				
• Moderate effect -- Moderate effect on public health				
• High effect -- Major effect on public health				
• Greatest effect – Severe effect on public health				

33 While there could be some differences in public health benefits and adverse effect among seasons for the Status Quo and the three oil and gas development scenarios, there is insufficient information to provide seasonally-specific effects characterizations for public health. Instead, effects characterizations are provided for an annual cycle for the Status Quo and the three oil and gas development scenarios.

Table D-75 Potential Effects of a Large Oil Release Event (Scenario 5) for Public Health

Season	**Platform or** Tanker Spill within the Plume **(surface r**elease)	**Platform Outside the Plume (sub-sea release)**	**Tanker Incident Outside the Plume (surface release)**
Ice	• Spatial extent of oil spill is likely to be contained, and clean-up effective. However, concerns over potential contamination of fish and other marine species may result in reduction in traditional food consumption.	• Moderate magnitude effect due to actual or perceived contamination of fish and other marine species. • Potential human health risk from ingesting contaminated sea food (although health advisories would help reduce this effect).	• Spatial extent of oil spill is likely to be contained, and clean-up effective. However, concerns over potential contamination of fish and other marine species may result in reduction in traditional food consumption.
Spring Transition	• Moderate to high magnitude effect due to actual or perceived contamination of fish, marine mammals and other marine species. Potential human health risk from ingesting contaminated sea food • Stress affecting family and community stability.	• Moderate to high magnitude effect due to actual or perceived contamination of fish, marine mammals and other marine species. Potential human health risk from ingesting contaminated sea food • Stress affecting family and community stability.	• Moderate to high magnitude effect due to actual or perceived contamination of fish, marine mammals and other marine species. Potential human health risk from ingesting contaminated sea food • Stress affecting family and community stability.
Open Water	• High public health effect due to reduced traditional food consumption related to actual or perceived wide-spread contamination of fish, beluga, and other traditionally harvested species. • Stress affecting family and community stability.	• High public health effect due to reduced traditional food consumption related to actual or perceived wide-spread contamination of fish, beluga, and other traditionally harvested species. • Stress affecting family and community stability.	• High public health effect due to reduced traditional food consumption related to actual or perceived wide-spread contamination of fish, beluga, and other traditionally harvested species. • Stress affecting family and community stability.
Fall Transition	• Moderate to high magnitude effect due to actual or perceived contamination of fish, marine mammals and other marine species. Potential human health risk from ingesting contaminated sea food • Stress affecting family and community stability.	• Moderate to high magnitude effect due to actual or perceived contamination of fish, marine mammals and other marine species. Potential human health risk from ingesting contaminated sea food • Stress affecting family and community stability.	• Moderate to high magnitude effect due to actual or perceived contamination of fish, marine mammals and other marine species. Potential human health risk from ingesting contaminated sea food • Stress affecting family and community stability.

Table D-75 Potential Effects of a Large Oil Release Event (Scenario 5) for Public Health

Season	Platform or Tanker Spill within the Plume (surface release)	Platform Outside the Plume (sub-sea release)	Tanker Incident Outside the Plume (surface release)
Longer-term/ Multi-year	• Actual health risk abating over time with reduction in exposure pathway, but concerns over contamination of fish and marine species may persist resulting in long-term reduction in traditional food consumption • Stress affecting family and community stability.	• Actual health risk abating over time with reduction in exposure pathway, but concerns over contamination of fish and marine species may persist resulting in long-term reduction in traditional food consumption • Stress affecting family and community stability.	• Actual health risk abating over time with reduction in exposure pathway, but concerns over contamination of fish and marine species may persist resulting in long-term reduction in traditional food consumption • Stress affecting family and community stability.
Legend			
• Least effect – No to minor effect on public health			
• Moderate effect -- Moderate effect on public health			
• High effect -- Major effect on public health			
• Greatest effect – Severe effect on public health			

D.4.6.8 Gaps and Recommendations

While there is a good level of baseline information on public health conditions in ISR, a comprehensive community health impact assessment would provide a more detailed understanding of linkages between environmental and socio-economic factors and health outcomes and behaviours. The most current population health data within the ISR dates from the 2014 Canadian Community Health Survey and the 2014 NWT community surveys.

The Inuvialuit should lead public health research to obtain more up to date information that reflects the latest trends and developments in population health in ISR communities (e.g., the Inuit Health Survey, the ISR Addictions and Mental Health Study). In addition, prior to the commencement of major industrial development activities in the ISR, the Inuvialuit should lead a region wide community health impact assessment to serve as a baseline for the project assessment and support mitigation and management plans. In addition, the current survey structure and questions should be re-examined to provide a more detailed understanding of linkages between environmental and socio-economic factors and health outcomes and behaviours. Such a study would better inform the development of activity specific mitigation measures.

Project specific socio-economic assessments should include the collection of information related to gender, sexual identity, and other relevant identity factors, to support an assessment of socio-economic impacts on vulnerable population groups that may be disproportionately affected by industrial development.

D.4.6.9 Follow-up and Monitoring

It is recommended that the Inuvialuit lead a region wide community health impact assessment prior to commencement of industrial development activities in the ISR.

APPENDIX E Summary of Residual Effects by Valued Component and Scenario

E.1 Atmospheric Environment

Atmospheric Environment	Residual Effects
Scenario 1	Increases in air contaminant, GHG, noise, and light emissions are expected with increases in vessel traffic and other transportation activities in the BRSEA Study Area. Air contaminant concentrations have been found to increase only slightly in Arctic communities due to marine vessel traffic. Greenhouse gas emissions are likely to increase due to increased vessel traffic, but their contribution to global GHG emissions would be negligible. Noise emissions would be transient and would likely be above background conditions only during piloting into dock. Light emissions are expected to be restricted to safety and navigation only, would be low and short in duration and occur outside of the polar summer. While effects on the Atmospheric Environment are expected to be adverse, potential effects are predicted to be negligible and limited to areas adjacent to the activities, dispersed over the BRSEA study area. Potential effects are expected to be multiple irregular events of short-term duration and reversible in nature. Given that increases in marine vessel traffic are tied to changes in sea ice coverage, the prediction and characterization of residual effects is made with high confidence. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of the Status Quo Scenario to the Atmospheric Environment is predicted to be negligible.
Scenario 2	While effects on the Atmospheric Environment are expected to be adverse, potential effects are predicted to be negligible and limited to areas adjacent to the activities dispersed over the BRSEA study area. Potential effects are expected to be multiple irregular events of short-term duration and reversible in nature. The prediction and characterization of residual effects is made with medium confidence due to the availability of information on emissions and residual effects for similar projects. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 2 to the Atmospheric Environment is predicted to be negligible.
Scenario 3	While emissions are higher than Scenario 2, the majority of the activities leading to increased emissions are far offshore. Effects on air quality, sound, and light from activities on the GBS and wareship are therefore expected to be low. The GHG emissions are expected to be higher than for Scenario 2 but would still represent a negligible change in national GHG emissions. Light emissions from marine vessels and other activities would be similar in magnitude compared to Scenario 2. Light conditions are expected to remain near baseline conditions within about a kilometre of the GBS and wareship, and less for other emissions from marine vessel activities. While effects on the Atmospheric Environment are expected to be adverse and year-round, potential effects are predicted to be negligible to low, limited to areas adjacent to the activities, and reversible. The prediction and characterization of residual effects is made with medium confidence due to availability of emissions and residual effects information for similar projects. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 3 to the Atmospheric Environment is predicted to be negligible.
Scenario 4	While effects on the Atmospheric Environment are expected to be adverse and year-round, potential effects are predicted to be negligible to low and limited to areas adjacent to the activities and reversible. The prediction and characterization of residual effects is made with medium confidence due to the availability of emissions and residual effects information for similar projects. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 4 to the Atmospheric Environment is predicted to be negligible.

Atmospheric Environment	Residual Effects
Scenario 5	The ambient concentrations of VOCs at coastal receptors are expected to be higher for spills on the ocean surface within the area of the Mackenzie River plume than for spills outside the plume, partly because of the shorter distance and partly because of the warmer sea surface temperature. These VOC concentrations may on occasion be above onshore ambient air quality standards for coastal receptors when the spill occurs near shore. For spills outside the area of the Mackenzie River plume and for spills during other seasons, the VOC concentrations are expected to be lower, and not exceeding onshore ambient air quality standards at coastal receptors. The cleanup activities are not expected to cause long-term effects associated with noise or light. Effects on the Atmospheric Environment are expected to be adverse and short-term, low in magnitude, reversible, and local to regional. The prediction and characterization of residual effects is made with medium confidence due to specific circumstances and season in which an oil spill may occur. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 5 to the Atmospheric Environment is predicted to be low.

E.2 Climate and Weather

Since the effects on climate change and weather are not measurable, the assessment involves preparing an order-of-magnitude estimate of GHG emissions and considering the magnitude, intensity, and duration in terms of contribution to regional, territorial, national and global emission totals, and ability to meet regulatory targets, where they exist. These comparisons have been provided as part of the Atmospheric Environment.

E.3 Oceanography

Oceanography	Residual Effects
Scenario 1-4	The effects of activities under Scenarios 1-4 on water quality are expected to be adverse, negligible, local, and multiple irregular events of short-term duration and reversible in nature. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenarios 1-4 to water quality is predicted to be negligible.
Scenario 5	The effects of an oil spill on water quality are expected to be adverse, of moderate magnitude, short to long-term, and regional to extra-regional, but reversible. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenarios 5 to water quality is predicted to be high.

E.4 Sea Ice

Sea Ice	Residual Effects
Scenario 1	Residual effects from single-event icebreaking activities in undisturbed areas from vessel transits are expected to be limited to the presence of a rough, linear path of rubble and broken ice, (i.e., limited to the footprint of the vessel's transited route) and be of low magnitude. The effects of icebreaking would diminish over time (i.e., short-term effects) as the sea ice refreezes and becomes overlain with drifted snowfall (i.e., the effect is naturally reversible). Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 1 to Sea Ice is predicted to be negligible.
Scenario 2	Sea ice properties may be affected in the local vicinity of the GBS in an otherwise undisturbed area (i.e., a low to moderate magnitude effect). When sea ice remains mobile, ice build-up around the structure may create artificial areas of ice deformation (pressure ridges) on the windward side, and areas of reduced ice floe sizes and artificial sea ice lead openings on the leeward side. These effects would be short-term in duration, and reversible. Low magnitude residual effects from multiple-regular icebreaking activities from the LNG carriers, condensate tankers and other vessel transits are expected to be limited to the presence of multiple rough, linear paths of rubble and broken ice, (i.e., limited to the footprint of the vessel's transited route). During the Ice Season, the reversible effects of icebreaking would diminish over time (i.e., short-term effects) as the sea ice refreezes and becomes overlain with drifted snowfall; however, this may be limited in duration if the same vessel track is used for subsequent transits. Changes in sea ice habitat as a result of icebreaking and the presence of industrial development associated with Scenario 2 are predicted to be localized and short to long-term in duration (i.e., single vessel passage versus multiple passages). The effects would be negligible to low in magnitude, except for moderate effects arising from icebreaking activities in land fast ice during the Spring Transition season. Habitat alterations from the presence of artificial sea ice leads is anticipated to potentially occur locally in sea ice leads created by vessel traffic and in the lee of the offshore structure; however, these are expected to of short duration (i.e., days to weeks). Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 2 to Sea Ice is predicted to be negligible.
Scenario 3	Sea ice may experience low-moderate magnitude residual effects in the local vicinity of a GBS associated with Scenario 3. When sea ice remains mobile, ice build-up around the structure may create artificial areas of ice deformation (pressure ridges) on the windward side, and areas of reduced ice floe sizes and artificial sea ice lead openings on the leeward side. These effects are predicted to be localized and short-term in duration (medium-term over the life of the GBS), and reversible. The overall effects from ice breaking would be low in magnitude, with the exception of moderate effects arising from potential icebreaking activities in land fast ice during the mid-late Spring and late Fall Transition seasons, and in the immediate vicinity of the GBS. There may be some low-magnitude adverse effects on the integrity of the sea ice surface as a transportation medium for local travel where icebreaking activities take place; however, these effects are expected to be confined to the footprint of the activity, short-term, and reversible.

Sea Ice	Residual Effects
Scenario 3 (cont'd)	Low magnitude residual effects from multiple-regular icebreaking activities from vessel transits through mobile sea ice are expected to be limited to the presence of multiple rough, linear paths of rubble and broken ice, (i.e., limited to the footprint of the vessel's transited route). The effects of icebreaking would diminish quickly over time (i.e., short-term effects) as the sea ice moves, refreezes and becomes overlain with drifted snowfall; however, this may be limited in duration if the same vessel track is used for subsequent transits. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 3 to Sea Ice is predicted to be low.
Scenario 4	Changes in sea ice as a result of icebreaking and the presence of offshore infrastructure associated with Scenario 4 are predicted to be localized and short or medium-term in duration. The effects would be negligible to low in magnitude, except for moderate effects arising from potential icebreaking activities in land fast ice during the mid-late Spring and late Fall Transition seasons. Sea ice leads are anticipated to potentially be created with the passage of vessel traffic, and in the lee of the offshore facilities, thus local in scope; however, these are expected to be short-term in duration and reversible. There may be some low adverse effects on the integrity of the sea ice surface as a transportation medium where icebreaking or ice management activities take place; however, these are expected to be confined to the footprint of icebreaking activities and be short-term in duration. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 4 to Sea Ice is predicted to be low.
Scenario 5	In the event of a large oil release in the Fall Transition or Ice seasons, quantities of oil may become trapped in brine channels and cavities for the remainder of the Ice Season and may be transported beyond the BRSEA Study Area through natural sea ice motion. Sea ice cover that melts out completely in the following summer would release the trapped oil to the water column, where spill response and recovery measures and natural biodegradation would help reduce oil in the environment. Sea ice floes that do not melt out entirely the following season would likely drain out most of the oil with natural brine channel drainage; however, low concentrations of contaminants would likely remain in the sea ice. None of these dynamics, however, would affect the extent, duration or dynamics of sea ice. The presence of the dark, sooty by-product of burning oil-in-ice would collectively decrease the albedo of the sea ice, particularly as the melt season advances, and in situ burning of oil would induce lateral melting. This could accelerate sea ice melt in the spring or delay freezing in the fall, and thus be an adverse, moderate magnitude, short-term, local to extra-regional effect of short-term duration on sea ice. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition l of Scenario 5 to Sea Ice is predicted to be low.

E.5 Coastal Dynamics and Sea Floor Geology

Coastal Dynamics and Sea Floor Geology	Residual Effects
Scenario 1-4	Although vessel activities associated with Scenario 1 are expected to increase in frequency and seasonal extent over the next 30 years, the effects on coastal stability are largely confined to the Open Water season. The effects from different types of vessel use would be adverse and low magnitude over a local geographic extent at an unknown frequency, perhaps low to moderate, and of short-term durations (hours or less for each vessel transit). With mitigation and management, the residual effects on coastline stability are expected to be negligible to low on local to regional geographic scales. Climate change in the form of lengthening of the Open Water shipping season and, thereby, the numbers of vessel movement events each year, could increase the residual effects. The effects of resuspended sediments and transport of these sediments toward the coastline from offshore wind energy turbines is expected to be negligible after mitigation. Dredging effects on coastal stability and subsea permafrost are expected to be highly localized (i.e., small areas near harbours or bases) and are expected to be negligible to low relative to natural processes along the length of the coastline of the BRSEA Study Area. The effects of dredging on subsea permafrost are also expected to be small. Effects of dredging on coastal stability and subsea permafrost are predicted to be negligible to low. In Scenario 2, the residual effects of subsea pipelines on the subsea permafrost conditions would occur over a small total area 15-20 ha; width of < 0.01 km over a length of 15-20 km). With suitable engineering design applied to mitigating the temperature differences and resulting heat or cold flux into the seafloor, the residual effects would be negligible. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 1-4 to Coastal Dynamics and Sea Floor Geology is predicted to be negligible.
Scenario 5	The residual effects of oil spills on coastal stability would be largely confined to the Open Water, the late Spring and early Fall Transition seasons. These effects would be adverse, but highly variable in magnitude and spatial extent depending on the amount and type of oil to be cleaned up and the location of the oil release relative to the coastline and sensitive sites. The magnitude of the effects on coastal stability could range from negligible to moderate with the effects confined to a local or small regional portion of the coastline. The frequency of occurrence of coastal stability effects is commensurate with the frequency of occurrence of a large oil spill, which is a low probability event. If an effect on coastal stability were to occur, it would likely be long-term or permanent. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 5 to Coastal Dynamics and Sea Floor Geology is predicted to be moderate.

E.6 Coastal Habitat

Coastal Habitat	Residual Effects
Scenario 1	Although effects to coastal habitat in Scenario 1 are expected to increase in frequency and seasonal extent over the next 30 years, potential effects are expected to be multiple irregular events of short-term duration, reversible in nature and negligible in magnitude. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 1 to Coastal Habitat is predicted to be negligible.
Scenario 2	Effects to Coastal Habitat in Scenario 2 are expected to increase in frequency and seasonal extent over the next 30 years. There would be an additional adverse effect from increased infrastructure development and vessel traffic; but effects are anticipated to be local, short to long-term, and low to negligible in magnitude. Vessel wake erosion is anticipated to be minimal, local multiple irregular events of short-term duration that can be mitigated with speed limits. Seabed disturbance is also anticipated to be limited to the areas where coastal infrastructure is constructed, i.e. to the footprint of the activity. Environmental protection plans and other mitigation measures (e.g., silt curtains) can be used to reduce effects on Coastal Habitat. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 2 to Coastal Habitat is predicted to be negligible.
Scenario 3	Effects to Coastal Habitat in Scenario 3 are expected to be similar to Scenario 1. There would be an additional adverse effect from increased vessel traffic. These effects are anticipated to be localized and mitigated with vessel speed limits and habitat buffers. No residual effects are anticipated from seabed disturbance. Given the combination of potential magnitude, and spatial and temporal extent, the residual effect condition of Scenario 3 to Coastal Habitat is predicted to be negligible.
Scenario 4	Potential effects, effects of climate change, mitigation measures, and cumulative effects for Scenario 4 on Coastal Habitat are anticipated to be the same as those described for Scenario 3. As such, the residual effect condition of Scenario 4 to Coastal Habitat is predicted to be negligible.
Scenario 5	Residual effects of oil spills on the Coastal Habitat are anticipated to be regional and long term in duration. The magnitude of effects varies depending on release size, type of oil, the season and location of the spill, and site-specific ocean and weather conditions. A large oil spill that directly contacts shorelines and associated coastal habitats is likely to result in high adverse effects on coastal habitats and the species and people that use these habitats. Impacts on habitat structure and function are predicted to be long-term, depending on the effectiveness of the spill response. Given the combination of potential magnitude, and spatial and temporal extent, the residual effects conditions of Scenario 5 to Coastal Habitat is predicted to be high.

E.7 Marine Lower Trophic Levels

Marine Lower Trophic Levels	Residual Effects
Scenario 1	Potential residual adverse effects of seabed disturbances and routine discharges on lower marine trophic level indicators are expected to be low magnitude, limited to the immediate footprint of the activity, and occur as multiple irregular events with medium-term duration. Potential effects are expected to be reversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 to Marine Lower Trophic Levels is predicted to be negligible.
Scenario 2	Potential residual adverse effects of seabed disturbances, routine discharges and artificial light on lower marine trophic level indicators are expected to be low magnitude, limited to the immediate footprint of the activity, and occur as continuous events with medium-term duration. Potential effects are expected to be reversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 2 to Marine Lower Trophic Levels is predicted to be negligible.
Scenario 3	Potential residual adverse effects of seabed disturbances, routine discharges and artificial light on lower marine trophic level indicators are expected to be low magnitude, limited to the GBS footprint and near-field areas, and occur continuously with medium-term duration. Potential effects are expected to be reversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 3 to Marine Lower Trophic Levels is predicted to be negligible.
Scenario 4	Given the frequency of vessel activity required for operations support and transport of oil, and the larger geographic extent of benthic habitat disturbance, potential residual adverse effects from seabed disturbances on lower marine trophic level indicators are expected to be low - moderate magnitude. Residual effects would be limited to local area around the footprint. Residual effects would occur continuously with medium-term duration and are anticipated to be reversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 4 to Marine Lower Trophic Levels is predicted to be low.
Scenario 5	Potential residual adverse effects from an oil spill on the lower marine trophic level are expected to be moderate to high magnitude, regional to extra-regional (given the potential spread of an oil slick along the coastline) and occur as a single event over a long-term to permanent duration. Most potential effects would be reversible (e.g., photosynthesis rates and plankton abundance and species composition), while others may be irreversible (e.g., damaged or altered shoreline habitats. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 5 to Marine Lower Trophic Levels is predicted to be high.

E.8 Marine Fish and Habitat

Marine Fish and Habitat	Residual Effects
Scenario 1	Interaction of activities associated with Scenario 1 with Marine Fish and Habitat is anticipated to be limited. The loss of seabed fish and fish habitat due to offshore wind farm(s) would be small, given broad distribution and general dominance of clay, silt and sand habitat throughout the region. Residual effects are predicted to be adverse, but low in magnitude, with multiple irregular events restricted to the immediate vicinity of the activity (i.e., local), and reversible. As similar activities have occurred in the BRSEA Study Area (e.g., construction of artificial islands, installation of offshore platforms) and elsewhere, the effects are well understood and the confidence in this prediction is high. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 to Marine Fish and Habitat is predicted to be negligible.
Scenario 2	Potential effects of site preparation activities (e.g., suction dredging, trenching), although adverse, would be temporary and reversible and are similar to natural disturbances caused by ice-scour and sediment precipitation from the Mackenzie River plume, although areas that have been denuded via dredging or disposal of large volumes of sediments (i.e., > 50 cm thickness) may display community level differences for up to a decade as the benthos recovers naturally. While this effect is adverse, benthic habitat is widely available throughout the Mackenzie estuary and the continental shelf. The magnitude of the effect is predicted be low during site preparation and negligible after the trench is infilled. Residual effects of disturbance would be medium term, localized to the site preparation area and reversible. Once the GBS loading facility is placed on the seabed, it would result in a long-term loss of 2 ha of fish habitat until decommissioning. With adherence to regulations under the Fisheries Act (e.g., habitat compensation in another area), no net loss of fish habitat would occur. Recovery of habitat within the affected footprint would be expected to occur within a period of one to 10 years. Since similar habitat is widely available, and physical disturbances to the seabed would be akin to natural disturbances caused by ice scour, the magnitude of residual effects from habitat loss is predicted to be negligible in magnitude, long-term, reversible and limited to the footprint. Effects of transiting through the kelp bed to and from Summers Harbour are difficult to assess since there no data on the use of the kelp bed by fish. If the kelp bed cannot safely be avoided, a residual effect could occur; however, the scale of this effect is unknown and dependent on the area of the kelp bed which may is disturbed. Overall, potential residual effects of habitat disturbance and habitat loss are predicted to be adverse, but negligible or low in magnitude. Residual effects would be limited to the footprint of the activity with multiple irregular events over medium-term duration Prediction confidence is high for effects of site preparation and infrastructure installation, but low for cropping of the kelp bed. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 2 to Marine Fish and Habitat is predicted to be negligible.

Marine Fish and Habitat	Residual Effects
Scenario 3	Seabed habitat anticipated to be lost or altered is not a limiting factor and is widely available in the region. With adherence to regulations under the Fisheries Act (e.g., habitat compensation in another area), no net loss of fish habitat would occur. The magnitude of residual effects is predicted to be low, limited to the footprint, long-term and reversible. Residual effects of underwater noise associated with seismic exploration are anticipated to be adverse and of low to moderate magnitude depending on the species, life stage and proximity to the noise source. Effects would be local, restricted to the immediate area of those activities, and be continuous for the duration of the survey. Effects are expected to be reversible in the short term (hours to days) following cessation of the noise source. Effects of transiting through the kelp bed to and from Summers Harbour are difficult to assess since there no data on the use of the kelp bed by fish. If the kelp bed cannot safely be avoided, a residual effect could occur; however, the scale of this effect is unknown and dependent on the area of the kelp bed which may is disturbed. Overall, potential residual effects on Marine Fish and Habitat are predicted to be adverse, but low to moderate in magnitude. Residual effects would be limited to the local area, continuous in frequency over short to long-term duration. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 3 to Marine Fish and Habitat is predicted to be low. Prediction confidence is moderate for the GBS facility and seismic survey but low for ice-breaking potential effects and cropping of the kelp bed since the knowledge level is poor for these last two effects.
Scenario 4	Fish habitat is widely available within the BRSEA study area and with adherence to regulations under the Fisheries Act (e.g., habitat compensation in another area), no net loss of fish habitat would occur. Residual effects are predicted to be adverse but negligible to low in magnitude and limited to the immediate area of the footprint for site preparation for drilling and infrastructure (and an area of sediment deposition around each site). Potential effects would be continuous in frequency over a medium term of duration (i.e., several Open Water seasons), and reversible through natural recolonization of benthos into affected habitat. Residual effects of underwater noise associated with the 3D seismic exploration are anticipated to be adverse and of low to moderate magnitude depending on the species, life stage and proximity to the noise source. Effects would be local, restricted to the immediate area of those activities, and be continuous for the duration of the survey. Confidence in these predictions is moderate given limited understanding of benthos recovery to physical disturbance or Arctic kelp ecology. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 4 to Marine Fish and Habitat is predicted to be low.
Scenario 5	Potential residual adverse effects on fish and fish habitat from a large oil release event are expected to be moderate to high magnitude and regional to extra-regional (given the potential spread of an oil slick along the coastline). It would be a single event and depending on the type and volume of oil, its geographic extent and trajectory, effects on nearshore and coastal habitats for fish, natural weathering, and the effectiveness of spill response measures, the duration of effects could range from several years to long-term. With continued spill response, shoreline cleanup measures and habitat restoration, potential effects would reversible, but effects would be long-term (fish health and population dynamics). Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 5 to Marine Fish and Habitat is predicted to be high.

E.9 Migratory Birds

Migratory Birds	Residual Effects
Scenario 1	Potential effects on migratory bird behaviour and mortality risk are expected to be adverse. However, with application of mitigation and planning measures to maintain aircraft above minimum altitudes, avoidance of important bird nesting and staging habitat during sensitive periods, and use of seasonal and designated shipping routes, potential effects are predicted to be low in magnitude and limited to the local area. Potential effects would be multiple irregular events with short-term duration and reversible in nature. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 to Migratory Birds is predicted to be negligible.
Scenario 2	Potential effects on migratory bird behaviour and mortality risk are expected to be adverse. However, with application of mitigation and planning measures (e.g. maintain aircraft above minimum altitudes wherever possible when flying over important bird nesting and staging habitat, and using seasonal and designated shipping routes), potential residual effects are not anticipated to affect the long-term sustainability of migratory bird populations in the region. Changes in behaviour of migratory birds (i.e. due to habitat alteration from aircraft and vessel traffic and the presence of platforms [sensory disturbance and artificial lighting effects]) and changes in mortality risk (i.e., due to collisions with infrastructure or vessels due to artificial lighting) are predicted to be low in magnitude, limited to the local area and would range from short to medium term. Effects are anticipated to be multiple irregular events and are expected to be reversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 2 to Migratory Birds is predicted to be negligible.
Scenario 3	Potential effects on migratory bird behaviour and mortality risk are expected to be adverse. However, with application of mitigation and planning measures to maintain aircraft above minimum altitudes, avoidance of important bird nesting and staging habitat by aircraft, and use of seasonal and designated shipping routes, potential residual effects are not anticipated to affect the long-term sustainability of migratory bird populations in the region. Potential changes in behaviour of migratory birds as a result of habitat alterations from aircraft and vessel traffic (including icebreakers) and changes in mortality risk (i.e., due to collisions with infrastructure or vessels due to artificial lighting) are predicted to be low in magnitude. Sensory disturbance due to offshore drilling and production activities are predicted to only affect loon species, primarily during migration and effects of light on birds would only be during the Spring Transition season (i.e., when birds are arriving) or late Open Water season when twilight occurs. Few to no migratory birds would be present during Fall Transition and Ice seasons. Effects are anticipated to be limited to the local area with multiple and irregular frequency. Potential effects are predicted to range from short- (e.g., seismic vessels, vessel transits, aircraft) to long-term (presence of the GBS and wareship, production activities and decommissioning) in duration and reversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 3 to Migratory Birds is predicted to be low.

Migratory Birds	Residual Effects
Scenario 4	Potential effects on migratory bird behaviour and mortality risk are expected to be adverse. However, with application of mitigation and planning measures to maintain aircraft above minimum altitudes, avoidance of important bird nesting and staging habitat by aircraft, and use of seasonal and designated shipping routes, potential residual effects may change baseline conditions but are not anticipated to affect the long-term sustainability of migratory bird populations in the region. Potential changes in behaviour of Migratory Birds as a result of habitat alterations from aircraft and vessel traffic (including icebreakers) and changes in mortality risk (i.e., due to collisions with infrastructure or vessels due to artificial lighting) are predicted to be low in magnitude. Sensory disturbance due to offshore drilling and production activities are predicted to only affect loon species, primarily during migration and effects of light on birds would only be during the Spring Transition season (i.e., when birds are arriving) or late Open Water season when twilight occurs. Few to no Migratory Birds would be present during Fall Transition and Ice seasons. Effects are anticipated to be limited to the local area with multiple and irregular frequency. Potential effects are predicted to range from short- (e.g., seismic vessels, vessel transits, aircraft) to long-term (presence of the GBS and wareship, production activities and decommissioning) in duration and reversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 4 to Migratory Birds is predicted to be low.
Scenario 5	Potential residual effects of oil spills on birds could be highly adverse and, in an extreme event, the viability of local or regional migratory bird populations could be affected. The extent of potential effects would depend on the volume of oil spilled, spill response mobilization time, effectiveness of containment measures, and ecological, environmental, and oceanographic conditions, as well as the extent of temporal and spatial overlap between the spill and use of key habitats by birds. Potential effects could be high magnitude and range from local to extra-regional in geographic extent. Given that oil spills are considered an accident or malfunction, they are predicted to be irregular in occurrence, but residual effects could persist from short-term to long-term in duration. Residual effects on migratory bird populations are anticipated to be reversible. Regardless of the timing (season) and location of a spill, there is the potential for oil to be transported to coastlines that are used by migratory birds during the Spring Transition and Open Water seasons. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 5 to Migratory Birds is predicted to be high.

E.10 Seabirds

Seabirds	Residual Effects
Scenario 1	Residual effects on seabird behaviour, health and risk of mortality are expected to be adverse. With the application of appropriate mitigation measures (e.g. avoidance of nesting colonies, additional spatial and temporal avoidance of sensitive and important habitat, use of minimum aircraft altitudes, use of shipping routes to avoid sensitive areas and seasonal periods, wildlife monitors), potential effects associated with habitat disturbance (air and underwater noise, artificial lights, physical displacement) are anticipated to be low – moderate in magnitude and limited to the local area around an activity. Potential effects are predicted to be multiple and irregular in frequency, dispersed over a wide area, short-term in duration and reversible (i.e., within hours to a day of passage). Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 to Seabirds is predicted to be negligible.
Scenario 2	Residual effects on seabird behaviour, health and risk of mortality are expected to be adverse. With the application of appropriate mitigation measures (e.g. avoidance of nesting colonies, additional spatial and temporal avoidance of sensitive and important habitat, use of minimum aircraft altitudes, use of shipping routes to avoid sensitive areas and seasonal periods, wildlife monitors), potential effects associated with habitat disturbance (air and underwater noise, artificial lights, physical displacement) are anticipated to be low – moderate in magnitude and limited to the local area around an activity. Potential effects are predicted to be multiple and irregular in frequency, dispersed over a wide area, short-term in duration and reversible (i.e., within hours to a day of passage). Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 2 to Seabirds is predicted to be negligible.
Scenario 3	Residual effects on seabird behaviour, health and risk of mortality are expected to be adverse. With the application of appropriate mitigation measures (e.g. avoidance of nesting colonies, additional spatial and temporal avoidance of sensitive and important habitat, use of minimum aircraft altitudes, use of shipping routes to avoid sensitive areas and seasonal periods, wildlife monitors), potential effects associated with habitat disturbance (air and underwater noise, artificial lights, physical displacement) are anticipated to be low – moderate in magnitude and limited to the local area around an activity. Potential effects are predicted to be multiple and irregular in frequency, dispersed over a wide area, short to long-term in duration and reversible (i.e., within hours to a day of passage). Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 3 to Seabirds is predicted to be low.
Scenario 4	Residual effects on seabird behaviour, health and risk of mortality are expected to be adverse. With the application of appropriate mitigation measures (e.g. avoidance of nesting colonies, additional spatial and temporal avoidance of sensitive and important habitat, use of minimum aircraft altitudes, use of shipping routes to avoid sensitive areas and seasonal periods, wildlife monitors), potential effects associated with habitat disturbance (air and underwater noise, artificial lights, physical displacement) are anticipated to be low – moderate in magnitude and limited to the local area around an activity. Potential effects are predicted to be multiple and irregular in frequency, dispersed over a wide area, short to long-term in duration and reversible (i.e., within hours to a day of passage). Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 4 to Seabirds is predicted to be low.

Seabirds	Residual Effects
Scenario 5	Potential residual effects of oil spills on birds could be highly adverse and, in an extreme event, the viability of seabird populations could be affected. The extent of potential effects would depend on the volume of oil spilled, spill response mobilization time, effectiveness of containment measures, and ecological, environmental, and oceanographic conditions, as well as the extent of temporal and spatial overlap between the spill and use of key habitats by birds. Potential effects could be high magnitude and range from local to extra-regional in geographic extent. Given that oil spills are considered an accident or malfunction, they are predicted to be irregular in occurrence, but residual effects could persist from short-term to long-term in duration. Residual effects on migratory bird populations are anticipated to be reversible. Regardless of the timing (season) and location of a spill, there is the potential for oil to be transported to coastlines that are used by migratory birds during the Spring Transition and Open Water seasons. In the event of an oil spill, seabird populations may not be able to recover from extensive adult mortality, which could affect their viability at local and regional scales. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 5 to Seabirds is predicted to be high.

E.11 Marine Mammals

Marine Mammals	Residual Effects
Scenario 1	While effects on Marine Mammals are expected to be adverse, potential residual effects are predicted to be low – moderate in magnitude, limited to the local area around the activity and dispersed. Potential effects would be multiple irregular events with short-term duration and reversible in nature. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 to Marine Mammals is predicted to be negligible.
Scenario 2	Potential effects of icebreaking and the presence of the GBS platform would result in habitat alterations for seals that would change baseline conditions but are not anticipated to affect the viability of seal populations in the region. While effects on Marine Mammals are expected to be adverse, potential effects are predicted to be low – moderate in magnitude and limited to the local area around the activity. Potential effects of sensory disturbance would be multiple regular events, often well dispersed across the BRSEA study area, with short-term duration and reversible in nature. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 2 to Marine Mammals is predicted to be negligible.
Scenario 3	Potential effects of icebreaking and presence of the GBS platform on seals are expected to be adverse with low magnitude since habitat alterations would change baseline conditions but are not anticipated to affect the viability of seal populations in the region. Increased tracts created by icebreakers may result in altered movement of whales and potentially increased potential for mortality if they become trapped in ice. The extent of potential effects of habitat alteration is expected to be limited to the local area around the development and along shipping routes. Potential effects would be multiple irregular events of medium-term duration and reversible in nature.

Marine Mammals	Residual Effects
Scenario 3 (cont'd)	Adverse effects of underwater noise would extend to the regional area, given the nature of the distances that underwater noise is known to travel and affect marine mammal behaviour. Potential effects are predicted to be low in magnitude, altering baseline conditions but not affecting the long-term resiliency or viability of marine mammal populations. Potential effects would be multiple regular events of medium-term duration and reversible in nature. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 3 to Marine Mammals is predicted to be low.
Scenario 4	Potential residual effects of activities associated with Scenario 4 (e.g., seismic survey, installation of FPSO and wareships, drilling, ice-breaking and shipping) are anticipated to be similar to what was described for Scenario 3, but further offshore over the continental slope (i.e., >100 km offshore versus 80 km offshore). Potential effects on seals are anticipated to be similar for Scenario 3 and 4 since seals are widely distributed throughout the BRSEA Study Area, and closely associated with the sea ice. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 4 to Marine Mammals is predicted to be low.
Scenario 5	Potential effects of an oil spill would be adverse and, depending on severity, population viability could be affected, resulting in moderate to high magnitude effects. Fur bearing mammals (i.e. seals) are expected to be more vulnerable to effects of oil than whales. Residual effects on Marine Mammals are expected to be regional or extra-regional in extent and long-term in duration. The probability of a spill occurring is very low; therefore, it is characterized as a single event. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 5 to Marine Mammals is predicted to be high.

E.12 Polar Bear

Polar Bear	Residual Effects
Scenario 1	While effects on Polar Bear are expected to be adverse, potential effects are predicted to be negligible in magnitude and limited to the footprint of the activity. Potential effects would be multiple irregular events with short-term duration, dispersed over the BRSEA study area, and reversible in nature. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 to Polar Bears is predicted to be negligible.
Scenario 2	Potential effects on Polar Bear are expected to be adverse with low magnitude. The extent of potential effects is expected to be limited to the local area around the development. Potential effects would be multiple regular events with medium-term duration and reversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 2 to Polar Bears is predicted to be negligible.

Polar Bear	Residual Effects
Scenario 3	Mitigation measures should include identification of maternal denning areas and reducing the risk of human bear conflict around the GBS; these measures are expected to reduce the frequency and magnitude of potential effects on behaviour and mortality risk. Potential effects on Polar Bear are expected to be adverse and low magnitude. The extent of potential effects is expected to be limited to the local area around the development and along shipping routes. Potential effects would be multiple regular events with medium-term duration and reversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 3 to Polar Bears is predicted to be negligible.
Scenario 4	Residual effects and the potential influence of climate change on the prediction of residual effects are anticipated to be similar to those described for Scenario 3. Residual effects associated with the transit of vessels through the Northwest Passage and Amundsen-Queen Maude Gulf during the Open Water Season is anticipated to be similar to what was described in Scenario 3. Potential effects are expected to be adverse and low magnitude since habitat alteration could change baseline conditions but is not expected to affect the long-term sustainability of the population. The extent of potential effects is expected to be limited to the local area around the development and along shipping routes. Potential effects would be multiple regular events with medium-term duration and reversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 4 to Polar Bears is predicted to be negligible.
Scenario 5	Potential residual effect of an oil spill on Polar Bear are adverse and could be moderate to high in magnitude depending on timing and location and may affect the long-term sustainability of polar bear populations in the region. A spill that occurs during the Ice or transitional seasons could result in effects on polar bear that are regional in extent and medium to long term. Given that oil spills are considered an accident or malfunction, they are predicted to be irregular in occurrence. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 5 to Polar Bears is predicted to be high.

E.13 Caribou

Caribou	Residual Effects
Scenario 1	There is limited potential for offshore activities to affect migratory barren-ground caribou, Peary caribou or the Dolphin and Union caribou population. As such, no residual effects are expected on Caribou (e.g., use of coastal habitats) from activities associated with Scenario 1.
Scenario 2	No residual effects on Caribou are predicted from activities outlined in Scenario 2.
Scenario 3	No residual effects on Caribou (e.g., use of coastal habitats) are predicted from activities outlined in Scenario 3.
Scenario 4	No residual effects on Caribou (e.g., use of coastal habitats) are predicted from activities outlined in Scenario 4.

Caribou	Residual Effects
Scenario 5	Given that oil spills are considered an accident or malfunction, they are predicted to be irregular in occurrence. While effects of an oil spill would be adverse, based on the effect pathways, it is unlikely that the viability of caribou herds would be affected by an offshore spill. The extent of these effects would depend on the volume of oil spilled, spill response mobilization time, effectiveness of containment measures, and ecological, environmental, and oceanographic conditions, as well as the extent of temporal and spatial overlap between the spill and use of coastlines by caribou. Should an interaction occur, potential residual effects on Caribou would be adverse and could be low to moderate in magnitude depending on timing and location. A spill that occurs during the calving season could result in effects on Caribou that are localized in extent and medium to long term. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition to Caribou is predicted to be low.

E.14 Economy

Economy	Residual Effects
Scenario 1	The Status Quo scenario is predicted to have a low to moderate magnitude positive effect on the regional economy and labour force within the ISR. This scenario results in limited additional capital investment within ISR communities. While there is predicted to be an increase in employment and economic opportunities associated with tourism, such activities would be infrequent, of short duration, and only experienced by coastal ISR communities. The construction of the wind energy facility would result in a short term and moderate increase in construction related employment (estimated at ~50 persons), with ten or less additional permanent jobs created for operations and maintenance. Assuming that the wind energy project lowers energy costs within communities that it supplies, this could result in a reduction in the average cost of living within those communities, creating a regional, long-term economic benefit. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 on the Economy is predicted to be positive and moderate. Absent specific information on scenario procurement and hiring, the prediction and characterization of residual effects is made with medium confidence.
Scenario 2	Activities associated with Scenario 2 are predicted to have a moderate to high magnitude positive effect on the economy within the ISR over the long-term. With application of effects management measures, such effects should extend throughout the ISR and to communities elsewhere in NWT and Yukon. Current negotiations and agreement on off-shore and self-government revenue sharing would help to clarify future economic benefits. With decommissioning and closure of the facility, beneficial effects related to capital inflows and direct project employment would cease. However, ISR, NWT and Yukon should continue to benefit economically from the retention of royalty and tax revenue earned throughout the operations period. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 2 on the Economy is predicted to be positive and high. Previous oil and gas development in the BRSEA Study Area was linked to a positive increase in GDP and local employment (Appendix D: Section D.4.1.1.5). However, absent specific information on project procurement and hiring, the prediction and characterization of residual effects is made with medium confidence.

Economy	Residual Effects
Scenario 3	Activities associated with Scenario 3 are predicted to have a high magnitude positive effect on the economy within the ISR. With application of effects management measures, such effects should extend throughout the ISR and to communities elsewhere in NWT and Yukon. Current negotiations and agreement on off-shore and self-government revenue sharing would help to clarify future economic benefits. The beneficial effects related to capital inflows and direct project employment would cease with decommissioning and closure of the offshore oil production facility. The ISR, NWT and Yukon should continue to benefit economically from the retention of royalty and tax revenue earned throughout the operations period. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 3 on the Economy is predicted to be positive and high. Previous oil and gas development in the Beaufort region was linked with a positive increase in GDP and local employment. However, absent specific information on project procurement and hiring, the prediction and characterization of residual effects is made with medium confidence.
Scenario 4	Activities associated with Scenario 4 are predicted to have a high magnitude positive economic effect on NWT and Yukon in general, and the ISR in particular, including benefits from capital inflows associated with site preparation and installation activities, increased GDP, increased employed, increased government revenue associated with taxation of corporate and personal income, and resource royalties sharing. Current negotiations and agreement on off-shore and self-government revenue sharing would help to clarify future economic benefits. However, absent specific information on project procurement and hiring, the prediction and characterization of residual effects and benefits is made with medium confidence. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 4 on the Economy is predicted to be positive and high.
Scenario 5	Overall effects of a large oil release event on the Economy are predicted to be adverse, moderate to high in magnitude with effects at a regional and intra-regional level. Effects on the Economy would be continuous and persist for the moderate- to long-term (i.e., effects would persist through the spill response and clean-up, as well as the recovery period for the physical, biological, and human systems). With recovery of the environment and human uses, as well as resumption of the offshore hydrocarbon development (or shipping). effects would reversible.

E.15 Demographics

Demographics	Residual Effects
Scenario 1	The new jobs created under Scenario 1 and implementation of management plans to counter population decline, outlined in Appendix D: Section D.4.2.2.2, may slow population decline in the ISR. However, under Scenario 1, the population within the region is predicted to continue to decline, and residual adverse effects on Demographics are expected to be neutral to negative in direction, low magnitude, regional, continuous, and long-term. Coastal erosion associated with climate-change could result in shifts in residents within the ISR (e.g., people moving away from coastal to inland communities such as Inuvik) or ISR residents moving from the region; both have a potential to adversely affect Demographics. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 to Demographics is predicted to be negligible (i.e., Scenario 1 may temporarily affect a decline in the ISR, but other factors would continue to have a greater effects on the decline over the long-term).
Scenario 2	Residual effects of Scenario 2 on Demographics are expected to be positive, continuous, long-term, and of low to moderate magnitude, with higher magnitude effects occurring during construction associated with the influx of the FIFO workforce. There is predicted to be a smaller permanent population increase in the ISR during operations, which would be present over the life of the project, and reversible upon decommissioning. During site preparation and installation of infrastructure, most population effects would occur during the Open Water seasons. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 2 to Demographics is predicted to be positive and low. As long as climate change does not affect the viability of the offshore export facility it would not substantially affect Demographics in the ISR. Previous oil and gas development in the BRSEA Study Area has demonstrated that the majority of workers for oil and gas projects would come from outside the ISR (Appendix D: Section D.4.1.1.5). However, absent specific information on worker requirements, hiring, and the extent of Inuvialuit participation in project employment for the scenarios, the prediction and characterization of residual effects is made with medium confidence.
Scenario 3	As in the case of Scenario 2, with the implementation of plans to encourage hiring of ISR residents, Inuvialuit may remain in their home communities, and inter-regional migration to Tuktoyaktuk and Inuvik might be limited. Employment opportunities, in addition to current initiatives by government and Inuvialuit to increase education and skills may encourage some previous ISR residents to return, reducing or reversing net out-migration from most ISR communities. Any in-migration of non-Inuvialuit to the region would be consistent with GNWT's objectives of stimulating population and economic growth. Residual effects of Scenario 3 on Demographics are considered to be positive, moderate magnitude, long-term and reversible. During site preparation and installation, most population effects would occur during the Open Water seasons. Operations related population effects would occur throughout the year. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 3 to Demographics is predicted to be positive and moderate. Previous oil and gas development in the BRSEA Study Area showed that the majority of workers for oil and gas projects would come from outside the ISR region (Appendix D: Section D.4.1.1.5). However, absent specific information on worker requirements and hiring, the prediction and characterization of residual effects is made with medium confidence.

Demographics	Residual Effects
Scenario 4	The residual effects of Scenario 4 on Demographics are similar to Scenario 3. Residual effects on Demographics are considered to be positive, moderate magnitude, long-term and reversible. During site preparation and installation, most population effects would occur during the Open Water seasons. Operations related population effects would occur throughout the year. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 4 to Demographics is predicted to be positive and moderate. Previous oil and gas development in the BRSEA Study Area showed that the majority of workers for oil and gas projects would come from outside the ISR region (Appendix D: Section D.4.1.1.5). However, absent specific information on worker requirements and hiring, the prediction and characterization of residual effects is made with medium confidence.
Scenario 5	A spill response for a large oil release would require mobilization of large numbers of non-resident FIFO personnel to manage and conduct the spill response and clean-up activities; this would result in a short-term increase in the ISR population. Ongoing cleanup and restoration would require a smaller workforce, likely drawn mainly from ISR residents, and supplemented by non-resident FIFO personnel. However, a large oil spill that results in severe environmental contamination and shoreline fouling could have a moderate to high long-term adverse effect on Demographics within the ISR, particularly if residents were to leave the region as a result of real or perceived degradation of lifestyle and reduced food security. Given the mix of adverse effects (i.e., possible long-term declines in the regional population) and positive benefits (i.e., short to medium-term increases in the regional population), the residual effect condition of a large oil release event on Demographics is predicted to be adverse and moderate.

E.16 Infrastructure

Infrastructure	Residual Effects
Scenario 1	Scenario 1 activities would result in only a small, short-term increase in population, primarily related to the construction of the renewable energy project. The movement of personnel, materials, and equipment associated with this project would require the use of transportation infrastructure within the ISR. However, by lodging crew in self-contained accommodations, the temporary population change occurring as a result of construction activities would have minimal, short-term adverse effects on Infrastructure within the ISR. The operation of the renewable energy facility would involve a permanent crew. It is possible that such individuals would be hired from within the ISR, resulting in no population change. If the operations workforce is from outside the ISR, because of the low number of additional persons, the effect on Infrastructure would be negligible. The overall population of the ISR is predicted to decline over the long term in Scenario 1, consistent with current forecasts. Therefore, the long-term demand for Infrastructure is anticipated to be similar or less than today. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 to Infrastructure is predicted to be negligible.

Infrastructure	Residual Effects
Scenario 1 (cont'd)	Detailed information on infrastructure within the ISR, such as capacity, current utilization, and sustaining maintenance requirements (i.e. maintenance needed to sustain current capacity) was not available for this analysis. Absent specific information on proponent provided infrastructure, such as worker accommodation facilities, the prediction and characterization of residual effects is made with medium confidence.
Scenario 2	Residual effects on existing Infrastructure within the ISR for the export facility are expected to be neutral to adverse (i.e., some increased demands would be felt in Inuvik, Tuktoyaktuk and possibly other communities early during construction and perhaps into operations). Effects are predicted to affect a low to moderate magnitude of local infrastructure outside of the service and supply base, be localized to specific communities, be continuous over the life of the project and be long-term (30 years or more). However, upgrades to existing infrastructure and building of new infrastructure would eventually help to reduce effects on local infrastructure and may benefit local communities over the medium- to long-term (e.g., improved airports, better accommodations, improved supplies and services businesses). Given the combination of potential magnitude, spatial extent and temporal extent for existing and potentially new infrastructure, the residual effect condition of Scenario 2 to Infrastructure is predicted to be low and adverse or low and positive. Detailed information on infrastructure within the ISR, such as capacity, current utilization, and sustaining maintenance requirements (i.e. maintenance needed to sustain current capacity) was not available for this analysis. Absent specific information on proponent provided infrastructure, such as worker accommodation facilities, the prediction and characterization of residual effects is made with medium confidence.
Scenario 3	Residual effects of Scenario 3 on Infrastructure are expected to be adverse, of moderate magnitude, affecting a local area around the supply and service bases, continuous throughout the life of the project, and long-term (i.e., for the life of the project through to the end of decommissioning). However, to the extent that this hypothetical offshore oil development (Scenario 3) facilitates new and upgraded infrastructure within the ISR, there also would be positive benefits (i.e., low to moderate amounts of improvements in local infrastructure with benefits continuous throughout the life of the project and long-term).Given the combination of potential magnitude, spatial extent and temporal extent for existing and potentially new infrastructure the residual effect condition of Scenario 3 to Infrastructure is predicted to be low and adverse or low and positive. Detailed information on infrastructure within the ISR, such as capacity, current utilization, and sustaining maintenance requirements (i.e. maintenance needed to sustain current capacity) was not available for this analysis. Absent specific information on proponent provided infrastructure, such as worker accommodation facilities, the prediction and characterization of residual effects is made with medium confidence.
Scenario 4	With mitigation and management measures, the residual adverse effects of Scenario 4 on Infrastructure are expected to be similar as for Scenarios 3 (Appendix D: Section D.4.3.4.3). Adverse). A effects are predicted to be of moderate magnitude, local, and continuous, and long—term (reflecting the longer production period and likely extension beyond 2050; Section 3.9). Infrastructure upgrades, new infrastructure and improved resiliency of existing infrastructure would provide positive benefits to local communities and the region that are expected to be continuous throughout most of the life of the project and long-term. Given the combination of potential magnitude, spatial extent and temporal extent for existing and new infrastructure, the residual effect condition of Scenario 4 to Infrastructure is predicted to be low and adverse or low and positive.

Infrastructure	Residual Effects
Scenario 5	Oil spills that require large numbers non-resident response personnel and support teams would increase demands on emergency, storage, and transportation infrastructure; this is expected to have an adverse effect on Infrastructure. Depending on the size and location of the oil release and the effects of weather and sea states of the oil release, a single oil release event would be expected to have a low to moderate magnitude adverse effect on Infrastructure that would be local (i.e., focused on specific communities or service and supply bases), medium-term in duration (i.e., > 5 years) and, once spill cleanup and restoration is complete, reversible. If the oil spill is such that it requires building new infrastructure, then the effect could also be low and positive. Given the combination of potential magnitude, spatial extent and temporal extent for existing and new infrastructure, the residual effect condition of Scenario 4 to Infrastructure is predicted to be low and adverse or low and positive. Detailed information on infrastructure within the ISR, such as capacity, current utilization, and sustaining maintenance requirements (i.e. maintenance needed to sustain current capacity) was not available for this analysis. Absent specific information on proponent provided infrastructure, such as worker accommodation facilities, the prediction and characterization of residual effects is made with medium confidence.

E.17 Traditional Activities

Traditional Activities	Residual Effects
Scenario 1	The Status Quo scenario is predicted to have a neutral magnitude effect on Traditional Activities in the BRSEA Study Area; while some effects to traditional harvesting would be adverse, there also could be benefits. Few changes are expected regarding quality and availability of species harvested for traditional purposes, success of traditional food harvests, or participation in traditional food harvesting. Wage employment also could help some individuals to purchase equipment and supplies to support traditional activities and travel (Appendix D: Section D.4.1.3.1). Inuvialuit traditional harvesting practices are expected to continue with little change, and with the application of Inuvialuit-appropriate mitigation plans, residual effects are anticipated to be local to negligible in geographic extent, affect little of the current harvesting activity, be irregular in frequency, and short-term in duration (i.e., individual interactions between other human activities and traditional harvesting would be in the range of hours)..Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 to Traditional Activities is predicted to be negligible. Information on traditional harvesting practices was available from a variety of TLK sources, harvest reports, and government databases. Based on this, and considering the potential effects of climate change, the prediction and characterization of residual effects is made with medium confidence.

Traditional Activities	Residual Effects
Scenario 2	Assuming application of proposed mitigation and management measures, overall residual effects on Traditional Activities under Scenario 2 are anticipated to be moderate and adverse, regional in context (i.e., while some effects are localized changes in access or species distributions could occur over large regional areas), irregular or continuous in frequency (depending on the occurrence and regularity of activities), and of long-term duration (infrastructure and ice transits, as well as employment of Inuvialuit would continue over the life of the project). Effects would only be reversible if local harvesters are able to continue harvesting in other areas. There also could be benefits such as the improved ability to purchase equipment and supplies to support harvesting activities and associated travel using income from wage employment (Appendix D: Section D.4.6.1.4). Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 2 to Traditional Activities is predicted to be adverse and moderate or positive and low. Information on traditional harvesting practices was available from a variety of TLK sources, harvest reports, and government databases. Based on this, and considering the potential effects of climate change, the prediction and characterization of residual effects is made with medium confidence.
Scenario 3	With the application of proposed mitigation and management measures, including ongoing engagement with affected Inuvialuit communities, residual effects on Traditional Activities under Scenario 3 are expected to affect a small proportion of traditional harvesting in the region (given that the location of most activities in this scenario are ~80 km or more offshore), on an irregular basis over the life of the development (i.e., long-term). There also could be benefits such as the improved ability to purchase equipment and supplies to support traditional harvest and associated travel using income from wage employment (Appendix D: D.4.6.1.4). The effects of climate change under Scenario 3 are anticipated to act in combination and further alter Inuvialuit Traditional Activities. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 3 to Traditional Activities is predicted to be adverse and low or positive and low. Information on traditional harvesting practices was available from a variety of TLK sources, harvest reports, and government databases. Based on this, and considering the potential effects of climate change, the prediction and characterization of residual effects is made with medium confidence.
Scenario 4	With the application of proposed mitigation and management measures, including ongoing engagement with affected Inuvialuit communities, HTC's, and individual harvesters regarding timing and location of proposed activities and associated mitigation measures, residual effects on Traditional Activities under Scenario 4 are expected to affect a low proportion of traditional harvesting in the region (given that the location of most activities occur ~100 km or more offshore), on an irregular basis over the life of the development (i.e., long-term). There also could be benefits such as the improved ability to purchase equipment and supplies to support traditional harvesting and associated travel using income from wage employment. The effects of climate change under Scenario 4 are anticipated to act in combination and further alter Inuvialuit Traditional Activities. traditional harvesting Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 4 to subsistence activity is predicted to be adverse and low or positive and low.

Traditional Activities	Residual Effects
Scenario 4 (cont'd)	Information on traditional activities was available from a variety of TLK sources, harvest reports, and government databases. Based on this, and considering the potential effects of climate change, the prediction and characterization of residual effects is made with medium confidence. Ongoing monitoring of harvesting activities and consultation with HTC's also would help in reducing potential conflicts with development (e.g., establishing timing windows for industrial activities close to Marine Protected Areas).
Scenario 5	The magnitude of effects of a large oil release on Traditional Activities could be severe or lower, and affect an area ranging from local to regional. Effects would be continuous and persist for the duration of the spill event, including the spill response and cleanup activities. Depending on the success of the response and cleanup, effects could continue for one to several years. Effects to Inuvialuit Traditional Activities are expected to be medium to long-term. Effects on harvested species would be reversible over time, but perceived concerns of contamination of harvested food by some Inuvialuit could extend effects on traditional harvesting. Some individuals may consider the effects of an oil spill on harvesting to be irreversible A robust monitoring system would be required to gather current information on the status of the marine environmental and harvesting to improve the confidence in the spill response and predictions for recovery of the marine environment. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 5 to subsistence activity is predicted to be adverse and high. The effects of climate change, including the reduction of sea ice in the BRSEA Study Area, may influence the effects predictions. Effects of an oil spill are likely to exacerbate effects of climate change on existing Inuvialuit harvesting activities, as well as effects on harvested species. Information on traditional harvesting practices was available from a variety of TLK sources, harvest reports, and government databases. Based on this, and considering the potential effects of climate change, the prediction and characterization of residual effects is made with medium confidence.

E.18 Cultural Vitality

Cultural Vitality	Residual Effects
Scenario 1	The Status Quo scenario is predicted to have a neutral effect on Cultural Vitality in the BRSEA Study Area (e.g., use of Inuvialuktun and other indigenous languages and participation in Traditional Activities). Changes to Cultural Vitality under this scenario are anticipated to be negligible. Assuming ongoing engagement of Inuvialuit residents in the ISR with regard to project planning and operation, residual effects under a Status Quo Scenario are characterized as local (i.e., the immediate area around the activity), irregular in occurrence, and short-term in duration and reversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 to Cultural Vitality is predicted to be neutral and negligible. Information relating to Cultural Vitality was available from TLK sources and government databases, but mostly focused on subsistence aspects of traditional practices. Absent further detailed information on components of Cultural Vitality, such as creative expression, prediction and characterization of residual effects is made with medium-to-low confidence.
Scenario 2	With application of proposed mitigation and management measures, including the hiring of Inuvialuit into project-related positions, flexible work rotations, recognition of Inuvialuit culture and practices by projects and in project facilities, and ongoing engagement with affected Inuvialuit communities, the majority of the residual effects on Cultural Vitality under Scenario 2 are anticipated to be adverse in direction, and affect a low proportion of traditional and cultural activities in coastal areas (given the proximity of the export facility and associated vessel and aircraft transits to coastal sites), regional in context, low magnitude, continuous in frequency, and of long-term duration (i.e., Inuvialuit would be employed and non-local workers would be present over the life of the project). Some benefits to Cultural Vitality could occur through an improved ability of Inuvialuit employees to purchase equipment and supplies for traditional activities and travel; support of cultural and communities initiatives and events and language retention programs by project proponents;, and direct involvement of Inuvialuit in the work force and improved cultural awareness by non-Inuvialuit employees. Effects to Cultural Vitality are not expected to be experienced uniformly. Whereas some individuals may consider the effects of Scenario 2 on Cultural Vitality to be reversible, others may not. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 2 to Cultural Vitality is predicted to be adverse and low. The effects of climate change on Cultural Vitality under Scenario 2 are similar to those under Scenario 1, and not expected to change the effects characterization. Information relating to Cultural Vitality was available from TLK sources and government databases, but mostly focused on subsistence aspects of traditional practices. Absent further detailed information on components of Cultural Vitality, such as creative expression, prediction and characterization of residual effects is made with medium-to-low confidence.

Cultural Vitality	Residual Effects
Scenario 3	With application of proposed mitigation and management measures, including the hiring of Inuvialuit into project-related positions, flexible work rotations, recognition of Inuvialuit culture and practices by projects and in project facilities, and ongoing engagement with affected Inuvialuit communities, the majority of the residual effects on Cultural Vitality under Scenario 3 are anticipated to be adverse in direction, localized to specific areas of vessel and aircraft activity, occur irregularly, and be long-term in duration (i.e., Inuvialuit would be employed and non-local workers would be present over the life of the project). Some benefits to Cultural Vitality could occur through an improved ability of Inuvialuit employees to purchase equipment and supplies for traditional activities and travel; support of cultural and communities initiatives and events and language retention programs by project proponents;, and direct involvement of Inuvialuit in the work force and improved cultural awareness by non-Inuvialuit employees. Effects to Cultural Vitality are not expected to be experienced uniformly. Whereas some individuals may consider the effects of Scenario 3 on Cultural Vitality to be reversible, others may not. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 3 to Cultural Vitality is predicted to be adverse and low. The effects of climate change under Scenario 3 are similar to those under a Status Quo scenario and are not expected to change the effects characterization. Information relating to Cultural Vitality was available from TLK sources and government databases, but mostly focused on subsistence aspects of traditional practices. Absent further detailed information on components of Cultural Vitality, such as creative expression, prediction and characterization of residual effects is made with medium-to-low confidence.
Scenario 4	With application of proposed mitigation and management measures, including the hiring of Inuvialuit into project-related positions, flexible work rotations, recognition of Inuvialuit culture and practices by projects and in project facilities, and ongoing engagement with affected Inuvialuit communities, the majority of residual effects on Cultural Vitality under Scenario 4 are anticipated to be adverse in direction, localized to specific areas of vessel and aircraft activity, , occur irregularly, and be long-term in duration (i.e., Inuvialuit would be employed and non-local workers would be present over the life of the project). Some benefits to Cultural Vitality could occur through an improved ability of Inuvialuit employees to purchase equipment and supplies for traditional activities and travel; support of cultural and communities initiatives and events and language retention programs by project proponents;, and direct involvement of Inuvialuit in the work force and improved cultural awareness by non-Inuvialuit employees. Effects to Cultural Vitality are not expected to be experienced uniformly. Whereas some individuals may consider the effects of Scenario 4 on Cultural Vitality to be reversible, others may not. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 4 to Cultural Vitality is predicted to be adverse and low. The effects of climate change under Scenario 4 are similar to those under a Status Quo scenario and are not expected to change the effects characterization. Information relating to Cultural Vitality was available from TLK sources and government databases, but mostly focused on subsistence aspects of traditional practices. Absent further detailed information on components of Cultural Vitality, such as creative expression, prediction and characterization of residual effects is made with medium-to-low confidence.

Cultural Vitality	Residual Effects
Scenario 5	In the unlikely event of a large oil release event, the magnitude of effects on Cultural Vitality could range from moderate to severe, and affect an area ranging from local to regional. Effects would be continuous and persist for the duration of the spill event, including the spill response and cleanup activities. Depending on the success of the response and cleanup, effects on Cultural Vitality could continue for one to several years. Effects to Cultural Vitality are expected to be medium to long-term. While effects on harvested species and habitats would be reversible over time, perceived concerns by some Inuvialuit about contamination of traditional cultural sites, harvested food, and water could persist, and some individuals may consider the effects of an oil spill on Cultural Vitality to be irreversible. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 5 to Cultural Vitality is predicted to be adverse and high. The effects of climate change, including the reduction of sea ice in the BRSEA Study Area, may influence the effects predictions. An oil spill on sea ice may be less difficult to contain and cleanup than one occurring in open water, so continued reduction of sea ice and increase in the length of the Open Water season could increase the adverse effects of spills. Information relating to Cultural Vitality was available from TLK sources and government databases, but mostly focused on subsistence aspects of traditional practices. Absent further detailed information on components of Cultural Vitality, such as creative expression, prediction and characterization of residual effects is made with medium-to-low confidence.

E.19 Public Health

Public Health	Residual Effects
Scenario 1	With the application of health management measures and adherence to applicable GNWT and YG occupational health and safety and public health regulations, residual effects on Public Health in Scenario 1 are predicted to be neutral to adverse, and of low magnitude with effects likely higher in consideration of climate change-related effects.. Positive benefits could also occur such as increased wage incomes (e.g., wind energy project, tourism development) and the ability to purchase equipment and supplies to support traditional activities and associated travel; such positive effects would help reduce or balance adverse effects. Residual effects would persist indefinitely, but could reverse with positive changes in health behaviours, improvements in food security and other social health determinants. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 1 to Public Health is predicted to be adverse and low (i.e., Scenario 1 may have some effects but other factors in the region would affect public health more). Because public health outcomes result from numerous factors, some of which may be related to scenario activities, and others independent, the prediction and characterization of residual effects is made with low confidence.

Public Health	Residual Effects
Scenario 2	Changes in Public Health associated with Scenario 2 are primarily related to increased average household income within ISR communities; these changes are anticipated to be both positive and adverse, of moderate magnitude, and persist throughout construction, operation, and decommissioning of the natural gas and condensate export facility. Change in Public Health due to food security and dietary changes may be both positive and adverse, with adverse effects reduced with successful implementation of public health education programs. Effects are expected to persist for the duration of the development through to decommissioning (i.e., long-term). While some effects may be reversible once development pressures are gone, effects such as adverse personal behaviour could persist unless counselling is effective in altering such behaviour. Given the mix of adverse effects and positive benefits to Public Health in Scenario 2, overall effects conditions are expected to be negligible. Because public health outcomes result from numerous factors, some of which may be related to scenario activities, and others independent, the prediction and characterization of residual effects is made with low confidence.
Scenario 3	With the application of mitigation and management measures, residual effects of Scenario 3 on Public Health are predicted to be similar to those for Scenario 2. Changes in Public Health related to increased average household income within ISR communities are anticipated to be both positive and adverse and persist throughout construction, operation, and decommissioning of a large-scale oil development on the continental shelf. Changes in Public Health due to food security and dietary changes may also be both positive and adverse, with adverse effects reduced with successful implementation of public health education programs. Both effects would be continuous for the life of the project (i.e., long-term). While some effects may be reversible once development pressures are gone, effects such as adverse personal behaviour could persist unless counselling is effective in altering such behaviour. Given the mix of adverse effects and positive benefits to Public Health in Scenario 3, overall residual effect condition is expected to be negligible. Because public health outcomes result from numerous factors, some of which may be related to scenario activities, and others independent, the prediction and characterization of residual effects is made with low confidence.
Scenario 4	With the application of mitigation and management measures, residual effects of Scenario 4 on Public Health are predicted to be a mixture of adverse and positive effects Changes related to increased average household income within ISR communities are anticipated to be both positive and adverse and persist throughout construction, operation, and decommissioning of the offshore oil development. Change in Public Health due to food security and dietary changes may also be both positive and adverse, with adverse effects reduced with successful implementation of public health education programs, as well as increased income and education. Both effects would persist for at least the duration of the project (i.e., long-term), and perhaps beyond. While some effects may be reversible once development pressures are gone, effects such as adverse personal behaviours could persist unless counselling is effective in altering such behaviours. Given the mix of adverse effects and positive benefits to Public Health in Scenario 4, overall residual effect condition is expected to be negligible. Because public health outcomes result from numerous factors, some of which may be related to scenario activities, and others independent, the prediction and characterization of residual effects is made with low confidence.

Public Health	Residual Effects
Scenario 5	Residual effects of an oil spill on Public Health would be adverse and vary widely depending on the location, season, and type of spill, as well as effectiveness of oil spill response and the amount of overlap with traditional activities and areas. A spill occurring within the late Fall Transition, Ice or early Spring transition season could have moderate magnitude effects on Public Health since many traditionally harvested species would not be present and ice might aid in containing oil for removal. However, because of concerns over potential contamination, traditional harvesting may be reduced regionally and long-term after a major oil spill, regardless of the season. Given the combination of potential magnitude, spatial extent and temporal extent, the residual effect condition of Scenario 5 to Public Health is predicted to be adverse and moderate.

APPENDIX F Summary of Mitigation Measures by Activity and Valued Component

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
Vessels (commercial, recreational, ice-breaking)	Atmospheric Environment	"Consult with Canadian Coast Guard to discuss limiting ship traffic during periods of ice cover (November to June). These consultations should include the Community Conservation Plan Working Group, the Hunters and Trappers Committee, and the Inuvialuit Game Council." (OCCP 2016: 42). · Follow stringent fuel standards to reduce air and GHG emissions from vessels. · Reduce idling or unnecessary engine operation to reduce air and noise emissions. · Recommend vessel routes that increase the distances between vessel and receptors to reduce exposure to air, noise, and light emissions. · Prioritize lighting used for navigation and safety to reduce light emissions."
	Caribou	Use existing and common travel routes by vessels, icebreakers and aircraft that avoid sensitive habitat where possible and practical
		Avoid vessel and icebreaking traffic in channels to the east of the Beaufort Sea during the Spring Transition and late Fall Transition seasons
		Manage the number and distribution of tourist operators to avoid potential effects on calving and use of winter habitat (TCCP 2016)
		For coastline areas identified as important for caribou seeking insect-relief, limit offshore vessel traffic within 1 to 3 km from June 20 to August 15 (after Clough et al. 1987)
	Coastal Dynamics and Sea Floor Geology	Adherence to reduced vessel operating speeds in harbours and the approaches to harbours
		Use of vessel routes that keep vessels away from coastlines that are particularly vulnerable to coastal erosion due to moderate to high levels of erosion associated with natural and climate change processes.
	Coastal Habitat	Restrictions of ship speeds: Reduce speeds to less than 10 knots in proximity to coastal habitat to reduce wake (Fonseca and Malhotra 2012)
		Conservation buffers: Identify important coastal habitat, and establish conservation buffers to guide development planning efforts
	Cultural Vitality	Ongoing engagement with Inuvialuit groups and communities regarding potential project-related effects from the use of ice breakers and increased vessel and aircraft traffic on traditional activities, sites and travel routes, as well as effects on harvested species. For example, sensory disturbance and direct effects on travel and site access could be managed by use of seasonally-specific routes for vessels and aircraft to avoid important traditional and cultural sites. Flight restrictions such as minimum flying altitudes near or over traditional and cultural sites would also reduce aircraft impacts
		Coordinate shipping times and routes, especially for nearshore transits, to avoid or reduce effects on Inuvialuit use of coastal camps and sites and travel to and from these sites

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
Vessels (commercial, recreational, ice-breaking) (cont'd)	Cultural Vitality (cont'd)	Limit the use of ice breakers and ice-strengthened vessels during the late Fall and early Spring Transition seasons to avoid disrupting Inuvialuit travel across sea ice. If possible, coordinate ice breaker routes to avoid or reduce spatial and temporal overlap with Inuvialuit use
		Use the existing co-management processes with Inuvialuit groups to help protect traditional activities and cultural sites during specific time periods through measures such as restricting uses of vessels and aircraft in and near exclusion zones or seasonal activity periods
	Marine Fish and Habitat	Confirm and mark anchorages in both harbours to reduce effects on marine fish habitat.
	Marine Mammals	Habitat protection setbacks and timing windows to protect sensitive foraging, migration, pupping, rearing, weaning or birthing lair habitat
		Use of existing and common travel routes by vessels and icebreakers where possible and practical
		Maintenance of a steady course and safe vessel speed by vessels (e.g., less than 10 knots) whenever possible
		Wildlife monitoring program on vessels, icebreakers, and platforms to identify marine mammals in the area and maintain safe operating distance
		Long term monitoring programs to collect additional data on population status, habitat use, body condition and response of marine mammals to human and development activities.
		Development and implementation of co-management strategies that define management goals and objectives and aligns standard marine mammal management policy across multiple marine users in the region (i.e., Beaufort Sea Beluga Management Plan (Fisheries Joint Management Committee 2013)).
	Migratory Birds	Use of existing and common travel routes by vessels and icebreakers where possible and practical
		Prohibiting unnecessary harassment of birds by vessels and aircraft
	Oceanography	Modelling results and timing windows could be used to reduce the potential for sediments to affect a region of importance to local biota at a specific time and monitoring during the work could confirm that work is stopped when sediment levels exceed an established threshold.
		Modelling of the transport and fate of the temporarily suspended sediment can be completed during project planning which can then be used to plan construction timing to avoid interactions with biological VCs.
	Polar Bears	For vessels traveling through the Northwest Passage and Amundsen-Queen Maude Gulf, use of timing windows and specific routes (to avoid important habitat areas), operational procedures (e.g., consistent course with reduced vessel speeds), and wildlife monitors
		Use of existing and common travel routes by vessels and icebreakers where possible and practical

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
Vessels (commercial, recreational, ice-breaking) (cont'd)	Polar Bears (cont'd)	Habitat protection setbacks and timing windows to protect sensitive foraging, rearing, or denning habitat from icebreakers, snowmobiles, and low flying aircraft
		Identification and monitoring of maternal denning habitat and development of requirements to avoid key sensitive areas during shipping and other activities (e.g., maintain safe operating distance)
	Public Health	Project proponents should inform communities on the timing and location of LNG carrier and condensate tanker movements, as well as ship transits between the service and supply base to the GBS loading platform.
		Require operators to consult with harvesters about potential effects and mitigation measures to reduce the effect of ice breaking on traditional harvesting and travel over ice.
		Establishment of a safety zone around the GBS to limit collision risk between small craft and vessels, and other threats to human safety (e.g., offloading of goods, noise).
		Air emissions from vessels and aircraft would be managed through regular maintenance and fuel type (for vessels). Emissions from the GBS production platform would not affect coastal locations (Section D.2.1).
	Sea Ice	Existing and common travel routes should be used by vessels and icebreakers where possible to reduce the footprint of ice disturbance areas.
		Icebreaking within landfast ice should be avoided, where possible, to mitigate effects on marine mammals and Inuvialuit community activities.
	Seabirds	Powerful search lights, essential for the safe operation of vessels in icy waters and for larger vessels (>150 BT) are also required by regulation. However, priority should be given to investigate alternative green light sources (low in red light which appear to attract seabirds, Ronconi et al. 2015), perhaps combined with image enhancing ice lookout techniques (Merkel 2010).
		Establishing safe vessel routes and operations protocols to avoid seabirds and sensitive seabird habitats; this would be especially important for routes to the east of the Beaufort Sea.
		Implementing a Seabird Management Plan that includes seabird monitoring for vessel-related activities
		Tanker transits eastward through Amundsen – Queen Maude Gulf and the Northwest Passage during the Open Water Season could result in interactions between vessels and seabirds in a number of areas that are through or close to high use areas for seabirds. Tankers and other vessels should be required to follow specific procedures to reduce interactions with large concentrations of seabirds; this might include spatial and temporal restrictions on specific shipping routes, use of wildlife monitors, and associated operational measures. However, as the proponent would be able to enforce specific requirements through a tanker acceptance program, managing tankers would likely be easier than managing the wider range of vessels expected to use this area as described in Scenario 1.

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
Vessels (commercial, recreational, ice-breaking) (cont'd)	Seabirds (cont'd)	Habitat protection setbacks and timing windows to protect sensitive breeding, moulting and staging habitat from aircraft and vessel disturbance
	Traditional Activities	Ongoing engagement with Inuvialuit groups and communities regarding project-related effects of the use of tankers and icebreakers on traditional harvesting (e.g., timing and routes for travel, avoidance of harvest locations during specific periods), and harvested species. For example, consultation with harvesters by proponents about potential effects and mitigation measures to reduce the effect of ice breaking on traditional harvesting and travel over ice.
		"Discussion between vessel and project operators and harvesters regarding potential effects and mitigation measures to reduce effects of ship transits and ice breaking on traditional harvesting and travel over ice"
		Development of specific vessel transit corridors and aircraft flight lines to minimize disturbance to wildlife and harvesters.
		Development of specific times of day during particular months for vessel travel and aircraft flights to minimize disturbance to wildlife and harvesters.
		Operators to inform communities on the timing and location of LNG carrier and condensate tanker movements, as well as ship transits between the service and supply base to the GBS loading platform
		Development of specific vessel transit corridors and aircraft flight lines to reduce disturbances to wildlife and harvesters.
		Development of specific times of day during particular months for vessel travel and aircraft flights to reduce disturbances to wildlife and harvesters.
		Exclusion zones or restricted activity periods which are co-created with Inuvialuit groups and communities and used to avoid disturbance from vessels and aircraft on specific harvesting areas. This could include identification of preferred routes for LNG and condensate tanker, other vessels and aircraft that reduce or avoid impacts either through activity timing and/or location (e.g., avoidance of bowhead whale aggregation areas).
Seismic surveys	Cultural Vitality	Effects of industrial and other activities on cultural vitality and use should be monitored to support decision-making systems for existing mitigation measures, future projects and co-management processes.
		As noted in Section D.3.5.4, wildlife monitoring program should be implemented on vessels, icebreakers, and platforms to identify marine mammals and marine birds in the area and maintain safe operating distance, as well as to monitor safety zones during seismic surveys to protect marine mammals from injury. These wildlife monitoring programs typically would involve teams of Inuvialuit monitors and marine mammal biologists.

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
Seismic surveys (cont'd)	Cultural Vitality (cont'd)	Additional mitigation measures include ongoing engagement with Inuvialuit groups and communities regarding project-related effects on cultural vitality and marine-based species of value to Inuvialuit in relation to 3D seismic programs, the FPSO and production drilling rigs, and tanker transits east and west of the BRSEA Study Area.
	Marine Fish and Habitat	Use of ramp-up procedures when starting air guns during seismic survey
	Marine Mammals	Monitored safety zones around the sound source would be maintained for the duration of the survey to protect marine mammals from injury.
		Temporal restrictions or use of alternate monitoring technology (e.g., passive acoustic monitoring) may be required if operating within specific habitat zones (e.g., bowhead feeding aggregations).
	Migratory Birds	Habitat protection setbacks and timing windows to protect sensitive nesting and staging habitat from sensory disturbance
	Seabirds	Mitigation measures for the 3D seismic surveys should be consistent with the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment. Although these mitigation measures are primarily designed to reduce the potential for injury to marine mammals, implementation of a ramp-up procedure may also reduce the likelihood of a seabird diving near the source at its highest operating sound level.
	Traditional Activities	"Ongoing engagement with Inuvialuit groups (e.g., IGC, FJMC, HTCs) and communities regarding project-related effects of: · • 3D seismic programs · • offshore activities · • increased tanker traffic to the west (year-round) and east (monthly during Open Water Season) · • effects to marine-based species of value to Inuvialuit · • incorporation of Inuvialuit knowledge of water, ice, animals, and areas into mitigation planning"
Offshore structures and related activities	Atmospheric Environment	Use of efficient technologies and processes for the installation and operation of the oil production GBS and operation of the wareship.
		Use of efficient technologies and processes for the installation and operation of the oil production FPSO.
		Use of efficient technologies and processes for the installation and operation of the GBS and pipeline(s).
	Caribou	Undertake long-term monitoring to collect additional data on population status, habitat use, body condition and response of caribou to human and development activities
	Coastal Dynamics and Sea Floor Geology	For offshore wind energy turbines, analysis/modelling of potential effects of resuspension and transport of sediments may be warranted, especially in areas in proximity to the coastline. Monitoring of suspended sediments transport might also be considered to confirm effects.

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
Offshore structures and related activities (cont'd)	Coastal Dynamics and Sea Floor Geology (cont'd)	The potential effect of heating of the seafloor from subsea pipelines can be mitigated through the geotechnical engineering design for the pipeline, in combination with the operation of the shore-based processing plant which determines the temperature of the LNG and condensate which is transported through the pipeline. The geotechnical engineering of the design and operation of the full facility can be used to reduce the effects of the operation of the pipeline on the natural permafrost immediately below the seafloor.
		Similar geotechnical design and operating measures can be considered for offshore structures such as GBS platforms, including the engineering design mitigation measures used to reduce the potential for destabilization around well-bores extending below GBS platforms.
		Dredging programs should include modeling and, if necessary, project monitoring during construction, to predict changes in sediment transport and coastal stability.
	Coastal Habitat	Use of directional drilling technology to install the nearshore portions of the dual pipelines would reduce or avoid disturbances to coastal habitat.
		Environmental protection plans and other mitigation measures (e.g., silt curtains) can be used to reduce effects on coastal habitat
	Marine Fish and Habitat	Development and implementation of environmental management plans for site preparation, installation and operation of offshore wind turbines.
		Use of least-risk work windows for in-water construction (e.g., dredging) to avoid sensitive life history stages of fish
		Identify routing for the dual pipelines to avoid sensitive habitats or key areas for marine fish.
		Conduct site preparation activities, where possible, under relatively calm conditions to reduce sediment dispersal.
		Use measures to reduce sediment resuspension and contain sediment dispersion (e.g., modeling of potential sediment dispersion to inform mitigation, silt curtain, choice of dredging equipment).
		Design and implementation of an Environmental Effects Monitoring (EEM) program to establish baseline health information for fish and benthic habitat for future effects to be measured against.
	Marine Lower Trophic Levels	Baseline conditions of benthic habitat and species health in the local area of the drilling platform should be established prior to the start of construction.
		Long-term monitoring should then be undertaken to monitor potential effects of drilling activity and operations on marine benthic habitat.
	Migratory Birds	Implement light management measures on coastal infrastructure and GBS to alter light spectrum and provide sky shielding, thus minimizing sensory disturbance and potential injury

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
Offshore structures and related activities (cont'd)	Polar Bears	Wildlife monitoring program to identify bears in the area and maintain safe operating distance. This could include remote observations using drones (e.g., around wind turbines)
		Long term monitoring program to collect additional data on population status, habitat use, body condition and response of polar bear to human and development activities
	Public Health	Schedule project activities based on information acquired from consultation with local residents to limit interference with harvesting or traditional land use activities.
	Seabirds	Designing and locating wind turbines (e.g., larger and fewer) to reduce the proportion of birds at potential for collision (e.g., consider movements and timing of movements of resident species, visibility of turbines, and flight patterns)
		Selecting appropriate light color, wavelength and intensity for lighting on the GBS loading platform and vessel to reduce bird attraction to platforms and vessels; avoiding the use of unnecessary lighting, shading; and directing lights towards the deck to reduce bird collisions.
	Traditional Activities	Development and implementation of environmental management plans for the construction and operation of offshore wind farm(s)
		A variety of mitigation measures to reduce effects of human and industrial activities and infrastructure on fish, migratory birds, seabirds, marine mammals, and polar bear (Section D.3) also would benefit traditional harvesting.
		Ongoing engagement to keep Inuvialuit groups and communities informed on project activities and schedules and develop collaborative approaches for environmental protection. For example, project activities could be scheduled to avoid or limit interference with harvesting or traditional land use activities. Conversely, if a specific project activity had to occur at a specific time or a specific place, hunters may be able to slightly shift the timing or location of harvesting to accommodate that specific activity.
		Undertake monitoring studies on key species movements and harvester activities in advance of offshore activities and compare with changes during activities. This could be done by expanding the work of the Inuvialuit Community Based Monitoring program.
		Ongoing monitoring of harvesting activities and consultation with HTC's also could help in identifying measures to reduce potential conflicts with development (e.g., establishing timing windows for industrial activities close to Marine Protected Areas).
Aircraft activities (fixed wing and helicopters)	Caribou	Adhere to minimum altitudes for aircraft (>610 m or 2000 feet) that are flying close to caribou, as recommended by the EIRB (2011, Appendix C). The Tuktoyaktuk Community Conservation Plan (TCCP 2016:126), Sachs Harbour Community Conservation Plan (SCCP 2016:64) and others include similar minimum flying altitudes

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
Aircraft activities (fixed wing and helicopters) (cont'd)	Cultural Vitality	Manage the number and type (i.e., fixed wing vs. helicopter) of low-level overhead flights along the coastlines and in nearshore areas to reduce effects to Inuvialuit hunters and fishers, coastal camps and wildlife. Of note, aircraft must maintain a minimum flight altitude of 300 m to 400 m above ground depending on the flight location and time of year (EIRB 2011, Appendix C).
		Use the existing co-management processes with Inuvialuit groups to help protect traditional activities and cultural sites during specific time periods through measures such as restricting uses of vessels and aircraft in and near exclusion zones or seasonal activity periods
	Migratory Birds	Adhering to IGC flight guidelines and recommended minimum flight altitudes (EIRB 2011, Appendix C), where possible
	Seabirds	Avoidance of low-level aircraft operations where not required as per Transport Canada protocols
		Prohibiting unnecessary harassment of birds by vessels, crew members and support aircraft
	Traditional Activities	Adherence to and enforcement of minimum aircraft altitudes during specific seasons and over specific areas (EIRB 2011, Appendix C)
Routine discharges and waste management	Infrastructure	This project could be expected to implement appropriate measures for the handling, transportation, and onshore disposal of solid and hazardous wastes. If it is feasible to use municipal utilities (potable water, sewage disposal, solid waste disposal) it would be expected that access to such services would be purchased through usage fees.
		Use of self-contained service and supply bases, including workforce accommodations, at the supply and service base, as well as on the GBS Loading platform (once operational).
		Appropriate handling, storage, transportation and onshore disposal of solid and hazardous waste.
	Marine Lower Trophic Levels	Regional monitoring and enforcement of ballast water management
		Local monitoring and enforcement of grey water discharge (see Section 2.5 for water quality mitigations measures)
		Regional long-term monitoring of plankton and benthic species abundance and distribution
	Migratory Birds	Properly containing and disposing of waste to reduce attraction of birds to vessels
		Prohibiting discharge of bilge water and other waste streams (Section 2.5).

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
Routine discharges and waste management (cont'd)	Oceanography	"Effects of discharges on water quality can be effectively reduced by adhering to waste treatment and disposal guidelines (Section 2.5). This includes: · • treatment of grey water, sewage and food wastes before disposal · • use of water-based muds · • treatment of water-based muds and associated wastes (e.g., sand and cuttings), produced water, and deck drainage to meet minimum thresholds for oil content · • zero discharge for synthetic and oil-based muds and hazardous waste"
	Public Health	Adherence to and enforcement of regulations and standards for treatment, disposal and handling of waste, including synthetic and oil-based muds, hazardous waste, and solid waste (Section 2.5).
	Seabirds	Properly containing and disposing of waste to reduce attraction of birds (i.e., gulls) to vessels
Logistical and administrative facilities	Cultural Vitality	Provision of country food in project work camps, including allowing Indigenous employees to bring their own traditional foods to project facilities and camps, and providing appropriate storage and cooking facilities in the project camp to prepare traditional foods for Indigenous workers (e.g., Baffinland and QIA 2019).
		Use of TLK in design, planning, construction, and operations of buildings and other project components
	Demographics	Addressing housing shortages in the ISR communities may also help address demographic changes, including out-migration.
		Actions to design, build, and maintain climate resilient communities are identified in GNWT's 2020 NWT Climate Change Strategic Framework, 2019-2023 Action Plan (GNWT 2019b). By improving climate change resilience, these actions may limit demographic changes in ISR communities that are influenced by climate change.
	Economy	Opportunities for ownership investment by Inuvialuit, including the ownership of the wind energy project, as well as infrastructure or equipment (ships, ice breakers, etc.).
	Infrastructure	The proponent for the renewable energy project might construct a self-contained logistics facility or lease an existing facility, including workforce accommodation and a supply and service base.
		"Monitor effects of industrial and other activities on infrastructure and services, as part of broader socio-economic monitoring, and use information to support decision-making systems for existing mitigation measures, future projects and co-management processes. "
	Public Health	Provide health and counselling services to workers within project work camps, this can include cultural advisers to provide support Inuvialuit employees (this approach is being used for the Mary River Project (Baffinland and QIA 2019).

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
General	Cultural Vitality	Continue engagement with potentially affected Inuvialuit residents and communities to provide up-to-date information on traditional activities to support project planning and timing
		Monitor effects of industrial and other activities on cultural vitality as part of broader socio-economic monitoring and use information to support decision-making systems for existing mitigation measures, future projects and co-management processes.
		Increasing the number of opportunities to use Inuvialuktun and other Indigenous languages in the workplace (e.g., use of Inuvialuktun on signage and in training materials and courses; cross-cultural training for non-local workers). For example, while English is the work language for the Mary River Mine, job applications can be made in Inuktitut or English. Lack of proficiency in English is not a barrier to employment at Baffinland, and company policies include Inuktitut in the workplace and communications (Baffinland and QIA 2019).
		Promoting use of Inuvialuktun and other Indigenous languages through language preservation and terminology workshops, development of technical dictionaries, and ongoing initiatives to identify needs for Inuvialuktun words or phrases for new technical terms.
		Flexible working shifts for Inuvialuit employees, such that participation in culturally-valued traditional and cultural activities can continue (e.g., Inuvialuit Games, cultural celebrations, trips to seasonal harvesting camps)
		Use of cultural advisers to provide support Inuvialuit employees (this approach is being used for the Mary River Project (Baffinland and QIA 2019).
		Cross-cultural training of non-local workers and contractors to reduce or avoid interference with traditional and cultural activities. This can include demonstrations of cultural activities and traditional uses (Baffinland and QIA 2019).
		Management of non-local workers while on work rotations in the north. For most past projects in the ISR, non-local workers have not been allowed or have been discouraged from recreational pursuits on the land (e.g., hunting and fishing) both through restrictions on allowable activities during their work rotations, and management of these individuals during transfer in and out of the ISR. For example, most non-local workers would arrive through logistics bases and would be accommodated on site (if required), before being transferred out to the development site and vice-versa. Of note, regulatory requirements would also limit harvesting by non-Inuvialuit. The Inuvialuit have exclusive harvesting rights to a number of large game species, migratory birds and fishing (other than with a road and reel); non-Inuvialuit have to be a resident for two years to be able to obtain a recreational hunting license.
		Engaging in discussions with Inuvialuit communities, the GNWT and YG concerning the limiting of non-local hunting, trapping, and fishing practices

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
General (cont'd)	Cultural Vitality (cont'd)	Allocate money from the financial benefits of development to fund Inuvialuit culture and language programs in communities and schools (e.g., language preservation and terminology workshops, development of technical dictionaries, and ongoing initiatives to identify needs for Inuvialuktun words or phrases for new technical terms).
		Provide financial support to cultural initiatives put forward by community groups such as women, elders, and youth
		Develop and implement a socio-economic agreement and management plan that contains commitments and actions to address socio-economic impacts, review of project performance, construction and operational monitoring, cumulative effects monitoring and adaptive management
		Monitor effects of industrial and other activities on cultural vitality, as part of broader socio-economic monitoring, and use information to support decision-making systems for existing mitigation measures, future projects and co-management processes.
	Demographics	"The GNWT recognizes the importance of supporting population growth as a key component of developing a strong and prosperous NWT economy (GNWT 2015). It is recognized that resource development would be the primary driver of the economy, but that economic growth is constrained by the limited availability of a skilled workforce. Measures identified in GNWT (2015) to support population growth in NWT include: · • Providing quality government programs and services that would encourage people to live and work in the NWT · • Marketing the NWT as a great place to live and work · • Improving actions to recruit and retain employees in the GNWT workforce"
		In accordance with Subsection 16(1) of the IFA, COGOA (Section 5.2) and CPRA (Section 21) (Section 2.11 this report), the project proponents would be required to develop benefit plans with the IRC, including commitments for employment, training, and education of Inuvialuit, as well as use of local services and suppliers.
		Restrict or focus hiring within the north to Inuvialuit, other Indigenous persons and other northern residents, including those permanently residing in NWT, Yukon and possibly Nunavut
		Designate all communities within ISR, as well as other NWT communities in the Mackenzie Delta, as points of hire.
		Provide transportation to and from points of hire
		Provide gender training, cultural sensitivity training, and cross-cultural awareness training to all project workers

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
General (cont'd)	Demographics (cont'd)	Develop and implement a socio-economic agreement and management plan that contains commitments and actions to address socio-economic impacts, review of project performance, construction and operational monitoring, cumulative effects monitoring and adaptive management
		Monitor effects of industrial and other activities on population and demographics, as part of broader socio-economic monitoring, and use information to support decision-making systems for existing mitigation measures, future projects and co-management processes.
	Economy	Early discussions with stakeholders to alert them to and discuss employment and business opportunities that may arise from the wind energy project.
		Supplier development initiatives to help local businesses prepare to support potential oil and gas activity.
		Communication with relevant Inuvialuit communities and representative organizations, through established and/or informal engagement processes, as required and requested.
		Conducting public consultation in potentially interested communities in the BRSEA Study Area by providing clear, non-technical information and an opportunity for additional mitigation measures to be developed to address public or stakeholder concerns related to the economy, including availability of jobs and other economic opportunities.
		Develop and implement a socio-economic agreement that contains commitments and actions to address socio-economic impacts, review of project performance, construction and operational monitoring, cumulative effects monitoring and adaptive management.
		In accordance with Subsection 16(1) of the IFA, Section 5.2 of COGA (Section 5.2), and Section 21 of CPRA (Section 2.11) the project proponents would be required to develop benefit plans with the IRC, including commitments for employment, training, and education of Inuvialuit. Inuvialuit businesses would benefit from supplier development initiatives and have fair access to opportunities to provide supplies and services.
		"Early engagement of Inuvialuit communities in the planning and preparation of spill response plans, establishment of equipment stores, and training and readiness of Inuvialuit and other responders."
	Infrastructure	"Regular communications with Inuvialuit communities and representative organizations, through established and/or informal engagement processes, as required and requested. "
		"Undertake regular update meetings in each of the Inuvialuit communities in the ISR to address public concerns prior to commencement of the project. "
		Normal and extreme weather and oceanographic conditions should be included in project design, materials selection, planning, and maintenance.

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
General (cont'd)	Infrastructure (cont'd)	Provide funding for addressing the indirect effects of a project on community services, including increased demand for childcare and Elder care that result from the increased employment of ISR residents
		Implement measures to discourage non-NWT and Yukon project workers from entering other NWT and Yukon communities during their transit between the project sites and their home communities.
		Develop and implement a socio-economic agreement and management plan that contains commitments and actions to address socio-economic impacts, review of project performance, construction and operational monitoring, cumulative effects monitoring and adaptive management
	Polar Bears	Polar bear safety program to educate workers and reduce potential human-bear conflict
		Development and implementation of co-management strategies that define management goals and objectives and align standard polar bear management policy across multiple marine users in the region (i.e., ISR Polar Bear Joint Management Plan [Joint Secretariat 2017])
	Public Health	It is anticipated that programs and services provided by the Inuvialuit Regional Corporation (Health and Wellness Division), GNWT Department of Health and Social Services, Yukon Department of Health and Social Services, and Indigenous Services Canada and would help manage public health effects related to Scenario 1.
		Provide lifestyle and money management counselling to workers and their families (preferably offered in both Inuvialuktun and English)
		Ongoing provision of public education regarding diet and lifestyle (preferably offered in both Inuvialuktun and English)
		Project proponents should implement health and medical response plans that would include, but not be limited to: prevention, control, and management of communicable disease outbreaks; provision of medical services and infrastructure; and medical evacuation protocols.
		Project proponents should develop and implement workplace occupational health and safety plans and procedures in compliance with GNWT and Yukon Occupational Health and Safety Regulations, and other applicable standards.
		Plan for likely increases in stress and family conflicts associated with employee absences and provide training and/or funding to health service providers so that they can address such demands.
		Flexible working shifts for Inuvialuit employees, such that participation in culturally-valued traditional and cultural activities can continue.
		Provide country food in project work camps, including allowing Indigenous employees to bring their own traditional foods to project facilities and camps, and providing appropriate storage and cooking facilities in the project camp to prepare traditional foods for Indigenous workers (e.g., Baffinland and QIA 2019).

Table F-1 Summary of Mitigation Measures by Activity and Valued Component

Activity	VC	Effects Management Measure
General (cont'd)	Public Health (cont'd)	Communicate with relevant Inuvialuit communities and representative organizations, through established and/or informal engagement processes, as required and requested.
		Conduct public consultation in potentially interested communities in the BRSEA Study Area by providing clear, non-technical information and an opportunity for additional mitigation measures to be developed to address public concerns on public health prior to commencement of projects.
		Develop and implement a socio-economic agreement and management plan that contains commitments and actions to address socio-economic impacts, review of project performance, construction and operational monitoring, cumulative effects monitoring and adaptive management
		Monitor effects of industrial and other activities on public health, as part of broader socio-economic monitoring, and use information to support decision-making systems for existing mitigation measures, future projects and co-management processes.
		Health and wellness programs provided by IRC, GNWT, YG and IRC outlined in Section D.4.6.2 would be provided to ISR residents in addition to proponent-provided health medical programs. Mitigation measures to limit adverse effects on traditional harvesting activities (Section D.4.4) and cultural vitality (Section D.4.5) also should be implemented.
	Traditional Activities	Development and implementation of co-management strategies for beluga whale, polar bear and other species (e.g., Beaufort Sea Beluga Management Plan 2013)
		Flexible work rotations for Inuvialuit employees (e.g., wind energy project, tourism) to allow participation in traditional activities such as hunting, fishing, and whaling in their appropriate seasons
		Past and more recent work on the Inuvialuit Harvest Study would be useful in predicting, planning mitigation for and monitoring effects of projects on traditional harvesting.
		"Provision of country food in project work camps, including allowing Indigenous workers to bring their own country foods and kitchens for preparation of country foods (Baffinland and QIA 2019)."