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16.0 ACCIDENTAL EVENTS

Accidental events could occur as a result of equipment malfunctions, human error, or exceptional natural events (e.g., earthquake, hurricane, submarine landslide). This section of the EIS addresses accidental spills to the marine environment that could occur during drilling and production activities. Equinor Canada’s commitments and procedures for spill prevention and response are presented to provide context for the spill risk and probability analysis, as well as the fate and behavior analysis that are used to inform the assessment of environmental effects of accidental spills on VCs.

The regulation of spill prevention and response preparedness at offshore drilling and production operations are the responsibility of the C-NLOPB, pursuant to the Accord Acts.

The C-NLOPB requires an Environmental Protection Plan that follows the Environmental Protection Plan Guidelines (NEB et al. 2011) and must include the identification of potential environmental emergencies and hazards, including spills, and reference to spill response plans and general emergency response plans and procedures that will be used in the case of an environmental emergency.

During Project activities, operational discharges are managed in accordance with Equinor Canada’s Environmental Protection and Compliance Monitoring Plan (EPCMP). Discharges not identified in the EPCMP are not permitted to be discharged and are considered a spill if released into the marine environment. Response and management of spill events is provided for in the Equinor Canada’s Project Oil Spill Response Plan (OSRP).

Under the Canada Shipping Act, 2001 (CSA), the vessel or facility operator involved will be the Responsible Party in the case where the source of the spill is a supply vessel, tanker, or, a shore-based facility. The CSA requires that these vessel and facility operators have response plans in place, personnel trained in oil spill response, and a contractual arrangement with a Transport Canada-certified Response Organization. The Eastern Canada Response Corporation (ECRC) is the Response Organization retained by Equinor Canada, supply vessels in every applicable case.

While the CSA regulations do not directly apply to the Project, Equinor Canada’s spill response capabilities meet or exceed Canada Shipping Act, 2001 standards.

16.1 Spill Prevention and Response

Equinor Canada maintains a strong commitment to safe, secure, and sustainable operations. Central to this commitment is a corporate Safety and Sustainability management system. Equinor Canada developed a management system to capitalize on the collective knowledge and best practice gained over many years, ensuring activities are conducted in a safe, secure, and sustainable manner and risks are effectively managed. Equinor Canada’s emergency management philosophy is to prevent spills from happening, and in the unlikely event a spill would occur, to reduce the impact of an emergency on people, environment, and the integrity of Equinor Canada, contractor, and third-party assets.

16.1.1 Spill Prevention

Equinor Canada recognizes that prevention is the most effective way to avoid environmental effects from accidental spills.

Facilities, processes, and management system procedures are intended and designed to reduce or eliminate the chance of a spill, even in the case of equipment failure, during all potential hydrocarbon handling operations. Routine maintenance and testing schedules will be established for all aspects of Project activities, with particular attention paid to process facilities, well control, product storage and handling, fuel transfer systems, and crude offloading. Prior to offshore activities commencing, practices and limits for operating in poor weather, high sea state, or sea ice or iceberg conditions will be established. Good communications and sound marine practices for all vessels will also improve the ability to prevent spills.

The Project will use preparedness processes including meteorological (weather forecasting and monitoring) and physical environmental (ice monitoring and installation instrumentation) to monitor for and respond to extreme environmental events. These processes may be used to identify the potentially threatening iceberg conditions under which precautionary riser / turret disconnection is required, or the forecasted storm conditions under which precautionary down-staffing should occur.

Proper environmental operating practices will be assured through regular inspections and audits of the drilling installation and FPSO. The general awareness of offshore workers will be increased through training, workshops, and health, safety and environment (HSE) meetings, including specific training in oil spill prevention, reporting and response requirements, and procedures. Personnel will be responsible and actively encouraged to report potential problems and 'near miss' incidents to avoid, to the extent possible, a re-occurrence that could result in a loss of containment or unauthorized release.

Oil spill prevention is a key focus of Equinor Canada’s plans and activities. Oil spill prevention, response, and overall preparedness approaches for the Project will be further developed and defined as the various regulatory review and approval processes move forward. Equinor Canada will develop and implement a Project OSRP, which will be submitted to the C-NLOPB as part of the Operations Authorization (OA) application process described in Chapter 1.

16.1.1.1 Well Control and Blowout Prevention

There are a number of control measures that are implemented during drilling operations to maintain well control and reduce risk of a well blowout. These control measures include mechanical controls and barriers that are implemented as part of well design (e.g., steel casing, fluids, blowout preventer [BOP] and Christmas tree (XT)) and drilling and monitoring procedures.

As noted in Section 2.6.3.2, the wellhead is installed after drilling the first two riserless sections of the well is complete. Once the wellhead is installed, the BOP is placed below the string of riser and connected to the wellhead and the remaining sections of the well are drilled. A BOP is a critical piece of safety equipment that houses a system of high*pressure components that prevent water or hydrocarbons from escaping into the environment in the event of an emergency or equipment failure.

The BOP is comprised of multiple rams capable of shearing the drill pipe and sealing the well. It is capable of being activated from various location on the drilling installation and is used immediately upon indication of a well kick. The BOP and other pressure control equipment are tested regularly in accordance with the Drilling and Production Guidelines (C-NLOPB and CNSOPB 2017). For additional details regarding the function of the BOP refer to Section 15.1.1.2 of the Flemish Pass EIS (Statoil 2017).

There are also control measures that are implemented after drilling is complete to maintain well control and reduce the risk of a blowout. As outlined in Section 2.6.3.2, once the well reaches total depth and the wellbore is conditioned, completions activities are conducted which include the installation of a downhole safety valve and the XT. During production and injection operations the downhole safety valve and XT are key components of the well barrier system. These components are tested regularly to ensure functionality and integrity during production and injection operations.

16.1.1.2 FPSO and Subsea Infrastructure

Spill prevention will be incorporated into the design and operations of the Project. Facilities, equipment and systems will be designed with consideration of preventing loss of hydrocarbons and chemicals. In addition, Equinor Canada will incorporate spill prevention measures into management plans required under the Safety and Sustainability management system and documents required for the OA (e.g., OSRP, EPCMP, etc.).

Potential aspects that will be taken into consideration may include, but are not limited to, production flowline materials, testing systems / flowlines during hookup and commissioning phase, flowline protection measures, routine inspection and maintenance, pressure sensors, leak detection, anti-corrosion coatings on applicable equipment, offloading and bunkering procedures, chemical storage areas, and training.

The Project is in the early stages of design, and therefore specific spill prevention measures have not been finalized.

16.1.2 Contingency Planning and Emergency Response

Equinor Canada’s emergency response philosophy is to reduce the impact of an emergency on people, environment, and the organization. Equinor Canada is committed to ensuring the safety of all people associated with its operations onshore and offshore. During an emergency, maintaining the safety of those initially unaffected; ensuring the safety of those responding to the incident; and rescuing those who may have been injured are the prime responsibilities of responders and those in command.

The following sections provide an overview of Equinor Canada’s contingency planning and emergency response including well capping and containment and spill response.

16.1.2.1 Contingency Planning

Prior to commencement of operations, Equinor Canada will develop contingency plans that will serve as the guidelines for the company’s response to an emergency. Potential emergencies will be identified in operations-specific hazard and risk analyses. The plans will outline the necessary procedures, personnel, equipment, and logistics support required to respond to an emergency incident in a safe, prompt, coordinated manner. The plans will be distributed to designated personnel who will be responsible for emergency response actions. The content of the plans will contain sufficient detail to enable personnel to respond in a coordinated and effective manner. Equinor Canada’s careful planning will help protect sensitive coastal resources and local fishing activities in the unlikely event of a release. The OSRP and Emergency Response Plan will identify key contacts that require notification in the event of a release, including regulatory agencies, spill contractors, and fishing authorities. These contacts will be made aware of the location or Project activities and schedule prior to the start and will help establish a reliable means of communication in the event of an emergency.

An emergency is defined by Equinor Canada as any unexpected occurrence resulting in or having the potential to result in:

- Death or serious injury / illness requiring hospitalization
- Environmental impact
- Major or significant damage to Equinor Canada or contractor property
- Concern for the integrity of Equinor Canada operations in the eyes of the public or regulatory agencies

The following contingency plans will be developed for the Project to address these emergencies:

- **Offshore Emergency Response Plan** – provides very specific role descriptions for personnel for a number of potential emergencies and provides a link between offshore operations and onshore responders.
- **Collision Avoidance Plan** – identifies potential collision situations involving the drilling installation and FPSO, describes communications with the threatening vessel and lists actions to be taken on the drilling installation and FPSO in the event the threatening vessel does not respond.
- **Ice Management Plan** – defines how personnel will monitor the movement of icebergs and pack ice approaching the Project Area and describes procedures for responding to threats including countermeasures such as iceberg deflection. Refer to Chapter 17 for more information on ice management.
- **OSRP** – defines procedures for first response to spills originating at the FPSO and drilling installation, and shuttle tanker during offloading, and includes consideration of various spill response tactics within the context of a Spill Impact Mitigation Assessment (SIMA) (refer to Section 16.1.2.3 for more information on spill response); includes a Wildlife Response Plan (Note that individual OSVs and/or vessels, including shuttle tankers, will have their own oil spill preparedness plan in place under the CSA, 2001). Refer to Appendix N for an outline of the OSRP and SIMA.

- **Well Containment Plan** – describes the procedures and operations associated with subsea source control and containment and includes a Well Capping Plan and a Relief Well Contingency Plan (refer to Section 16.1.2.2 for more information on well containment).

As part of Equinor Canada's Incident Management System processes, Incident Action Plans will be developed that may include the following response strategies, depending on the magnitude of the offshore spill event. The magnitude of potential spills is divided into three levels, or tiers, as outlined in Section 16.1.2.3.

- Depending on the volume and metocean conditions, implement mechanical recovery through deployment of absorbent booms, ocean rated skimmers and booms
- Response with vessel-based dispersant application to quickly treat the oil before it has the opportunity to spread
- Response with aerially applied dispersants, which can be quickly deployed and treat large surface areas rapidly and efficiently
- Implement subsea dispersant injection application as soon as possible, if warranted, to treat most oil spilled at the source before it encounters surface water resources
- Deploy in situ burning (ISB) equipment to burn thick oil near the source
- Continue to use aerially applied dispersant as a primary response tool for oil further from the source where mechanical recovery/in situ burn operations are less effective
- Use aerial dispersant application during calm seas on emulsified oil
- Outfit vessels of opportunity (VOO) with appropriate oil spill response tools to provide a fleet of vessels that can be a line of defense against surface oil approaching shorelines
- In the extremely unlikely event of shoreline impact, sensitive shorelines will receive prioritization for protective booming

Emergency preparedness also requires directed training and response exercises. Designated Equinor Canada personnel, including contractors, will receive emergency training. All personnel will undergo an orientation to elements of emergency response planning. Offshore personnel will receive a general overview of evacuation alarms and procedures and response organization. Offshore emergency teams and crews of dedicated standby vessels will receive specialized training with emphasis on hands on experience. Equinor Canada has a global team of emergency response personnel and specialists that are available to support local emergency operations, if required.

A regular program of response exercises will be conducted to confirm readiness of all personnel. These exercises will train personnel in emergency procedures, test preparedness of personnel, and provide a means of developing continued improvement to emergency procedures.

16.1.2.2 Well Capping and Containment Plan

Equinor Canada's well control philosophy is focused on prevention using safety / risk management systems, management of change procedures, and global standards.

In the extremely unlikely event of a blowout, Equinor Canada's primary objective would be to stop the flow as quickly as possible. This would involve shutting in at the wellhead and killing the well through the wellhead.

In the extremely unlikely event that well control measures fail to control the well, a capping stack may be required. A capping stack is a specialized piece of equipment used to "cap" (i.e., stop or divert) well flow while work is being undertaken to permanently kill the well (e.g., through relief well drilling). Capping stacks are designed to withstand the maximum anticipated wellhead pressure to stop the spill and/or divert the flow to surface vessels for management and recovery of the hydrocarbons. A description of well capping and containment is provided in Appendix N. Equinor Canada will prepare a Well Capping and Containment Plan that will describe the initiation, mobilization, and deployment of a capping stack and other containment equipment to the wellsite. Capping stack equipment would be sourced through Equinor Canada's membership with Oil Spill Response Limited (OSRL). The preferred method of mobilization of the CSS is by sea. Mobilization by air introduces additional risk and the increased logistics associated with air travel and road transport also increases the overall complexity of the logistical operation. More information on transportation of the CSS is provided in Appendix N.

Before the CSS can be installed and used to shut in the well, a number of separate operations take place depending on the incident scenario, all of which can occur while the CSS is being mobilized and transported to site. These are:

1) Subsea Survey
2) BOP Intervention
3) Debris Clearance
4) Subsea Dispersant Operations
5) Capping Operations

The OSRL Notification and Activation Procedure, as outlined in Appendix N, would be initiated immediately following the extremely unlikely event of a subsurface blowout. Equinor Canada would contact OSRL immediately via their 24-hour emergency phone number.

It is anticipated that the CSS could be mobilized and deployed within 18-36 days of the incident occurring. The lower end of the time range is the scenario that includes mobilization of a capping stack from Norway in the summer, with favourable weather for rapid transit and installation, and transport direct to the wellsite (no port call) for installation. The 36-day scenario assumes mobilization of the secondary capping stack from Brazil in the winter, reduced transit speeds due to ice and weather, inclusion of a port call for testing and commissioning prior to mobilizing to the wellsite, and a longer installation time due to technical or weather delays. The precise duration for cap installation and closure would be highly dependent on a number of factors including sea states and local conditions specific to the incident. Equinor Canada would mobilize and install the capping stack as rapidly as safely possible. In the extremely unlikely event of a blowout, Equinor Canada's emergency response processes require the initiation of mobilization of both capping stacks in Norway and Brazil, although the capping stack in Norway is considered the primary stack as it is closest with the shortest transit time. For the purposes of the spill trajectory modelling, the longest capping duration (36 days) was assumed to be conservative.

Relief well drilling, and the subsequent dynamic kill, is considered a back-up strategy in the event that shut-in and/or killing the well through the wellhead is not possible or is unsuccessful. Whereas a capping stack is a temporary measure, relief well drilling is used to permanently shut-in flow to the well. It is estimated that a relief well can be executed in approximately 100 to 115 days. Section 2.6.3.2 indicates that it takes approximately 45 to 85 days to drill and complete a well. This timeframe takes into consideration that the drilling installation is on site. In the extremely unlikely event of a blowout, the drilling installation would likely experience damage and may not be in a position, from an integrity and safety perspective, to drill the relief well, therefore another drilling installation would be required and mobilized to site. The 115 days for a relief well considers the mobilization to site, time for regulatory permitting (e.g., inspections, customs, Certificate of Fitness) and technical considerations.

The actual duration for relief well execution may be higher or lower than these estimated ranges. The precise duration would be highly dependent on the local operating conditions, well design and subsurface location. The worst-case subsurface blowout modelling scenario assumes 115 days to drill a relief well.

Further Equinor Canada emergency response information related to well capping and containment is provided in Appendix N.

16.1.2.3 Spill Response

Spill response will develop in phases based on the level of planning that is required. Equinor Canada’s OSRP will be developed using a tiered response to oil spills.

For response planning purposes, the severity of potential hydrocarbon spills has been divided into three levels, or Tiers. This classification allows for an appropriate initial response to each level of spill and provides for the escalation of the response should the potential impact of the spill increase. Each Tier will require a successively higher level of operational effort and management.

The parameters to be considered in selecting the appropriate level of response include:

- Size and nature of the spill
- Environmental and operational conditions at the time of the spill
- Vessel and equipment availability
- Numbers and qualifications of personnel available at site
- On-site waste hydrocarbon storage
- Corporate exposure to risk and liability as a result of the hydrocarbon spill

The three levels are defined as follows:

- A Tier 1 spill poses the least threat of impact, and can be managed using resources available at site, with limited onshore support
- A Tier 2 spill response requires local shore-based management support and resources in addition to those already at site, and mutual aid agreements may be activated. Response contractors may be required. Equinor Canada’s global response team may be activated

- A Tier 3 spill has the potential to affect Equinor Canada business operations and may require considerable corporate and contract resources drawn from local, regional, and international sources, and mutual aid agreements may be activated. Equinor Canada's global response team will be activated

Equinor has established a Global Incident Management Assist Team (GIMAT) that can support local Incident Management Teams (IMT) in all locations. The GIMAT is built upon an Incident Management System (IMS) oil spill response model and is comprised of personnel from Equinor Canada who are trained to lead Sections, Branches, and Units in the IMS organization, as well as Deputy Incident Commanders and the Command Staff. The GIMAT has response competence relevant to the respective functions.

The GIMAT can be deployed depending on scale of the incident such as:

- Tier 3 level oil spill incident when a full IMS structure and operational planning cycle is required
- Tier 2 level oil spill incident which could be long lasting and resource intensive
- At incidents of a magnitude larger than the local incident management team is able to handle

The GIMAT will muster if the IMT asks for such assistance. The Incident Commander together with the Crisis Manager are the ones that initiate the mobilization of these extra resources.

Equinor Canada is committed to implementing spill response measures for as long as is required to remediate spilled oil, including remediation of shoreline areas where oil has made contact. The primary objective of spill response is to ensure that the response options utilized will maximize the effectiveness of the response while minimizing overall harm to environmental, socio-economic, and cultural resources. The types of long-term remediation measures are dependent on the size of the spill and the area and resources affected and would be developed in consultation with the C-NLOPB and ECCC's National Environmental Emergencies Centre (NEEC).

Incident Command System

Equinor Canada will adopt the Incident Command System organizational structure for emergency response management. The Incident Command System structure has been widely adopted by major operators and emergency response agencies. It provides a systematic approach to incident management and emergency response, providing clear roles and responsibilities as well as lines of communication between different functional groups involved in the response, including coordination of internal and external responders.

Response Contractors and Agencies

Equinor Canada will draw on external resources as necessary for Tier 2 and 3 spill response. This may include use of response organizations such as ECRC and, in particular for Tier 3 spills, OSRL. Assistance can also be provided through mutual aid agreements with other operators. Refer to Appendix O for additional information regarding response resources. Depending on the size and nature of the spill (i.e., Tier 1, 2 or 3), the OSRP will include the type and quantity of response equipment required (including equipment and expertise that will be available within local, regional, and global response organizations and/or through mutual aid agreements with other operators).

ECRC

ECRC is a certified response organization under the *Canada Shipping Act, 2001*, which is privately owned through membership agreements with individual operators including Equinor Canada. ECRC provides marine oil spill response services acting under the direction of an On-Scene Commander of the "responsible party", providing a plan of action, equipment, resources, and operational management in the clean-up effort. ECRC maintains oil spill response equipment in six ECRC locations, including one in St. John's, Newfoundland and Labrador (NL). Refer to Appendix N for additional information associated with ECRC including response outside the EEZ.

OSRL

OSRL is an international industry-funded spill response organization that provides its members with global access to oil spill response personnel and equipment. As a shareholding member of OSRL, Equinor has access to specialized Tier 2 and 3 equipment and experts, which includes resources associated with their subsea division - Subsea Well Intervention Services (SWIS). SWIS provides OSRL members access to subsea intervention capabilities including aerial dispersant application, subsea dispersant injection application, and capping and containment equipment. OSRL's expertise and resources are located across the world to facilitate effective and efficient response to oil spill incidents, including command, control and communications equipment, and shoreline cleanup equipment.

Canadian Coast Guard

Additionally, in the event of a spill, the Canadian Coast Guard (CCG) may be engaged, through a Memorandum of Understanding with the C-NLOPB, to provide response advice and field monitoring of the response. The CCG also has an inventory of oil spill response equipment which may be suitable for offshore use.

C-NLOPB

The C-NLOPB is designated as the lead regulatory agency in offshore spill incidents under the National Environmental Emergencies Contingency Plan and the CCG Environmental Response Marine Spills Contingency Plan – National Chapter. The C-NLOPB has overall responsibility to ensure that the operator is taking all reasonable measures to prevent further spillage and to mitigate the effects and impacts of the spill. If the C-NLOPB determines that an operator is not taking reasonable measures, then the C-NLOPB's Chief Conservation Officer (CCO) can direct those measures taken or can assume the management of the response effort. The C-NLOPB also has the authority to call upon Environment Canada and Climate Change (ECCC) National Environmental Emergencies Centre (NECC) for expert advice.

The NEEC is ECCC's focal point for the provision of scientific advice, such as weather forecast, contaminant dispersion and trajectory modelling, fate and behaviour of hazardous substances, the establishment of clean-up priorities and techniques, as well as the protection of sensitive ecosystems and wildlife such as seabirds and fish. The NEEC can avail of the services and expertise of centres within ECCC, such as the Emergencies Science and Technology Section, the Meteorological Service of Canada, and the Canadian Wildlife Service, to provide scientific support in the event of a spill.

Equinor Canada has not relied on the C-NLOPB during past offshore activities for advice or service related to spill response, and the same would apply to the Project. Equinor Canada is responsible for any spills that originate within the designated safety zone associated with the Project.

Mutual Aid Agreement

Equinor Canada is a participating operator to a mutual aid agreement between active operators in the Grand Banks. The agreement allows operators to provide assistance to each other in the event of an emergency.

Spill Response Tactics and Spill Impact Mitigation Assessment

The OSRP will consider a range of offshore spill response tactics as described in Table 16.1 and may also involve tracking of the spilled oil. Additional information regarding these response measures can be found in Appendix O. Surveillance and tracking are undertaken using a variety of methods (aerial reconnaissance, vessel tracking, satellites) in combination with mechanical tracking devices. The surveillance information is used to assist in real-time trajectory modelling, maximize efficacy of response measures, and assist with the development of strategic response options.

Table 16.1 Spill Response Tactics

Option	Comments	Environmental Effects Considerations
Natural Attenuation / Degradation	• Represents the “no-response option” or unmitigated spill option • Weathered hydrocarbon breaks into small droplets by wave action • Droplets are naturally metabolized by micro-organisms • Effectiveness improves as wind and sea state increase • Monitoring would likely involve remote sensing and aerial observations; monitoring effort is affected by poor visibility (e.g., fog and daylight)	• No action scenario represented in predictive spill trajectory modelling • Surface oil can persist longer, increasing risk of interaction with seabirds, marine mammals and sea turtles at surface, sensitive areas and shorelines • Effects on commercial and Indigenous fisheries due to fisheries closures based on surface oil sheen

Table 16.1 Spill Response Tactics

Option	Comments	Environmental Effects Considerations
Mechanical Containment and Recovery	• Containment and recovery of surface oil through absorbent booms, SSVS and ocean-rated skimmers and booms is currently world-class • Can be effective but limited by sea state and visibility, encounter rate of boom system and need for high logistics support • Low recovery rates as slick spreads • Sorbent boom will be on supply vessels • Tier 2 / 3 containment and recovery equipment will be available through a contracted Response Organization • Monitoring would likely involve remote sensing and aerial observations; monitoring effort is affected by poor visibility (e.g., fog and daylight)	• Provides environmental benefit over natural attenuation/degradation
Chemical Dispersion (Surface Dispersant Application, Subsea Dispersant Injection)	• Authorization required from C-NLOPB before application • Only two spill treating agents (Corexit® EC9500A and Corexit® EC9580A) have received regulatory approval for use in Canada (the intended use of Corexit® EC9580A is to treat substrate) ((Canada Oil and Gas Operations Act) (SOR/2016-108)) • Increases distribution area of oil by breaking it up into smaller droplets, enhancing natural dispersion and biodegradation processes • Dispersants, as approved, can be applied at surface (aerially or from vessels) or through subsea dispersant injection (SSDI); requires mobilization of specialized equipment and dispersants • Meteorological conditions are key factors determining effectiveness and method of application • SSDI is less sensitive to weather conditions and allows for continuous (24 hour) response (not hampered by visibility) • Reduces surface exposure and resulting health and safety risk to response workers • Monitoring to determine effectiveness is usually conducted using internationally recognized “Special Monitoring of Applied Response Technologies” protocols	• Reduces surface oil and volatile organic compounds at water surface and therefore reduces risk of adverse effects on human responders, seabirds, and marine mammals and sea turtles at surface as well as for workers • Increases exposure to dispersed oil in water column for fish, marine mammals, and sea turtles although concentrations of dispersed oil dilute rapidly to below lethal thresholds • Will increase short-term exposure of dispersed oil to fish but decrease in surface oil could result in reduced duration of fisheries closure • Public perception of toxicity of dispersants can indirectly affect commercial and Indigenous fisheries after fisheries closure has been lifted • Reduces risk of nearshore and shoreline interaction

Table 16.1 Spill Response Tactics

Option	Comments	Environmental Effects Considerations
In Situ Burning	• Authorization required from the C-NLOPB before implementation • Requires mechanical recovery with fire resistant booms • Oil is herded until it reaches a thickness that supports combustion (typically between 2 and 5 mm), and is ignited using flares, torches or other devices • Used to quickly reduce the volume of surface oil that would otherwise reach shorelines or sensitive areas • Effective but limited by meteorological conditions (calm seas and light winds) • Monitoring would likely involve remote sensing and aerial observations; monitoring effort is affected by poor visibility (e.g., fog and daylight)	• Reduces amount of oil in water but increases oil particulate matter resulting in localized air quality effects. However, unlikely to require air quality monitoring given distance from human receptors. • May leave a residual oil on surface of water (burn residue) • Toxicity of water column under burn area may increase • May be affects to the microsurface layer of water, but areas affected would be very small
Sources: EMCP 2011; Coelho et al. 2017		

A SIMA (previously referred to as a Net Environmental Benefit Analysis) will be undertaken by Equinor Canada as part of the OSRP during the OA approval process with the C-NLOPB. The SIMA for this Project will build on the SIMA that was developed for Equinor Canada's OSRP for their 2017 exploration drilling program in the Flemish Pass and is on file with C-NLOPB (Coelho et al. 2017).

The SIMA will evaluate benefits and drawbacks of different response tactics considering feasibility and effectiveness of implementation in different spill scenarios and prevailing conditions. A major component of this exercise involves considering the environmental effects of each response tactic against a base case of no tactical response (i.e., natural attenuation / degradation). The SIMA considers the physical environment of the Project Area (e.g., wind and wave conditions, currents, ice conditions, air and seawater temperature, visibility) as well as potential resources of concern (i.e., VCs) and involves a risk assessment of response options (see Table 16.1) for summer and winter conditions. The risk assessment uses a methodology developed by the American Petroleum Institute, International Petroleum Industry Environmental Conservation Association and International Oil and Gas Productions (API-IPIECA-IOGP) (IPIECA 2018). The outcome of the SIMA is impact mitigation scores indicating the potential for reducing or increasing risk relative to the baseline condition of "natural attenuation" for each response method, which can then be used to help select the best response tactics for any given spill scenario. The SIMA process is an important part of contingency planning, and can be used to support exercises, drills, and training. In the event of an actual spill, the SIMA process provides direction on response strategy and can be adjusted as necessary to manage specific response actions and end points (Coelho et al. 2017). An overview of the SIMA developed by Equinor Canada for the 2017 exploration drilling program is provided in Appendix O and is intended to provide an overview of typical content in a SIMA, however, the content in the SIMA for this Project is subject to change.

Shoreline Protection and Clean Up

In the event oil is predicted to make contact with shoreline areas, measures to protect these areas can be implemented. Barriers (boom and berms) can be used to deflect and protect sensitive coastal environments from surface oil. Deflection booming is used to divert oil to a suitable collection point at shore or at sea. Protection booming can also be used to hold or prevent oil from reaching shore. Additionally, sand, sand bags, and earthen barriers can be used to prevent oil entering specific areas. Selection of equipment and strategies is dependent on local conditions, access to areas, and results of real-time spill trajectory modelling.

In the event that oil is predicted to reach shoreline, or makes contact with shore, a shoreline response program will be initiated. Shoreline clean-up assessment technique (SCAT) teams will be mobilized to perform systematic surveys to document the location, degree and type of shoreline oiling. ECRC has detailed shoreline sensitivity maps for the Island of Newfoundland. This information will be used establish shoreline treatment recommendations appropriate for each area. Treatment measures can include a range of options including, but not limited to, low-pressure flushing, mechanical collection, manual cleaning, plowing, soil washing, and natural attenuation. SCAT teams will also be used to monitor and evaluate the effectiveness of the clean-up operations. Engagement with local stakeholders in affected areas is necessary to be build consensus on objective and goals for the response effort.

Oiled Wildlife Response

Oiled wildlife response may be required for fauna encountered at sea and on the shorelines of NL. Equinor Canada will draw upon the expertise and equipment of specialist contractors to support the oiled wildlife response effort. There are two licensed bird handling and rehabilitation centres for treatment and rehabilitation in NL-Suncor Environment Centre (St. John's), and NL Environmental Association (Ship Cove). For the Suncor Environment Centre in St. John's, prior to commencing any offshore operations Equinor Canada partners with Suncor to cooperate in maintaining the centre and sharing access to it. The Suncor Environment Centre would be the primary destination for oiled or injured seabirds for veterinarian-controlled triage, stabilization, and treatment. In addition, during operations Equinor Canada maintains an agreement with an on-call veterinarian for the bird handling centre.

Oiled wildlife response typically is based on a three-tier approach:

1) Primary response: surveillance to determine the location and extent of wildlife injuries and death; and deflecting oil away from areas of high sensitivity where practicable
2) Secondary response: deterring fauna from affected or potentially affected areas; and pre-emptive capture and exclusion activities
3) Tertiary response: capture and stabilization of oiled wildlife (using boats, or on the shoreline); transport to treatment facilities and treatment of affected fauna

Spill response and response to oiled wildlife, including surveillance and documentation, will be described in Equinor Canada's Project OSRP.

Oiled seabirds that can be readily, and safely, collected will be approached. Oiled and deceased wildlife observed will be collected from the water when weather and safety conditions permit and provided to CWS. Notification and shipment of oiled birds will be completed in accordance with conditions in the *Seabird Handling Permit*. The cleaning of oiled seabirds must be conducted by skilled responders. Any process utilized for cleaning birds will be based on the guidelines established by the CWS for the establishment and operation of a treatment facility for oiled birds.

The following wildlife monitoring activities will be undertaken in the event of an offshore spill:

- Downwind aerial and vessel surveillance in advance of the drifting slick to identify seabirds and marine mammals at risk.
- Employment of bird hazing techniques to deter seabirds from the affected area, using vessels, aircraft, and sound making devices.
- Recovery, evaluation and appropriate treatment for affected seabirds and delivery of birds to a central location for shipment to shore, and then to CWS.

Wildlife deterrent techniques can be used to encourage wildlife to move from, or avoid, locations that are in the projected pathway of the spill. All deterrent techniques will be determined in consultation with CWS and a permit will be obtained should hazing be implemented. Hazing techniques can also be used to deter wildlife from entering into spill areas. Hazing should be carefully planned and executed, with guidance from CWS, since hazed wildlife could move into other areas of the spill. Potential hazing techniques include:

- Sound, including pyrotechnics, shotgun or pistol-launched projectiles, air horns, motorized equipment, and recorded bird alarm sounds.
- Scare devices, including deployment of Mylar tape, helium-filled balloons, and scarecrows (either human or predator effigies) on affected beaches.
- Herding wildlife using aircraft, boats, or other vehicles.
- Hazing by human presence.

Remediation

Remediation measures are dependent on the size of the spill and the area and resources affected. Equinor Canada would use their internal specialists and external remediation expertise and contractors (e.g., OSRL, ECRC) to develop and implement long-term remediation strategies and plans. These would be developed in consultation with the C-NLOPB and the NEEC and other government agencies as necessary.

Financial

In addition to the spill response measures, an operator must demonstrate that they have the financial resources to meet a liability obligation of $1 billion in order to obtain an authorization to complete drilling and production activities in the NL Offshore Area. The objective of the financial requirement is to prove that the operator has the ability to: 1) respond to a serious incident such as a major spill; and 2) pay for all actual losses or damages incurred by any person as a result of the incident. Losses and damages include loss of income, future loss of income and, with respect to any Indigenous peoples of Canada, loss of harvesting, fishing, and gathering opportunities.

In addition, an operator must provide minimum of $100 million in “financial responsibility”. This financial responsibility must be available to the C-NLOPB, to be accessed by the C-NLOPB, if needed, in response to an incident involving the release of debris and/or a spill, or an authorized discharge, emission or escape of oil or gas. This is effectively a financial “deposit” and is required in order to ensure that the C-NLOPB has unfettered access to funds for clean-up and remediation, should the C-NLOPB deem that an operator has not taken appropriate action in response to an incident.

16.2 Potential Accidental Event Scenarios

Section 7.6.1 of the EIS Guidelines states:

> *The failure of certain works caused by equipment malfunctions, human error or exceptional natural events (e.g., earthquake, hurricane, submarine landslide) could cause major environmental effects. The proponent will therefore conduct an analysis of the risks of accidents and malfunctions, determine their effects, and present preliminary emergency response measures.*

In particular,

> *The effects of accidental spills and blowouts will therefore require assessment in the EIS, including fate and behaviour modelling, and hydrologic trajectory modelling for worst-case large-scale spill scenarios that may occur, including any assumptions, limitations, and formulated hypotheses, accompanied by supporting documentation of methodologies and the cumulative results of the modelling.*

Potential accidental event scenarios that could occur during the Project have been identified based on historic industry trends / incidents and the activities of the proposed Project. A summary of these events and the associated preventative and response barriers is presented below. It is possible that additional accidental event scenarios other than those presented below could occur. Further information about accidental event scenarios are described in the Safety Plan, which is submitted to the C-NLOPB as part of the OA regulatory approval process.

The following sections outline the potential accidental risk events that could result in a release of hydrocarbons, chemicals, SBM or emissions, resulting in potential adverse environmental effects. There is potential for a spill to occur as a result of these accidental events.

16.2.1 Local Conditions and Natural Hazards

Accidental events associated with local conditions and natural hazards such as extreme weather conditions and external events (e.g., seismic events, icebergs, hurricane, submarine landslide potential) are addressed in Section 17.3.3. However, to the extent that these accidental events may result in a spill to the marine environment, the potential environmental effects presented herein remain relevant.

16.2.2 Dropped Objects

Dropped objects refers to items accidentally falling either onboard the FPSO and/or drilling installation (e.g., from a crane on to the decking below) or falling from the installation to the seafloor striking subsea infrastructure. Subsea infrastructure includes mooring lines and anchors, well templates, flowlines, umbilicals, and risers (see Section 2.5.3.1 for a discussion on subsea equipment). Large objects dropped from height on an installation or vessel pose a health and safety risk as personnel could be injured or killed. Dropped objects may also damage the installation where safety of operations is affected or where a loss of primary containment occurs, and hydrocarbons are released into the marine environment.

The risk of dropped objects is managed through the use of tested and certified lifting equipment and ropes, clear specifications for equipment limits, and the use of agreed and controlled lifting plans. An object could fall from the FPSO and/or drilling installation during extreme weather events. Potential meteorological conditions are considered in the design of the FPSO and subsea infrastructure and in the selection of a drilling installation such that these installations are capable of operating safely. The Project will use weather forecasting to monitor and prepare for a response to extreme weather.

With regards to dropped object damaging subsea equipment, the need for protection of subsea infrastructure from dropped objects or other interference will be assessed. Well templates may be designed with trawl protection, which will also protect the wellheads from dropped objects.

In March of 2016, Shell Canada Limited reported an incident to the CNSOPB where the riser and lower marine riser package were accidentally released to fall to the seabed during high waves and heave conditions, while drilling an exploration well in offshore Nova Scotia waters (CNSOPB 2017). Typically, the riser is not attached to the drilling installation when in transit or moving to or away from site; it is stored on the rig deck. The riser is installed with the BOP stack (see Section 2.6.3). After drilling is completed and the well is safely suspended or abandoned, the riser is retrieved and stored on the rig deck before moving offsite. Before the riser is retrieved, all fluids are removed and replaced by seawater; therefore, there is no potential for fluid loss to the environment.

In certain circumstances, the riser and BOP remains attached when transiting between well sites. Under these circumstances, the riser is filled only with seawater and supported by the top drive and/or rotary table to prevent loss of riser or BOP. The C-NLOPB must be informed of these events and requires certain measures to be implemented to prevent incidents from occurring, including undertaking a riser transit analysis, weather forecasting, limiting speed of the drilling installation, attaching a beacon to the BOP to track its offset below the drilling installation, and having an ROV transit ahead of the drilling installation to look for potential obstacles in the path of the transit.

If other inert objects, such as ROVs and sampling equipment were lost then efforts would be made to retrieve the equipment, however, if the equipment could not be retrieved for technical or safety reasons, then the equipment would be deemed inert and sit on the seabed. Equinor Canada intends on taking a proactive approach and ensuring that adequate mitigation measures are identified / implemented to prevent dropped objects.

Therefore, with all these mitigations in place, there is a very low probability of a dropped object overboard, and if such an incident were to occur, there would be no significant environmental effect due to it being an inert object that would lie on the seafloor and may encourage habitat for benthic species, similarly to subsea infrastructure as discussed in Section 9.2.2.1.

If an inert object was lost to the seafloor, Equinor Canada would work directly with the C-NLOPB, prepare an incident investigation report, and implement decisions made by the C-NLOPB and other applicable regulators (i.e., DFO and ECCC).

16.2.3 Loss of Stability or Structural Integrity

Stability is managed by controlling the distribution of weight both across the installation and below and above the waterline. A loss of stability or structural integrity could cause the installation to list, capsize, or sink.

A loss of stability or structural integrity could be caused by a design or operation error, specifically its ballast system, or by an extreme weather event. Other events, for example a vessel collision, or a fire or explosion during a loss of well control event, could also result in the loss of stability or integrity to the FPSO and/or drilling installation.

A loss of stability could also result in a loss of primary containment on the drilling installation and/or FPSO, which could result in adverse environmental consequences. There is also a possibility that a loss of drilling installation stability could cause a loss of well control.

Some of the key barriers that are in place to prevent a loss of stability or structural integrity include the use of positioning and control systems, alarms, and operator interventions for the proper operation of the FPSO and/or drilling installation, including careful control of variable load by personnel. Robust FPSO and/or drilling installation design, including the use of inherently safe design systems, is verified through third-party verification via the Certificate of Fitness and Equinor Canada's drilling installation intake process. The maritime aspects of the FPSO will additionally be covered with compliance to Transport Canada regulations and being classed by a recognized international Classification Society. Maintenance and inspection processes are designed to test and regularly check equipment to confirm that it is still operating. Appropriately trained and competent personnel will be used in operations. As stated previously, the Project will use weather and natural hazard preparedness processes, such as weather forecasting tools. In the event either the FPSO or the drilling installation loses position, emergency disconnect protocols will be in place, which will outline procedures to be implemented to shut in production and/or drilling operations and allow the FPSO / drilling installation to move off location.

16.2.4 Loss of Well Control and Subsurface Blowouts

Primary well control is the use of wellbore fluid density to provide sufficient hydrostatic pressure to prevent the influx of formation fluid into the wellbore. Loss of primary well control will, if a permeable formation is exposed, allow formation fluid to flow into the wellbore and is referred to as a "kick". The severity of the kick depends on the porosity and the permeability of the formation, the difference between the formation pressure and the hydrostatic pressure of the drilling fluid, and the reaction time of the drill crew.

In the extremely unlikely event that both primary and secondary well control measures fail, an uncontrolled release from the well consisting of drilling mud, brine, water, gas, or oil may occur referred to as a blowout. Mitigating measures for a blowout scenario including capping, relief well drilling / killing, and spill response are discussed in Section 16.1.

For drilling operations, Section 15.1.1.2 of the Drilling EIS (Statoil 2017) provides a detailed overview of the causes and prevention measures for loss of well control activities. A loss of well control resulting in a subsurface blowout with a continuous release of oil represents the worst-case scenario for an accidental spill event. As described above, Equinor Canada has various mechanisms in place to prevent a loss of well control and therefore the risk of a subsurface blowout occurring is extremely low (see Section 16.3.4). Section 16.4 provides an overview of spill modelling undertaken in support of the EIS. Potential environmental effects of a subsurface blowout on the VCs is presented in Section 16.7.

16.2.5 Batch Spills

Spills attributed to causes other than blowouts account for the vast majority of spills related to offshore drilling and production activities. These spills are also more likely to be smaller, with lower volumes (Section 16.3.5). Batch spills, which can occur from an FPSO, drilling installation, flowline at the seafloor, transshipment tanker, or supply vessel, are generally instantaneous or short-duration discharges that can involve the release of different types of hydrocarbons including crude oil, diesel, hydraulic fluid, aviation fuel, or whole synthetic based muds. These spills can occur accidentally during handling or transfer of cargo and during operations and maintenance activities. They can occur as a result of human error and/or equipment malfunction or failure.

Batch crude and diesel spill scenarios have been modelled in terms of probability of occurrence, as well as for fate and effects (see Section 16.4). The probability of crude and diesel batch spills occurring over the life of the Project is presented in Section 16.3.5. For spills of SBM, the probabilities are discussed in Section 16.3.6, and modelling results are provided in Section 16.5. Potential environmental effects of batch spills on each of the VCs is presented in Section 16.7.

16.2.6 Vessel Collision

A vessel collision in transit or in Project Area could include loss of primary containment of hydrocarbons, which could result in adverse effects to the receiving environment. While there is some potential for an accidental event to occur during any such activity, the possibly of, and potential environmental effects that may be associated with such an incident are very low. The supplying and off-loading of Project-related vessels will occur within an existing industrial port facility, which handles supply vessel activity associated with multiple offshore operations and which operates in compliance with relevant legislation and regulations around materials handling, marine transits, and required spill prevention and response. Similarly, vessel traffic to and from these facilities in the nearshore environment will likewise be subject to applicable regulatory requirements, including requirements for vessel pilotage as required.

Incidents related to offshore oil and gas activities are reported to and recorded by the C-NLOPB. A total of 112 incident disclosures to date have been reported by the C-NLOPB as of December 10, 2018. Of these, four were related to supply vessels. One was related to a fire on a supply vessel while in-transit, approximately 100 km from St. John's. Three were related to supply vessels while "in-field" (at a drilling installation or production installation) and included a contact between a supply vessel and drilling installation, a medevac, and the loss of an empty container overboard (C-NLOPB 2018). For other vessel incidents (not oil and gas related), from January 1995 to September 2018, 21 vessel collisions, and 3 "near collisions" or "allisions" (striking a stationary object) were recorded in the NL region. The majority of these incidents involved Canadian Coast Guard vessels and/or fishing vessels. For other vessel incidents (not oil and gas related), between 2005 and 2016, there were six vessel collisions involving two or more vessels in, near, or east of St. John's in the designated Atlantic Region. All were fishing, commercial or government vessels not associated with the offshore oil industry. Four of these occurred in or near St. John's Harbour (2007, 2008, 2009, 2018), one at Cape Race (2008), and one off the east coast of NL (2012). Of the five incidents, four involved collisions between vessels, and one was a collision with an object or vessel (not distinguished) (Transportation Safety Board of Canada 2018).

16.2.6.1 Transit to and from Project Area

The Project will include supply and support vessel between existing port facilities and the offshore Project Area as required throughout the duration of the Project. As described in Section 2.6.4, it is anticipated that at peak, when production and drilling operations are occurring simultaneously, there will be a maximum of 16 vessel transits. While other activities may require support vessels, the peak activity is not anticipated to be surpassed. Supporting vessels that are involved in Project activities will travel in an essentially straight line between port and the Project Area, a common oil and gas industry practice in this region for several decades. Based on the estimated level of vessel transits per month to support the BdN Project (see Section 2.6.4.2), the Project is not expected to result in a significant increase to the average number of vessel transits to port. While some of the Project phases will overlap in time (resulting in a slight increase in the number of transits), it is likely that these numbers could decrease as synergies are explored,

There have been no near-shore supply vessel groundings or spills over the greater than 30-year history of oil and gas exploration in the NL offshore area. Other analysis of potential hydrocarbon spills in the nearshore environment off St. John's have indicated that such a spill event would see hydrocarbon moving to the east and not contacting the shoreline (RMRI 2006); refer to Section 16.6 for additional details.

Pursuant to the CSA, a vessel or facility operator involved will be the Responsible Party in the case where the source of the spill is a supply vessel or, a shore-based facility. Equinor Canada's responsibility for spill prevention, response, mitigation and/or follow-up is within the established safety zone of the offshore installation. However, as outlined in Section 2.6.4.2, vessels from third-party suppliers will be required to have valid marine certification from Transport Canada and meet regulatory requirements set out by Canada and international organizations, as well as meeting Equinor Canada's marine vessel vetting requirements. The CSA requires that these vessel and facility operators have response plans in place, personnel trained in oil spill response, and a contractual arrangement with a Transport Canada-certified Response Organization (see Section 16.1.2.3).

16.2.6.2 Within the Project Area

It is possible that there could be a collision between a vessel in the Project area and either the drilling installation or the FPSO. A collision could also arise if the FPSO and/or drilling installation moves from its designated position or during an extreme weather event, such as an intense storm, which may cause the installation to lose its position.

As stated in Section 2.5.4, an anti-collision zone will be established for the FPSO and drilling installation. Marine vessels are not allowed to enter the zone without the permission of Offshore Installation Manager.

Measures such as robust positioning systems, certified marine crew, navigation aids, weather and ice radars, and alarms will be used to keep the FPSO, drilling installation and/or vessels, including transhipment tankers during offloading, on position and to highlight the presence of other vessels and changing weather or ice conditions. Processes and protocols for collision assessment avoidance, communication and navigational aids will be implemented.

Consequences of a marine collision could include a loss of primary containment of hydrocarbons, or it could cause other accidental events such as a loss of stability or loss of well control. Response barriers are in place to reduce the possibility of these consequences arising, such as fire and explosion suppression and protection systems, evacuation and escape protocols, and emergency unlatching protocols.

The measures to be put in place to prepare, prevent, and respond to such a scenario are presented in Section 16.1.2. Mechanisms and arrangements with response organizations for emergency response are also presented in Section 16.1.2.

16.2.7 Summary of Accidental Events Scenarios

Based on information provided above, the following spill scenarios were selected for detailed spill fate and behaviour modelling, and effects assessment, based on consideration of Project activities and potential environmental risk.

- Subsurface blowouts - two locations in Project Area
- Batch crude spills - various sizes, surface and subsurface
- Batch diesel spill
- SBM whole mud spill - two locations in Project area, surface and subsurface
- Vessel-to-vessel collision – in vessel traffic route

These scenarios are summarized in Table 16.2 and are considered representative of credible worst-case spill scenarios that could result from an accidental event.

Table 16.2 Accidental Event Scenarios for Effect Assessment

Category of Spill Size	Scenario	Location	Scenario Name
Unmitigated Uncontrolled Well Releases			
Very Large 1,590 – 23,848 m³	Subsurface blowout; 10,500 m³/d of crude oil for 36 days	Site 1 - within Core BdN Development Area, at proposed well template location in sensitive area; approximately 1,100 m water depth	Site 1-36
	Subsurface blowout; 10,500 m³/d of crude oil for 36 days	Site 2 - within Project Area; approximately 500 m water depth	Site 2-36
	Subsurface blowout; 10,500 m³/d of crude oil for 115 days	Site 1 - within Core BdN Development Area, at proposed well template location in sensitive area; approximately 1,100 m water depth	Site 1-115
	Subsurface blowout; 10,500 m³/d of crude oil for 115 days	Site 2- within Project Area, approximately 500 m water depth	Site 2-115
Batch Spills			
Very Large 1,590 – 23,848 m³	Batch - loss of 8,300 m³ at surface of crude oil associated with loss of cargo cell in FPSO	Proposed FPSO Location	Site P- FPSO
Large 159 – 1590 m³	Loss of 1,000 m³ at surface of crude oil associated with crude offloading to a shuttle tanker	Proposed FPSO Location	Site P-Off
	Loss of 500 m³ of crude oil at seafloor from a seafloor flowline	Site 1 - within Core BdN Development Area, at seafloor in sensitive area; approximately 1,100 m water depth	Site 1-Flow
Moderate 1.59 – 15.9 m³	Loss of 6 m³ of marine diesel at surface associated with bunkering operations	Proposed FPSO location	Site P-Bunk
SBM Spills – Site 1 and Site 2			
Moderate to Large 15.9 – 159 m³	Loss of 60 m³ of SBM at surface associated with loss from mud holding tank on drilling installation	Site 1 and Site 2	Site 1 - Mud Site 2 – Mud
Large 159 – 1590 m³	Loss of 275 m³ of SBM from the riser at approximately 20 m above seafloor	Site 1 and Site 2	Site 1 - Flex[a] Site 2 - Flex
	Loss of 275 m³ of SBM associated with disconnection of BOP in an emergency event	Site 1 and Site 2	Site 1 – BOP[b] Site 2 – BOP

Table 16.2 Accidental Event Scenarios for Effect Assessment

Category of Spill Size	Scenario	Location	Scenario Name
Vessel Collision (Nexen Energy ULC 2018)			
Large 159 – 1590 m³	Loss of 750 m³ of marine diesel associated with a vessel to vessel collision	Vessel traffic route, nearshore	
[a] Rig components contributing to volume: Marine riser; choke, kill, booster and surface lines; mud-gas separator [b] Rig components contributing to volume: Marine riser; choke, kill, booster and surface lines; mud-gas separator			

16.3 Spill Risk and Probabilities

Environmental Research Consulting prepared the following probability analyses of offshore spills and blowouts in support of the BdN Development Project EIS. The analyses consider the probability of both continuous longer-term, larger scale blowouts, as well as smaller scale, shorter-term batch spills (crude, diesel and SBM) as described in Section 16.2.5. The probability of various kinds of potential spill releases and well blowouts and their respective volumes were analyzed with the application of a fault tree analysis that included Monte Carlo simulations. This methodology allows for incorporation of uncertainty in fault tree estimate inputs, as well as the incorporation of distributions of probabilities of various outcomes.

There are three important aspects to determining the “spill risk” associated with offshore development activities:

- Determining the likelihood or probability that a well blowout or other well release will occur
- Determining the potential oil spillage volumes that might occur and the probabilities that the spill will be a large-scale spill
- Determining the potential impacts of hypothetical spills

The following section addresses the first two aspects, the third aspect is addressed in Sections 16.7 and 16.8. This section reviews the available data and findings based on historical research of offshore spills to determine the probabilities for spills and the potential spill volumes that might be involved.

In addition, this analysis complements the modelling and assessment of potential spill scenarios conducted in support of the EIS for the Project by providing a perspective on the probability of occurrence and the probability distributions of spill volumes. The modelled scenarios of hypothetical spills are listed in Table 16.3. Note, for the purposes of discussion, volumes are expressed in barrels and cubic meters, which are rounded to the nearest whole number.

Table 16.3 Modelled Hypothetical Spill Scenarios for the BdN Project

Spill Name	Spill Source	Spill Site	Event Type	Oil Type	Spill Rate	Duration	Total Volume
Subsurface Blowout							
Site 1-36	Well	Site 1	Subsurface blowout	Crude	10,500 m^3/d 66,043 bbl/d	36 days	378,000 m^3 2,377,548 bbl
Site 1-115	Well	Site 1	Subsurface blowout	Crude	10,500 m^3/d 66,043 bbl/d	115 days	1,207,500 m^3 7,594,947 bbl
Site 2-36	Well	Site 2	Subsurface blowout	Crude	10,500 m^3/d 66,043 bbl/d	36 days	378,000 m^3 2,377,548 bbl
Site 2-115	Well	Site 2	Subsurface blowout	Crude	10,500 m^3/d 66,043 bbl/d	115 days	1,207,500 m^3 7,594,947 bbl
Batch Spills							
Site P-FPSO	FPSO	FPSO Location	Surface FPSO spill	Crude	4,150 m^3/d 26,103 bbl/d	2 days	8,300 m^3 52,205 bbl
Site P-Off	FPSO offloading	FPSO Location	Surface FPSO spill	Crude	Instantaneous	1 hour	1,000 m^3 6,290 bbl
Site 1-Flow	Seafloor Flowline[a]	Site 1	Seafloor release	Crude	500 m^3/d 3,145 bbl/d	1 day	500 m^3 3,145 bbl
Site P-Bunk	Vessel bunkering	FPSO Location	Surface batch spill	Marine diesel	Instantaneous	2 min.	6 m^3 38 bbl
SBM Spills							
Site 1-Mud	Mud tank	Site 1	Surface mud tank release	SBM	Instantaneous	0.5 hour	60 m^3 377 bbl
Site 1-Flex	Flex joint	Site 1	Subsea flex joint failure	SBM	Instantaneous	3 hours	275 m^3 1,730 bbl
Site 1-BOP	BOP	Site 1	Subsea BOP disconnect	SBM	Instantaneous	1 hour	275 m^3 1,730 bbl
Site 2-Mud	Mud tank	Site 2	Surface mud tank release	SBM	Instantaneous	0.5 hour	60 m^3 377 bbl
Site 2-Flex	Flex joint	Site 2	Subsea flex joint failure	SBM	Instantaneous	3 hours	275 m^3 1,730 bbl
Site 2-BOP	BOP	Site 2	Subsea BOP disconnect	SBM	Instantaneous	1 hour	275 m^3 1,730 bbl

[a] Flowline releases are one of the types of “other well releases” categorized in Holand (2013).

For the blowout scenarios, the hypothetical 36-day release duration is based on the maximum time for a successful capping and containment operation. The hypothetical 115-day release duration is based on the maximum time for the successful drilling of a relief well.

The probabilities of the hypothetical subsurface blowout scenarios at the two locations are based on the drilling of between 10 to 40 development wells that would be drilled over the course of three to five years, with the possibility of Project Area Tiebacks where up to an additional 20 wells could be drilled. The field life of the Core BdN Development is expected to be 12 to 20 years; if Project Area Tiebacks occur, the life of field could be up to 30 years.

The analysis in this section assumes that drilling could occur at any time of year, with the first well drilled in 2023 (see Section 2.6.3.2) and that it can take approximately 45-85 days to drill and complete a development well (see Section 2.6.3.2).

16.3.1 Existing Sources of Spill Inputs in NL Offshore

Based on analyses of historical spill data, it was determined that during the 1990s, total inputs of oil from anthropogenic sources in coastal areas of eastern Canada have averaged 9,000 barrels (bbl) (1,431 m^3) annually, and in offshore areas, 2,700 bbl (429 m^3) annually, for a total of 11,700 bbl (1,860 m^3). Spill volumes off eastern Canada have decreased significantly in the last decade to approximately 600 bbl (95 m^3).

In addition to anthropogenic inputs from spills, urban runoff, and vessel and facility operations, natural seepage may also contribute to overall hydrocarbon inputs in the region. Several natural seeps have been identified in the region, though there are no quantifications of annual inputs from this source.

Offshore exploration and production activities offshore NL have spilled a total of 2,759 bbl (439 m^3) of hydrocarbons (not including SBM; refer to Table 16.4) in 478 incidents over the last 21 years, according to data from the C-NLOPB (up to 19-Nov-2018). Approximately 99 percent of the total volume of oil spillage occurred during development and production activities. A total of 33 incidents totaling 33 bbl (5 m^3) occurred during exploration activities. Offshore exploration activities over the time period 1997 through 2018 also resulted in 11 SBM spills for a total of 776 bbl (122 m^3). Development and production activities resulted in the spillage of 1,314 bbl (209 m^3) of SBM in 44 incidents.

The data in Table 16.4 include reported incidents up to 19-Nov-2018, and this information was one of the sources used to determine spill probabilities.

Well-related spills occur relatively infrequently during offshore operations. Most well spills involve releases of less than 100 bbl (16 m^3) over the course of less than one day. Additionally, large-scale exploratory well blowouts are very rare events. The greatest concern about blowout scenarios is for the potential volume that may be released into the environment.

Table 16.4 NL Offshore Exploration and Production Spills (1997 to November 2018)

Year	Exploration						Development & Production						Total					
	Spill Number			Bbl			Spill Number			Bbl			Spill Number			Bbl		
	HC	SBM	All	HC	SBM	All	HC	SBM	All	HC	SBM	All	HC	SBM	All	HC	SBM	All
1997	1	0	1	0.3	0.0	0.3	10	0	10	10.6	0.0	30.6	11	0	11	10.9	0.0	30.9
1998	4	0	4	20.1	0.0	20.1	22	2	24	3.7	12.6	64.3	26	2	28	23.8	12.6	84.4
1999	11	0	11	10.7	0.0	10.7	28	8	36	7.3	46.4	125.7	39	8	47	18.0	46.4	136.4
2000	1	0	1	1.0	0.0	1.0	4	5	9	0.4	29.6	48.0	5	5	10	1.4	29.6	49.0
2001	0	0	0	0.0	0.0	0.0	15	2	17	0.8	35.2	70.0	15	2	17	0.8	35.2	70.0
2002	0	0	0	0.0	0.0	0.0	24	2	26	0.2	77.1	129.2	24	2	26	0.2	77.1	129.2
2003	1	1	2	0.6	27.7	28.3	19	4	23	1.8	167.5	215.3	20	5	25	2.4	195.2	243.6
2004	0	0	0	0.0	0.0	0.0	50	5	55	1,043.5	680.0	1,833.4	50	5	55	1,043.5	680.0	1,833.4
2005	0	0	0	0.0	0.0	0.0	40	1	41	1.2	25.4	108.6	40	1	41	1.2	25.4	108.6
2006	3	1	4	0.1	3.8	3.9	31	3	34	3.9	19.1	90.9	34	4	38	4.0	22.8	94.8
2007	0	1	1	0.0	465.5	465.5	37	1	38	0.6	6.9	83.5	37	2	39	0.6	472.3	548.9
2008	0	0	0	0.0	0.0	0.0	35	1	36	30.3	0.6	102.9	35	1	36	30.3	0.6	102.9
2009	4	0	4	0.1	0.0	0.1	37	0	37	1.8	0.0	75.8	41	0	41	1.9	0.0	75.9
2010	3	0	3	0.0	0.0	0.0	16	0	16	1.2	0.0	33.2	19	0	19	1.2	0.0	33.2
2011	2	5	7	0.3	180.8	181.1	36	2	38	3.5	28.9	108.5	38	7	45	3.8	209.7	289.5
2012	0	0	0	0.0	0.0	0.0	7	0	7	0.1	0.0	14.1	7	0	7	0.1	0.0	14.1
2013	0	0	0	0.0	0.0	0.0	11	2	13	39.3	1.4	66.7	11	2	13	39.3	1.4	66.7
2014	0	1	1	0.0	5.4	5.4	11	3	14	1.4	6.9	36.4	11	4	15	1.4	12.4	41.8
2015	1	1	2	0.0	92.9	92.9	1	1	2	0.0	0.9	4.9	2	2	4	0.0	93.8	97.9
2016	1	0	1	0.0	0.0	0.0	3	0	3	0.0	0.0	6.0	4	0	4	0.0	0.0	6.0
2017	1	1	2	0.0	0.0	0.0	5	0	5	0.0	0.0	10.0	6	1	7	0.0	0.0	10.0
2018	0	0	0	0.0	0.0	0.0	3	2	4	1,574.6	176.1	1,759.8	3	2	4	1,574.6	176.1	1,759.8
Total	33	11	44	33	776	809	445	44	488	2,726	1,314	5,018	478	55	532	2,759	2,091	5,827
Avg	**1.5**	**0.5**	**2.0**	**1.5**	**35.3**	**36.8**	**20.2**	**2.0**	**22.2**	**123.9**	**59.7**	**228.1**	**21.7**	**2.5**	**24.2**	**125.4**	**95.0**	**264.9**

Data extracted from C-NLOPB (2018) spill statistics [http://www.cnlopb.ca/information/statistics/
HC = Hydrocarbon; SBM = Synthetic-based [drilling] mud
2018 data above are through 19 November 2018.

In the current analysis, a blowout is defined as “a loss of well control or uncontrolled flow of formation or other fluids, including flow to an exposed formation (an underground blowout) or at the surface of the seabed (a surface blowout), flow through a diverter, or uncontrolled flow resulting from a failure of surface equipment or procedures.”[1] This definition encompasses incidents in which fluids other than oil are released. Only 41 percent of blowouts involve the release of any oil, as opposed to brine, water, or gas. The majority of surface blowouts from wells last less than five days.

16.3.2 Benchmarking of Project Hypothetical Blowout Scenarios

The analysis of blowout probabilities was based on a large database that includes 607 offshore blowouts and well releases that have occurred worldwide since 1955 (Holand 2013, 2016). While the vast majority of well blowouts and releases involve the spillage of small quantities of oil, these data also include a number of larger-volume (1,000-bbl and large) incidents shown in Table 16.5. The largest of these blowouts was the *Ixtoc I* (1979 to 1980) and the most recent are the Macondo MC252 (2010) and the Montara (2009). Of the 25 largest offshore well blowouts, 20 occurred between 1964 and 1992.

16.3.3 Methodology for Estimating Probabilities of Well Blowouts and Releases

The technical approach to estimating the probabilities of well blowouts and subsea releases for the Project involved the application of a fault-tree model that involved a series of sequential probabilities:

- Probability that there would be a causal event (e.g., outside force damage, corrosion, well component failure, BOP failure);
- Probability that the event would cause a non-blowout release or a blowout; and
- Probability that the blowout or release would involve oil rather than gas.

The probabilities of these sequential events were based on historical data for development wells, including the incorporation of water depth, which influences the likelihood of a blowout or release.

The volumes of the hypothetical spills were based on flow rate and duration. The flowrate for blowouts was based on the range of potential flowrates for typical development wells up to a maximum as provided by Equinor Canada. The duration of flow was determined by the time to either natural bridging, or intervention by capping and containment, or relief well. The probabilities that the stoppage of flow would be brought about by natural bridging or one or the other form of intervention were based on historical probabilities. The maximum time for the two interventions, 36 days for capping and containment, and 115 days for relief well drilling, were based on information provided by Equinor Canada. The volumes for well releases were based on historical data.

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[1] This definition is consistent based on that applied by the US Bureau of Safety and Environmental Enforcement (https://www.bsee.gov/stats-facts/offshore-incident-statistics/loss-of-well-control) [30 CFR Chapter II §250.187]. It is generally consistent with the definitions as applied in other contexts, such as the research analyses conducted (Holand 2006, 2013, 2016).

Table 16.5 Largest Offshore Well Blowouts (1,000 bbl and over) [a b]

Well	Start Date	Location	Bbl Spilled	Oil Type	Type of Well	Flow Rate (bbl/d)			Duration (days)	Source Control Method
						Peak	Avg.	Lowest		
Ixtoc I -HIGH	6/3/1979	Bahia del Campeche, Mexico	10,190,000	crude	exploratory	unknown	35,000	unknown	290	Well capped
Macondo MC252-HIGH	4/20/2010	Gulf of Mexico	4,200,000	crude	exploratory	60,000	49,400	unknown	85	Well capped
Ixtoc I -LOW	6/3/1979	Bahia del Campeche, Mexico	3,300,000	crude	exploratory	30,000	20,000	10,000	290	Well capped
Macondo MC252-LOW	4/20/2010	Gulf of Mexico	2,450,000	crude	exploratory	35,900	28,800	unknown	85	Well capped
Bull Run/ Atwood Oceanics	1/1/1973	Dubai, UAE	2,000,000	crude	development drilling	unknown	unknown	unknown	unknown	Unknown
Abkatun 91	10/1/1986	Bahia del Campeche, Mexico	247,000	crude	workover	unknown	unknown	unknown	unknown	Unknown
Montara - HIGH	9/21/2009	Timor Sea, Australia	214,300	crude	development drilling	2,000	400	400	74	Relief wells
Ekofisk Bravo B-14	4/20/1977	North Sea, Norway	202,381	crude	workover	28,080	28,080	28,080	7	Well capped
Funiwa 5	1/17/1980	Forcados, Nigeria	200,000	crude	development drilling	12,500	12,500	12,500	16	Well bridged naturally
Hasbah 6	10/2/1980	Gulf, Saudi Arabia	105,000	crude	exploratory	11,667	11,667	11,667	9	Well capped
Alpha Well 21 Platform A	1/28/1969	Pacific	100,000	crude	production	9,090	9,090	unknown	11	Well capped
Iran Marine Intl.	12/1/1971	Gulf, Iran	100,000	crude	development drilling	5,000	unknown	unknown	unknown	Unknown

Table 16.5 Largest Offshore Well Blowouts (1,000 bbl and over) [a][b]

Well	Start Date	Location	Bbl Spilled	Oil Type	Type of Well	Flow Rate (bbl/d)			Duration (days)	Source Control Method
						Peak	Avg.	Lowest		
Main Pass Block 41-C	3/1/1970	Gulf of Mexico	65,000	crude	production	3,000	2,200	1,000	30	Well capped
Yum II/ Zapoteca	10/10/1987	Bahia del Campeche, Mexico	58,643	crude	exploratory	unknown	30,000	unknown	51	Well capped
South Timbalier B-26	12/1/1970	Gulf of Mexico	53,095	crude	wireline	unknown	unknown	unknown	unknown	Unknown
Trinimar Marine 327	8/8/1973	Gulf of Paria, Venezuela	36,650	crude	development drilling	unknown	2,000	unknown	5	Well capped
Montara - LOW	9/21/2009	Timor Sea, Australia	28,600	crude	development drilling	2,000	390	unknown	74	Relief wells
Ship Shoal 149/199	10/1/1964	Gulf of Mexico	11,847	crude	unknown	unknown	unknown	unknown	unknown	Unknown
Greenhill Timbalier Bay 251	9/29/1992	Gulf of Mexico	11,500	crude	production	3,120	1,440	120	14	Unknown
Frade	11/7/2011	Campos Basin, Brazil	3,700	crude	exploratory	600	600	unknown	6.2	Unknown
Hebert Bravo 1A	2/19/1979	Gulf of Mexico	3,500	condensate	unknown	unknown	unknown	unknown	unknown	Unknown
Ship Shoal 29	7/1/1965	Gulf of Mexico	1,690	crude	unknown	unknown	unknown	unknown	unknown	Unknown
Uniacke G-72	2/22/1984	Nova Scotia	1,500	gas condensate	exploratory	300	unknown	unknown	10	Unknown
Ship Shoal 72	3/16/1969	Gulf of Mexico	1,060	crude	unknown	unknown	unknown	unknown	unknown	Unknown

[a] Two estimates are provided for *Ixtoc I*, Macondo MC252, and Montara blowouts. The estimates are shown separately in decreasing order of volume.

[b] Data based on: Alpine 1971; Gill et al. 1985; Monahan et al. 2001; Borthwick 2010; Hauck et al. 2010; Commonwealth of Australia 2011; Dokken 2011; Oldenburg et al. 2011; McNutt et al. 2012a, 2012b; Fitch et al. 2013; US vs. BP et al. 2014, 2015.

The values for probabilities and variable values (as shown in Tables 16.6 and 16.7) were input into a Monte Carlo simulation of a fault tree analyses for both probability and spill volume.

Table 16.6 Variables in Fault Tree Analysis for Project Well Spill Probability Analysis

Variable[a]	Assumed Value(s)	Basis/Reference
Total Development Wells for Core BdN Development Phase	40 wells, maximum	Equinor communication
Core BdN Development - Production Wells[b]	20 wells	Equinor Communication
Production time for each producing well for the Project	12 years	Equinor communication
Total wells - Project Area Tiebacks	20 wells	Equinor communication
Production Wells – Project Area Tiebacks	10 wells	Equinor communication
Production time – Project Area Tiebacks	10 years	Equinor communication
Development Blowout Probability [c]	2.8 x 10^{-4} per well	Based on data in Holand 2013; Holand 2016
Production Blowout Probability	3.5 x 10^{-5} per well-year	Based on data in Holand 2013; Holand 2016
Completion Blowout Probability	4.1 X 10^{-4} per well	Based on data in Holand 2013; Holand 2016
Workover Blowout Probability	9.9 x 10^{-4} per well workover	Based on data in Holand 2013; Holand 2016
Wireline Blowout Probability	9.06 x 10^{-6} per wireline job	Based on data in Holand 2013; Holand 2016
Development drilling non-blowout release probability [a]	2.1 x 10^{-4} per well	Based on data in Holand 2013; Holand 2016
Production well non-blowout release probability	1.9 x 10^{-5} per well-year	Based on data in Holand 2013; Holand 2016
Completion non-blowout release probability	3.7 x 10^{-4} per well	Based on data in Holand 2013; Holand 2016
Workover non-blowout release Probability	1.07 x 10^{-3} per well	Based on data in Holand 2013; Holand 2016
Wireline non-blowout release probability	1.1 x 10^{-5} per well	Based on data in Holand 2013; Holand 2016
Adjustment for Water Depth (Deeper Wells) - Blowouts	1.4 (for deeper wells)	Based on Holand 2013
Adjustment for Water Depth (Deeper Wells) – Well Releases	0.5 (for deeper wells)	Based on Holand 2013
Blowout Causal Event Probability (Subsurface Release)	4.0 x 10^{-5} to 8.1 x 10^{-4}/well-year	Based on Holand 2013
Development drilling time	2.5 months per well	Based on data in Holand 2013; Holand 2016
Number of wireline jobs	1.7 per production well-year	Based on data in Holand 2013; Holand 2016

Table 16.6 Variables in Fault Tree Analysis for Project Well Spill Probability Analysis

Variable[a]	Assumed Value(s)	Basis/Reference
Number of workovers	1 work-over per production well-year	Based on data in Holand 2013; Holand 2016
Non-Blowout No-Spillage Probability [d]	0.59	Scandpower 2006; OGP 2010
Non-Blowout Spillage Probability	0.41	Scandpower 2006; OGP 2010
Blowout No-Spillage Probability	0.59	Scandpower 2006; OGP 2010
Blowout Spillage Probability	0.41	Scandpower 2006; OGP 2010

[a] Non-blowout releases include loss of well control events that are considered “well releases” or “diverted well releases,” as in the Holand (2016) study.

[b] Only producing wells are considered for blowouts and well releases. Injector wells are not expected to have blowouts or releases of hydrocarbons

[c]. The probabilities for development drilling are based on deep well-depth rates.

[d] Non-blowout no-spillage probability is based on probability that there will only be gas flow rather than oil spillage

Table 16.7 Variables for Development Well Spill Volume Distribution Simulation

Variable	Assumed Value(s)	Basis/Reference	Distribution Type
Non-Blowout Spill Volume	0.000013–3,145 bbl 0.000002 m³ to 500 m³	C-NLOPB data; high range based on Equinor communication	Log-Normal
Blowout Flowrate	100–66,043 bbl/d 16 – 15,000 m³/d	Maximum based on Equinor communication	Log-Normal
Blowout Natural Bridging Time	0.02–5 days	Holand 2013.	Weibull
Blowout Capping/ Containment Time	5–36 days	Dyb et al. 2012 with maximum based on Equinor communication	Weibull
Blowout Relief Well Time	75–115 days	Dyb et al. 2012 with maximum based on Equinor communication	Weibull
Blowout Bridging Probability	0.84	Danenberger 1980; Holand 2006; Scandpower 2006; Dyb et al. 2012.	Discrete value
Blowout Capping and Containment Probability	0.06	Danenberger 1980; Holand 2006; Scandpower 2006; Dyb et al. 2012.	Discrete value
Blowing Relief Well Probability	0.10	Danenberger 1980; Holand 2006; Scandpower 2006; Dyb et al. 2012.	Discrete value

Probabilities of well blowouts and releases are based on historical data. It is highly likely that blowout potential will decrease in the future and will involve smaller volumes due to technological advances. Caia et al. (2018) conducted a fault-tree analysis of blowouts including newer intervention technologies developed after the Macondo MC252 incident and concluded that these interventions would reduce the duration of flow, thereby reducing the total volume of the blowout, by 30 percent to 60 percent. Their analysis predicted much smaller volumes of release.

16.3.4 Approach to the Calculation of Blowout and Well Release Probabilities for the Project

Analyses of international and national historical offshore well spill data verify that large blowouts (i.e., incidents involving loss of well control or uncontrolled flow) and non-blowout well releases (i.e., incidents involving the flow of oil or gas from some point in a well where flow was not intended) can be considered relatively rare events (i.e., with a probability of 2.8 x 10^{-4} per well for development drilling and 3.5 x 10^{-5} per well-year for wells in production; Table 16.6).

The probability analyses for blowouts and well releases from the Project were based on a "life-cycle" approach for each well–from development through production, including workover and wireline operations during production–with the following assumptions. All input probabilities were based on previously-conducted international studies and historical data, as listed in Tables 16.6 and 16.7.

The estimated probability that a specific individual development well from the proposed Project would have a blowout varies by location, with the difference being attributable to water depth, with blowouts being 40 percent more likely for deeper sites, and well releases being 40 percent less likely for deeper sites.

The "probabilities" of blowouts and well releases during development drilling noted above and applied in the analysis were originally derived from determining the number of recorded incidents per the number of development wells. The blowout probability of 2.8 x 10^{-4} per well means that in the historical data there was one blowout recorded for every 3,571 development wells drilled. The probabilities of blowouts or well-releases during production are based on the number of observed blowouts/well-releases divided by the number of well-years, i.e., the sum of the number of wells times each well's production time. (For example, 500 wells producing for 10 years each would equal 5,000 well-years.).

The overall probability of at least one blowout (or well release) occurring for the BdN Project is dependent on the number of development wells that are actually drilled, with the probability increasing directly with the number of wells drilled. These probabilities include the very low probabilities of more than one well experiencing a blowout. If the probability of one well having a blowout is 1.61 x 10^{-4}, the probability of blowouts for two wells is two times the probability of the single well or 3.32 x 10^{-4}. This includes the smaller probability of both wells having a blowout, which is the probability of one blowout raised to the power of the number of wells–or 2.26 x 10^{-8}. With 10 wells, the probability of at least one blowout increases to 1.61 x 10^{-3}, which includes the smaller probability of 1.17 x 10^{-6} that there could be multiple blowouts amongst the 10 wells. The differences between the calculations of the probability of at least one blowout or well-release for the Project with potentially varying numbers of wells and the probability of one blowout for those wells minus the summation of the probabilities of varying numbers of multiple blowouts are less than one half of one percent and were considered to be within a reasonable margin of error. Providing a per-development well or per-production well-year probability that could be multiplied by the number of development wells or production well-years (number of wells times the estimated production years) allows for a simple calculation that could easily be adjusted for the number of wells or production time period. The considerably more remote probabilities of multiple blowouts or well releases were excluded.

Probability estimates are provided for blowouts during development drilling and well releases from wells in production. Probability for blowouts during drilling considers the probability per well, multiplied by the total number of development wells to be drilled over the life of the Project. The probability of a well release from a producing well considers the number of production wells in operation multiplied by the average life of a producing well (well-years).

16.3.5 Estimated Blowout and Well Release Probabilities from the Project

The probabilities of blowouts while drilling a development well are provided in Tables 16.8 and 16.9 and are based on historical spill data. It is important to note that, for instance, the probability for the 'moderate' volume category (i.e., 1.61×10^{-4} for Site 1 and 1.15×10^{-4}) are the historical probability for this size of spill or larger (i.e., it includes the probabilities for the larger volume sizes) in different water depths. Therefore, conservatively, the historic probability of a blowout of any volume size, in approximately 1,100 m water depth, would be 1.61×10^{-4} and 1.15×10^{-4} for water depths of 500 m. Spill probabilities for the Project, including the modelled scenarios, are provided in the context of historical data. For the BdN Project, the probability of a blowout occurring for the volume of the modelled worst-case blowout scenarios is between 1.15×10^{-9} to 3.22×10^{-9}, or between a 1 in 310,000,000 to 1 in 870,000,000 chance of occurring, depending on water depth and total volume released. The calculated probabilities for subsurface blowouts while drilling a development well, by volume category, for Sites 1 and 2 are summarized in Table 16.8 and Table 16.9. The "return period" is the timeframe during with a blowout event would be expected at least once. For development wells, that timeframe is the development period, which was assumed to be approximately 2.5 months. The development blowout return periods are also shown in years. For example, a moderate-sized blowout would be expected once in 1,300 years of continuous development drilling. An extremely large (>150,000-bbl) blowout might be expected once during 2,500 years of continuous development drilling.

Table 16.8 Probabilities of Project Well Blowouts by Volume Category Site 1: Development Drilling

Volume Category	Per well	Approximate return period (development periods) and (years)	Core BdN Development (40 wells)	Project Area Tiebacks (20 wells)
Moderate 10–100 bbl 1.59–15.9 m³	$1.61 \text{ X } 10^{-4}$	6,200 development periods (1,300 years)	6.44×10^{-3}	9.66×10^{-3}
Large 1,000–10,000 bbl 159–1,590 m³	1.45×10^{-4}	6,900 development periods (1,400 years)	5.8×10^{-3}	8.7×10^{-3}
Very Large 10,000–150,000 bbl 1,590–23,848 m³	1.13×10^{-4}	8,800 development periods (1,800 years)	4.52×10^{-3}	6.78×10^{-3}
Extremely Large >150,000 bbl >23,848 m³	8.06×10^{-5}	12,000 development periods (2,500 years)	3.22×10^{-3}	4.84×10^{-3}

Table 16.8 Probabilities of Project Well Blowouts by Volume Category Site 1: Development Drilling

Volume Category	Per well	Approximate return period (development periods) and (years)	Core BdN Development (40 wells)	Project Area Tiebacks (20 wells)
Scenario Site 1-36 2,377,548 bbl 378,000 m³	3.22 x 10^{-9}	310,000,000 development periods (65 million years)	1.29 x 10^{-7}	1.93 x 10^{-7}
Scenario Site 1-115 7,594,947 bbl 1,207,500 m³	1.61 x 10^{-9}	620,000,000 development periods (130 million years)	6.44 x 10^{-8}	9.66 x 10^{-8}

Table 16.9 Probabilities of Project Well Blowouts by Volume Category Site 2: Development Drilling

Volume Category	Per well	Approximate return period Development periods (years)	Core BdN Development (40 wells)	Project Area Tiebacks (20 wells)
Moderate 10–100 bbl 1.59–15.9 m³	1.15 x 10^{-4}	8,700 development periods (1,800 years)	4.60 x 10^{-3}	6.90 x 10^{-3}
Large 1,000–10,000 bbl 159–1,590 m³	1.03 x 10^{-4}	9,700 development periods (2,000 years)	4.12 x 10^{-3}	6.18 x 10^{-3}
Very Large 10,000–150,000 bbl 1,590–23,848 m³	8.04 x 10^{-5}	12,000 development periods (2,500 years)	3.22 x 10^{-3}	4.82 x 10^{-3}
Extremely Large >150,000 bbl >23,848 m³	5.76 x 10^{-5}	17,000 development periods (3,500 years)	2.30 x 10^{-3}	3.46 x 10^{-3}
Scenario Site 1-36 2,377,548 bbl 378,000 m³	2.30 x 10^{-9}	430,000,000 development periods (90 million years)	9.20 x 10^{-8}	1.39 x 10^{-7}
Scenario Site 1-115 7,594,947 bbl 1,207,500 m³	1.15 x 10^{-9}	870,000,000 development periods (180 million years)	4.60 x 10^{-8}	6.90 x 10^{-8}

Estimated probabilities of blowout from wells in production are provided in Tables 16.10 and 16.11. The probabilities are presented in well-years. As noted in Section 2.3, it is estimated that half of the wells to be drilled for the Project will be production wells. Therefore, it is estimated that there would be 20 production wells for the Core BdN Development and 10 production wells should tiebacks occur. The average production life for the wells is estimated to be 12 years. Therefore, there are 240 well-years for the Core BdN Development, and, should tiebacks occur, there would be 120 well-years. As noted above, conservatively, the probability of a blowout or well-release of any size from a producing well ranges between 5.89 x 10^{-5} and 8.25 x 10^{-5}, depending on water depth. For the Core BdN Development, if all 20 production wells were in production, the probability of a blowout would be 1.98

x 10^{-2}. Should tiebacks occur, the probability would range from 5.89 x 10^{-3} and 9.90 x 10^{-3}, depending on water depth.

Table 16.10 Probabilities of Project Well Blowouts by Volume Category Site 1: Production Wells

Volume Category	Per well-year	Approximate return period (well-years)	Core BdN Development (240 well-years)	Potential Future Tieback (120 well-years)
Moderate 10–100 bbl 1.59–15.9 m³	8.25 x 10^{-5}	12,000	1.98 x 10^{-2}	9.90 x 10^{-3}
Large 1,000–10,000 bbl 159–1,590 m³	7.43 x 10^{-5}	13,000	1.78 x 10^{-2}	8.92 x 10^{-3}
Very Large 10,000–150,000 bbl 1,590–23,848 m³	5.78 x 10^{-5}	17000	1.39 x 10^{-2}	6.94 x 10^{-3}
Extremely Large >150,000 bbl >23,848 m³	4.13 x 10^{-5}	24000	9.91 x 10^{-3}	4.96 x 10^{-3}
Scenario Site 1-36 2,377,548 bbl 378,000 m³	1.65 x 10^{-9}	606,000,000	3.96 x 10^{-7}	1.98 x 10^{-7}
Scenario Site 1-115 7,594,947 bbl 1,207,500 m³	8.25 x 10^{-10}	1,210,000,000	1.98 x 10^{-7}	9.90 x 10^{-8}

Table 16.11 Probabilities of Project Well Blowouts by Volume Category Site 2: Production Wells

Volume Category	Per well	Approximate return period	Core BdN Development (400 well-years)	Project Area Tiebacks (100 well-years)
Moderate 10–100 bbl 1.59–15.9 m³	5.89 x 10^{-5}	17,000	2.36 x 10^{-2}	5.89 x 10^{-3}
Large 1,000–10,000 bbl 159–1,590 m³	5.30 x 10^{-5}	19,000	4.12 x 10^{-2}	5.30 x 10^{-3}
Very Large 10,000–150,000 bbl 1,590–23,848 m³	4.12 x 10^{-5}	24,000	1.65 x 10^{-2}	4.12 x 10^{-3}
Extremely Large >150,000 bbl >23,848 m³	2.95 x 10^{-5}	34,000	1.18 x 10^{-2}	2.95 x 10^{-3}

Table 16.11 Probabilities of Project Well Blowouts by Volume Category Site 2: Production Wells

Volume Category	Per well	Approximate return period	Core BdN Development (400 well-years)	Project Area Tiebacks (100 well-years)
Scenario Site 1-36 2,377,548 bbl 378,000 m³	2.30×10^{-9}	430,000,000	4.72×10^{-7}	1.18×10^{-7}
Scenario Site 1-115 7,594,947 bbl 1,207,500 m³	1.15×10^{-9}	870,000,000	2.36×10^{-7}	5.89×10^{-8}

16.3.6 Batch Spills

Other spills may potentially occur from offshore operations, including subsea releases (i.e., flowlines), surface batch crude spills from the FSPO and/or surface batch diesel spills from vessels, hydraulic or lubricating oils from drilling installation and FPSO, bunkering operations and other miscellaneous sources. The following sections provide the probabilities for batch spills per volume of the varying types of batch spills modelled for the EIS.

16.3.6.1 Batch Spills from FPSO

Based on historical data for FPSO spills, the data indicates that large spills from an FPSO are relatively rare. The largest FPSO spill occurred in the late 1990s when the Texaco Captain spilled 3,900 bbl (620 m³) due to human error. According to a study conducted for the US in 2001 (Minerals Management Service 2001), there have been 206 FPSO spills totaling 4,641 bbl up to that point, which included the 3,900-bbl Texaco Captain spill.

It is important to note that the number of historical spills from FPSOs is quite limited and therefore these probabilities are based on a relatively small data set. Unlike the SINTEF database for historical well blowouts and releases, there is not a similar database for FPSO spills. Very large FPSO spill rates were based on available international data as this category of spill has not occurred in the C-NLOPB jurisdiction. For spills less than 1,000 bbl (159 m³) (for which no international data exists), the probability estimates provided in Section 16.3.5.2 are based on C-NLOPB data.

The estimated FPSO spill rates are provided in Table 16.12, which are based on the estimated production rates for the Project. These are used to develop the probabilities of spills from FPSOs by volume category (Table 16.13).

Table 16.12 Estimated FPSO Spill Rate

Assumed Production Rate		1,000-bbl Spill Rate per bbl Production	Estimated Spill per Year		
bbl/d	bbl/year		1,000-bbl	10,000-bbl	100,000-bbl
94,347 (15,000 m³/d)	34,436,655	3.7×10^{-11}	0.0013	0.00013	0.000013
188,694 (30,000 m³/d)	68,873,310	3.7×10^{-11}	0.0025	0.00026	0.000026

Table 16.13 Probabilities of FPSO Oil Spillage by Volume Category

Volume Category	Per Well Year	Approximate Return Period
Large 1,000–10,000 bbl / 159–1,590 m³	0.00013	7,500
Very Large 10,000–150,000 bbl / 1,590–23,848 m³	0.000013	75,000
Extremely Large >150,000 bbl / >23,848 m³	0.0000013	750,000

16.3.6.2 Other Batch Spills

For the smaller batch spills, including small crude and diesel spills, spill data and historical well data on the number of wells drilled from the C-NLOPB (see Table 16.4 above), were analyzed to derive per-well rates as shown in Table 16.14. The C-NLOPB data also includes batch spills from production facilities such as FPSO and subsea infrastructure, therefore the probability analyses below is inclusive of all production batch spills.

Table 16.14 Oil Spill Rate per Well for NL Offshore Region (1997-2018)

Year	Number of Spills per Well						Volume (bbl) Spilled per Well					
	Exploration			Develop/Production			Exploration			Develop/Production		
	HC	SBM	All	HC	SBM	All	HC	SBM	All	HC	SBM	All
1997	0.50	0.00	0.50	2.50	0.00	2.50	0.13	0.00	0.13	2.66	0.00	2.66
1998	1.33	0.00	1.33	2.20	0.20	2.40	6.70	0.00	6.70	0.37	1.26	1.63
1999	1.38	0.00	1.38	1.75	0.50	2.25	1.34	0.00	1.34	0.46	2.90	3.35
2000	0.25	0.00	0.25	0.20	0.25	0.45	0.25	0.00	0.25	0.02	1.48	1.50
2001	0.00	0.00	0.00	1.00	0.13	1.13	0.00	0.00	0.00	0.05	2.35	2.40
2002	0.00	0.00	0.00	0.96	0.08	1.04	0.00	0.00	0.00	0.01	3.08	3.09
2003	0.25	0.25	0.50	1.00	0.21	1.21	0.16	6.92	7.08	0.10	8.81	8.91
2004	0.00	0.00	0.00	2.00	0.20	2.20	0.00	0.00	0.00	41.74	27.20	68.94
2005	0.00	0.00	0.00	2.35	0.06	2.41	0.00	0.00	0.00	0.07	1.49	1.56
2006	0.23	0.08	0.31	2.38	0.23	2.62	0.01	0.29	0.30	0.30	1.47	1.76

Table 16.14 Oil Spill Rate per Well for NL Offshore Region (1997-2018)

Year	Number of Spills per Well						Volume (bbl) Spilled per Well					
	Exploration			Develop/Production			Exploration			Develop/Production		
	HC	SBM	All	HC	SBM	All	HC	SBM	All	HC	SBM	All
2007	0.00	0.20	0.20	3.36	0.09	3.45	0.00	93.09	93.09	0.06	0.62	0.68
2008	0.00	0.00	0.00	3.50	0.10	3.60	0.00	0.00	0.00	3.03	0.06	3.09
2009	1.33	0.00	1.33	4.11	0.00	4.11	0.02	0.00	0.02	0.20	0.00	0.20
2010	0.60	0.00	0.60	1.78	0.00	1.78	0.00	0.00	0.00	0.13	0.00	0.13
2011	0.40	1.00	1.40	5.14	0.29	5.43	0.06	36.16	36.21	0.50	4.13	4.64
2012	0.00	0.00	0.00	0.78	0.00	0.78	0.00	0.00	0.00	0.01	0.00	0.01
2013	0.00	0.00	0.00	1.22	0.22	1.44	0.00	0.00	0.00	4.37	0.16	4.53
2014	0.00	0.25	0.25	1.10	0.30	1.40	0.00	1.35	1.35	0.14	0.69	0.84
2015	0.13	0.13	0.25	0.20	0.20	0.40	0.00	11.62	11.62	0.00	0.18	0.18
2016	0.25	0.00	0.25	0.25	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
2017	0.33	0.33	0.67	0.33	0.00	0.33	0.00	0.01	0.01	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.19	0.13	0.31	0.00	0.00	0.00	98.42	11.01	109.42
Avg[a]	**0.32**	**0.10**	**0.42**	**1.74**	**0.14**	**1.89**	**0.39**	**6.79**	**7.19**	**6.94**	**3.04**	**9.98**
[a]C-NLOPB data current through 19-Nov-2018												

Using this data, probabilities of small batch spills of crude and diesel were calculated, with results as shown in Table 16.15.

Table 16.15 Probabilities of Batch Spills by Volume Category

Volume Category	Per Well Year	Approximate Return Period
Very Small <1 bbl / <0.159 m^3	0.017	46
Small/ 1–10 bbl / 0.159-1.59 m^3	0.077	13
Moderate 10–100 bbl / 1.59–15.9 m^3	0.011	91
Moderate/Large 100–1 000 bbl / 15.9–159 m^3	0.0073	140

16.3.7 SBM Spills

The C-NLOPB spill data for spills of SBMs from both exploration and production operations in NL were combined. The data only include spills larger than one litre due to the lack of specificity in oil type in the C-NLOPB data for the smaller spills.[2] Annual spillage is shown in Table 16.16. There were

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[2] This is the reason that the data in this table do not precisely match with the data in Table 16.16.

54 SBM spills during 1997 through 2018, an average of 2 spills per year. The total volume spilled in that time period was 2,090 bbl (332 m³), an average of 95 bbl (15 m³) per year and 39 bbl (6 m³) per spill incident.

Table 16.16 SBM Spills in NL Offshore (C-NLOPB Data)

Year	Number of Spills			Total Volume (bbl)			Average Volume (bbl)		
	Exp.	Prod.	All	Exp.	Prod.	All	Exp.	Prod.	All
1997	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
1998	0	2	2	0.00	12.63	12.63	0.00	6.32	6.32
1999	0	8	8	0.00	46.37	46.37	0.00	5.80	5.80
2000	0	5	5	0.00	29.56	29.56	0.00	5.91	5.91
2001	0	2	2	0.00	35.22	35.22	0.00	17.61	17.61
2002	0	2	2	0.00	77.05	77.05	0.00	38.53	38.53
2003	1	4	5	27.68	167.48	195.15	27.68	41.87	39.03
2004	0	5	5	0.00	679.95	679.95	0.00	135.99	135.99
2005	0	1	1	0.00	25.35	25.35	0.00	25.35	25.35
2006	1	3	4	3.77	19.06	22.83	3.77	6.35	5.71
2007	1	1	2	465.45	6.85	472.30	465.45	6.85	236.15
2008	0	1	1	0.00	0.63	0.63	0.00	0.63	0.63
2009	0	0	0	0.01	0.00	0.01	0.00	0.00	0.00
2010	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
2011	5	2	7	180.78	28.94	209.72	36.16	14.47	29.96
2012	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
2013	0	2	2	0.00	1.40	1.40	0.00	0.70	0.70
2014	1	3	4	5.41	6.94	12.35	5.41	2.31	3.09
2015	1	1	2	92.93	0.90	93.83	92.93	0.90	46.92
2016	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
2017	1	0	1	0.02	0.00	0.02	0.02	0.00	0.02
2018	0	1	1	0.00	176.11	176.11	0.00	176.11	176.11
Total	11	43	54	776	1,314	2,090.48	70.55	30.56	38.71
Average/ Year	1	2	2	35	60	95.02	Grand Averages		

The SBM spill volumes varied greatly from 0.013 bbl (2.07 litres) up to 607.6 bbl (96,600 litres). Note that there are likely SBM spills of one litre or less, but the format of the C-NLOPB data did not make analyses on these smaller spills possible.[3] Eleven of the SBM spill incidents occurred during the exploration phase and 43 occurred during production.

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[3] Spills of less than one litre were not identified with respect to released substance.

For the proposed BdN development project, the estimated annual frequencies of SBM spills of varying sizes were estimated to be as shown in Table 16.17. The annual frequency of a spill of any volume – from very small to the largest likely SBM spill volume of 610 bbl (based on historical data from CNLOPB), is 0.15 per well. Probabilities increase based on the number of wells. The probabilities for increasingly larger spills are lower. Note that for the SBM spills, there is no difference between the two locations.

Table 16.17 Probability of SBM Spills for BdN Project for Development Wells

Litres	Bbl	Per Well Year	Return Period
Any volume		0.15	7
10	0.063	0.034	29
100	0.63	0.024	41
1,000	6.3	0.037	27
10,000	63	0.041	24
60,000	377	0.01	100
275,000	1,730	0.0005	2000

16.3.8 Cumulative Probability of Spill Occurrences in Flemish Pass Area

In the EIS Guidelines, the Proponent is required to indicate how the Project may affect the overall probability of spill occurrences in the Flemish Pass area. Other potential sources of spills outside the Project include vessels (e.g., fishing vessels, survey vessels) and exploration drilling programs. In general terms, the overall spill probability in an area increases as the number of wells (i.e., the activity level) increases. The probability analysis presented above for the BdN Project, provide probabilities on a ‘per well’ basis such that the probabilities can readily be extrapolated based on the number of wells.

Table 16.18, which is adapted from Equinor Canada’s Drilling EIS (Statoil 2017) provides probability of blowouts and batch spills for exploration drilling for various release volume categories.

Equinor Canada is the operator of the majority of the exploration licenses in the Flemish Pass. Table 16.19 provides the cumulative estimated probabilities of spills during exploration drilling and development drilling (see Table 16.8). It is conservative as it assumes that the probabilities are additive. As probability assessments consider spills at varying water depths and volumes, Table 16.19 includes the more conservative probability for a small volume released from a blowout and not the modelled scenarios, as described in Section 16.3.4.

Table 16.18 Flemish Pass EIS – Probabilities of Batch Spillage by Volume

Volume Category	Probability (Frequency in Exploration Period)	
	35-Day Exploration Duration/Well	65-Day Exploration Duration/Well
	1 well	1 well
Small (< 1 bbl; <159 litres)	0.037	0.069
Small/Moderate (1-10 bbl; 159-1,590 litres)	0.0046	0.0085
Moderate/Large (100-1,000 bbl; 15.9-159 m³)	0.0023	0.0044
Subsurface Blowout	1 x 10^{-4}	
Source Statoil 2017		

Table 16.19 Estimated Cumulative Spill Probability for Production and Exploration

Volume Category	BdN Project Development Drilling Probabilities of Spills (per well)	Exploration Drilling Probabilities of Spills (per well)	Cumulative Spill Probability* (per well)
Batch Spills			
Small <1 bbl / <0.159 m³	0.077	0.069	0.15
Small/Moderate 1–10 bbl / 0.159-1.59 m³	0.011	0.0085	0.020
Moderate/Large 100–1,000 bbl / 15.9–159 m³	0.0073	0.0044	0.012
Subsurface Blowouts			
BdN Site 1	1.61 x 10^{-4}	1 x 10^{-4}	2.7.1 x 10^{-4}
BdN Site 2	1.15 x 10^{-4}		2.15 x 10-4
* numbers rounded to nearest significant figure			

The cumulative probabilities noted are based on a per-well basis. This is not a realistic scenario and overestimates the probability of a blowout. It assumes that all wells are producing wells and does not account for injection wells. Whereas for BdN approximately half of the wells drilled will be production wells. Probability analysis does not account for the depletion of hydrocarbons in the reservoir as the well is produced, therefore the amount of hydrocarbon available to be released decreases overtime. Furthermore, if Project Area Tiebacks were undertaken, these wells would likely be drilled later in the Project life. Overall, development wells are drilled and phased in over time and are not present for life of Project (12-20 years for Core BdN Development; 10-18 years for Project Area Tiebacks). Therefore, to assume that for the Core BdN Development a total 40 wells will be in production for 20 years with hydrocarbons present is inaccurate.

16.4 Fate and Behaviour of Potential Spills

RPS conducted trajectory and fate modelling for unmitigated subsurface blowouts and batch spills of crude oil and marine diesel to support the evaluation of environmental effects of accidental events (refer to Appendix E).

Three-dimensional oil spill trajectory and fate modelling and analyses were performed to support evaluation of the potential effects that releases of hydrocarbons may have in the marine environment, offshore NL. RPS's nearfield OILMAPDeep blowout model and the far-field Spill Impact Model Application Package (SIMAP) trajectory, fate, and effects models were used.

16.4.1 Overall Modelling Approach

Two release locations were used for spill modelling at representative sites within the Core BdN Development Area (Site 1) and the overall Project Area (Site 2) (Table 16.20); (see Figure 16-1). Site 1 was chosen as the site for a potential subsurface blowout and batch spills within the Core BdN Development Area as it is located within a Special Area (see Section 6.4). Site 2 is a shallower site within the overall Project Area and is representative of a shallower location where Project Area Tiebacks may occur. Batch spills are also modelled from the proposed FPSO location within the Core BdN Development Area (see Section 16.4.4).

Table 16.20 Hypothetical Subsurface Release Locations and Stochastic Scenario Information

Scenario Parameter	Release Locations of Subsurface Blowout Scenarios			
Block	Site 1		Site 2	
Latitude	47.958818° N		47.889718° N	
Longitude	46.211357° W		47.037747° W	
Water Depth of Release	1,134 m		500 m	
Product	Bay du Nord			
Model Duration	160 d			
Gas to Oil Ratio	45.9 m^3/m^3			
Pipe Diameter	8.5 in. (21.59 cm)			
Oil Discharge Temperature	75°C			
Release Rate	10,500 m^3/d			
Release Duration	36 d	115 d	36 d	115 d
Total Released Volume	378,000 m^3	1,207,500 m^3	378,000 m^3	1,207,500 m^3
Number of Runs within Stochastic Analysis	171 annual (81 winter & 90 summer)	172 annual (83 winter & 89 summer)	171 annual (81 winter & 90 summer)	172 annual (83 winter & 89 summer)

Spill scenarios modelled for the EIS are listed in Table 16.21.

Table 16.21 Modelled Hypothetical Spill Scenarios for the BdN Project

Spill Name	Spill Source	Spill Site	Event Type	Oil Type	Spill Rate	Duration	Total Volume
Subsurface Blowout							
Site 1-36	Well	Site 1	Subsurface blowout	BdN	10,500 m^3/d 66,043 bbl/d	36 days	378,000 m^3 2,377,548 bbl
Site 1-115	Well	Site 1	Subsurface blowout	BdN	10,500 m^3/d 66,043 bbl/d	115 days	1,207,500 m^3 7,594,947 bbl
Site 2-36	Well	Site 2	Subsurface blowout	BdN	10,500 m^3/d 66,043 bbl/d	36 days	378,000 m^3 2,377,548 bbl
Site 2-115	Well	Site 2	Subsurface blowout	BdN	10,500 m^3/d 66,043 bbl/d	115 days	1,207,500 m^3 7,594,947 bbl
Batch Spills							
Site 1-Flow	Flowline	Site 1	Seafloor release	BdN	500 m^3/d 3,145 bbl/d	1 day	500 m^3 3,145 bbl
Site P-FPSO	FPSO	Site P	Surface FPSO spill	BdN	4,150 m^3/d 26,103 bbl/d	2 days	8,300 m^3 52,205 bbl
Site P-Off	FPSO offloading	Site P	Surface FPSO spill	BdN	instantaneous	1 hour	1,000 m^3 6,290 bbl
Site P-Bunk	Vessel bunkering	Site P	Surface batch spill	Marine diesel	instantaneous	2 min.	6 m^3 38 bbl
SBM Spill							
Site 1-Mud	Mud tank	Site 1	Surface mud tank release	SBM	instantaneous	0.5 hour	60 m^3 377 bbl
Site 1-Flex	Flex joint	Site 1	Subsea flex joint failure	SBM	instantaneous	3 hours	275 m^3 1,730 bbl
Site 1-BOP	BOP	Site 1	Subsea BOP disconnect	SBM	instantaneous	1 hour	275 m^3 1,730 bbl
Site 2-Mud	Mud tank	Site 2	Surface mud tank release	SBM	instantaneous	0.5 hour	60 m^3 377 bbl
Site 2-Flex	Flex joint	Site 2	Subsea flex joint failure	SBM	instantaneous	3 hours	275 m^3 1,730 bbl
Site 2-BOP	BOP	Site 2	Subsea BOP disconnect	SBM	instantaneous	1 hour	275 m^3 1,730 bbl

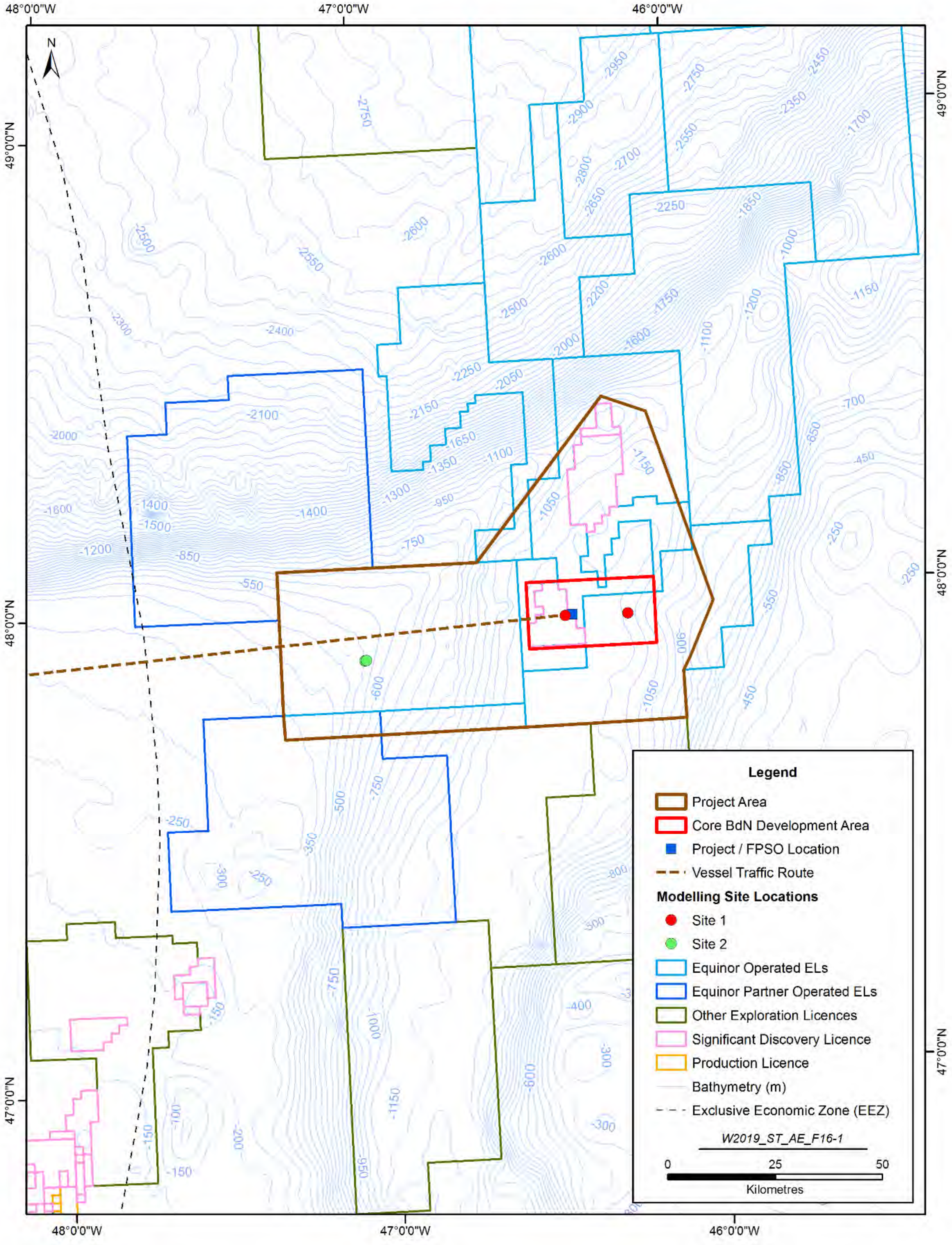


Figure 16-1 Location of Spill Trajectory Modelling

Subsurface blowouts near the seafloor were modelled separately at each location in a stochastic analysis that included 171 or 172 individual model runs per location. This analysis investigated the influence of environmental variability throughout the year over multiple years, on the trajectory and fate of released oil. Results from stochastic analyses were broken into two seasons depending on the majority of modelled days falling within either ice-free conditions (summer) from May through October or periods with ice-cover (winter) from November through April. Analysis of representative deterministic scenarios were conducted for individual trajectories that were identified as the 95th percentile "worst case" for surface oil exposure, water column concentration, and shoreline contact from blowouts near the seafloor modelled in the stochastic analysis, as well as for batch spills of BdN crude and marine diesel.

The estimated volumes of hydrocarbons released in the subsurface blowout scenarios (Table 16.20) are conservative (i.e., high) based upon the current knowledge of subsurface properties and potential blowout scenarios. Uncontrolled well discharge analysis was undertaken to assess the potential worst-case credible discharge that could occur as a result of an unmitigated blowout incident at two potential locations. The flowrates analysis was determined in consideration of reservoir properties based on data from previous drilling experience in the Project Area. The durations of flow rates were determined by Equinor Canada in consideration of spill response measures to stop the flow of oil, such as installation of a capping stack (36 days) and/or drilling a relief well (115 days). It is the opinion of Equinor Canada that the most likely (although extremely unlikely) credible "worst-case" release scenario would be the shorter duration subsurface blowout that required a capping stack to contain the release. This scenario is considered "worst-case" as it is an unrestricted release of oil from the seafloor (without consideration of the BOP, riser, or other restrictions that would likely reduce flow rate) that was allowed to continue without implementation of any response or containment measures to reduce flow or recover oil. In reality, spill response and containment measures would be implemented in the event of a spill to reduce potential adverse effects, thus mitigating the impact of a spill.

As described in Section 16.3, the representative batch spills modelled for the EIS represent worst case scenarios. The maximum volumes for each of these batch spill scenarios are greater than the maximum volume of similar spills reported to the C-NLOPB since 1997 (see Table 16.22) and therefore, and therefore deemed suitable for worst-case scenarios. In addition, the maximum volumes modelled exceed the total volume released over a 21-year period. The modelled volumes for batch spills are very conservative.

Table 16.22 Overview of C-NLOPB Batch Spill Records with Volumes Modelled for Crude, Diesel and SBM

Product	C-NLOPB Records from 1997 up to 19-Nov-2018				Maximum Volume Modelled (m³)
	# of spills reported	Average volume (m³)	Maximum volume (m³)	Total volume (m³)	
Crude	63	6.8	250.0	429.9	8,300
Diesel	27	0.2	2.1	4.8	6
SBM	41	5.6	74.0	229.9	275
Note: Information on the C-NLOPB is reported in litres but represented in cubic metres above Source: C-NLOPB 2018; C-NLOPB website up to November 19, 2018					

The hypothetical releases modelled in this study may be considered representative of other potential releases in the Project Area. As described earlier, final subsea layout has yet to be determined. The depth of release (500 m and 1,134 m, respectively) are within the range of areas present within the Project Area. The hypothetical spill locations were chosen to represent the range in water depths over the Project Area where drilling and production activities may occur, and proximity to sensitive areas. In the unlikely event of an actual oil spill, the trajectory, fate, and effects will be strongly determined by the specific environmental conditions, the precise locations and types of species present, and a myriad of details related to the event and specific timeframe. Modelled results are a function of the scenarios simulated and the input data used. The goal of this study was not to forecast every detail that could potentially occur, but to describe a range of possible consequences and effects of oil spills under various representative scenarios, located in different water depths and at varying distances to sensitive receptors within and around the Project Area, for the purposes of impact assessment and assessment of oil spill response measures required for the Project.

16.4.1.1 Stochastic Approach

This modelling study employed a stochastic approach to determine the range of potential trajectories and fates of hypothetical hydrocarbon releases based upon the variable forcing conditions (e.g., wind and currents). Stochastic modelling provides a probabilistic view of the likelihood that a given region might experience effects from released hydrocarbons over many possible environmental conditions occurring within and across multiple years.

Hypothetical release scenarios were simulated using the OILMAPDeep and SIMAP modelling packages, two three-dimensional trajectory and fate models developed by RPS. OILMAPDeep was used to define the near-field dynamics of the subsurface blowout plume which was then used as the initial conditions for the far-field modelling conducted in SIMAP. These near-field plume dynamics include the location and size of the subsurface plume at the termination (i.e., trap) height and the characterization of the oil droplet size distribution. Typically, the near-field model is on the timescale of seconds and length scale of hundreds of metres, whereas the far-field model is on the scales of hours / days and many kilometres. These models are described in Appendix E.

A stochastic approach was used in SIMAP to determine the potential footprint of areas that may be affected by a release of oil based upon variability in meteorological and hydrodynamic conditions. A stochastic scenario is a statistical analysis of tens to hundreds of individual trajectories resulting from the same release event, with each trajectory starting at a randomized time from a relatively long-term window. The stochastic approach analyzes the same type of release under varying environmental conditions to provide the anticipated variability in probable movement and behaviour of the release. In a stochastic analysis, multiple model runs (tens to hundreds of releases) are laid upon one another to create a cumulative footprint of releases. Further analyses provide two types of information for specific thresholds of interest including: 1) the probability that a given area may experience contamination, and 2) the shortest amount of time required for oil to reach any point within the predicted area. To analyze the probability or likelihood of potential effects, specific thresholds for surface oil thickness and shoreline oiling are used (Table 16.23). Figures and further analyses in this study include the lower socioeconomic thresholds of concern calculated from stochastic results. Additional information on the stochastic approach can be found in Appendix E.

Table 16.23 Thresholds Used to Define Areas and Volumes Exposed Above Levels of Concern

Threshold Type	Cutoff Threshold	Rationale/Comments (Socio-economic, Response, Ecological)	Visual Appearance	References
Oil Floating on Water Surface	0.04 g/m²	Socio-economic: A conservative threshold used in several risk assessments to determine effects on socio-economic resources (e.g., fishing may be prohibited when sheens are visible on the sea surface). Socio-economic resources and uses that would be affected by floating oil include commercial, recreational and subsistence fishing; aquaculture; recreational boating, port concerns such as shipping, recreation, transportation, and military uses; energy production (e.g., power plant intakes, wind farms, offshore oil and gas); water supply intakes; and aesthetics.	Fresh oil at this minimum thickness corresponds to a slick being barely visible or scattered sheen (colorless or silvery/grey), scattered tarballs, or widely scattered patches of thicker oil.	French McCay et al., 2011; French McCay et al., 2012; French McCay, 2016; Lewis, 2007, Bonn Agreement 2009, 2011
	10 g/m²	Ecological: Mortality of birds on water has been observed at and above this threshold. Sublethal effects on marine mammals, sea turtles, and floating Sargassum communities are of concern.	Fresh oil at this thickness corresponds to a slick being a dark brown or metallic sheen.	French et al., 1996; French McCay, 2009 (based on review of Engelhardt, 1983, Clark, 1984, Geraci and St. Aubin 1990, and Jenssen 1994 on oil effects on aquatic birds and marine mammals); French McCay et al., 2011; French McCay et al., 2012; French McCay, 2016

Table 16.23 Thresholds Used to Define Areas and Volumes Exposed Above Levels of Concern

Threshold Type	Cutoff Threshold	Rationale/Comments (Socio-economic, Response, Ecological)	Visual Appearance	References
Shoreline Oil	1.0 g/m²	Socio-economic/Response: A conservative threshold used in several risk assessments. This is a threshold for potential effects on socio-economic resource uses, as this amount of oil may trigger the need for shoreline cleanup on amenity beaches and affect shoreline recreation and tourism. Socio-economic resources and uses that would be affected by shoreline oil include recreational beach and shore use, wildlife viewing, nearshore recreational boating, tribal lands and subsistence uses, public parks and protected areas, tourism, coastal dependent businesses, and aesthetics.	May appear as a coat, patches or scattered tar balls, stain	French-McCay et al., 2011; French McCay et al., 2012; French McCay, 2016
	100 g/m²	Ecological: This is a screening threshold for potential ecological effects on shoreline flora and fauna, based upon a synthesis of the literature showing that shoreline life has been affected by this degree of oiling. Sublethal effects on epifaunal intertidal invertebrates on hard substrates and on sediments have been observed where oiling exceeds this threshold. Assumed lethal effects threshold for birds on the shoreline.	May appear as black opaque oil.	French et al., 1996; French McCay, 2009; French McCay et al., 2011; French McCay et al., 2012; French McCay, 2016
In Water Concentration	1.0 ppb (µg/L) of dissolved PAHs; corresponds to approximately 100 ppb (µg/L) of whole oil (THC) in the water column (soluble PAHs are approximately 1 percent of the total mass of fresh oil)	Water column effects for both ecological and socio-economic (e.g., seafood) resources may occur at concentrations exceeding 1 ppb dissolved PAH or 100 ppb whole oil; this threshold is typically used as a screening threshold for potential effects on sensitive organisms.	N/A	Trudel et al. 1989; French-McCay 2004; French McCay 2002; French McCay et al. 2012

*Thresholds used in supporting stochastic results figures. For comparison, a bacterium is 1-10 µm in size, a strand of spider web silk is 3-8 µm, and paper is 70-80 µm thick. Oil averaging 1 g/m² is roughly equivalent to 1 µm.

It is important to note that although large footprints of oil contamination are depicted for stochastic analyses, they are not the expected distribution of oil from any single release. These maps do not provide any specific information on the quantity of oil in a given area. They simply denote the probability of oil exceeding the given threshold passing through each grid cell location in the model domain over the entire model duration (160 days), based on the entire ensemble of runs (171 or 172 individual releases for both locations). Only probabilities of ≥1 percent were included in the map output, as lesser probabilities represent random noise in each set of 171 / 172 trajectories. Stochastic maps of water column concentration of dissolved hydrocarbons depict the likelihood that concentrations will exceed the identified threshold at any depth within the water column, but do not specify the depth at which this occurs and do not imply that the entire water column (i.e., from surface to bottom) will experience a concentration above the threshold.

Stochastic results are also useful in planning for oil spill response, as they characterize the probability that regions may experience contamination above specified thresholds, taking into account the wind and wave variability that is expected from many potentially-different release scenarios over time.

16.4.1.2 Deterministic Approach

Individual trajectories of interest were identified and selected from the stochastic ensemble of results for the deterministic analysis. The deterministic trajectory and fate simulations provided an estimate of the oil's transport through the environment as well as its physical and chemical behavior for a specific set of environmental conditions. While the stochastic analysis provides insight into the probable behavior of oil releases given historic wind and current data for the Project Area, the deterministic analysis provides individual trajectory, oil weathering information, expected concentrations or thicknesses of oil contamination, mass balance, or other information related to a single release at a given location and time.

Representative deterministic scenarios (i.e., single trajectory) (Table 16.24) were identified from each set of stochastic subsurface blowout results. Individual scenarios were selected based upon the size of the surface oil footprint, the mass of oil on shorelines, and the concentration of dissolved hydrocarbons in the water column, based upon a set of highly conservative socioeconomic thresholds:

- Surface oil average thickness >0.04 µm
- Shore oil average concentration >1.0 g/m²
- Subsurface (within the water column) dissolved hydrocarbon concentrations >1.0 µg/L

The selected scenarios included the identified 95th percentile runs for surface oil footprint, shoreline oil length, and water column concentration identified for each release location. In addition to these six deterministic scenarios, four surface releases were modelled as batch spills, including three surface release volumes (8,300 m³/d [crude oil], 1,000 m³/d [crude oil], and 6 m³/d [marine diesel]) and one subsurface release volume (500 m³/d [crude oil]).

Table 16.24 Selected Representative Deterministic Scenarios

Scenario Parameter	Release Parameters for Representative Deterministic Scenarios															
	95th percentile – Site 1						95th percentile – Site 2						Batch Spills			
Representative Scenario	Surface Oil Exposure Area	Water Column Oil Mass	Shoreline Contact Length	Surface Oil Exposure Area	Water Column Oil Mass	Shoreline Contact Length	Surface Oil Exposure Area	Water Column Oil Mass	Shoreline Contact Length	Surface Oil Exposure Area	Water Column Oil Mass	Shoreline Contact Length	FPSO Release	Offloading Release	Bunkering	Production Flowline Release
Release Site	Site 1						Site 2						FPSO Location			Site 1
Release Type	Subsurface Blowout						Subsurface Blowout						Surface Release			Subsurface Release
Depth of Release	1,134 m						500 m						Surface			1,134 m
Released Product	Bay du Nord crude oil						Bay du Nord crude oil						Bay du Nord crude oil		Marine Diesel	Bay du Nord crude oil
Release Duration	36 d			115 d			36 d			115 d			2 d	1 hr	2 mins	1 d
Release Rate	10,500 m³/d						10,500 m³/d						4,150 m³/d	1,000 m³/hr	0.05 m³/hr	500 m³/d
Total Released Volume	378,000 m³			1,207,500 m³			378,000 m³			1,207,500 m³			8,300 m³	1,000 m³	6 m³	500 m³
Model Duration	160 d						160 d						30 d			
Modelled Start Date and Season	2/18/2010 Winter	11/6/2010 Winter	2/27/2006 Winter	12/28/2009 Winter	5/27/2008 Summer	12/8/2010 Winter	11/29/2009 Winter	4/24/2012 Summer	4/6/2008 Summer	1/14/2010 Winter	9/8/2010 Winter	12/8/2010 Winter	6/4/2009 (calmest site-specific period identified between 2006-2012)			

16.4.2 Model Input Data

Geographical data including habitat mapping and shoreline identification and classification were obtained from multiple data sources. ECCC shoreline and habitat data was used for NL areas. Additional site-specific data from the New Brunswick Department of Natural Resources and Nova Scotia Department of Natural Resources were used. For the US shoreline, the US National Oceanic and Atmospheric Administration's (NOAA) Environmental Sensitivity Index and Maine Department of Environmental Protection's Environmental Vulnerability Index were used. Bathymetry was characterized using databases provided by NOAA National Geophysical Data Center and General Bathymetric Chart of the Oceans (see Section 3 of Appendix E for details).

Currents for the North Atlantic region were acquired from the US Navy Global HYCOM (HYbrid Coordinate Ocean Model) circulation model. For this study, daily current data were obtained for the period January 2006 through December 2012 for the North Atlantic region. HYCOM is a primitive-equation ocean general circulation model that evolved from the Miami Isopycnic-Coordinate Ocean Model (MICOM). MICOM has become one of the premier ocean circulation models, having been subjected to several validation studies. As with any hydrodynamic model, there is the potential that local currents may deviate from predictions based upon grid resolution and small-scale variability in ocean circulation dynamics. However, it is believed that the data that was used are sufficient for this type of modelling.

Climate Forecast System Reanalysis (CFSR) model. All data were acquired for the period between 2006 and 2012 (see Section 3 of Appendix E for details). The movement and behavior of released oil is greatly affected by the presence of sea ice. Oil trapped in or under sea ice will weather more slowly than oil released in open water. Algorithms in SIMAP for modelling the movement and behavior of oil in the presence of sea ice are based on the percentage of ice coverage (also commonly referred to as ice concentration).

Two hydrocarbon products were modelled for this study at the three release locations. The two product types include BdN crude oil and marine diesel. BdN crude oil was modelled for the subsurface blowouts at Site 1 and Site 2, the surface batch spills at the FPSO location, and the seafloor flowline batch spill at Site 1. Marine diesel was modeled for the surface vessel transfer batch spill at the FPSO location. The physical and chemical data used to characterize these oils was provided by Equinor Canada, with additional assays and measurements by SL Ross Environmental Research Ltd. (2016) and Intertek (2016).

BdN crude is a light crude oil with low viscosity and a high aromatic content (Tables 16.25 and 16.26). Equinor Canada provided ECCC with samples of BdN crude in 2017. The marine diesel modelled is a standard diesel that also has a low viscosity and high content of soluble hydrocarbons. The low viscosity and high soluble content of these oil products provides conservative approximations of anticipated concentrations in the water following a release, as a relatively large proportion of constituents have the potential to dissolve into the water column, when compared to oils with lower soluble content.

Table 16.25 Physical Properties for the Two Oil Products Used in Modelling

Physical Property	BdN Crude Oil	Marine Diesel
Density (g/cm³)	0.84553 @16°C 0.85800 @0°C	0.83100 @15°C 0.83089 @16°C
Viscosity (cP)	5.0 @20°C 53.0 @0°C	2.76 @15°C 2.76 @15°C
API Gravity	35.85	38.8
Pour Point (°C)	-9	-50
Interface Tension (dyne/cm)	15.5	27.5
Emulsion Maximum Water Content (%)	72	0

Table 16.26 Fraction of the Whole Oil Comprised of Different Distillation Cuts for the Two Oil Products

Distillation Cut[a]	Boiling Point (°C)	Description	BdN Crude Oil	Marine Diesel
AR1	<180	highly volatile and soluble monoaromatic hydrocarbons (BTEX[b] and MAHs C_6-C_9)	0.023739	0.019333
AR2	180 - 264	semi-volatile and soluble 2-ring aromatics (MAHs and PAHs C_{10}-C_{12})	0.004166	0.011410
AR3	265 - 380	low volatility and solubility 3-ring aromatics (PAHs C_{13}-C_{18})	0.066998	0.015605
AL1	<180	highly volatile aliphatics (C_4-C_8)	0.206261	0.144667
AL2	180 - 280	semi-volatile aliphatics (C_9-C_{16})	0.160834	0.478690
AL3	280 - 380	low volatility aliphatics (C_{17}-C_{23})	0.168002	0.303295
THC1	<180	total hydrocarbon fraction 1 (sum of AR1 and AL1)	0.230000	0.164000
THC2	180 - 280	total hydrocarbon fraction 2 (sum of AR2 and AL2)	0.165000	0.490100
THC3	280 - 380	total hydrocarbon fraction 3 (sum of AR3 and AL3)	0.235000	0.318900
Residuals	>380	aromatics ≥4 rings and aliphatics >C_{20} that are neither volatile nor soluble	0.37000	0.02700

[a] Note that the terms “aromatic” and “aliphatic” are used in a modelling context. “Aromatic” refers to all soluble and volatile hydrocarbons and may include actual aliphatic compounds (by chemical definition) that are soluble. In the modelling context, “aliphatic” refers to insoluble and volatile hydrocarbons.

[b] BTEX (benzene, toluene, ethylbenzene, xylene), MAHs (monocylic aromatic hydrocarbons), and PAHs (polycyclic aromatic hydrocarbons) are the more soluble, bioavailable, and potentially toxic components in oil.

Note that the total hydrocarbon concentration (THC) is the sum of the aromatic (AR) and aliphatic (AL) groups. Numbers of carbons in the included compounds are listed.

16.4.3 Subsurface Blowout Model Results

In total, four unmitigated subsurface blowout release events were evaluated as part of this study. Oil and gas were introduced to the water column through an 8.5-inch orifice near the seafloor at a rate of 10,500 m^3/d to simulate an uncontrolled release from the wellhead frequently referred to as a blowout. The modelled release depth ranged from 500 m (Site 2) to 1,134 m (Site 1) at the sediment / water interface at the two identified release locations. BdN crude oil was modelled without the application of mitigation or response measures to exit each wellhead for both 36 and 115 days.

Graphical depictions of surface oil thickness, in-water concentrations, and shoreline and sediment contamination have been provided for stochastic and deterministic analyses. For each stochastic scenario, results images include both probability and minimum time for specific threshold exceedances. For deterministic scenarios, results include cumulative footprints of surface oil thickness, in-water concentrations, and shoreline and sediment contamination.

The results from both the unmitigated subsurface blowouts and topside releases presented below illustrate the spatial extent of the water surface and shoreline oil contamination. Stochastic results include:

- The probability footprints for surface oil in excess of 0.04 µm
- The corresponding minimum time for surface oil to exceed a threshold of 0.04 µm
- The probability footprints of shoreline oil in excess of 1 g/m^2
- The corresponding minimum time for surface oil to exceed a threshold of 1 g/m^2

The probabilities of oiling were based on a statistical analysis of the ensemble of individual trajectories modelled for each release scenario. Stochastic figures do not imply that the entire contoured area would be covered with oil in the event of a release, nor do they provide any specific information on the quantity of oil in a given area. Rather, these figures denote the probability of oil exceeding socioeconomic effects thresholds over all stochastic runs (171 / 172 individual releases for the annual scenario), at all modelled time steps (over 160 days), and for each point within the modelled domain. Note that only probabilities of greater than or equal to 1 percent were included in the map output.

16.4.3.1 Stochastic Results

The minimum time footprints correspond with the associated probability of oiling map. Each figure illustrates the shortest amount of time required (from the initial release) for each point within the footprint to exceed the defined threshold. The time reported is the minimum value for each point from the entire ensemble of trajectories. Together, probability and minimum time figures can be interpreted together to read: “There is X percent probability that oil will exceed the identified threshold at a specific location, and this exceedance can occur in as little as Y days”.

Summaries of the stochastic analyses of potential surface oil and water column concentration by dissolved hydrocarbons depict areas to the east of the release sites as having the highest potential likelihood (>90 percent) to exceed conservative socioeconomic thresholds (Figures 16-2 to 16-25). Lower probabilities of threshold exceedance are predicted to the north and south (10 percent to 25 percent), while generally <25 percent of all releases have the potential to exceed thresholds to the west of the hypothetical release locations. In many cases, oil exposure above the identified threshold was predicted to extend beyond the extent of the model domain predominantly to the east and south. In these scenarios, the environmental forcing mechanisms (i.e., wind and currents) and the long timeframe modelled (160 days) allowed for the transport of oil at extremely conservative (low) thresholds outside of the model domain. The oil that was predicted to be transported out of the domain would have traveled hundreds of kilometres away from the hypothetical release location and typically would have done so on time scales greater than 25-50 days following the release. Based upon weathering rates, the oil that is predicted to be transported outside of the model domain would be highly weathered. At this point of weathering, the lighter and more toxic ends of the hydrocarbon would have evaporated and/or degraded, which would reduce the toxicity of the remaining oil. The water-soluble components of hydrocarbons have a high bioavailability and thus the potential to cause acute toxic effects on marine organisms. As oil weathers and evaporates, the amount of water-soluble components, which are volatile, in the weathered oil decreases, thereby reducing its toxicity.

There were several identified differences in the distribution and spatial extent of predicted threshold exceedances between the modelled release scenarios at the two locations. The shallower site (Site 2) had greater areas with >1 percent and 90 percent probability of surface oil exceeding 0.04 µm for both the short (36-day) and long (115-day) releases, when compared to the deeper site, Site 1. In general, no large differences in areas exceeding water column thresholds were predicted between the two sites. The length of shoreline that was susceptible to oil making contact from a 36-day release was greater at Site 2, compared to Site 1, while the length of susceptible shoreline was generally greater at Site 1 for the 115-day release.

For the two release durations modelled, the 115-d release scenarios had slightly larger areas of >1 percent probability surface oil, water column oil, and shoreline oil exceeding the identified thresholds, when compared to the 36-d release scenarios. However, the longer duration releases had much larger predicted areas of 90 percent probability of exceedance. Due to the longer duration and therefore larger amount of oil being released, the 115-day release scenarios had a higher potential to exceed surface oil, water column oil, and shoreline oil thresholds. However, because both the 36-day and 115-day simulations were modelled for 160 days, all releases experienced the same environmental forcing (i.e., wind and currents). Because of this, large differences in the >1 percent probability contours were not predicted.

Based upon 171 or 172 individual trajectories for the 36-d and 115-d durations, respectively, most of the shoreline contact was predicted to occur on the Avalon Peninsula and southern shore of the Island of Newfoundland (10 percent to 25 percent probability), and the southeast coast of Labrador (1 percent to 10 percent probability). As the Avalon Peninsula/southern shore of Newfoundland is closer to the release locations, this area experiences a higher probability of oil making contact. The probability of oil making contact with the shoreline was less than a 22 percent to 25 percent for any given point within all scenarios, with the worst case predicted for the 115-day winter release scenarios. For each modelled stochastic scenario, oil has the potential to reach shore within 13 to 15 days for winter scenarios and 31 to 35 days for summer scenarios. Therefore, the oil that was predicted to make contact with shorelines was expected to be highly weathered (i.e., lighter and more toxic components would have evaporated, dissolved, and degraded thereby reducing the toxicity of the residual oil), as minimum time estimates ranged from weeks to over a month.

Two seasons (summer and winter) were investigated to determine differences caused by seasonal variations in met-ocean conditions. Overall, summer scenarios had smaller predicted extents for both surface and water column oil (>1 percent probability), when compared to the winter scenarios. Therefore, the areas of 90 percent probability were greater in the summer scenarios, as oil was contained within a smaller region. Due to the larger predicted extent in winter scenarios, more shoreline area was susceptible to contact with oil when compared to summer scenarios. As stated previously, stochastic figures do not imply that the entire contoured area would be covered with oil in the event of a single release, nor do they provide any information on the quantity of oil in each area. The large threshold exceedance footprints in annual results are not the expected exposure from any single release of oil, but rather areas where there is >1 percent probability that exposure above the thresholds was predicted to occur, based on the combination of either 171 or 172 (annual), 90 or 89 (summer), or 81 or 83 (winter) individual releases (i.e., blowouts) analyzed together.

Figures 16.2 to 16.25 display the results by season (annual, winter, and summer), by the size of the regions within specific probability bins in the modelled domain.

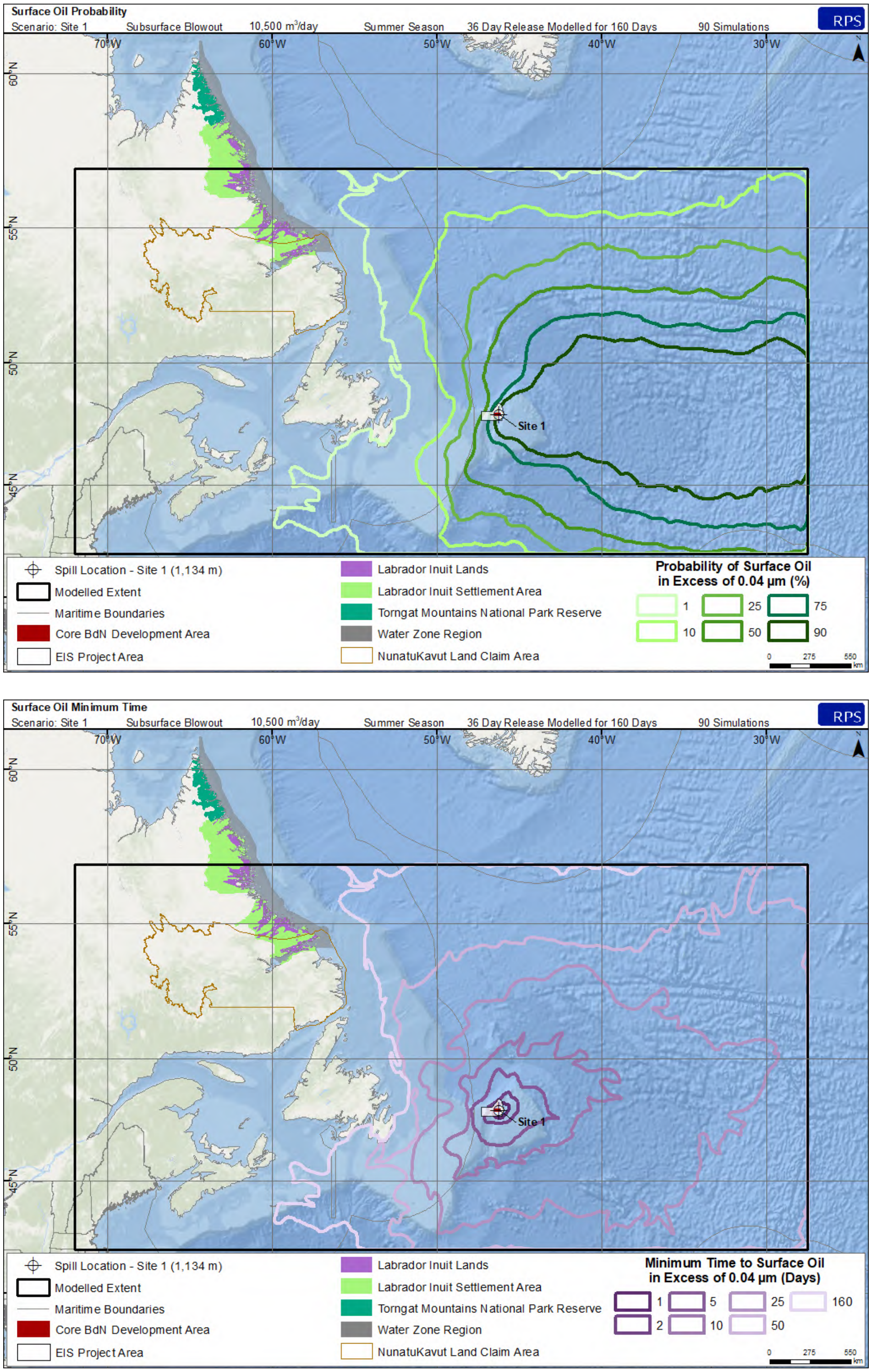


Figure 16-2 **Unmitigated 36-day Release in Summer (Site 1) - Probability of Average Surface Oiling (top) and Minimum Time to Surface Oil (bottom) in Excess of 0.04 µm**

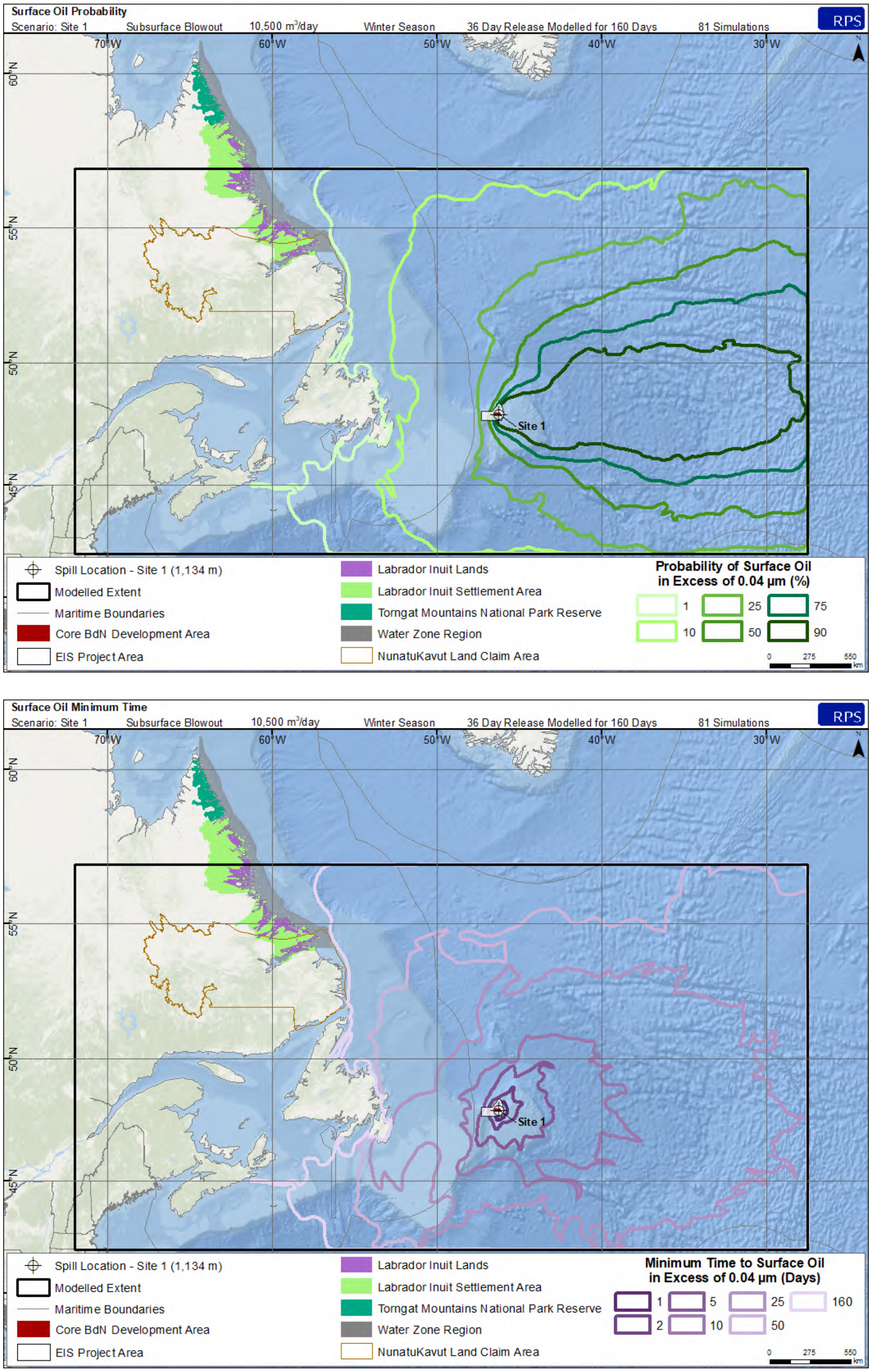


Figure 16-3 Unmitigated 36-day Release in Winter (Site 1) - Probability of Average Surface Oiling (top) and Minimum Time to Surface Oil in Excess of 0.04 µm (bottom)

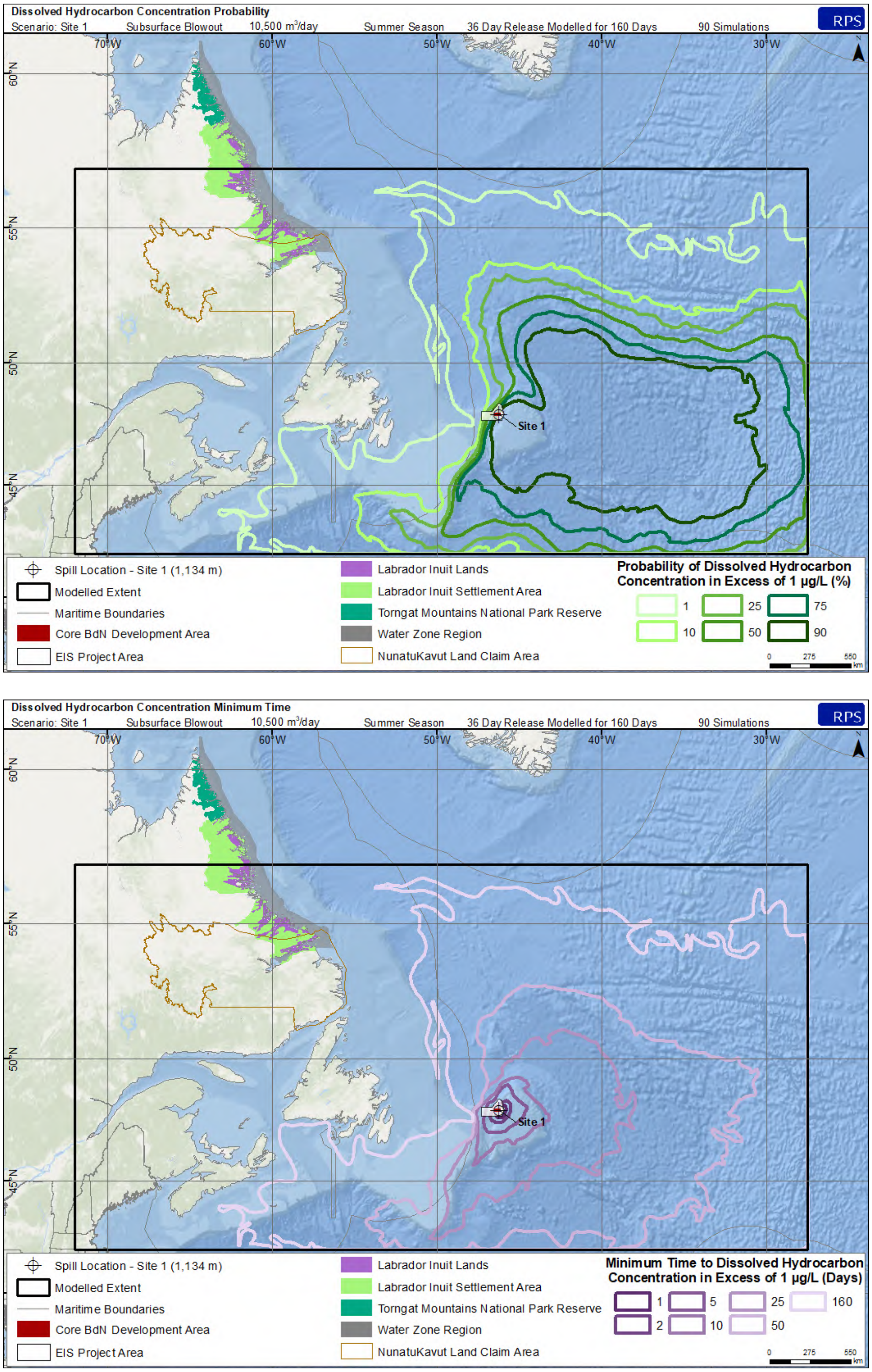


Figure 16-4 Unmitigated 36-day Release in Summer (Site 1) - Probability of Dissolved Hydrocarbon Concentrations (top) and Minimum Time to Threshold Exceedance of 1 µg/L (bottom)

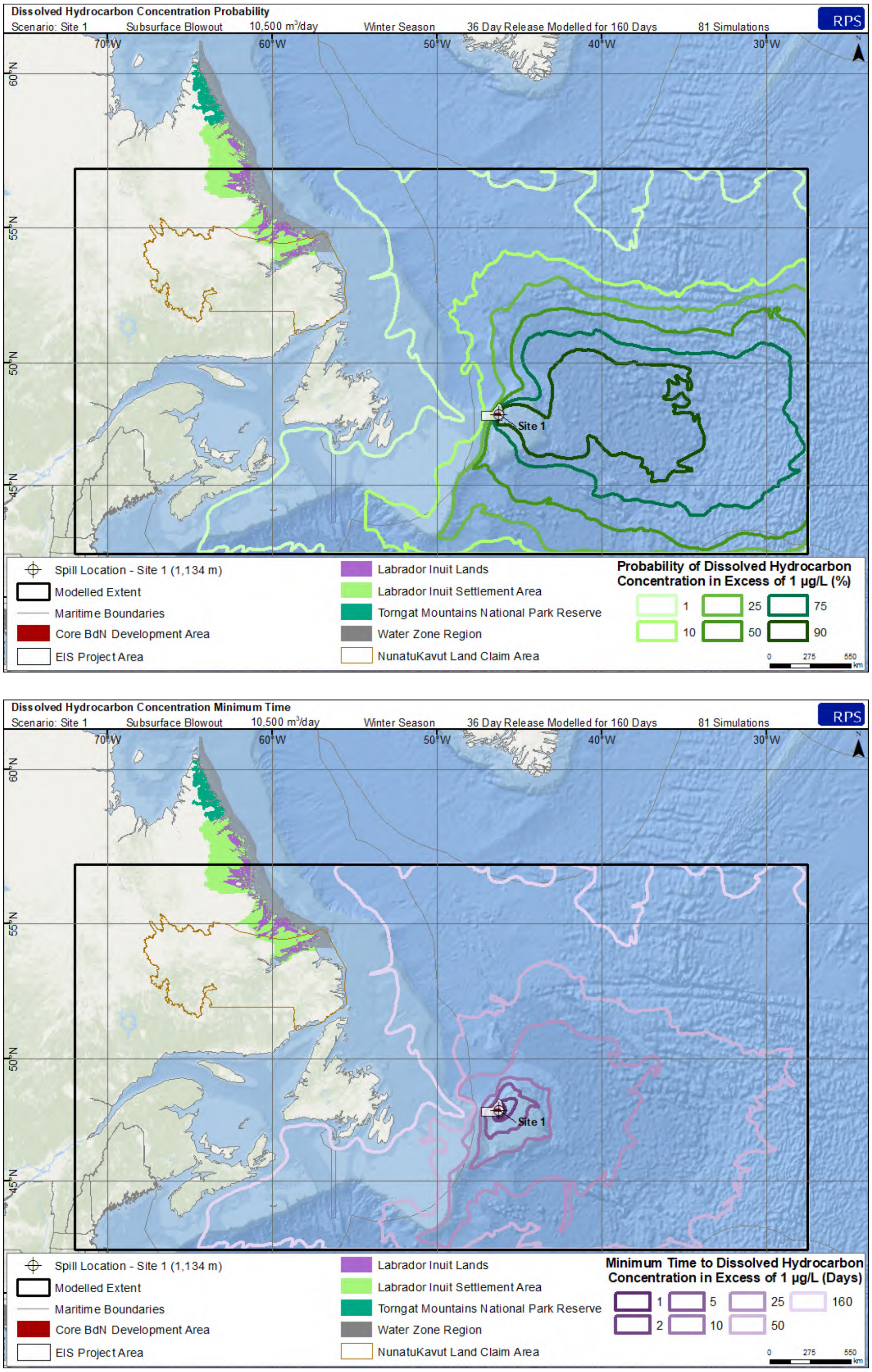


Figure 16-5 Unmitigated 36-day Release in Winter (Site 1) - Probability of Dissolved Hydrocarbon Concentrations (top) and Minimum Time to Threshold Exceedance of 1 µg/L (bottom)

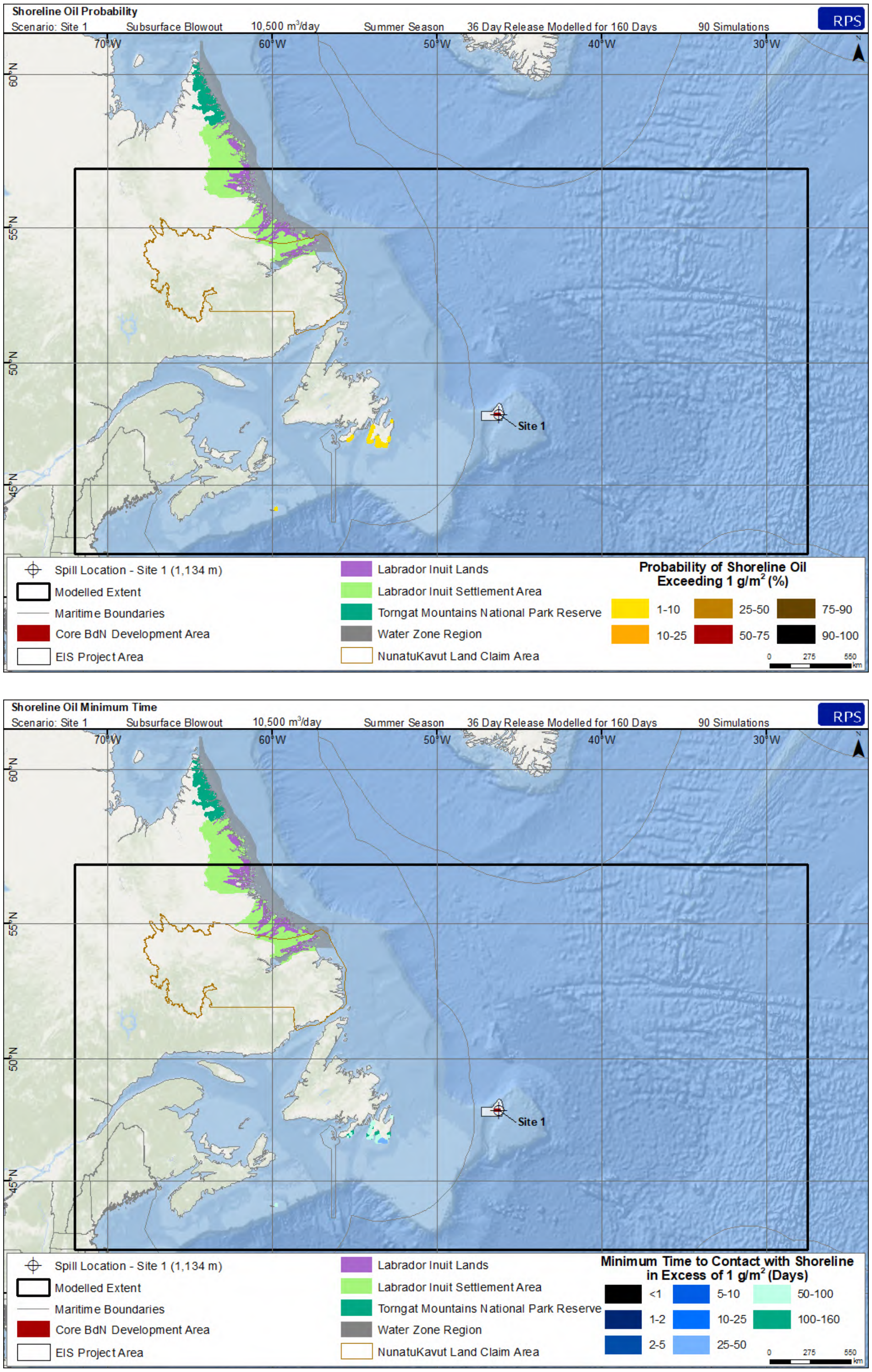


Figure 16-6 Unmitigated 36-day Release in Summer (Site 1) - Probability of Shoreline Oil (top) and Minimum Time to Contact with Shoreline in Excess of 1 g/m² (bottom)

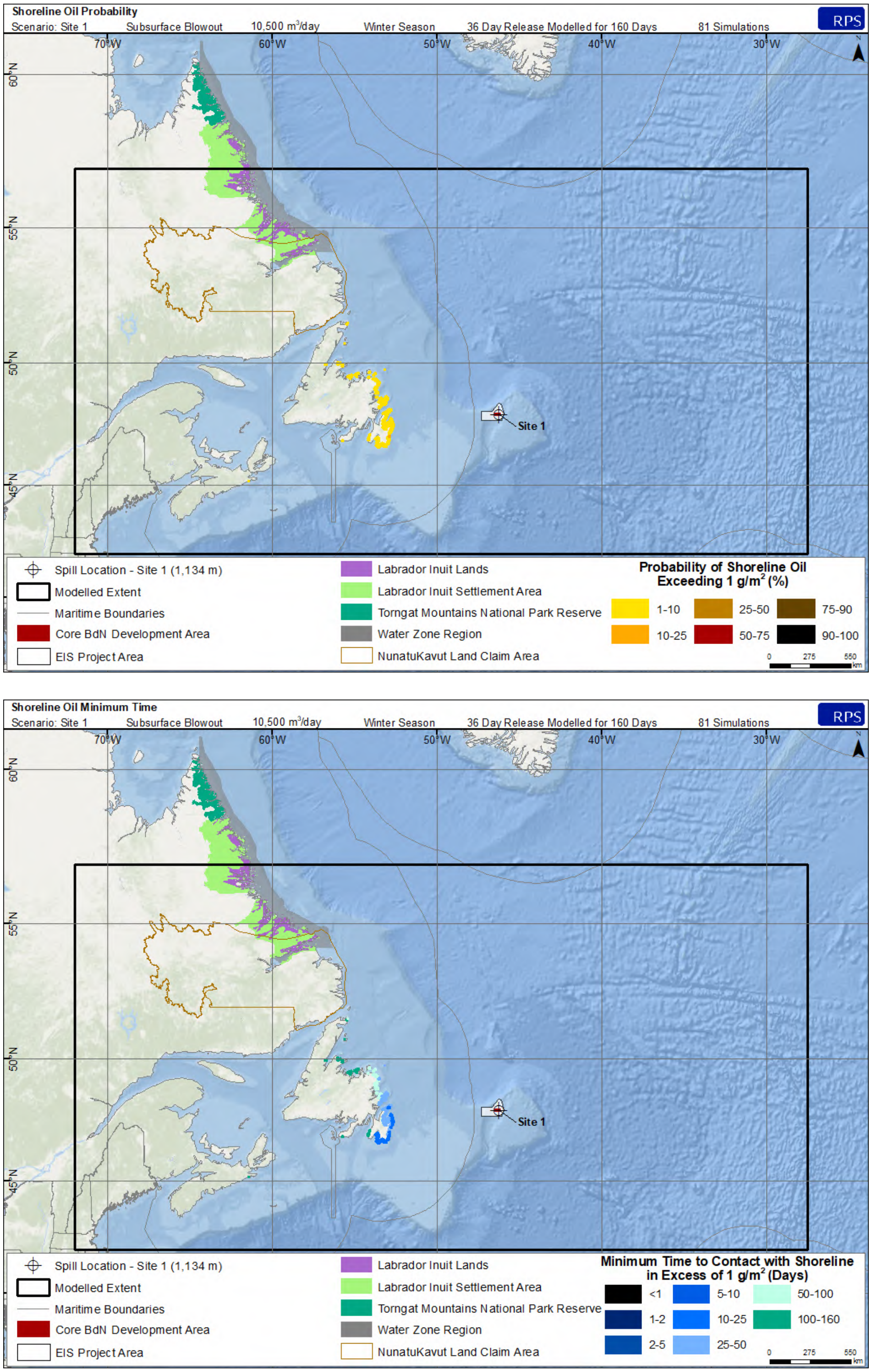


Figure 16-7 Unmitigated 36-day Release in Winter (Site 1) - Probability of Shoreline Oil (top) and Minimum Time to Contact with Shoreline in Excess of 1 g/m² (bottom)

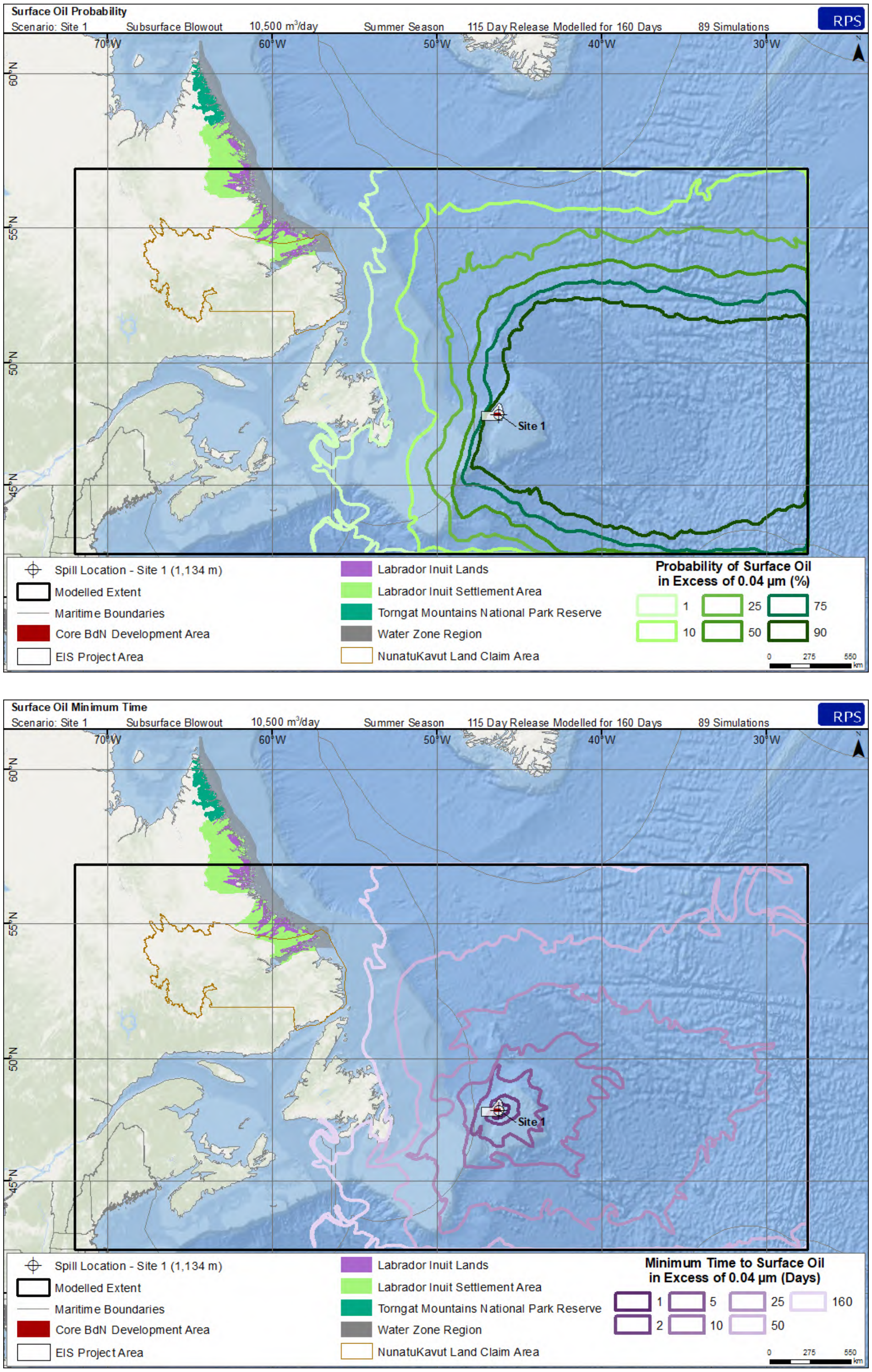


Figure 16-8 Unmitigated 115-day Release in Summer (Site 1) - Probability of Average Surface Oiling (top) and Minimum Time to Surface Oil in Excess of 0.04 µm (bottom)

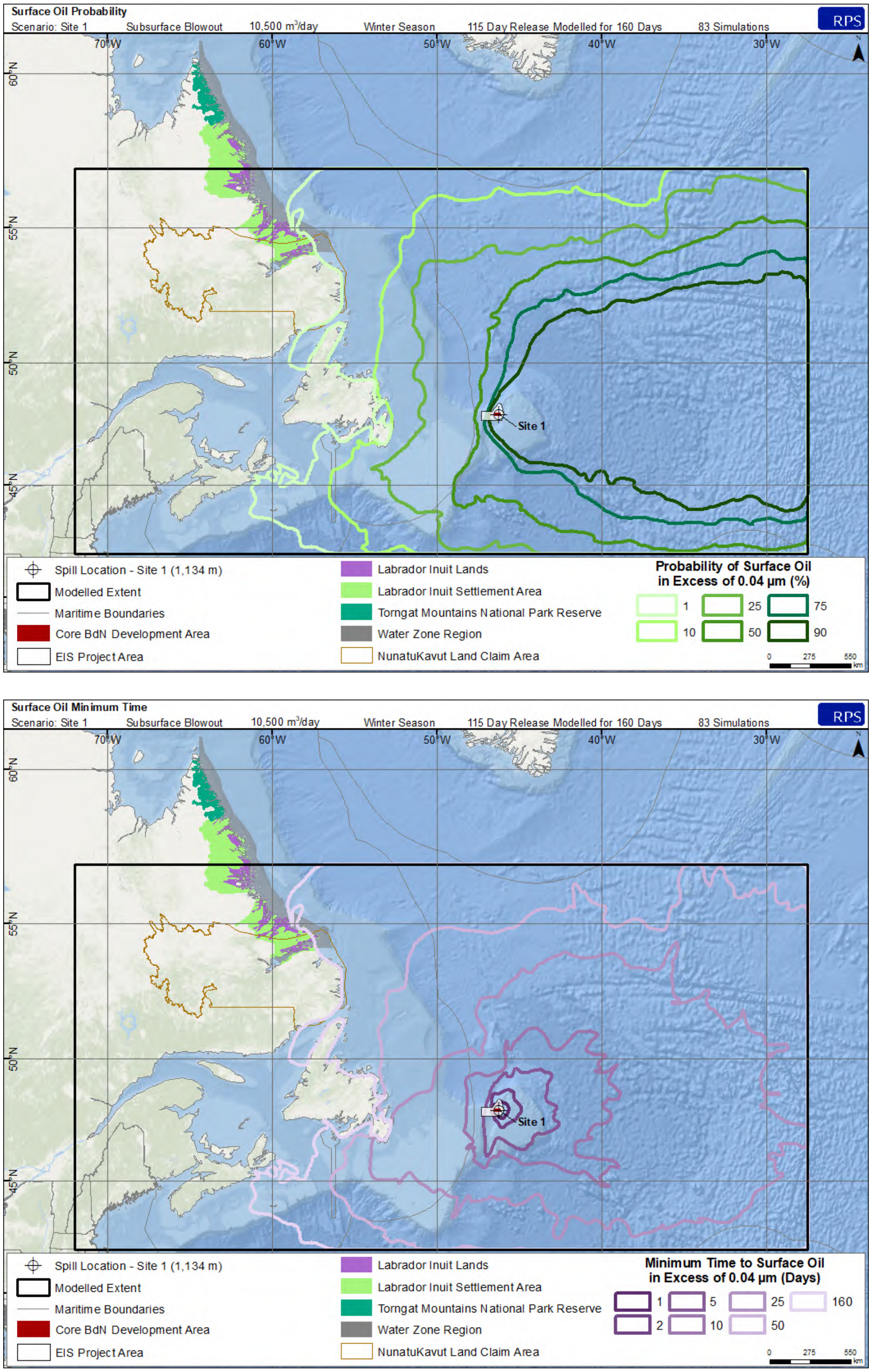


Figure 16-9 Unmitigated 115-day Release in Winter (Site 1) - Probability of Average Surface Oiling (top) and Minimum Time to Surface Oil in Excess of 0.04 µm (bottom)

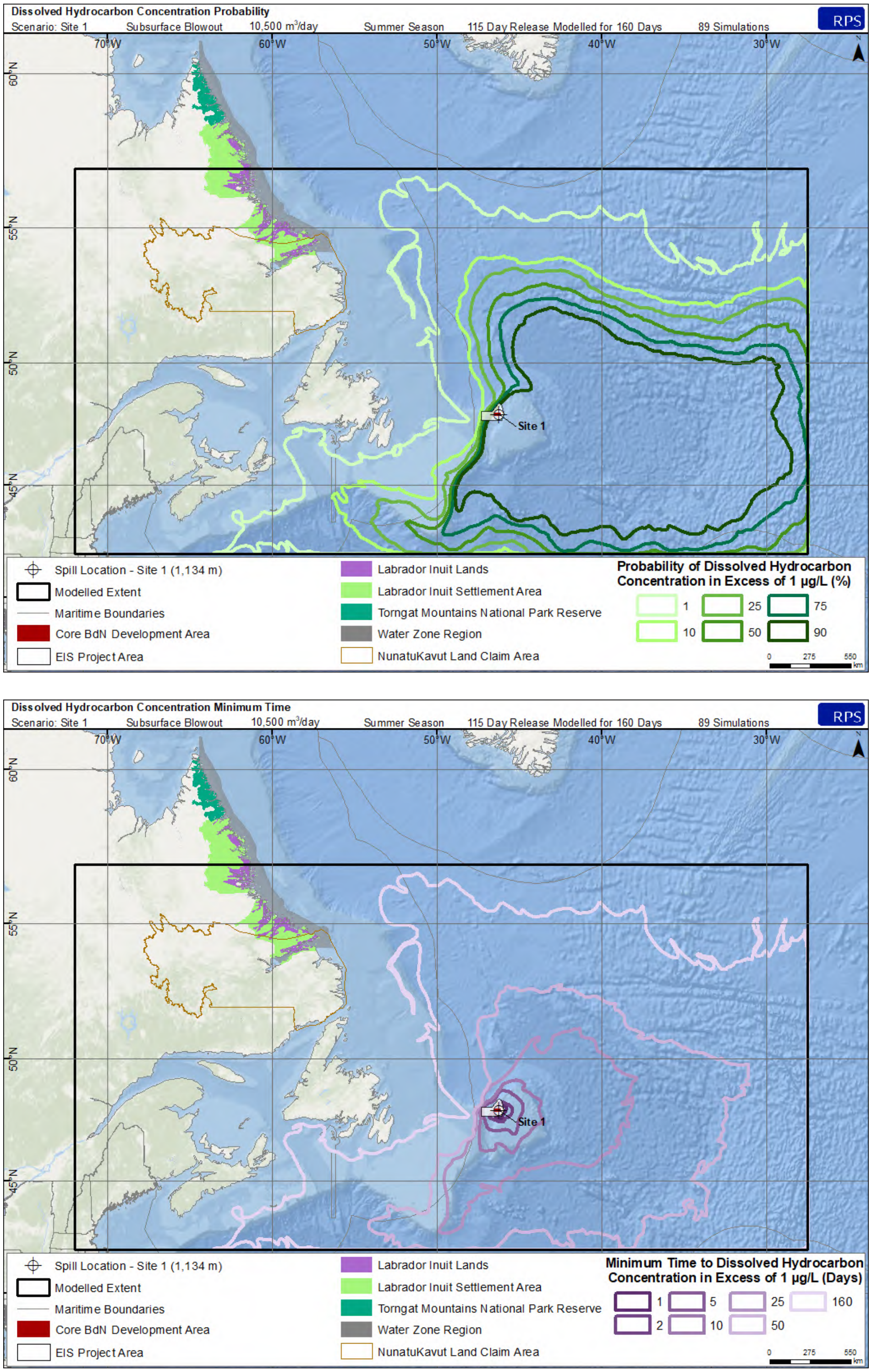


Figure 16-10 Unmitigated 115-day Release in Summer (Site 1) - Probability of Dissolved Hydrocarbon Concentrations (top) and Minimum Time to Threshold Exceedance of 1 µg/L (bottom)

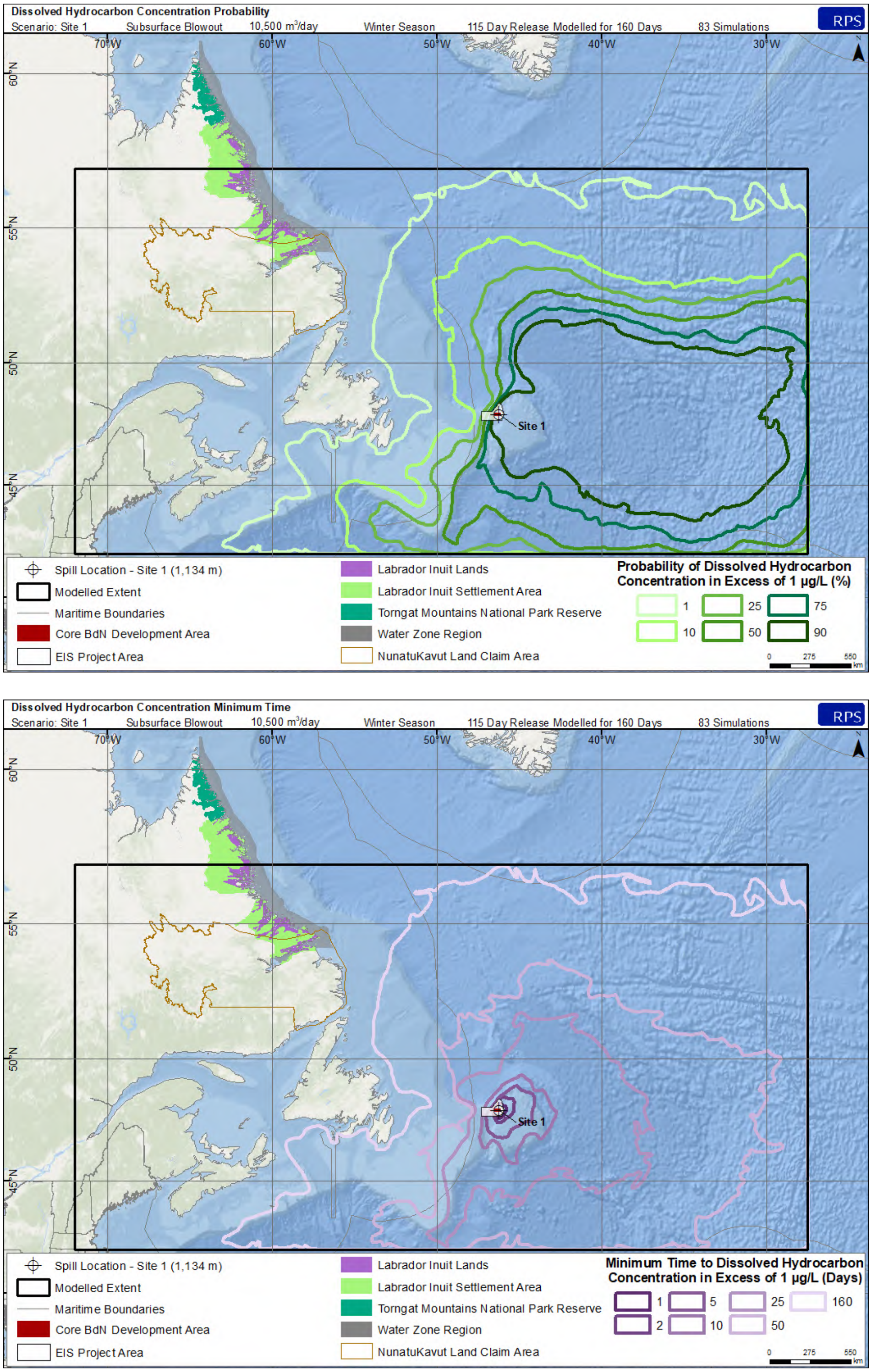


Figure 16-11 Unmitigated 115-day Release in Winter (Site 1) - Probability of Dissolved Hydrocarbon Concentrations (top) and Minimum Time to Threshold Exceedance of 1 µg/L (bottom)

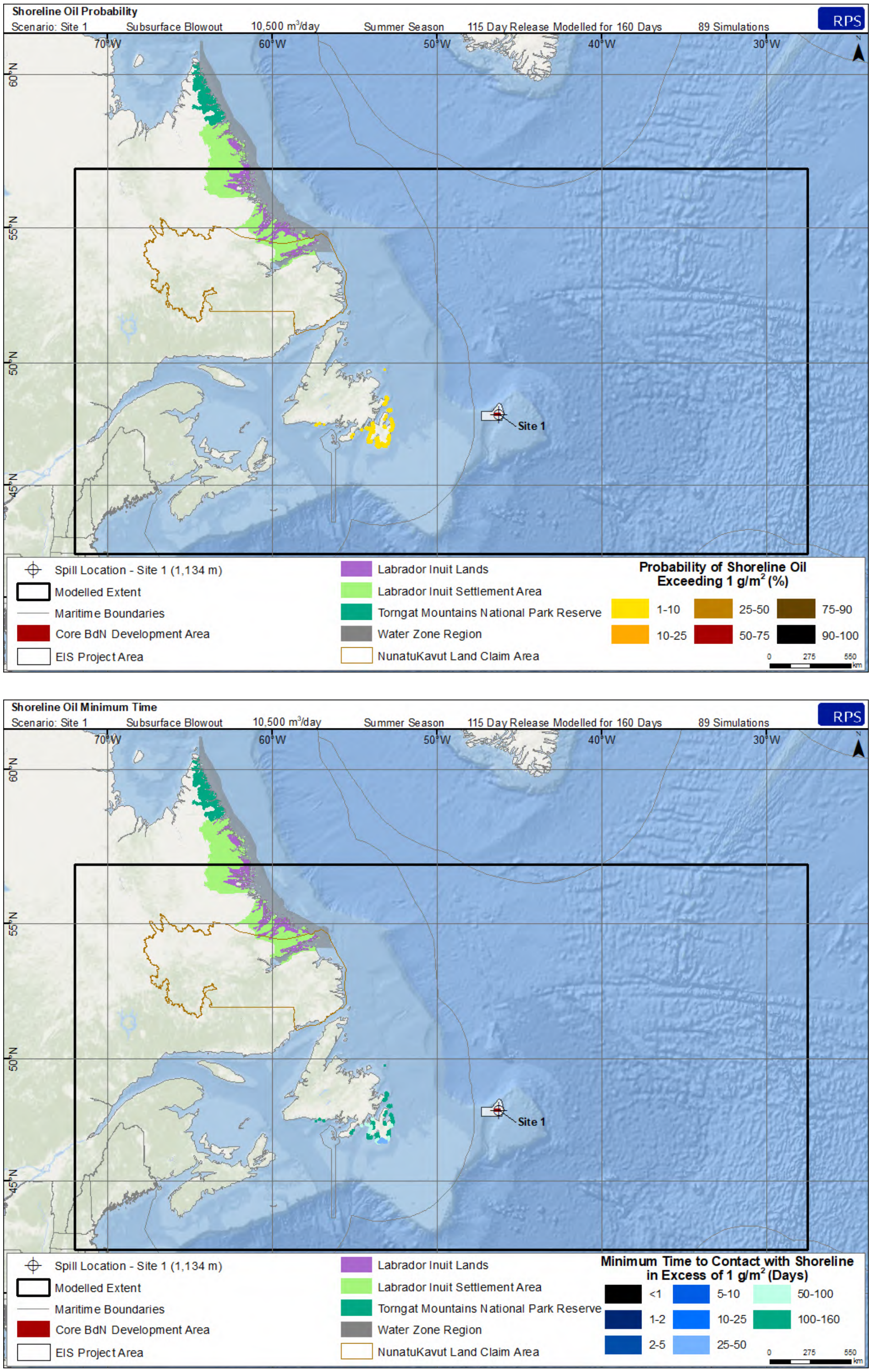


Figure 16-12 Unmitigated 115-day Release in Summer (Site 1) - Probability of Shoreline Oil (top) and Minimum Time to Contact with Shoreline in Excess of 1 g/m² (bottom)

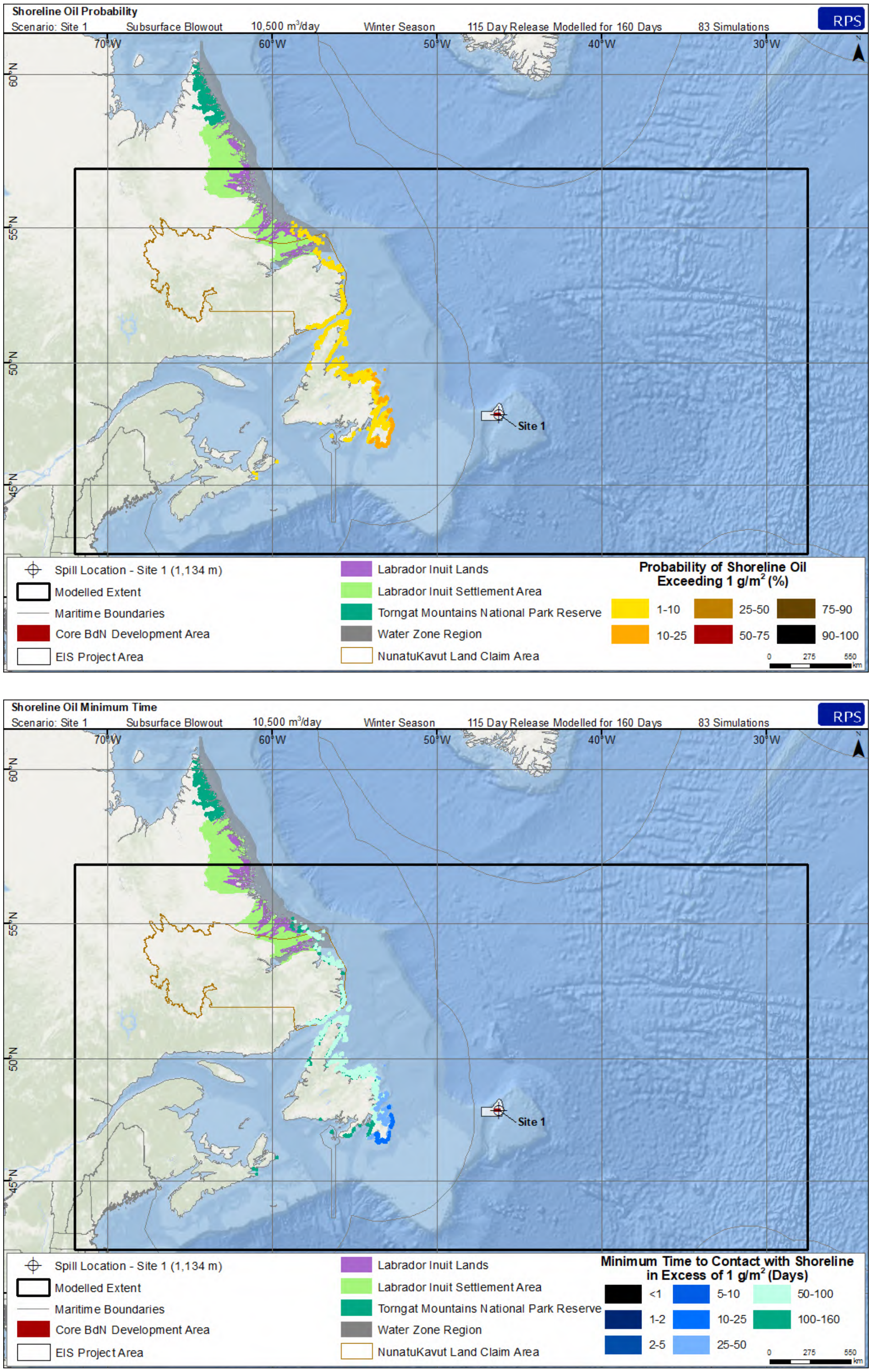


Figure 16-13 Unmitigated 115-day Release in Winter (Site 1) - Probability of Shoreline Oil (top) and Minimum Time to Contact with Shoreline in Excess of 1 g/m^2 (bottom)

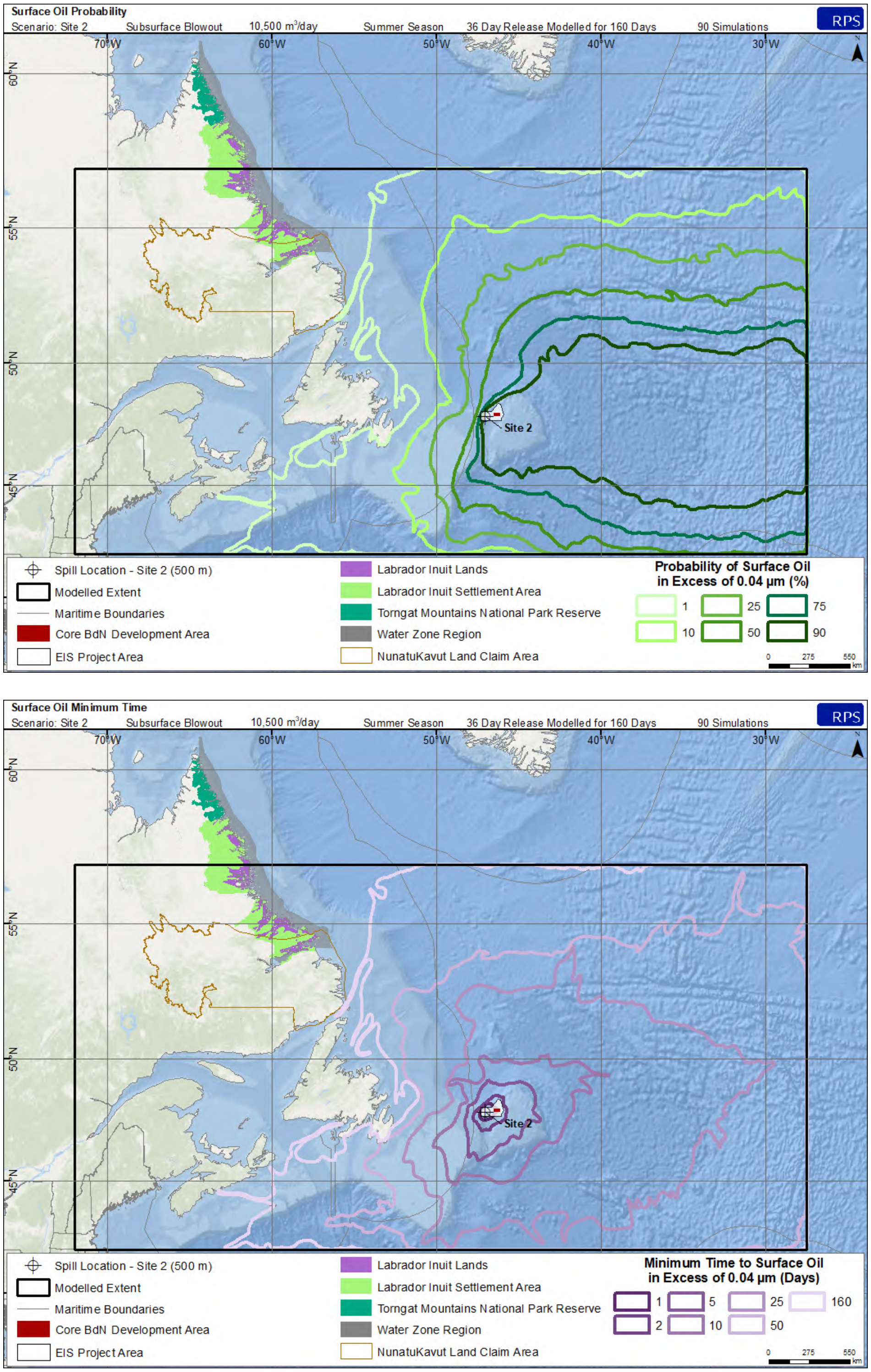


Figure 16-14 Unmitigated 36-day Release in Summer (Site 2) - Probability of Average Surface Oiling (top) and Minimum Time to Surface Oil in Excess of 0.04 µm (bottom)

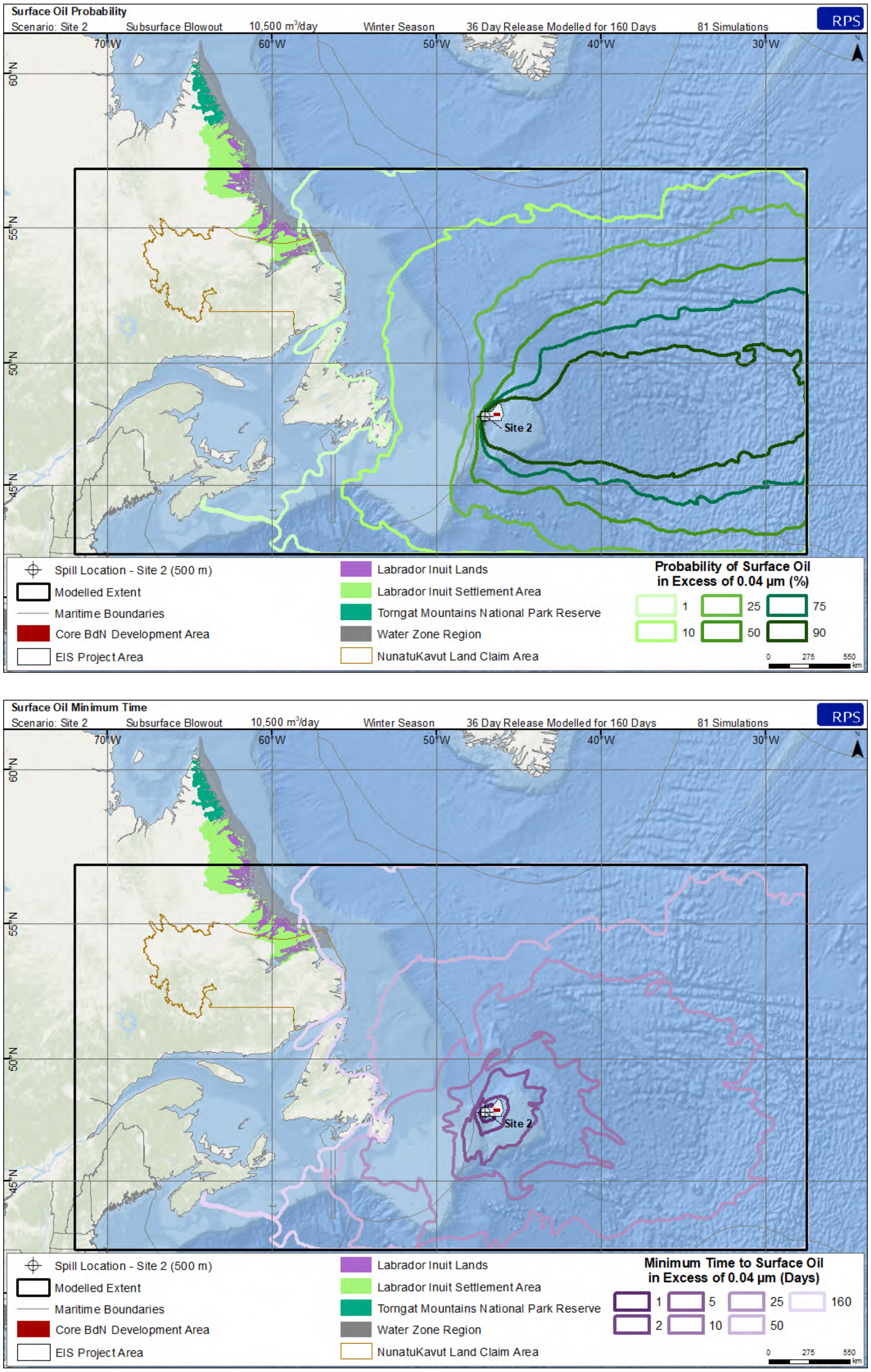


Figure 16-15 Unmitigated 36-day Release in Winter (Site 2) - Probability of Average Surface Oiling (top) and Minimum Time to Surface Oil in Excess of 0.04 µm (bottom)

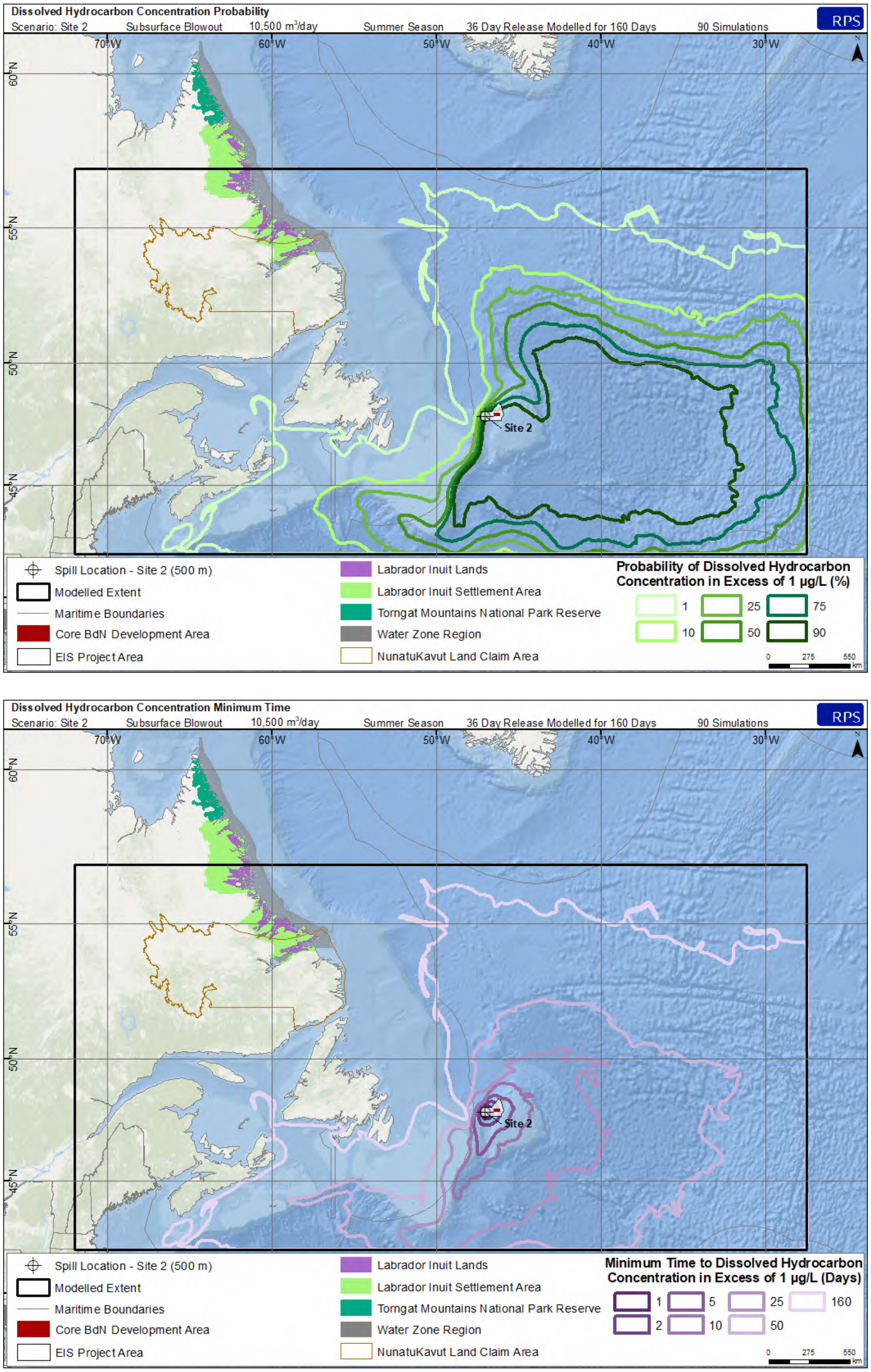


Figure 16-16 Unmitigated 36-day Release in Summer (Site 2) - Probability of Dissolved Hydrocarbon Concentrations (top) and Minimum Time to Threshold Exceedance of 1 µg/L (bottom)

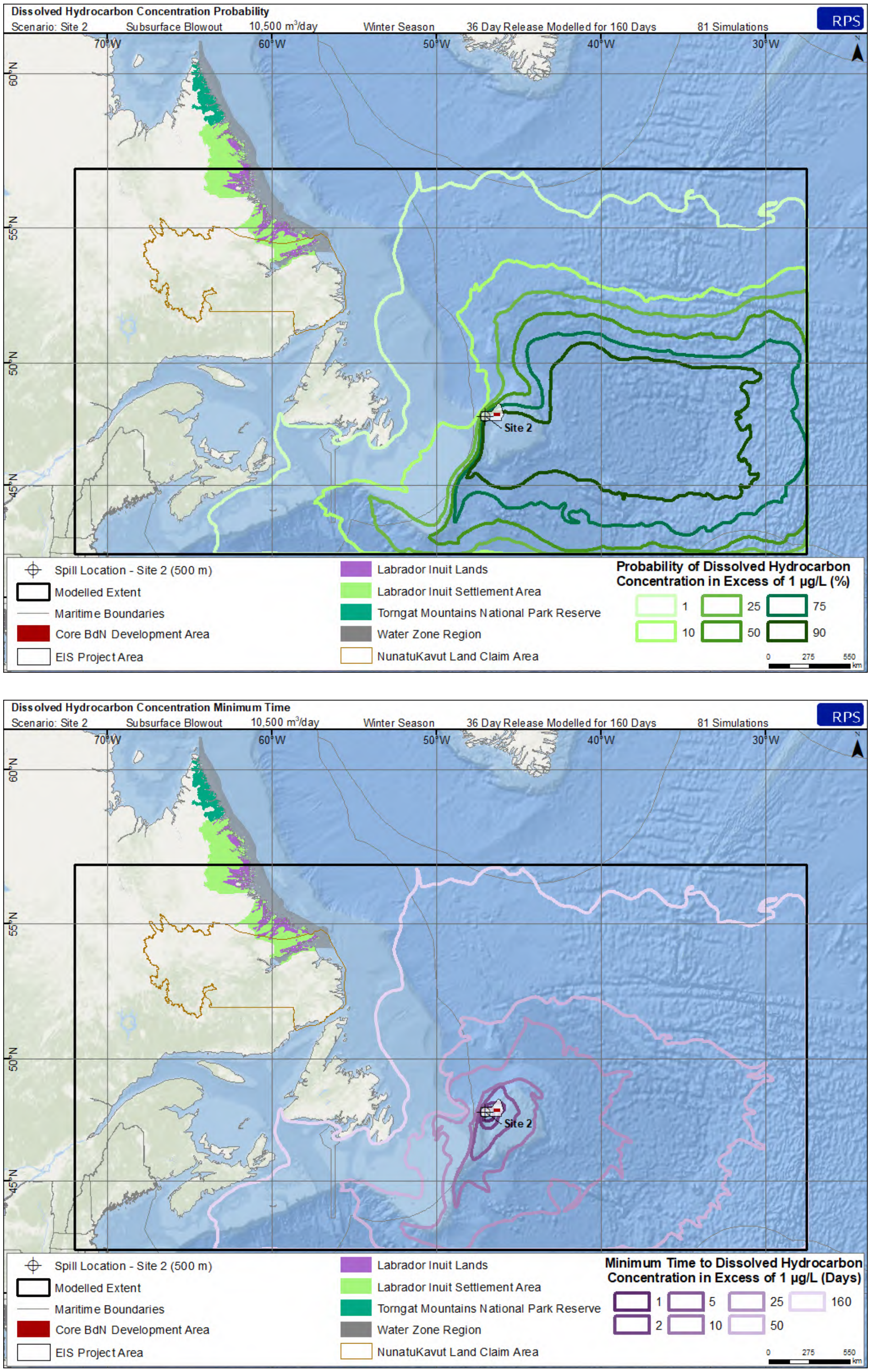


Figure 16-17 Unmitigated 36-day Release in Winter (Site 2) - Probability of Dissolved Hydrocarbon Concentrations (top) and Minimum Time to Threshold Exceedance of 1 µg/L (bottom)

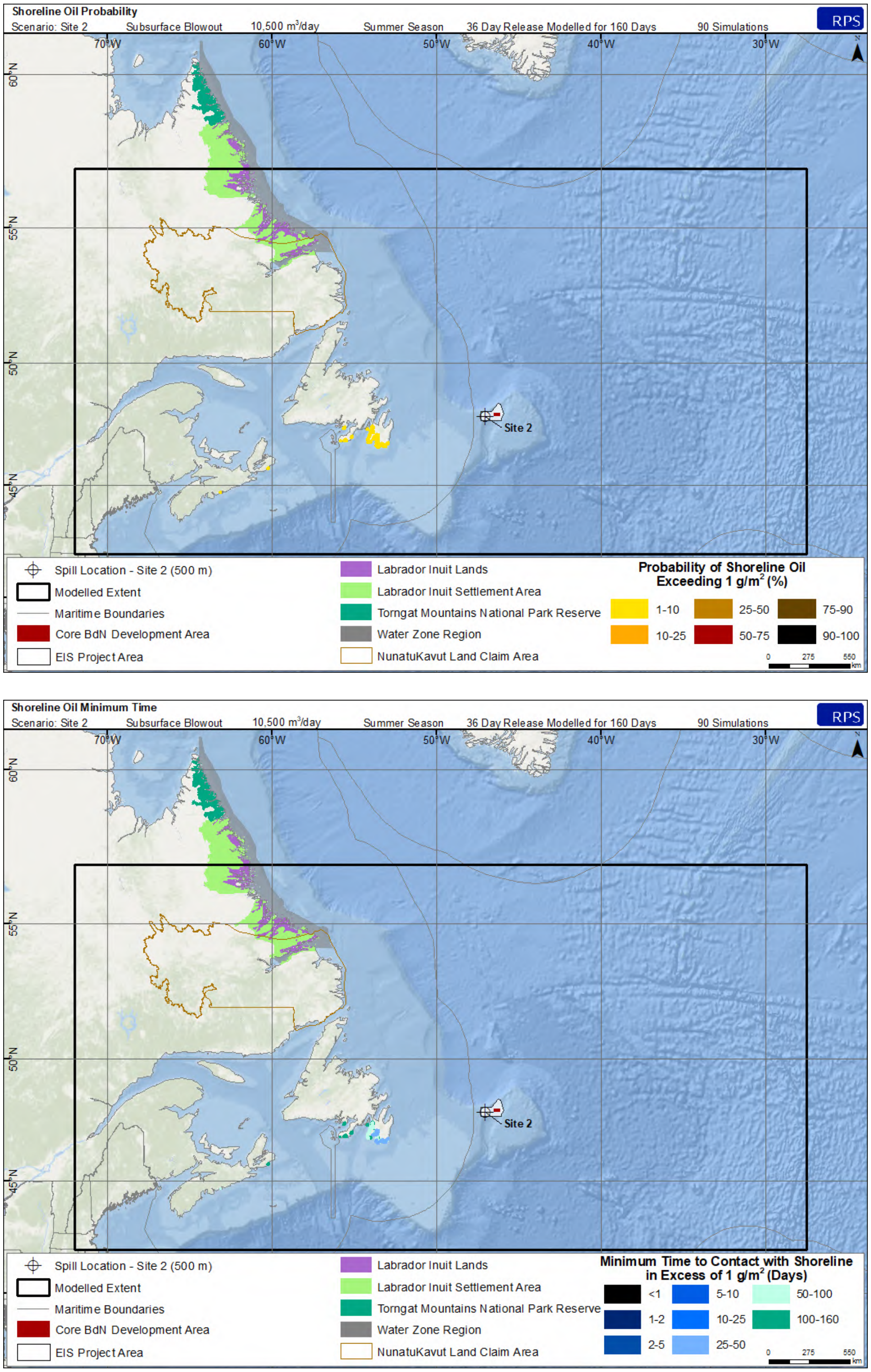


Figure 16-18 Unmitigated 36-day Release in Summer (Site 2) - Probability of Average Shoreline Oil (top) and Minimum Time to Contact with Shoreline in Excess of 1 g/m² (bottom)

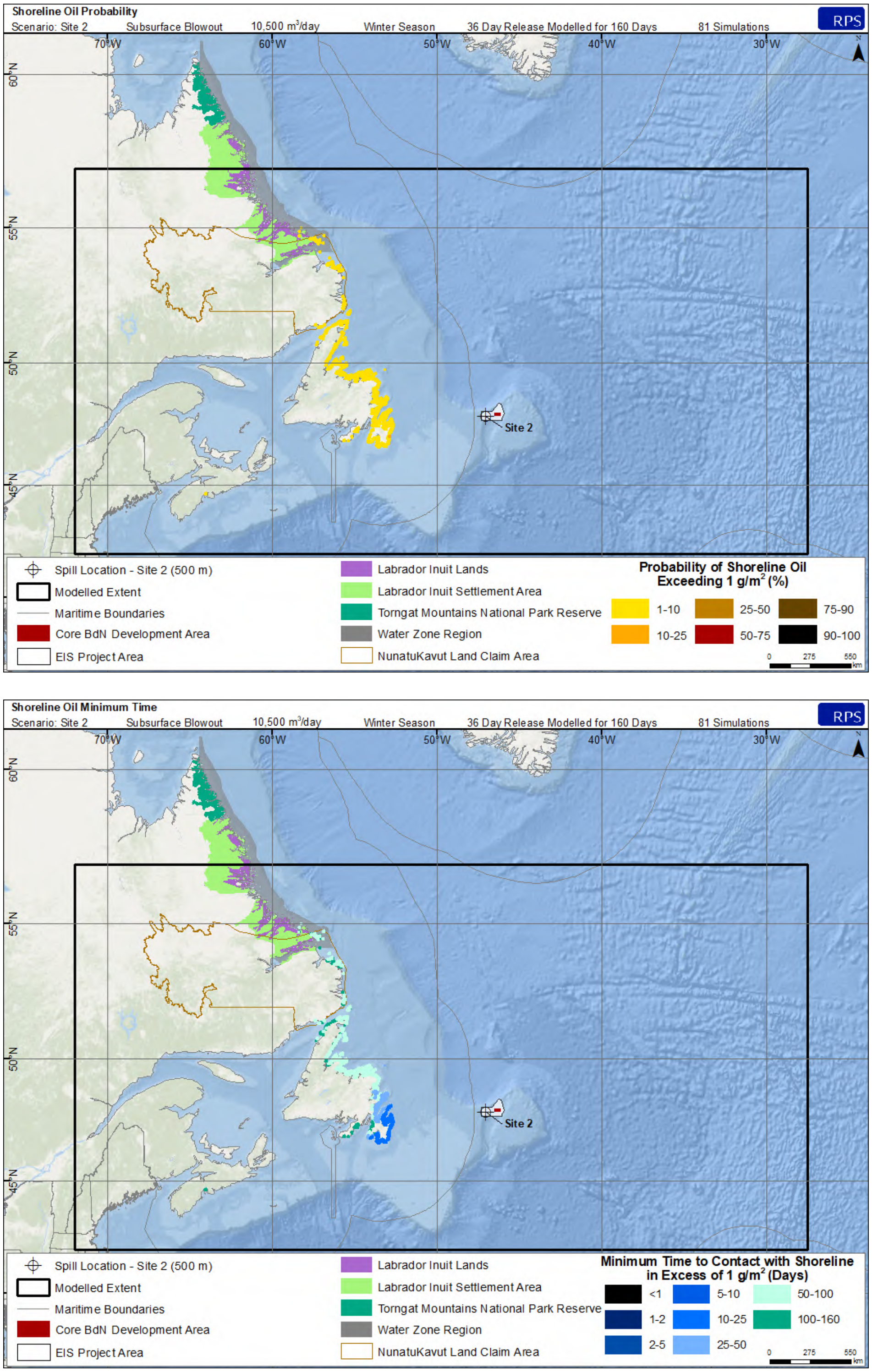


Figure 16-19 Unmitigated 36-day Release in Winter (Site 2) - Probability of Shoreline Oil (top) and Minimum Time to Contact with Shoreline in Excess of 1 g/m² (bottom)

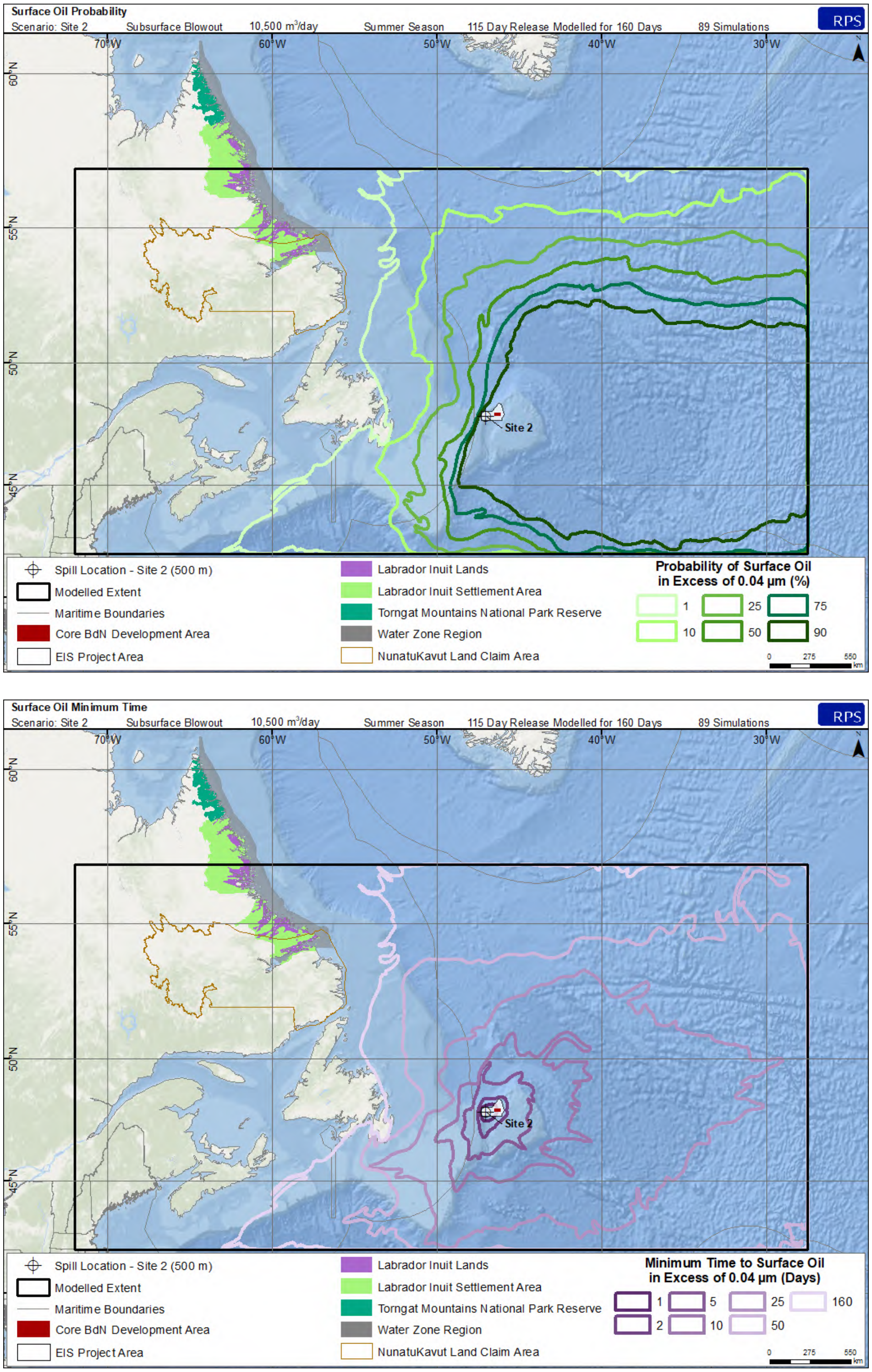


Figure 16-20 Unmitigated 115-day Release in Summer (Site 2) - Probability of Average Surface Oiling (top) and Minimum Time to Surface Oil in Excess of 0.04 µm (bottom)

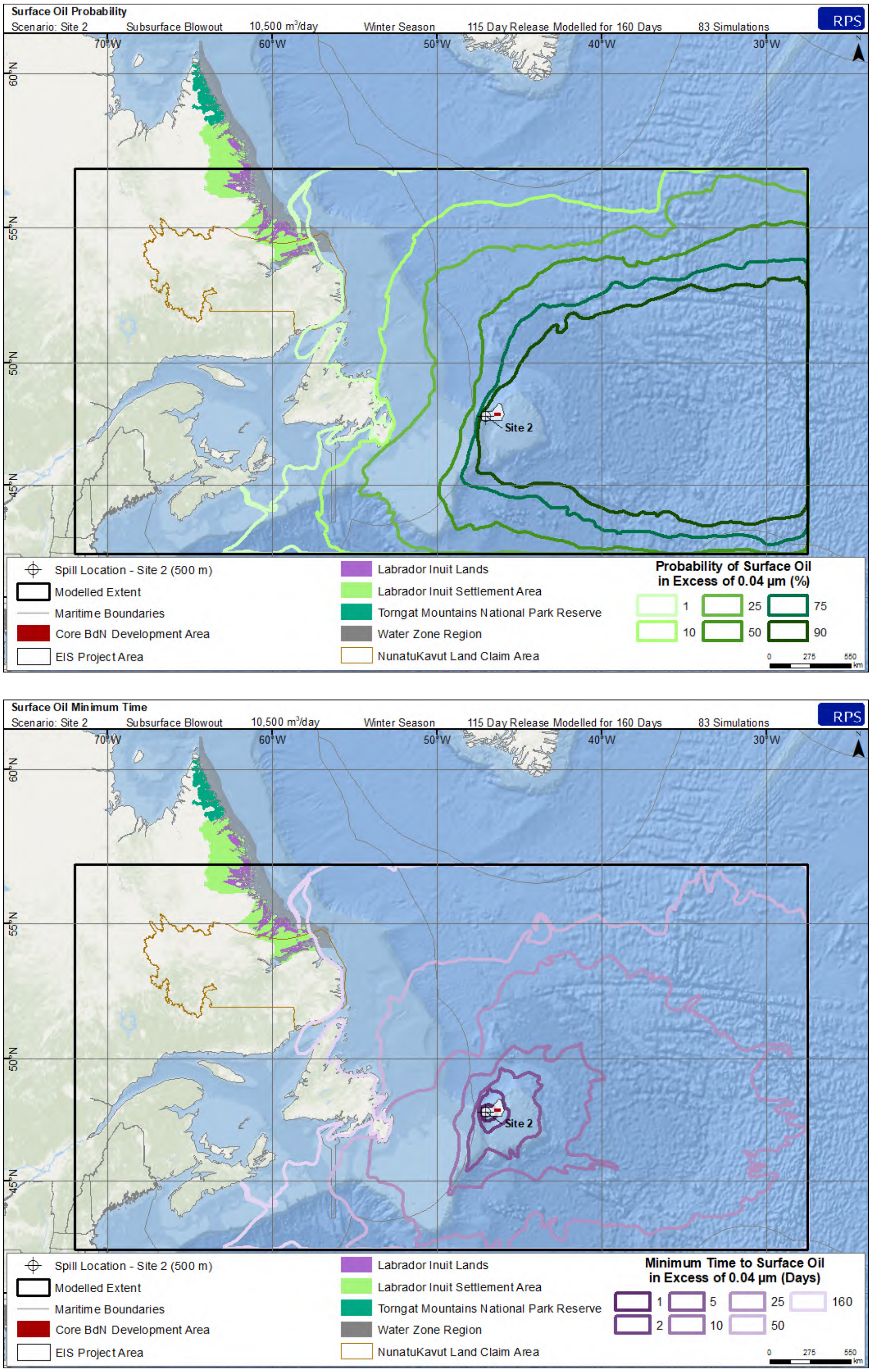


Figure 16-21 Unmitigated 115-day Release in Winter (Site 2) - Probability of Average Surface Oiling (top) and Minimum Time to Surface Oil in Excess of 0.04 µm (bottom)

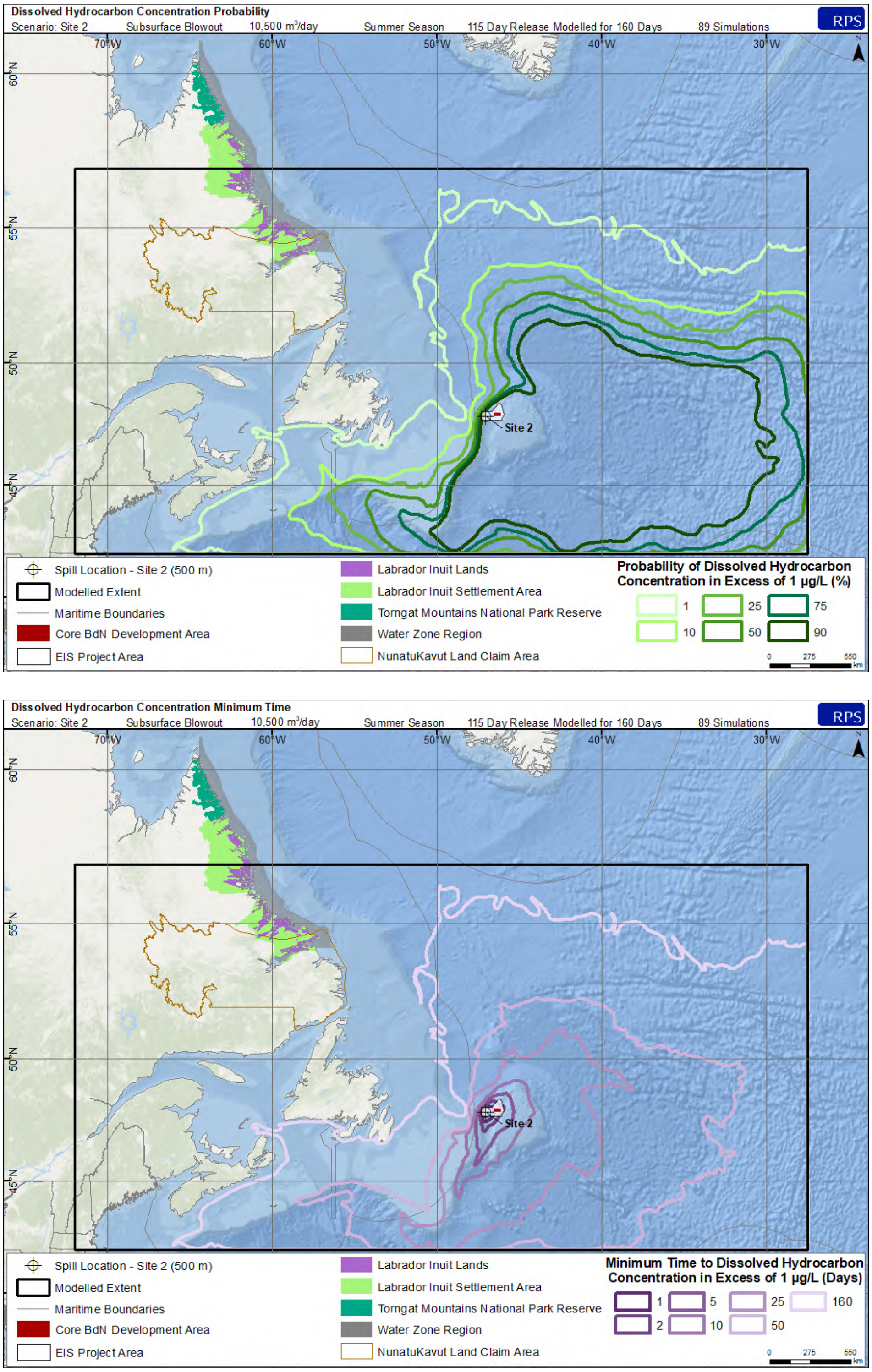


Figure 16-22 Unmitigated 115-day Release in Summer (Site 2) - Probability of Dissolved Hydrocarbon Concentrations (top) and Minimum Time to Threshold Exceedance of 1 µg/L (bottom)

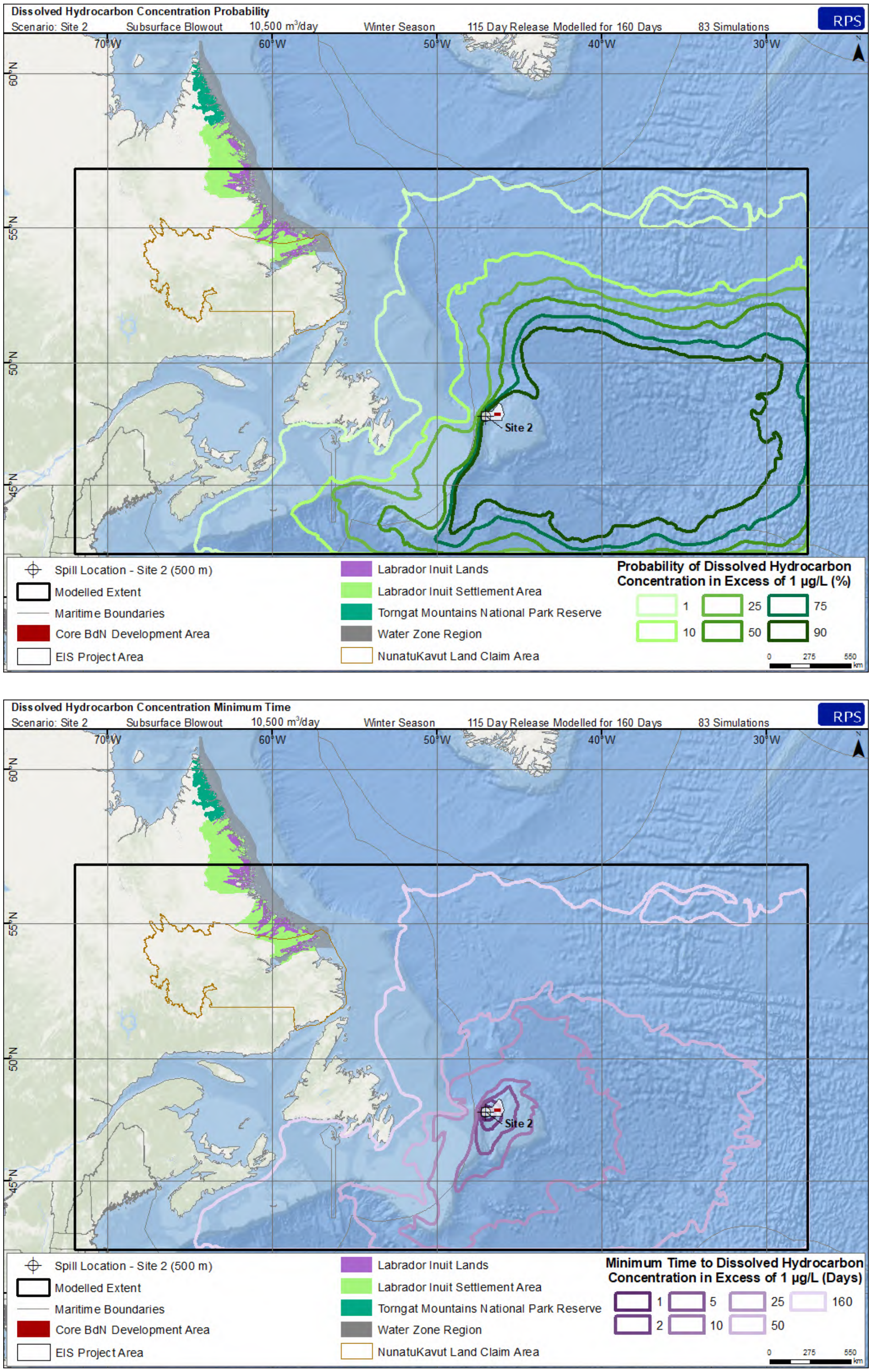


Figure 16-23 Unmitigated 115-day Release in Winter (Site 2) - Probability of Dissolved Hydrocarbon Concentrations (top) and Minimum Time to Threshold Exceedance of 1 µg/L (bottom)

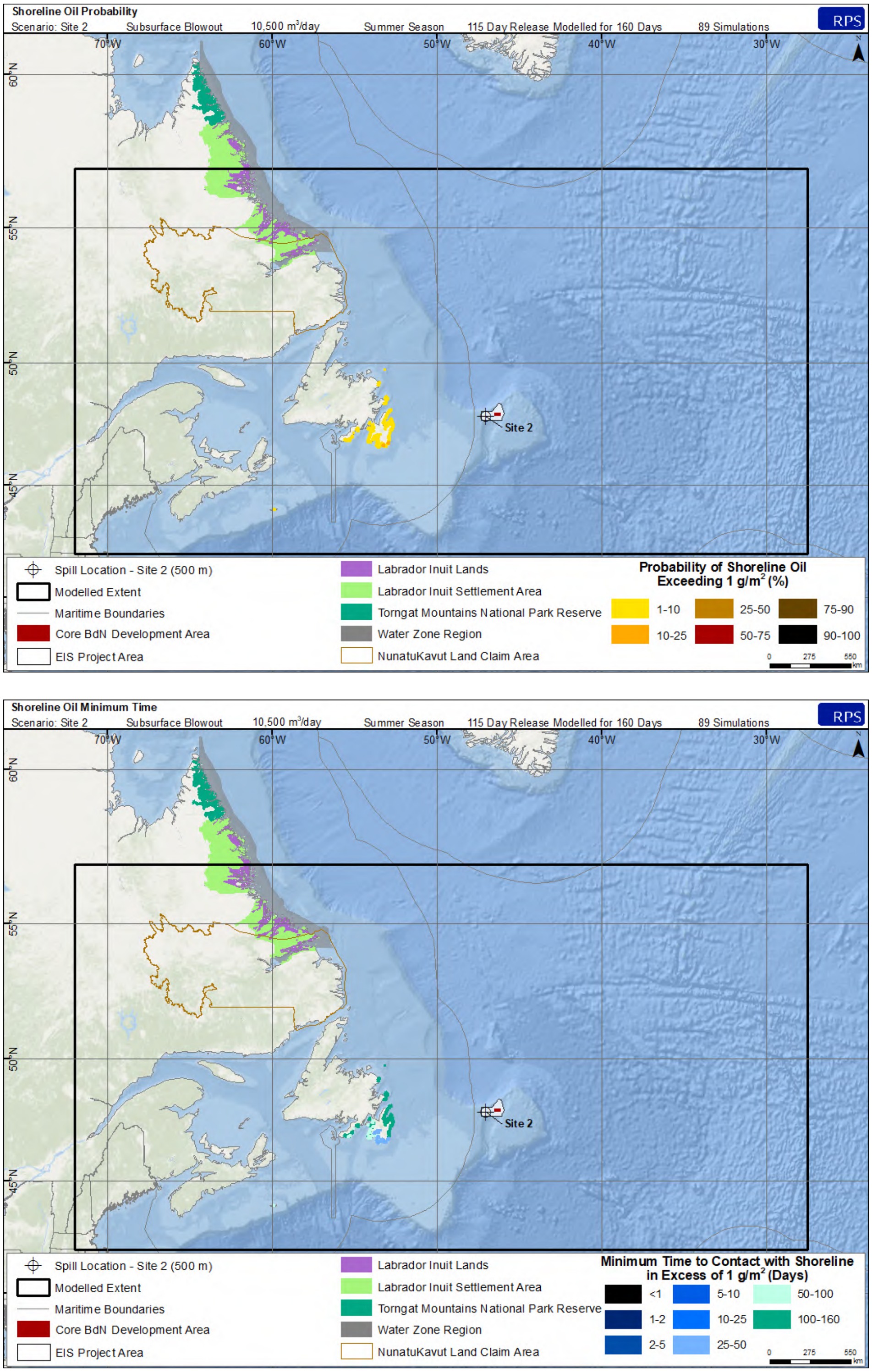


Figure 16-24 Unmitigated 115-day Release in Summer (Site 2) - Probability of Shoreline Oil (top) and Minimum Time to Contact with Shoreline in Excess of 1 g/m² (bottom)

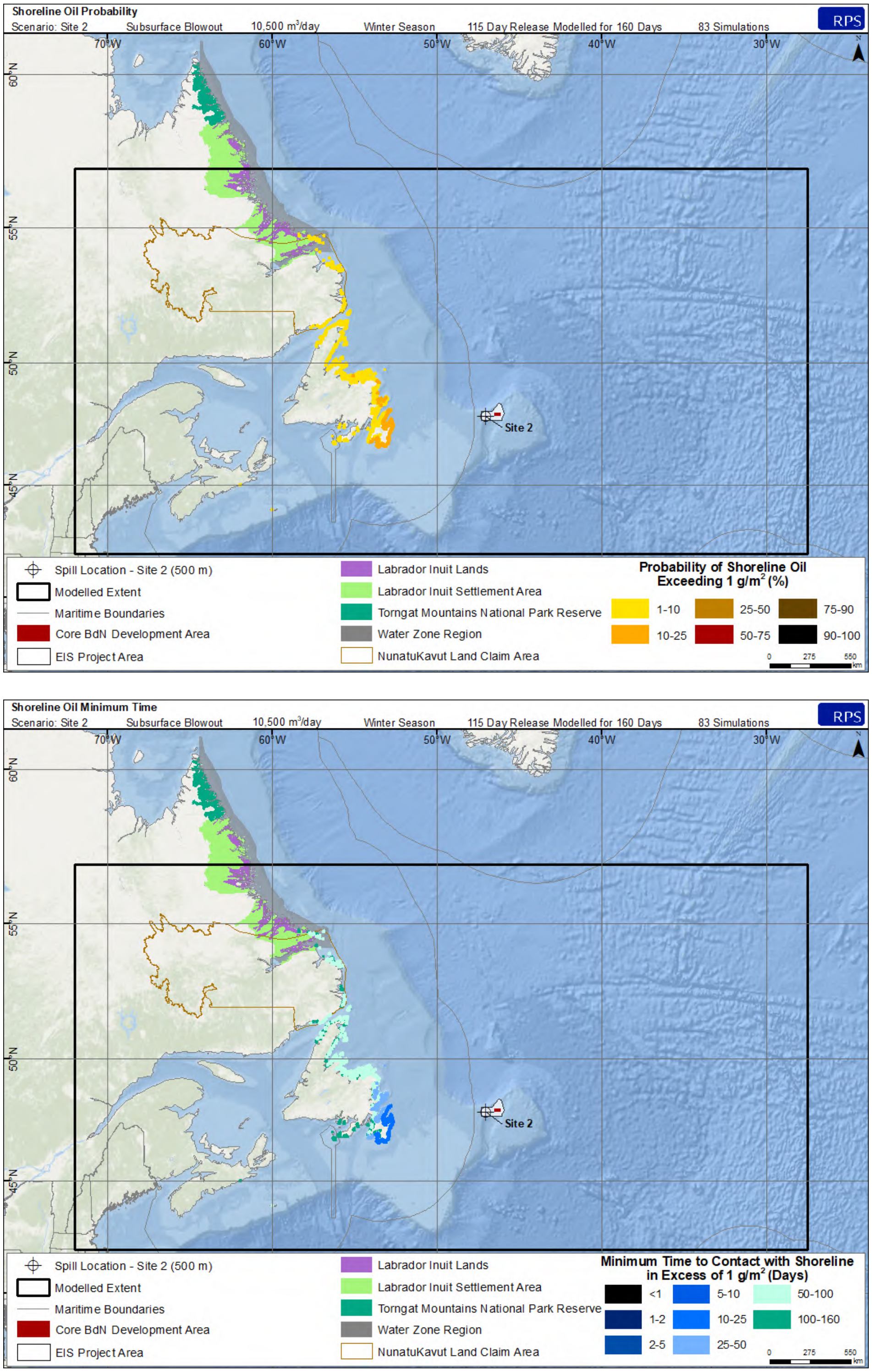


Figure 16-25 Unmitigated 115-day Release in Winter (Site 2) - Probability of Shoreline Oil (top) and Minimum Time to Contact with Shoreline in Excess of 1 g/m² (bottom)

16.4.3.2 Deterministic Results

Representative deterministic cases (i.e., worst case) representing the maximum surface areas, shoreline lengths, and total hydrocarbon concentrations exceeding specified thresholds for 95th percentile surface, shoreline contact and water column trajectories at Site 1 and Site 2 were further examined to determine the fate and transport of oil.

The 95th percentile cases represent what could be expected from a "credible worst case" unmitigated blowout, where the environmental conditions would be such to maximize potential exposure. Note that all scenarios assume a completely unmitigated release, which is an unlikely situation, as spill response measures would be employed in the event of a release. In addition, each identified representative deterministic scenario had a different starting date/time and therefore different environmental forcing throughout the modelled 160 days.

For both sites, the released oil was predicted to rise rapidly to the surface where it spread, being transported by surface winds and currents creating discontinuous patchy surface slicks. For most representative deterministic scenarios, the amount of oil remaining on the surface at the end of the simulation (after 160 days) ranged between two to 13 percent, with approximately 0.01 percent remaining in the sediment. This is due to the highly volatile nature and larger fraction of lower molecular weight compounds of the BdN crude and therefore results in large percentages of the crude oil evaporated (45 percent to 51 percent) and degraded (27 percentage to 36 percent), totalling 72 percent to 87 percent over the course of 160 days. Entrainment into the water column was predicted to range between <1 percent and 3 percent at the end of the 160-day model run. Shoreline contact was relatively minimal (with respect to total release volume) for these simulations, where even the 95th percentile shoreline contact case (worst case) was predicted to have less than 0.1 percent of the released oil reaching shorelines. In all simulations, portions of the oil traveled outside the model grid after 160 days, with a maximum of 23 percent leaving the model domain.

The figures provided in this section (Figures 16-27 to 16-32) depict the cumulative footprint of the thickest/highest concentration of oil predicted to be within each region over the entire modelled duration. Therefore, the depicted footprints are much larger than the amount of oil that would be present in a region at any given time following the release of oil. Furthermore, the predicted thickness or concentration would be the maximum observed at each point at a single point in time, implying that contamination would never be greater and would likely be less at all points other than the maximum. This concept is illustrated in Figure 16-26, which portrays predicted surface oil thickness at five specific time steps or "snapshots" in time (days 2, 10, 50, 100, and 160) for the 95th percentile surface oil thickness case at Site 1. Note the patchy and discontinuous nature of the predicted footprint as the released oil was predicted to spread and thin over time in Figure 16-26. Also note that the thickness at each point within each snapshot is typically less than the cumulative maximum depicted in Figure 16-27. The area covered by the cumulative maximum footprint is much larger in Figure 16-28, which depicts the same modelling output, but each timestamp was overlaid on each other, and thus shows the maximum surface oil thickness that was predicted to occur at each location over the entire modelled time period. These cumulative footprints provide overly conservative estimates of potentially affected areas as compared to the likely footprint represented by "the snapshots" at given times.

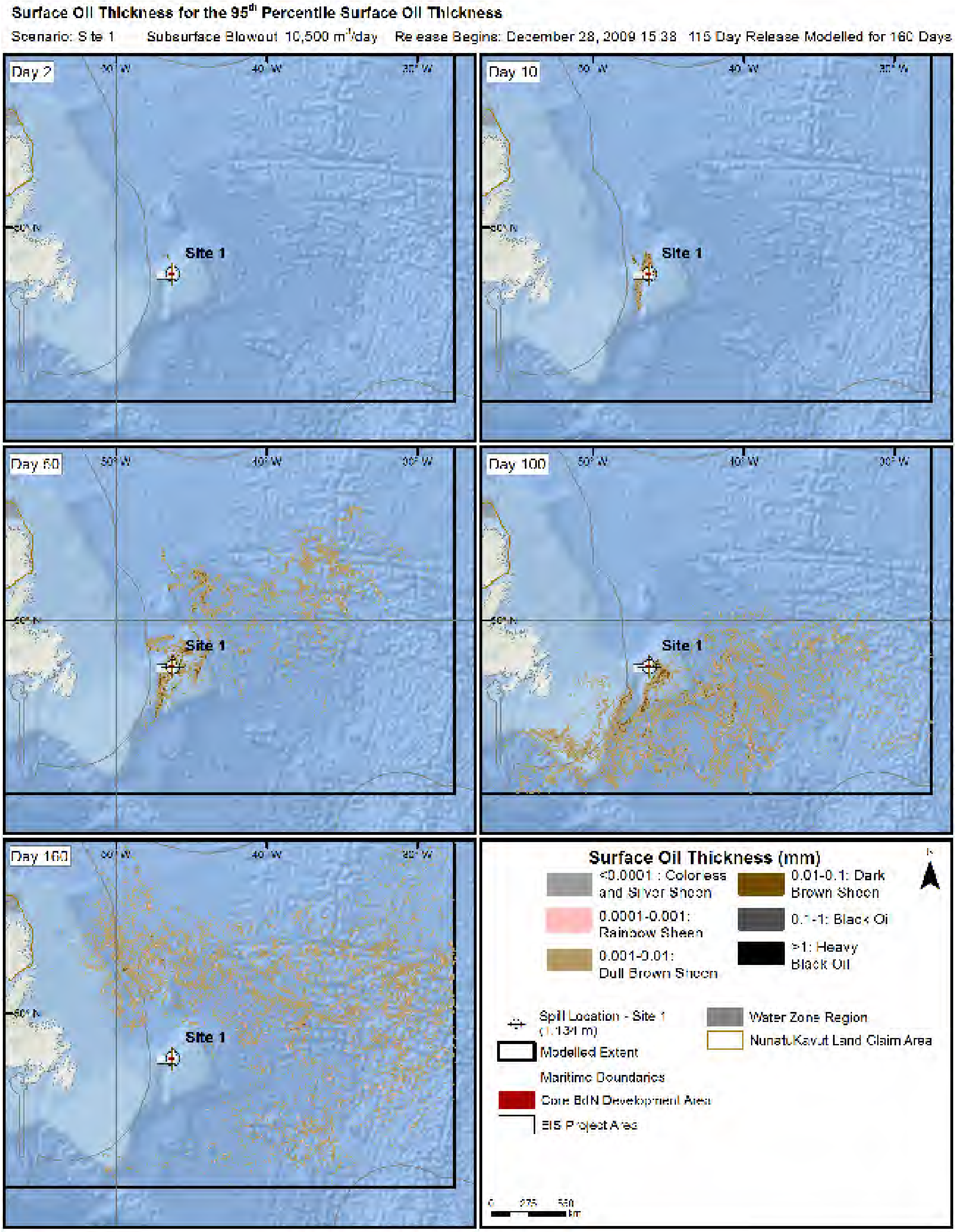


Figure 16-26 Predicted surface oil thickness for the 95th percentile unmitigated surface oil exposure case for Site 1 at days 2, 10, 50, 100, and 160

For each of the 95th percentile surface oil cases at both Site 1 and Site 2, the identified scenarios were predicted to occur during the winter season. Cumulative maximum floating surface oil for the identified 95th percentile scenarios for surface oil exposure cases for the releases at Site 1 and Site 2 are provided in Figures 16-27 and 16-28, respectively. The higher winds during these periods of time likely transported the oil further in these winter runs, resulting in a larger surface oil footprint and therefore selection as the 95th percentile case. In each of the modelled scenarios, surface oil was predicted to be thickest closest to the release location, with maximum thicknesses corresponding to a visual appearance of black oil within a few kilometres of the release location. Most of the surface oil in all cases was predicted to have an average thickness within the range of 0.001 to 0.1 mm (1 to 100 μm), which would result in a visual appearance that would be patchy and discontinuous dull brown to dark brown sheens. Thickest oil was predicted to be located within 10 km of the release site (0.1 to 1 mm; black oil), with thinner 0.0001 to 0.001 mm (rainbow sheen) oil making up the outer fringes of the release after 160 days. The smaller volume 36-day releases at Site 1 and Site 2 resulted in smaller predicted footprints which tended to cover regions to the south and east of the release sites, while the 115-day releases were predicted to result in larger surface oil footprints that included regions to the north in addition to the areas to the south and east of the release sites.

The stranding of oil on shorelines was unlikely for the majority of the released volume due to a combination of the forcing parameters (i.e., wind and currents) transporting surface and entrained oil generally to the east away from shorelines. Predicted total hydrocarbon concentrations on shorelines at the end of the modelled simulations were identified. for the 95th percentile shoreline exposure cases for the releases at Site 1 and Site 2 (Figures 16-29 and 16-30). In each of the 95th percentile shoreline exposure cases, the combination of wind and current conditions resulted in <0.1 percent of the total release volume predicted to make contact with the shoreline. Although the percent of unmitigated released oil contacting shorelines is a small fraction of the total volume of oil released, the THC on shorelines was predicted to exceed 500 g/m^2, which was above the socioeconomic (1 g/m^2) and ecological (100 g/m^2) thresholds. The majority of the predicted oil contact with shorelines occurred on the Avalon Peninsula. Contact with the shoreline from the 36-day releases was predicted to occur 45 to 92 days into the simulation and would therefore likely contain highly weathered oil (i.e., lighter and more toxic components would have evaporated, dissolved, and degraded thereby reducing the toxicity of the residual oil) that was patchy and discontinuous. Shoreline contact from the representative 115-day releases was predicted to initially occur at 14 to 15 days into the simulation and would also be weathered, patchy and discontinuous. Differences in timing for each representative deterministic scenario are the result of different start dates/times and therefore a different set of wind and current conditions throughout the modelled simulations.

Maximum total hydrocarbon concentrations within the water column for the identified 95th percentile water column exposure cases for the releases at Site 1 and Site 2 are shown in Figures 16-31 and 16-32, respectively. Note that the predicted concentrations are vertical maximums (i.e., highest concentration at any depth) and typically were associated with the surface tens of metres.

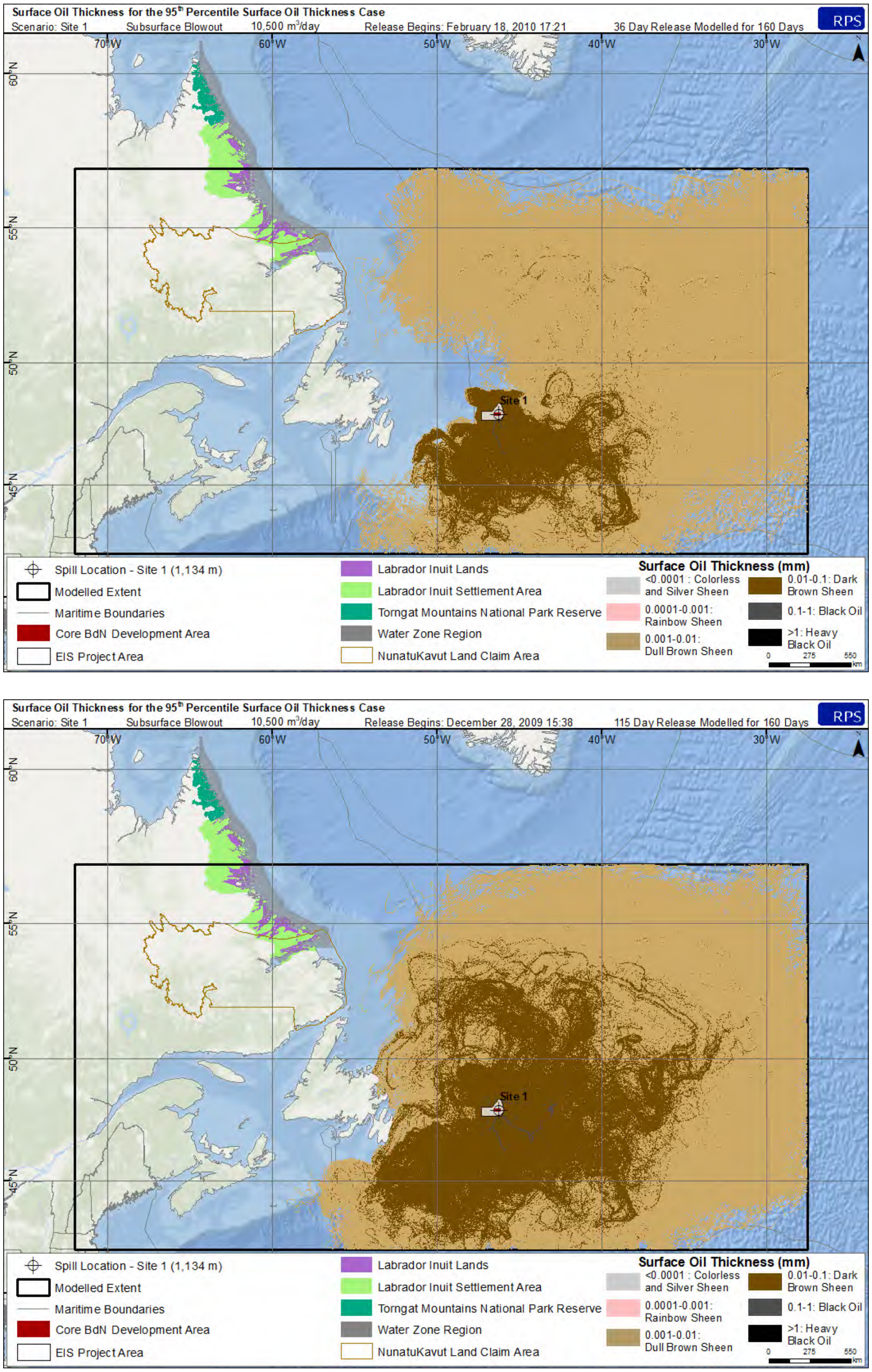


Figure 16-27 Surface oil thickness for the 95th percentile surface oil thickness case (unmitigated) at Site 1 for the 36-day (top) and the 115-day release (bottom)

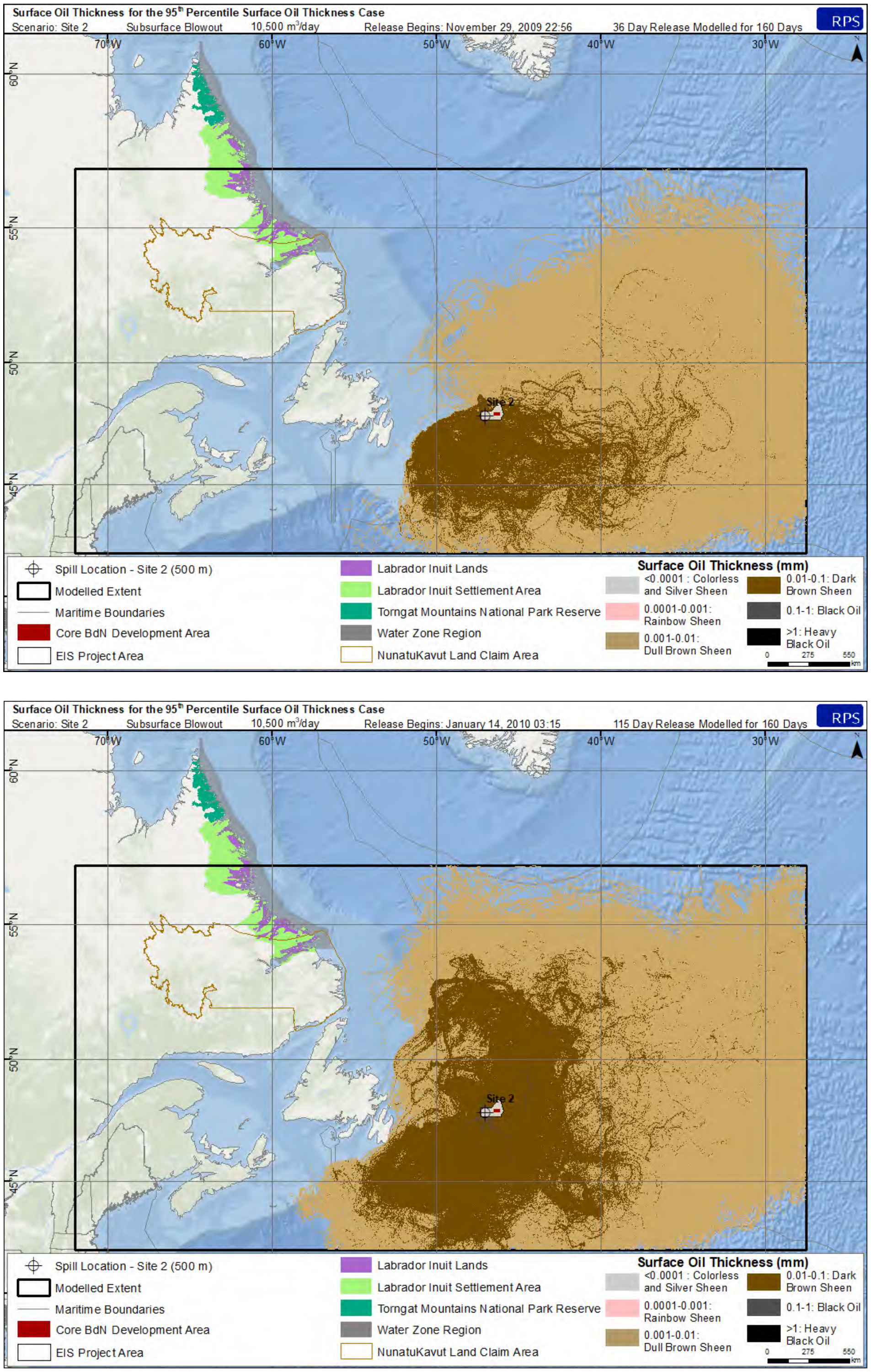


Figure 16-28 Surface oil thickness for the 95th percentile surface oil thickness case (unmitigated) at Site 2 for the 36-day (top) and the 115-day release (bottom)

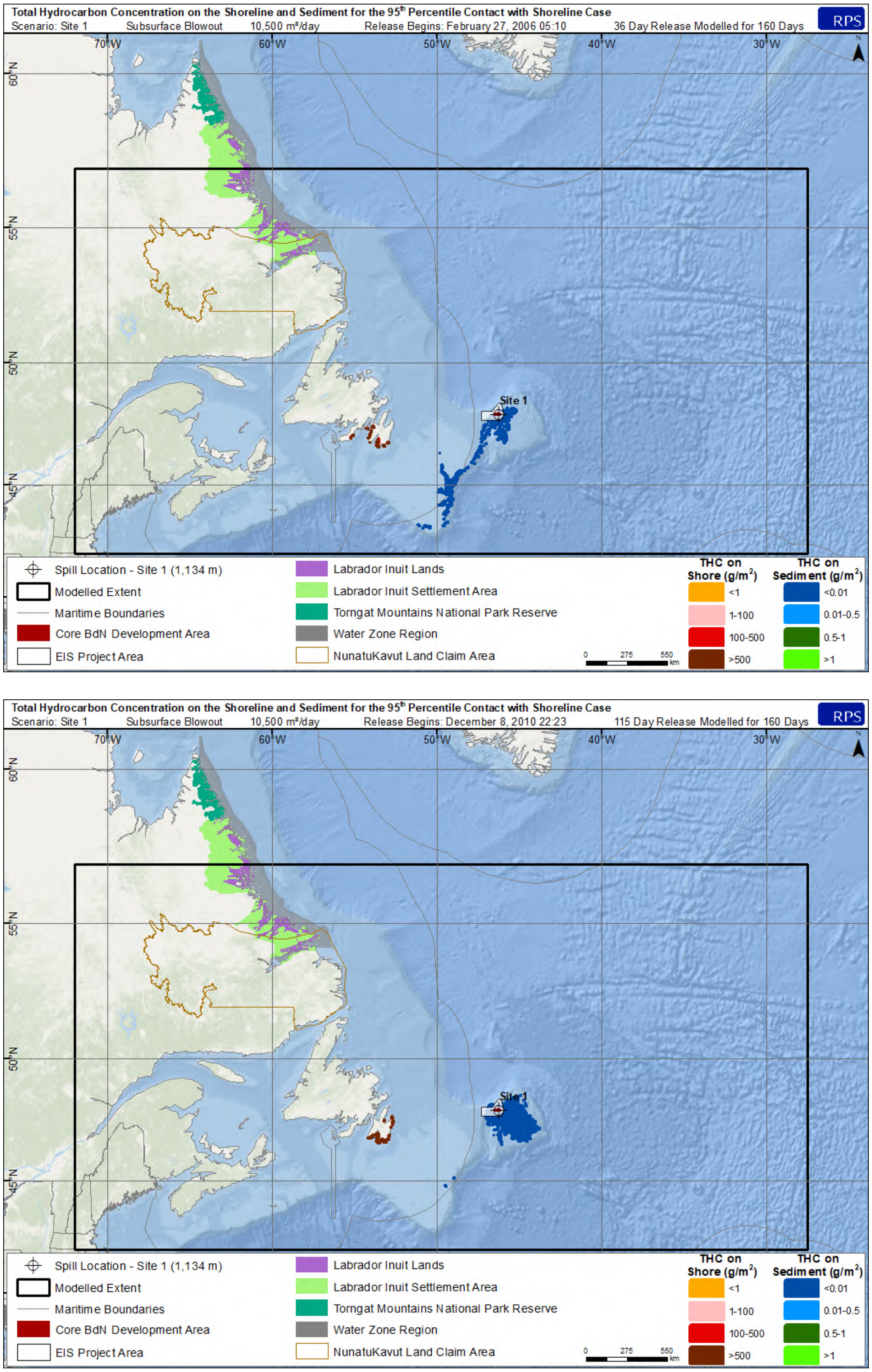


Figure 16-29 Total hydrocarbon concentration (THC) on the shore and sediment for the 95th percentile contact with shoreline case from a subsurface blowout at Site 1 site for the 36-day (top) and the 115-day release (bottom)

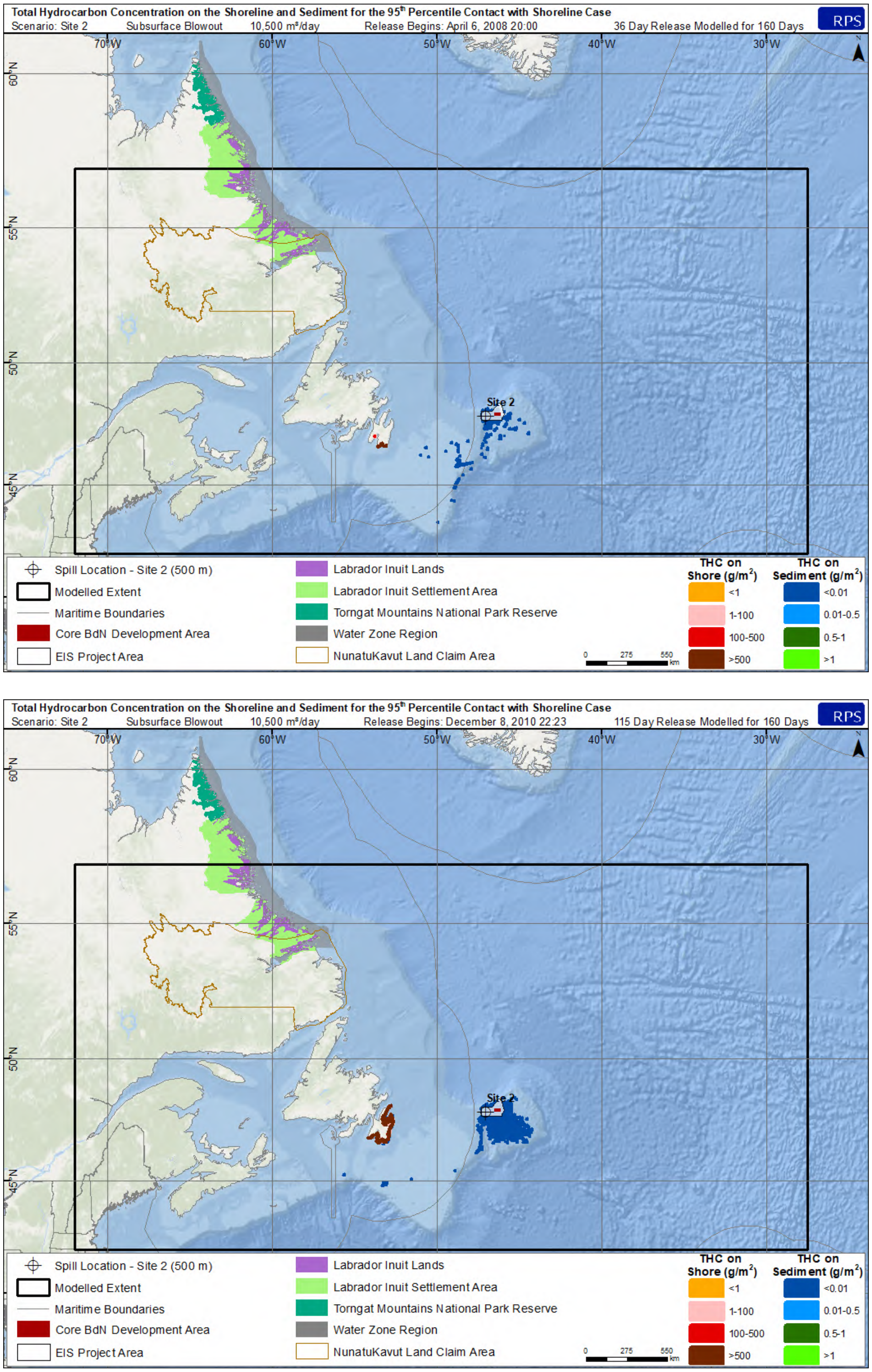


Figure 16-30 Total hydrocarbon concentration (THC) on the shore and sediment for the 95th percentile contact with shoreline case from a subsurface blowout at the Site 2 site for the 36-day (top) and the 115-day release (bottom)

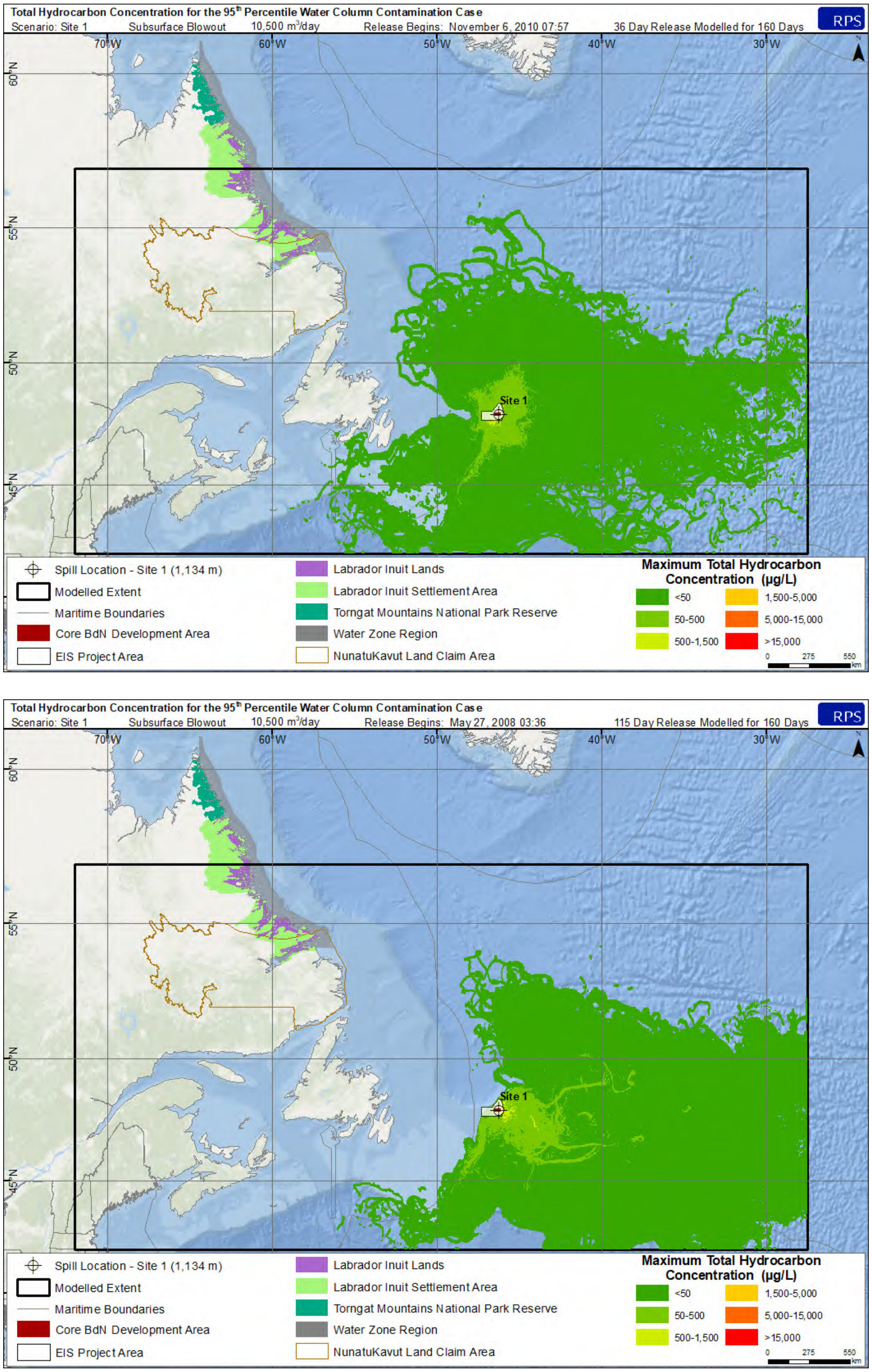


Figure 16-31 Maximum total hydrocarbon concentration (THC) at any depth in the water column for the 95th percentile water column case from an unmitigated subsurface blowout at Site 1 for the 36-day (top) and the 115-day release (bottom)

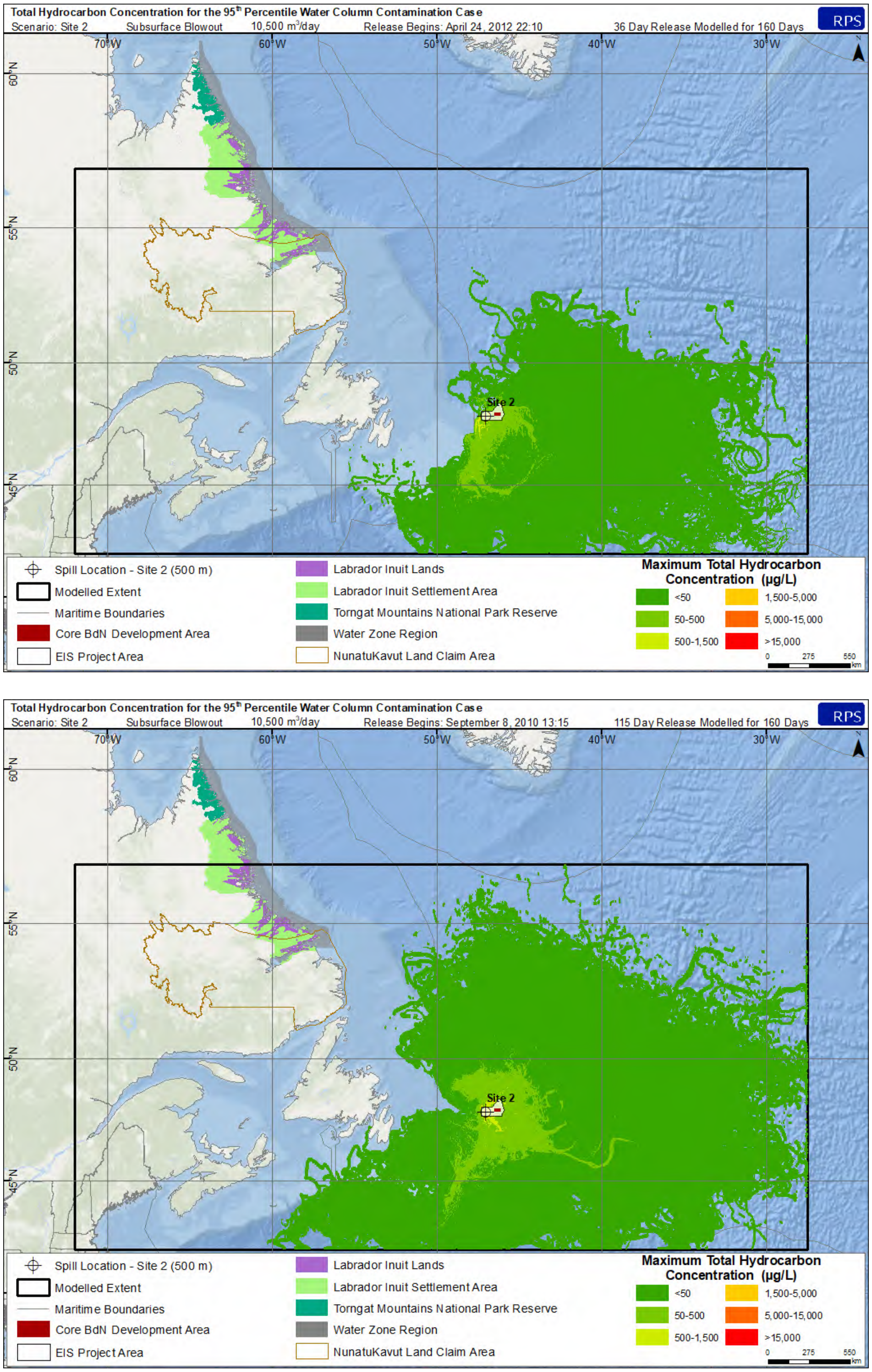


Figure 16-32 Maximum total hydrocarbon concentration (THC) at any depth in the water column for the 95th percentile water column case from an unmitigated subsurface blowout at the Site 2 for the 36-day (top) and the 115-day release (bottom)

Concentrations of total hydrocarbons in the water column were predicted to the be highest around the release site, with concentrations exceeding the threshold for THC (100 µg/l) remaining offshore and in a much smaller areal extent than for surface oil. As total hydrocarbons represent the dissolved phase (i.e., soluble fraction making up <1 percent of the whole oil) plus the particulate phase (i.e., whole oil droplets) within the water column, THC has a much larger footprint than the predicted dissolved phase. For each site, the 115-day release was predicted to result in a larger overall cumulative footprint, as well as a larger footprint of the higher concentrations. The footprints of these predicted concentration exceedances are very similar to the surface oil trajectories, with the largest portion of the oil predicted to be transported towards the east. While the highest concentrations of THC are predicted near or at surface, the majority of the predicted THC concentrations within the cumulative footprint are within tens of metres of the surface. This is due to the majority of the predicted THC being the result of entrained oil from wind-induced surface-breaking waves forcing surface oil into the water column. Elevated concentrations of soluble hydrocarbons at or near the surface may extend for several kilometres; however, natural dispersion and degradation would reduce the predicted in-water concentrations rapidly as the distance from the release location increased.

16.4.4 Batch Spills

Four unmitigated batch releases were modelled to be representative of spills that could occur from different sources during Project activities (Table 16.27) and included spills of marine diesel and BdN crude oil. All batch spills were modelled for 30 days.

Table 16.27 Modelled Batch Spill Scenarios for the BdN Project

Spill Name	Spill Source	Spill Site	Event Type	Oil Type	Spill Rate	Duration	Total Volume
Site 1-Flow	Flowline[a]	Site 1	Seafloor release	BdN	500 m^3/d	1 day	500 m^3
					3,145 bbl/d		3,145 bbl
Site P-FPSO	FPSO	Site P	Surface FPSO spill	BdN	4,150 m^3/d	2 days	8,300 m^3
					26,103 bbl/d		52,205 bbl
Site P-Off	FPSO offloading	Site P	Surface FPSO spill	BdN	Instantaneous	1 hour	1,000 m^3
							6,290 bbl
Site P-Bunk	Vessel bunkering	Site P	Surface batch spill	Marine diesel	Instantaneous	2 min.	6 m^3

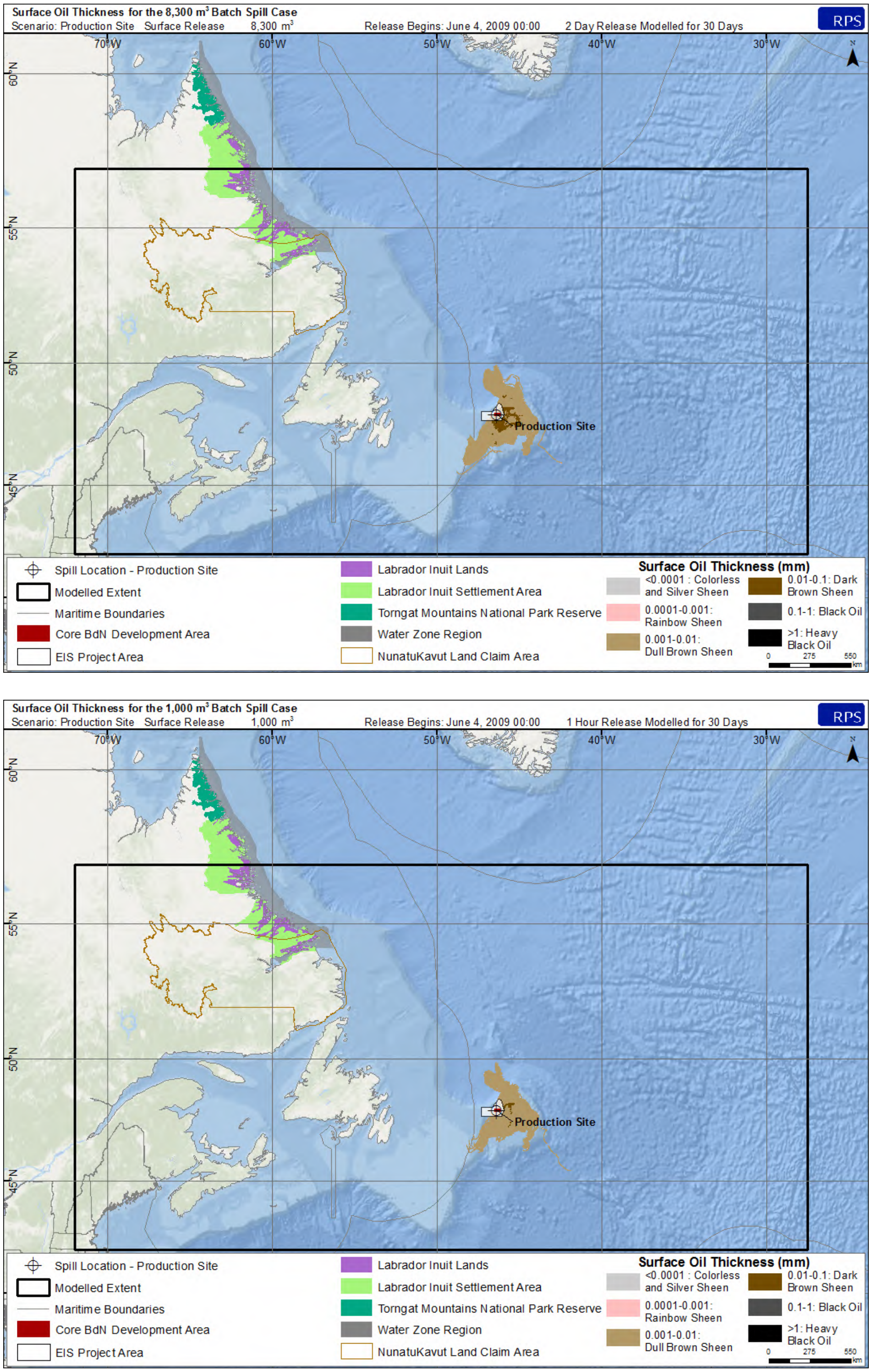
[a] Flowline releases are one of the types of “other well releases” categorized in Holand 2013.

The marine diesel used in the bunkering batch spill is a standard marine diesel used widely in offshore activity. It has a low viscosity and a high aromatic content. The batch spills of crude oil were modelled for the BdN Crude, which was used in the subsurface blowouts. The scenarios were selected to occur during the calmest wind-speed period during the summer/ice-free conditions, which would result in the largest amount of oil on the water surface (i.e., the “worst-case” scenario). The selected date was June 4, 2009.

For the unmitigated batch spills at the FPSO location, surface releases of crude oil (8,300 m^3 and 1,000 m^3) were predicted to result in 37 percent to 39 percent of the released volume evaporating to the atmosphere, 29 percent remaining on the water surface, 22 percent to 24percent degraded, 10 percent to 11 percent remaining entrained in the water column, 0.01 percent on sediments and 0 percent contacted the shore at the end of the 30 day model simulations. Both of these batch spills resulted in cumulative maximum surface oil of >0.04 um (>0.04 g/m^2) threshold extending approximately 200 to 300 km to the east of the release location (Figure 16-33). Thicker dark brown sheens (0.01 to 0.1 mm) were predicted within 100 km or less of the release location, while thinner dull brown sheens (0.001 to 0.01 mm) were predicted to extend approximately 375 km southeast from the release site. The areas where concentrations of THC in the water column were predicted to exceed 500 µg/L were in the immediate vicinity of the release site for both spill scenarios (Figure 16-34). There was no shoreline oiling predicted from the batch spills; all oil remained offshore.

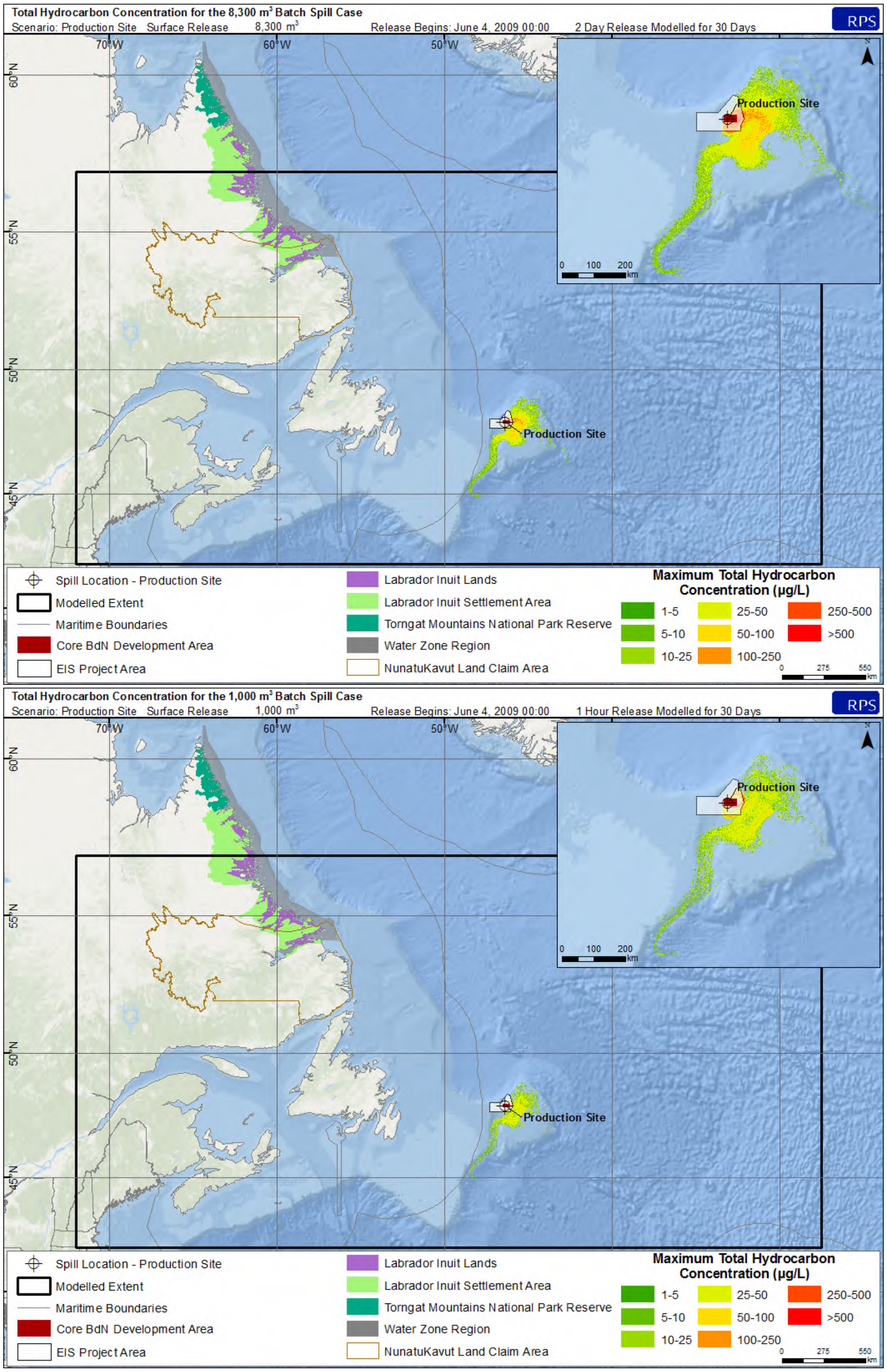
The unmitigated seafloor flowline release of 500 m^3 of crude was predicted to result in a primarily dull brown sheen (0.001 to 0.01 mm) that extended approximately 300 km southwest from the release location (Figure 16-35). At the end of the 30-day simulation, 42 percent of the total release volume was predicted to evaporate, 32 percent to remain on the water surface, 20 percent degraded, while, 6 percent entrained, and no oil was predicted to be found on sediments or shorelines. In-water THC concentrations of up to 100 µg/L within 250 km from the release site were predicted (Figure 16-36). Shoreline oiling was not predicted.

At the end of the 6 m^3 marine diesel surface batch spill, 58 percent of the total release volume was predicted to evaporate, 30 percent degraded 12 percent entrained in the water column, and <1 percent remained at the water surface. Surface oiling was predicted to result in a patchy and discontinuous distribution of colorless or silver sheen of oil < 0.0001 mm (0.1 µm) close the release location, where the area of oil >0.04 µm was limited to 84 km^2 (Figure 16-37). The marine diesel batch spill resulted in the smallest volume of water predicted to be exposed to THC concentrations exceeding 1 µg/L, where concentrations were generally less than 5 µg/L in an area within 200 km of the release site (Figure 16-38).



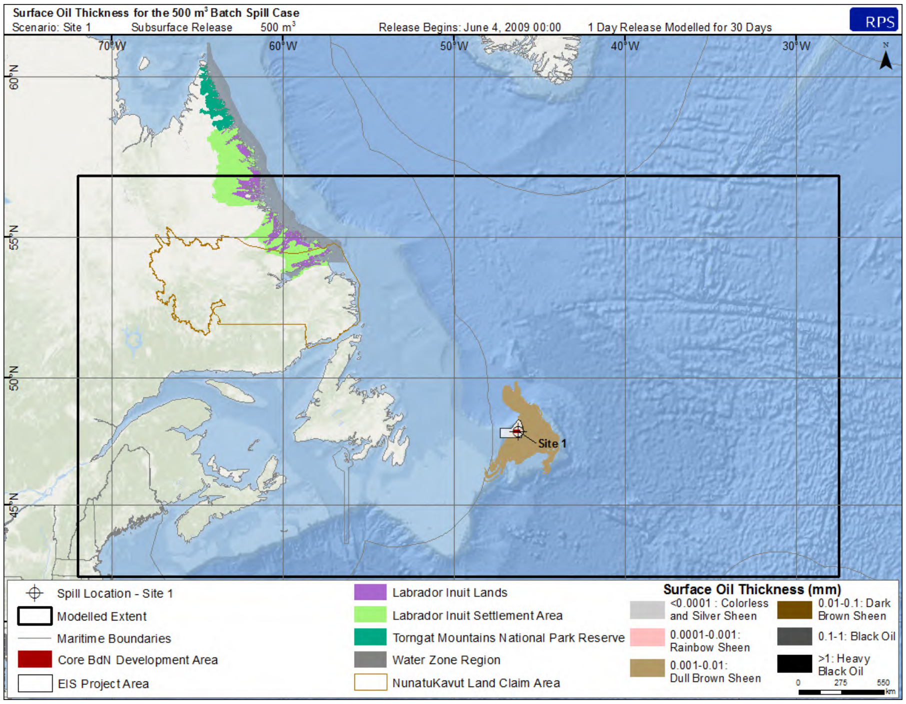
Note: The minimum thickness of surface oil > 0.04 µm is displayed (cumulative over all modelled time steps).

Figure 16-33 Surface Oil Thickness for the Unmitigated FPSO Site Surface Batch Spills of 8,300 m³ (top) and 1,000 m³ (bottom)



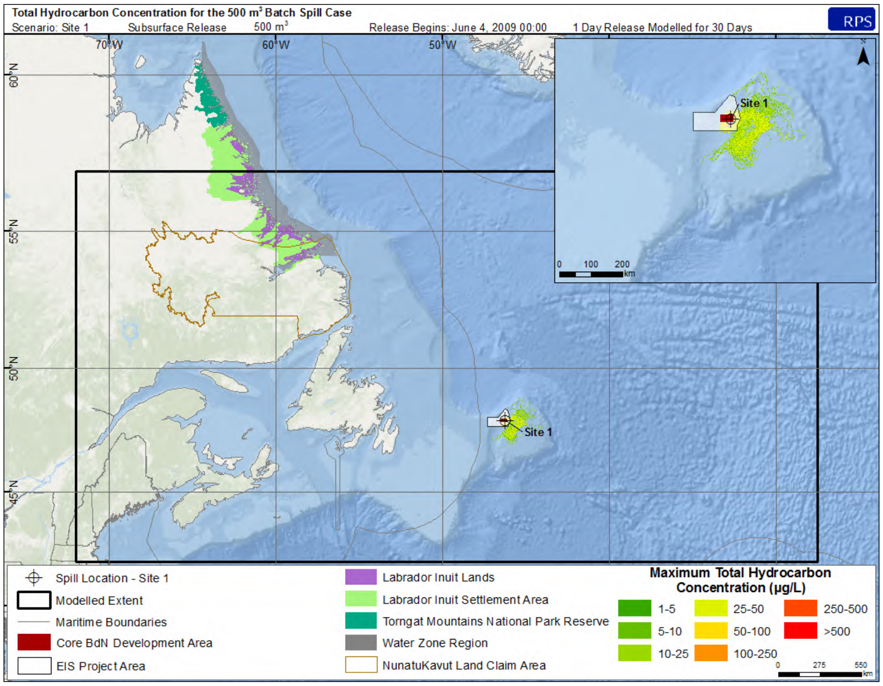
Note: The minimum threshold of THC >1 µg/L is displayed (cumulative over all modelled time steps).

Figure 16-34 Maximum Total Hydrocarbon Concentration at any Depth in the Water Column for the Unmitigated FPSO Site Surface Batch Spills of 8,300 m³ (top) and 1,000 m³ (bottom)



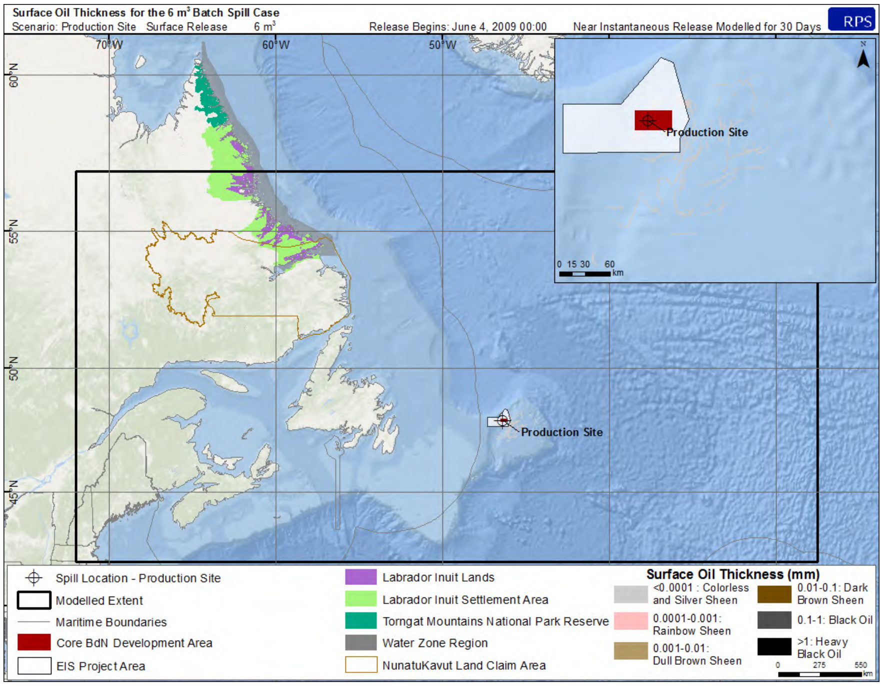
Note: The minimum thickness of surface oil >0.04 µm is displayed (cumulative over all modelled time steps).

Figure 16-35 Surface Oil Thickness for the Unmitigated Site 1 Flowline Batch Spill of 500 m³



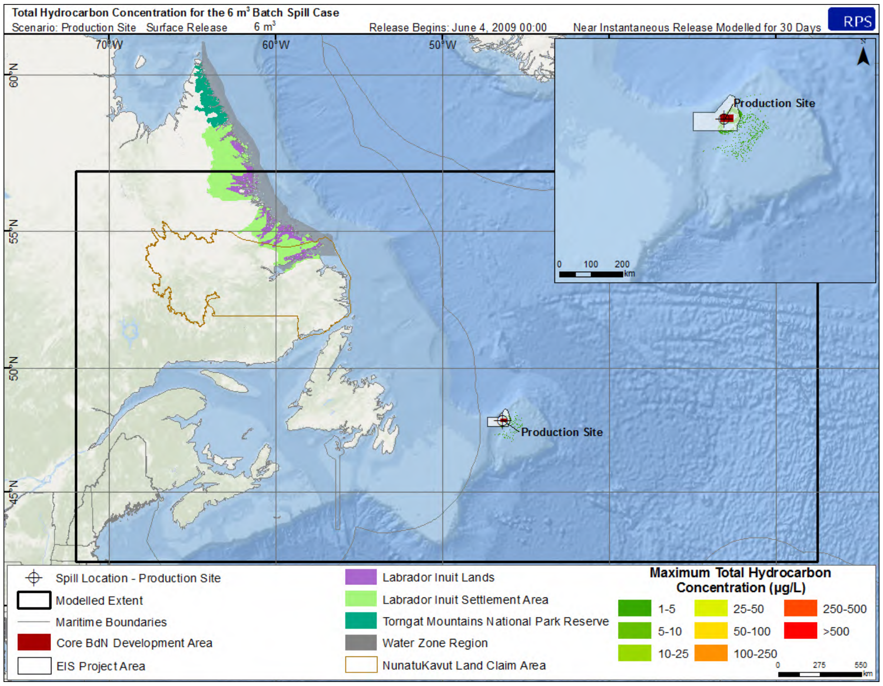
Note: The minimum threshold of THC >1 µg/L is displayed (cumulative over all modelled time steps).

Figure 16-36 Maximum Total Hydrocarbon Concentration at any Depth in the Water Column for the Unmitigated Site 1 Flowline Batch Spill of 500 m³



Note: The minimum thickness of surface oil >0.04 µm is displayed (cumulative over all modelled time steps).

Figure 16-37 Surface Oil Thickness for the Unmitigated FPSO Site Marine Diesel Surface Batch Spill of 6 m³



Note: The minimum threshold of THC >1 µg/L is displayed (cumulative over all modelled time steps).

Figure 16-38 Maximum Total Hydrocarbon Concentration at any Depth in the Water Column for the FPSO Site Marine Diesel Surface Batch Spill of 6 m³

16.4.5 Uncertainties

The SIMAP model has been developed over several decades to include past and recent information from laboratory-based experiments and real-world releases to simulate the trajectory and fate of discharged oil. However, there are limits to the complexity of processes that can be modelled, as well as gaps in knowledge regarding the affected environment. Assumptions based on available scientific information and professional judgment were made in the development of the model, which represent a best assessment of the processes and potential exposures that could result from oil releases.

The major sources of uncertainty in the oil fate model are:

- Oil contains thousands of chemicals with differing physical and chemical properties that determine their fate in the environment. The model must, out of necessity, treat the oil as a mixture of a limited number of components, grouping chemicals by physical and chemical properties.
- The fate model contains a series of algorithms that are simplifications of complex physical-chemical processes. These processes are understood to varying degrees.
- The model treats each release as an isolated, singular event and does not account for any potential cumulative exposure from other sources of contamination.
- Several physical parameters, including but not limited to, hydrodynamics, water depth, total suspended solids concentration, and wind speed were not sampled extensively throughout the entire modelled domain. However, the data that did exist was sufficient for this type of modelling. When data was lacking, professional judgment and previous experience was used to refine the model inputs.

SIMAP has been validated against many real-world releases including the Deepwater Horizon oil spill, where it was used in the US Government's Natural Resource Damage Assessment. In this specific example, a small portion of the released oil may have sunk as a result of the interaction of released oil with sediments, drilling muds, and other material used in response efforts such as procedures used to seal a leaking well. These are currently areas of active research. While there are additional fate processes that may result in slight differences in the ultimate fate of oil, these processes are known to have relatively lower effects on the total volume of oil in each environmental compartment (on the order of single percentages different, depending on the release and receiving environment) as compared to the fate processes such as entrainment, which are already being modelled. The science and algorithms that may be used to model these processes have not been developed in the scientific community to the point of a consensus or use in modelling. Ongoing research topics currently underway include the formation of marine oil snow (MOS), photo-degradation, droplet size distributions, and other research areas. These and other multi-year research projects are often considered for incorporation in modelling.. While research in these areas may lead to some improved accuracy in spill modelling, they would not have a material impact on the BdN EIS modelling results for the purposes of environmental impact assessment.

In the unlikely event of an actual release of oil, the trajectory, fate, and potential biological exposure will be strongly determined by the specific environmental conditions, the precise locations, and a myriad of details related to the event and specific timeframe of the release. Modelled results are a function of the scenarios simulated and the accuracy of the input data used. The goal of this study was not to forecast every detail that could potentially occur, but to describe a range of possible consequences and exposures of oil releases under various representative scenarios. The spill modelling completed for the BdN Project is extremely conservative. The layers of conservatism include:

- Extremely low probability worst case subsurface blowout rates were modelled, with the probability of occurrence of 1 in 207,000,000 to 1 in 414,000,000
- 95th percentile (i.e., worst case scenario) simulation of the results of the 171-172 deterministic model simulations were selected
- Batch spill scenarios modelled were very conservative with volumes being greater than the maximum volume of similar spills reported to the C-NLOPB since 1997. In addition, the maximum volumes modelled exceed the total volume released over a 21-year period. In the case of a surface crude oil release, the modelled scenario was approximately 20 times the cumulative spill volume in the region over a 21-year period
- Worst-case environmental (weather) conditions were selected for modelling the batch spill scenarios
- All modelled scenarios were ‘unmitigated’ which assumes no spill response measures were taken. In an actual event, spill response measures would be implemented that would likely reduce the impact of a release

Therefore, the level of confidence associated with the spill modelling completed for this EIS is considered adequate for effects assessment and in Project planning in determining level of response equipment required during BdN operations.

16.4.6 Summary of Trajectory Model Results

Stochastic results characterize the probability that regions may experience contamination above specified thresholds. Within the footprints, the highest predicted likelihood of contamination above 0.04 µm (75 percent to 90 percent) occurred to the east and south of the release site, while there was a much lower probability (<25 percent) for oil being transported to the north or west towards shorelines. Footprints depicting higher probability contours (90 percent) are much smaller than the total footprint (>1 percent)

The probability of oil making contact with the shoreline was less than a 22 percent to 25 percent for any geographic location out of all modelled scenarios, with the longest lengths of susceptible shoreline predicted for the 115-day winter release scenarios. The minimum time predicted for oil to make contact with the shorelines occurred after 13 to 15 days for winter scenarios and 31 to 34 days for summer scenarios. Therefore, the oil that was predicted to make contact with shorelines in each scenario was expected to be weathered, as minimum time estimates ranged from weeks to over a month. Most of the shoreline contact was predicted to occur on the south eastern shores of Newfoundland on the Avalon Peninsula (10 percent to 25 percent probability), and on the southeast coast of Labrador (1 percent to 10 percent probability).

The environmental effects assessment considers the credible worst-case spill events, which were identified from the stochastic assessment as representative deterministic cases. Each of the identified scenarios represented the maximum surface areas, shoreline lengths, and total hydrocarbon concentrations exceeding specified thresholds for 95th percentile surface, shoreline contact and water column trajectories at Site 1 and Site 2. At the end of the 160-day simulations, between 45 percent to 51 percent of crude oil was predicted to be evaporated, 27 percent to 36 percent degraded, between two to 13 percent remained on the surface and approximately 0.01 percent remained on sediments. Entrainment into the water column was predicted to range between <1 percent and 3 percent at the end of the 160-day model run. Shoreline contact was relatively minimal (with respect to total release volume) for these simulations, where even the 95th percentile shoreline contact case (worst case) was predicted to have less than 0.1 percent of the released oil reaching shorelines. In all simulations, portions of the oil were predicted to be transported outside the model domain after 160 days, with a maximum of 23 percent leaving the model grid.

Shoreline oiling was predicted to occur between four and 25 percent of the time, depending on location, from the stochastic analysis, with an average probability of 3.4 percent. For the representative worst-case scenarios for shoreline oiling, less than one percent of the total release volume was predicted to make contact with the shore. The majority of oil was predicted to contact the Avalon Peninsula, with first contact with shoreline oiling occurring within 14-15 days (115-d scenario) or at day 45 (36-d scenario). Given the predicted time to shore, oil would be highly weathered (i.e., lighter and more toxic components would have evaporated, dissolved, and degraded thereby reducing the toxicity of the residual oil).

Worst-case representative water column exposure scenarios predicted that concentrations of total hydrocarbons were highest near the release sites. The predicted cumulative footprint for water column exposure would be similar to the surface oil exposure cases, with most of the oil transported to the east. The majority of the predicted total hydrocarbons would be within tens of meters of surface, as oil would be cycling between surface floating oil and the upper mixed layer as entrained oil. During calm periods with low winds oil would rise to the surface. During higher energy periods, wind-induced surface breaking waves would entrain surface oil into the water column.

Accidental discharges which result in small volume near-instantaneous batch spills of crude and marine diesel resulted in smaller areas and volumes of potential contamination, when compared to the blowout scenarios. At the end of the 30-day simulation of BdN surface batch spill of crude oil (8,300 m^3 and 1,000 m^3), 37 percent to 39 percent of the released volume was predicted to evaporate to the atmosphere, 29 percent remain floating on the water surface, 22 percent to 24 percent degraded, 10 percent to 11 percent remained entrained in the water column, 0.01 percent adhered to sediments, and 0 percent contacted the shore. At the end of the marine diesel surface batch spill, 58 percent was predicted to evaporate, 30 percent degraded, 12 percent entrained into the water column, and <1 percent was predicted to remain on the water surface. At the end of the 30-day simulation of the seafloor batch spill (flowline), 42 percent was predicted to evaporate, 32 percent remained on the water surface, and 20 percent degraded, while 6 percent was entrained in the water column.

Accidental event scenarios are modelled as an unmitigated spill and do not include the procedures Equinor Canada has in place to prevent and/or respond to such an incident (Section 16.1) or the unlikely potential of an accidental event occurring.

16.5 Whole SBM Spill

The accidental release of whole SBM was modelled by RPS at representative sites within the Project Area where drilling activities could occur in waters depths ranging from approximately 350 m to 1,200 m. Hypothetical deterministic simulations were performed at the same two locations used for oil spill trajectory modelling, Site 1 and Site 2 (Table 16.28). More information on the whole SBM spill modelling can be found in Appendix F.

Table 16.28 Modelled SBM Spill Scenarios for the BdN Project

Spill Name	Spill Source	Spill Site	Event Type	Oil Type	Spill Rate	Duration	Total Volume
Site 1-Mud	Mud tank	Site 1	Surface mud tank release	SBM	Instantaneous	0.5 hour	60 m³ 377 bbl
Site 1-Flex	Flex joint	Site 1	Subsea flex joint failure [a]	SBM	Instantaneous	3 hours	275 m³ 1,730 bbl
Site 1-BOP	BOP	Site 1	Subsea BOP disconnect[b]	SBM	Instantaneous	1 hour	275 m³ 1,730 bbl
Site 2-Mud	Mud tank	Site 2	Surface mud tank release	SBM	Instantaneous	0.5 hour	60 m³ 377 bbl
Site 2-Flex	Flex joint	Site 2	Subsea flex joint failure	SBM	Instantaneous	3 hours	275 m³ 1,730 bbl
Site 2-BOP	BOP	Site 2	Subsea BOP disconnect	SBM	Instantaneous	1 hour	275 m³

[a] Rig components contributing to volume: Marine riser; choke, kill, booster and surface lines; mud-gas separator
[b] Rig components contributing to volume: Marine riser; choke, kill, booster and surface lines; mud gas*separator

As outlined in Table 16.28, the maximum volume of SBM modelled exceeds the largest volume spilled offshore NL, and therefore is representative of a worse case event. Each of these simulations (different jet sizes, speeds, and release locations at both sites) was performed for two different current regimes (12 total simulations) to evaluate how ocean current variability in the region may affect the patterns of SBM dispersion. The water depths are approximately 1,134 m for Site 1 and 500 m for Site 2.

Discharge simulations were completed using RPS's MUDMAP modelling system. The MUDMAP model is used to predict the transport of solids releases in the marine environment and the resulting seabed deposition. The model inputs include information regarding the discharge characteristics (e.g., release location, rate of discharge), the properties of the sediment (e.g., particle sizes, density), as well as environmental characteristics (bathymetry and ocean currents), to predict the transport of solids through the water column. The model output consists of the movement and shape of the discharge plume, the concentrations of insoluble (i.e., cuttings and mud) discharge components in the water column, and the accumulation of discharged solids on the seabed. The model predicts the transport of solid particles from the time of discharge or release to initial settling on the seabed.

Bathymetry was characterized using databases provided by NOAA National Geophysical Data Center and GEBCO. Currents for the North Atlantic region were acquired from the three-dimensional HYCOM (HYbrid Coordinate Ocean Model) circulation model. For this study, daily current data were obtained, and trends were analyzed for the period of January 2006 through December 2012 for the North Atlantic region. As with any hydrodynamic model, there is the potential that local currents may deviate from predictions based upon grid resolution and small-scale variability in ocean circulation dynamics. However, the data used is sufficient for this type of modelling.

Runs were initialized with different release parameters including depth of release, current regimes, release rates, release durations, and SBM settling velocities to best characterize the range of potential seabed depositions and water column concentrations resulting from an accidental release of SBM. The output of MUDMAP simulations are concentration grids that describes loading to the water column and seabed associated with each accidental release simulation

16.5.1 Site 1

16.5.1.1 Predicted Seabed Deposition

MUDMAP was used to predict seabed deposition at Site 1 from potential accidental releases of SBM for each scenario. Figures 16-39 to 16-41 present seabed deposition associated with the release of each of the accidental SBM release simulations. Table 16.29 summarizes the areal extent of seabed deposition resulting from the modelled releases. Table 16.30 summarizes the maximum distance seabed deposition extends from the release sites.

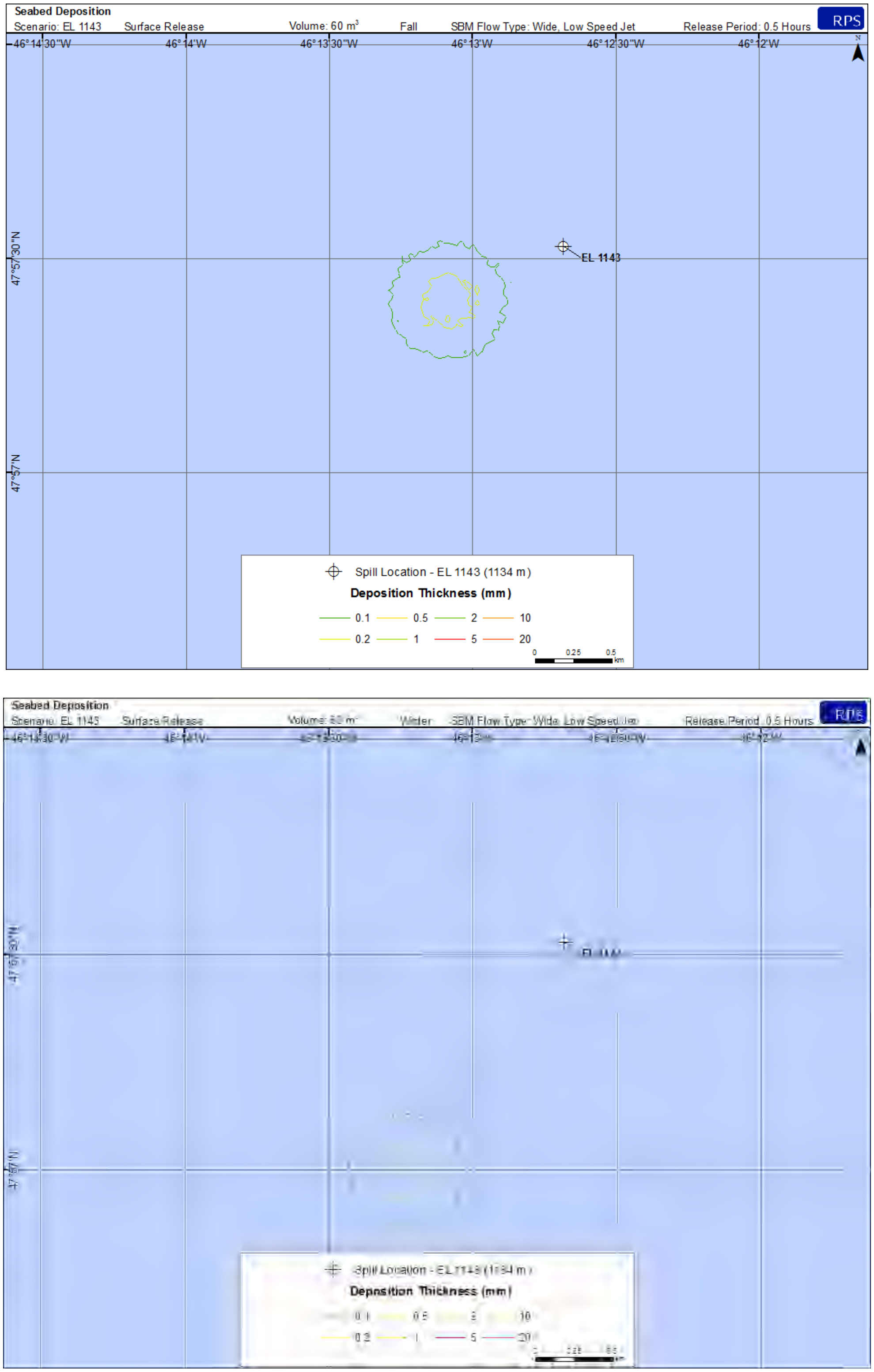


Figure 16-39 Predicted thickness from an unmitigated accidental surface release of 60 m³ SBM at Site 1 in Fall (top) and Winter (bottom)

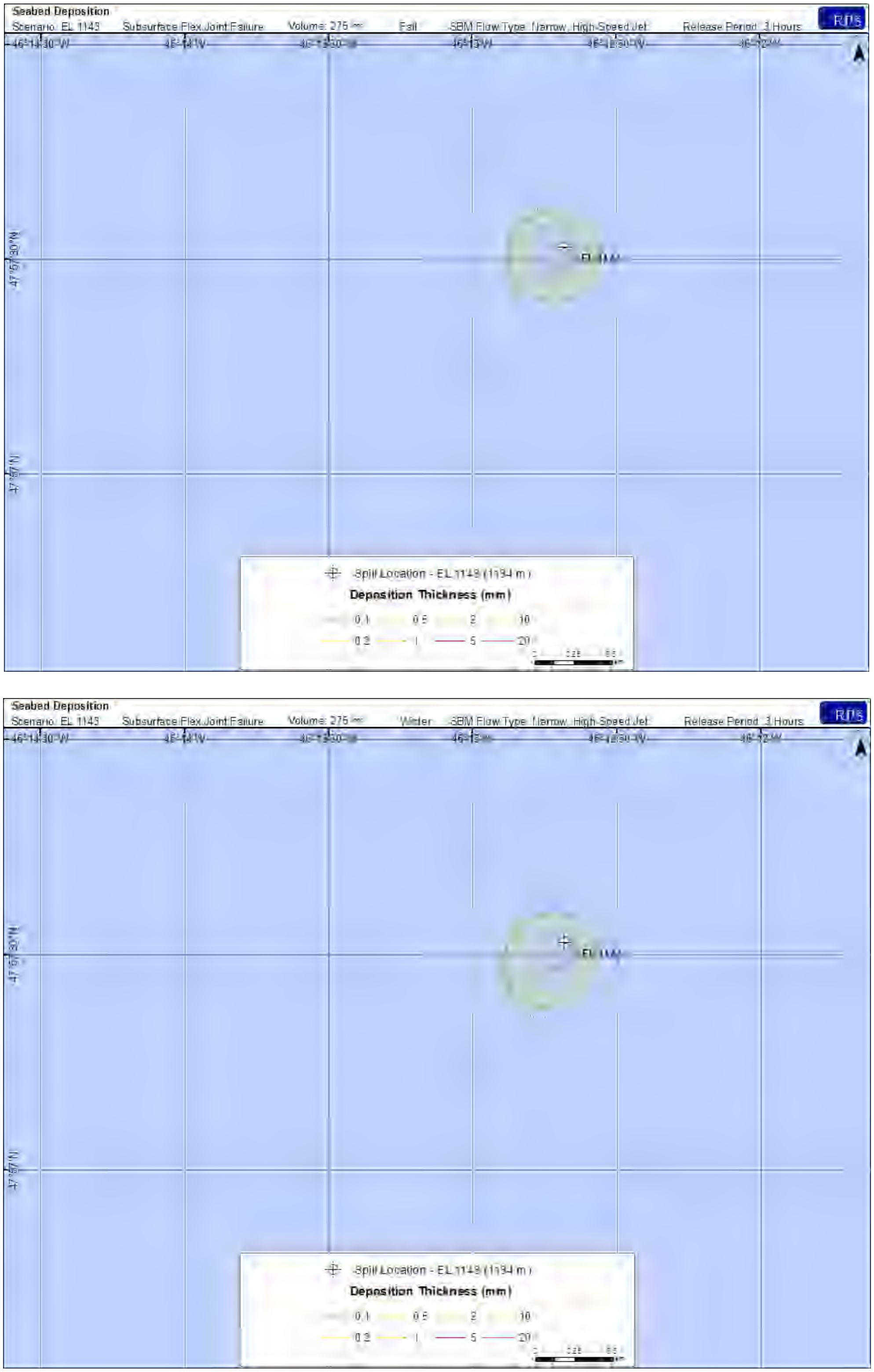
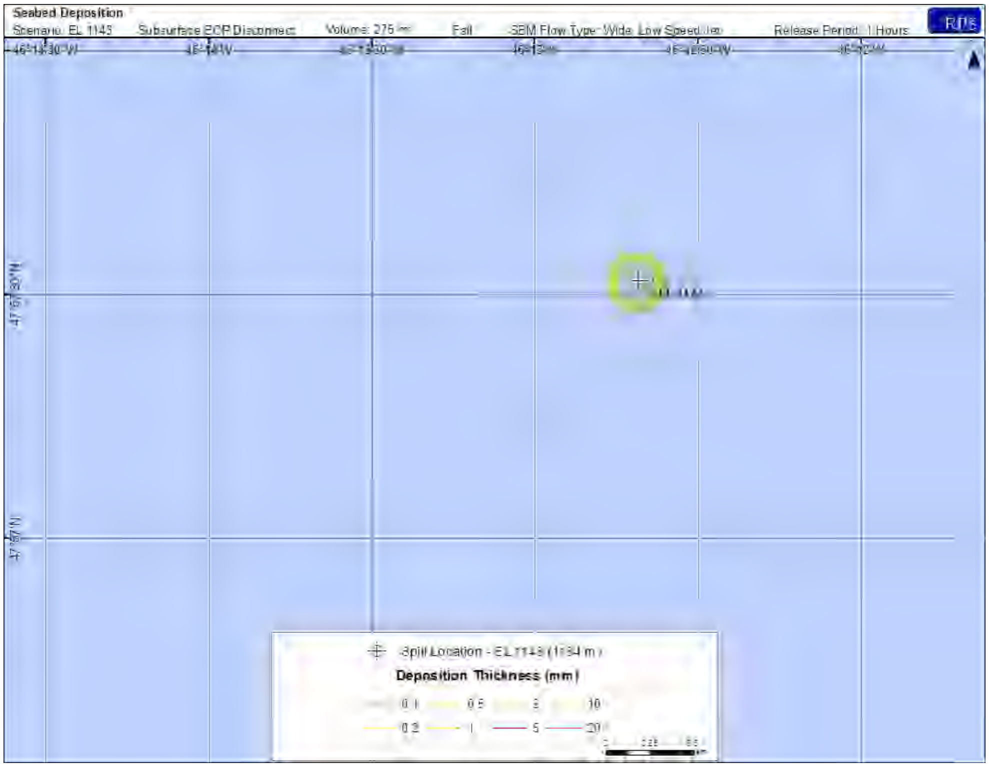


Figure 16-40 Predicted thickness from a flex joint failure accidental seabed release 275 m³ at Site 1 Fall (top) and Winter (bottom)



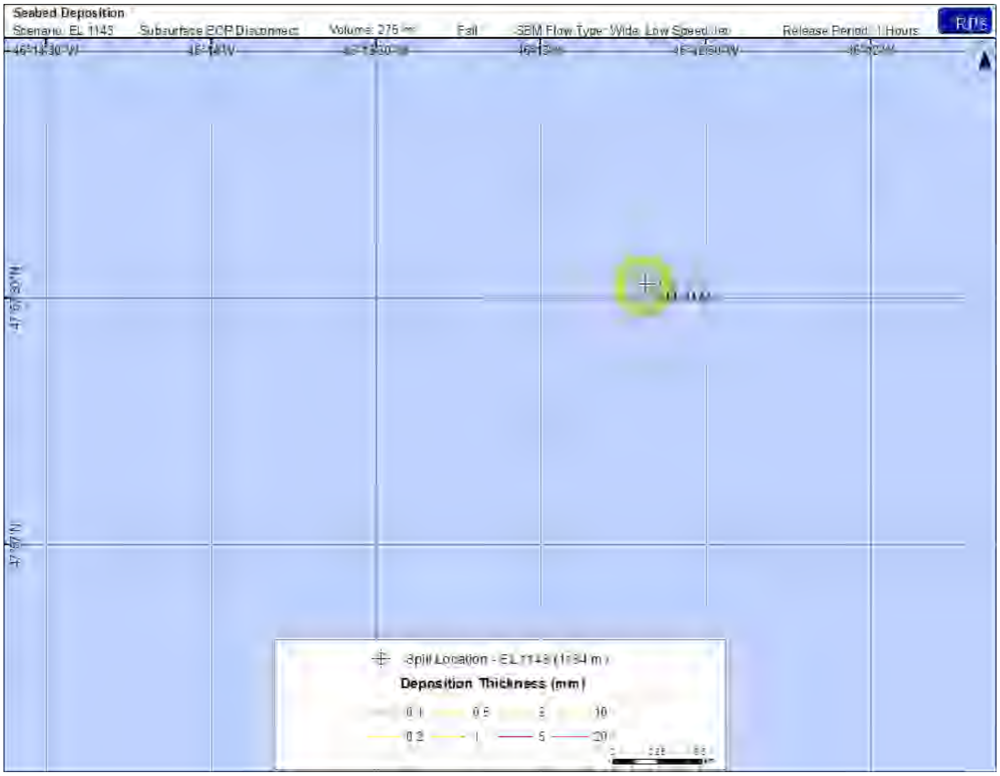


Figure 16-41 Predicted thickness from a BOP disconnect accidental seabed release 275 m^3 at the Site 1 release site in Fall (top) and Winter (bottom)

Table 16.29 Areal Extent of Seabed Deposition (by thickness interval) for Site 1 Simulations

Deposition Thickness (mm)	Cumulative Area Exceeding (km²)					
	Surface Tank Spill (Fall)	Surface Tank Spill (Winter)	Flex Joint Failure (Fall)	Flex Joint Failure (Winter)	Subsea BOP Disconnect (Fall)	Subsea BOP Disconnect (Winter)
0.1	0.19647	0.19314	0.12188	0.1301	0.03533	0.03557
0.2	0.03834	0.03125	0.09884	0.10587	0.03204	0.03202
0.5	0	0	0.07035	0.07333	0.02596	0.02611
1	0	0	0.0511	0.05233	0.02165	0.02198
2	0	0	0.03427	0.03463	0.01778	0.01783
5	0	0	0.01596	0.01503	0.01215	0.01222
10	0	0	0.00428	0.00343	0.0081	0.00814
20	0	0	0	0	0.00426	0.00428

Table 16.30 Maximum Distance of Thickness Contours (distance from release site) for Site 1 Simulations

Deposition Thickness (mm)	Maximum extent from release site (km)					
	Surface Tank Spill (Fall)	Surface Tank Spill (Winter)	Flex Joint Failure (Fall)	Flex Joint Failure (Winter)	Subsea BOP Disconnect (Fall)	Subsea BOP Disconnect (Winter)
0.1	0.81	1.46	0.29	0.36	0.14	0.15
1	0	0	0.17	0.22	0.1	0.11
10	0	0	0.06	0.08	0.06	0.07

16.5.1.2 Predicted Water Column Concentrations

Figures 16-42 through 16-53 present maximum water column concentrations associated with the release of each accidental SBM release simulation. Each figure pair includes a top-down view as well as a cross-section of the release. These figures do not represent any instantaneous snapshot of water column concentrations, but instead depict the maximum, time-integrated total suspended solids (TSS) within the study domain for each modelled release. Table 16.31 summarizes the areal extent of water column concentrations resulting from the modelled releases. Table 16.32 summarizes the maximum distance water column concentrations extend from the release sites.

Figure 16-42 Predicted water column concentration from an accidental surface release of 60 m³ at Site 1 (Fall)

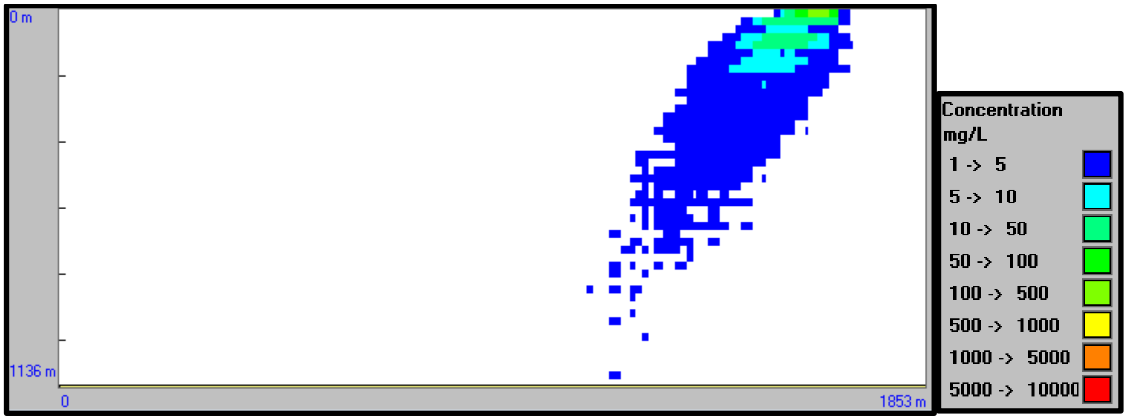


Figure 16-43 Cross-sectional view of predicted water column concentration from an accidental surface release of 60 m³ at Site 1 (Fall)

Figure 16-44 **Predicted water column concentration from an accidental surface release of 60 m³ at Site 1 (Winter)**

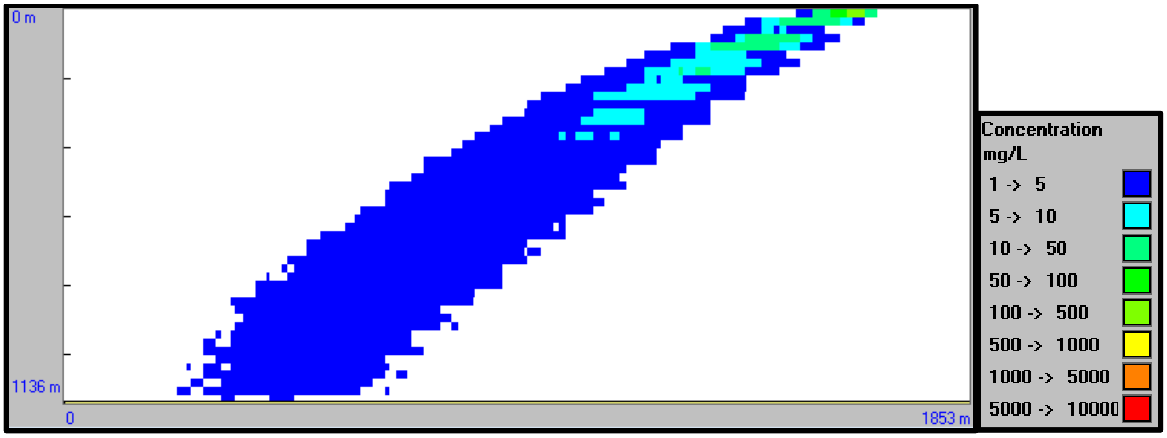


Figure 16-45 **Cross-sectional view of predicted water column concentration from an accidental surface release of 60 m³ at Site 1 (Winter)**

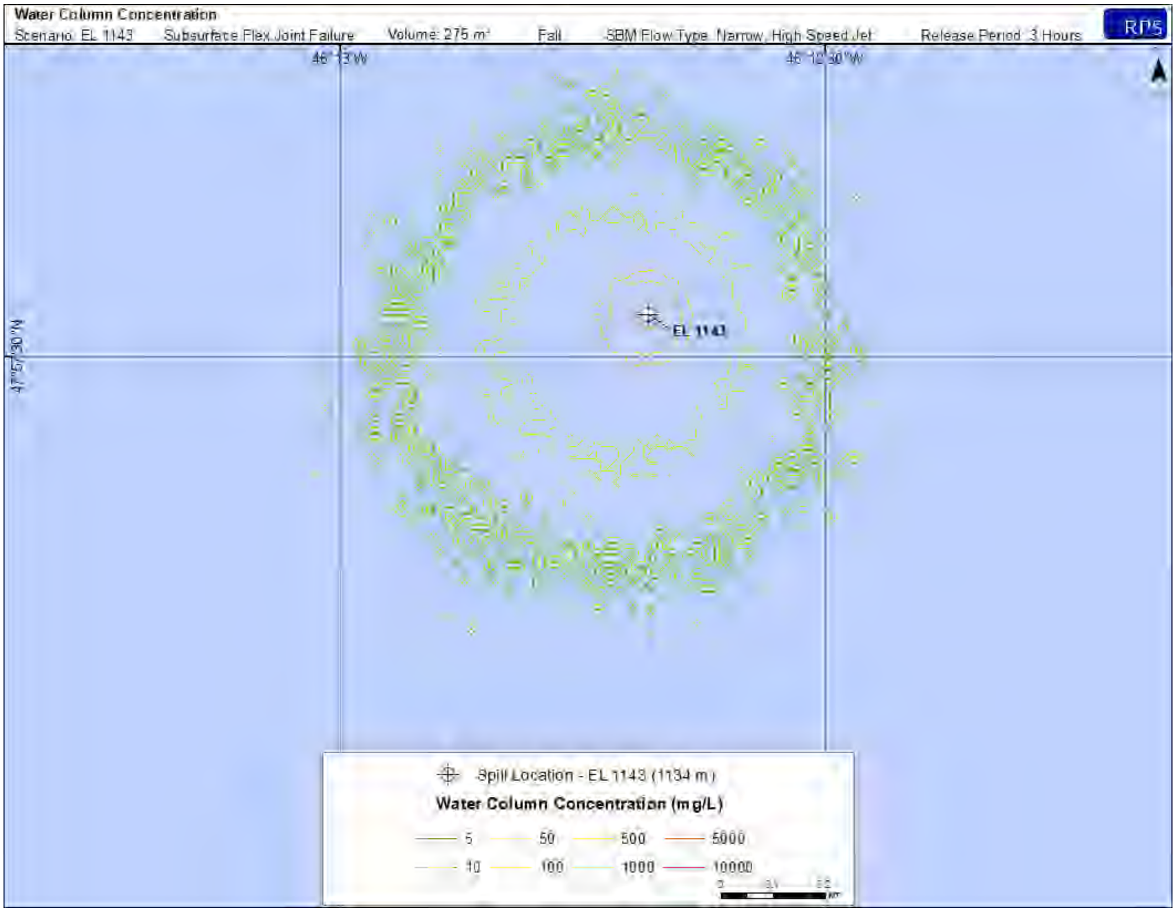


Figure 16-46 Predicted water column concentration from a flex joint failure accidental seabed release 275 m³ Site 1 (Fall)

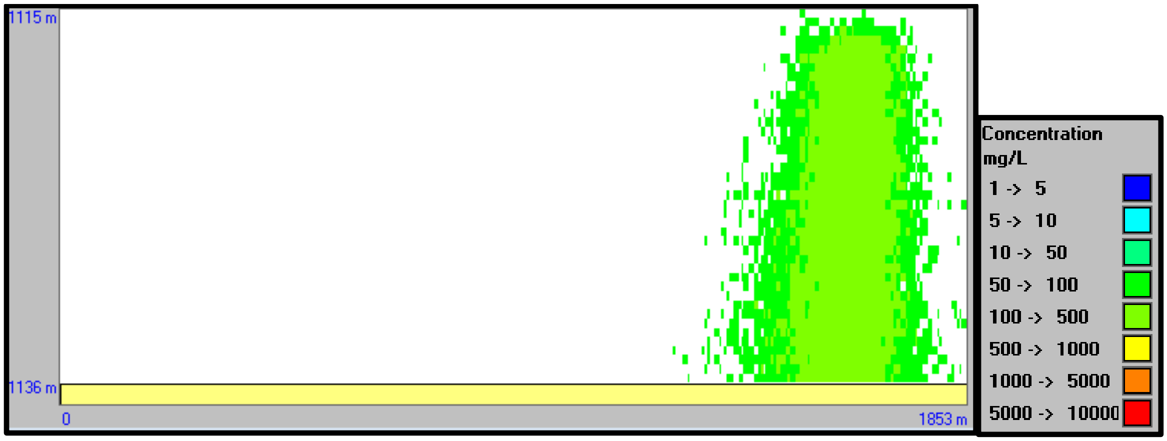


Figure 16-47 Cross-sectional view of predicted water column concentration from a flex joint failure accidental seabed release 275 m³ at Site 1 (Fall)

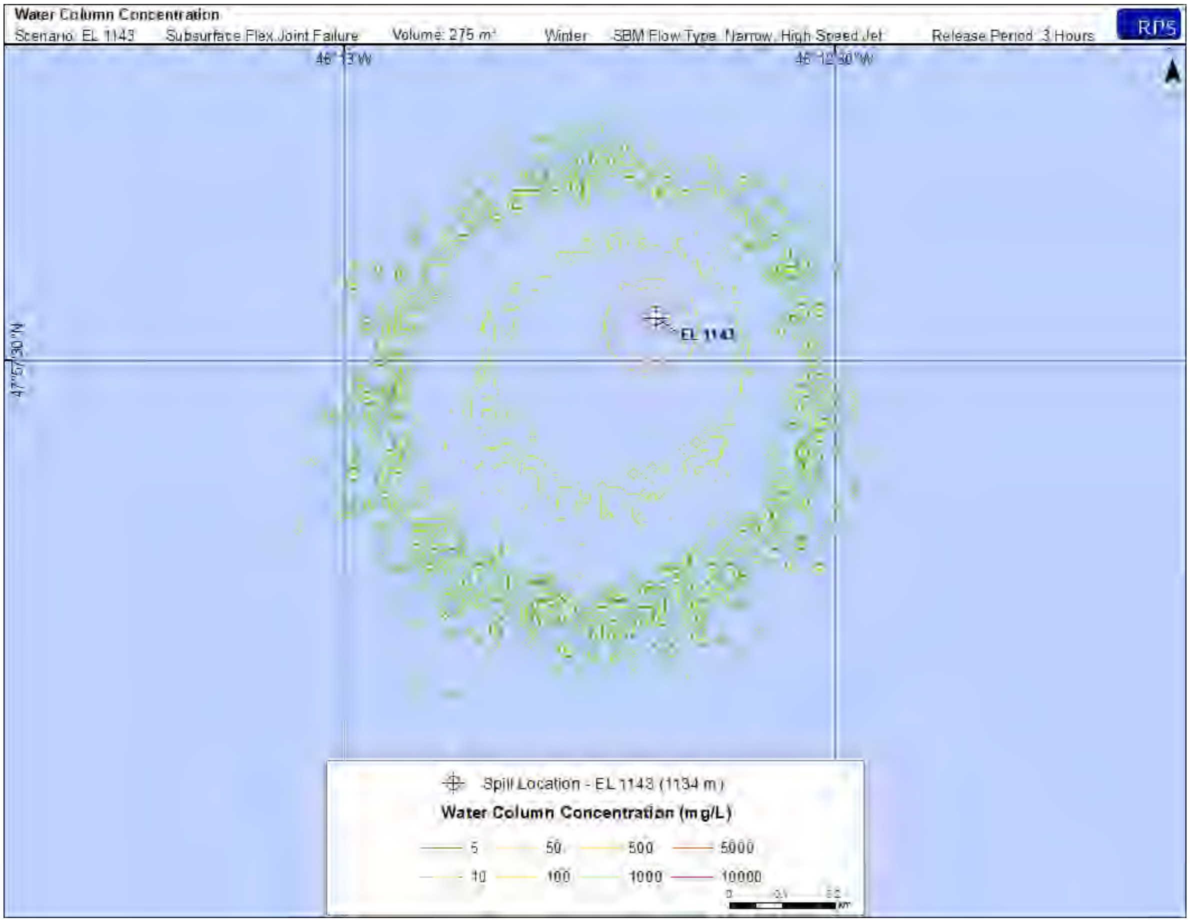


Figure 16-48 Predicted water column concentration from a flex joint failure accidental seabed release 275 m³ at Site 1 (Winter)

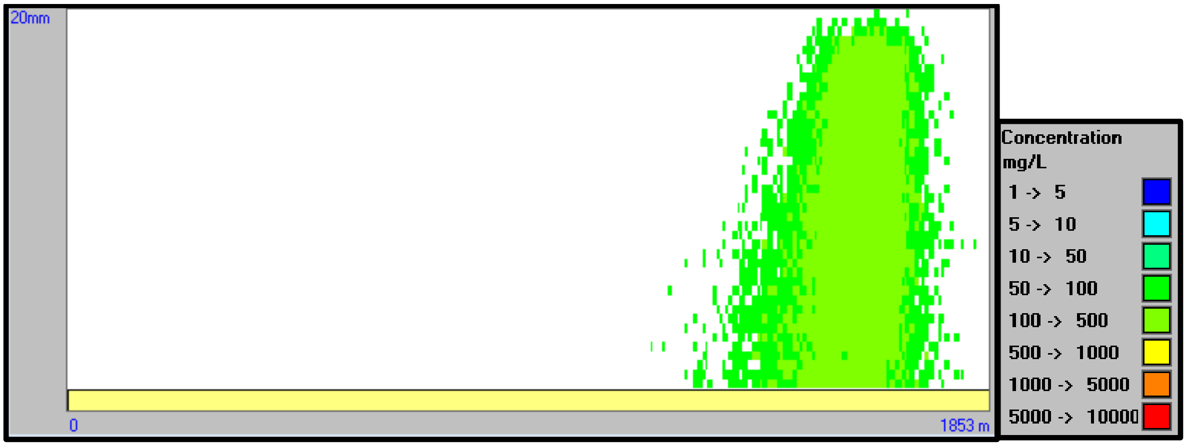


Figure 16-49 Cross-sectional view of predicted water column concentration from a flex joint failure accidental seabed release 275 m³ at Site 1 (Winter)

Figure 16-50 Predicted water column concentration from a BOP disconnect accidental seabed release 275 m³ at Site 1 (Fall)

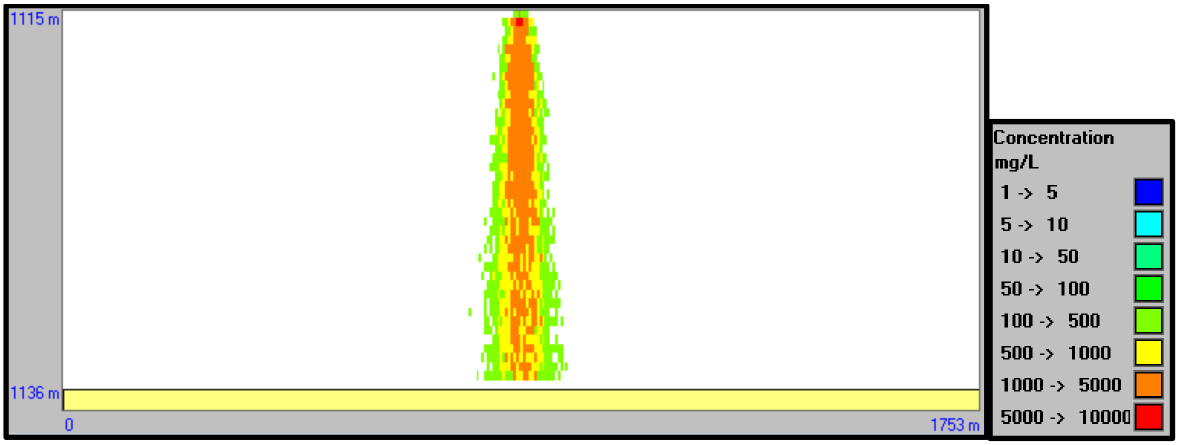


Figure 16-51 Cross-sectional view of predicted water column concentration from a BOP disconnect accidental seabed release 275 m³ at Site 1 (Fall)

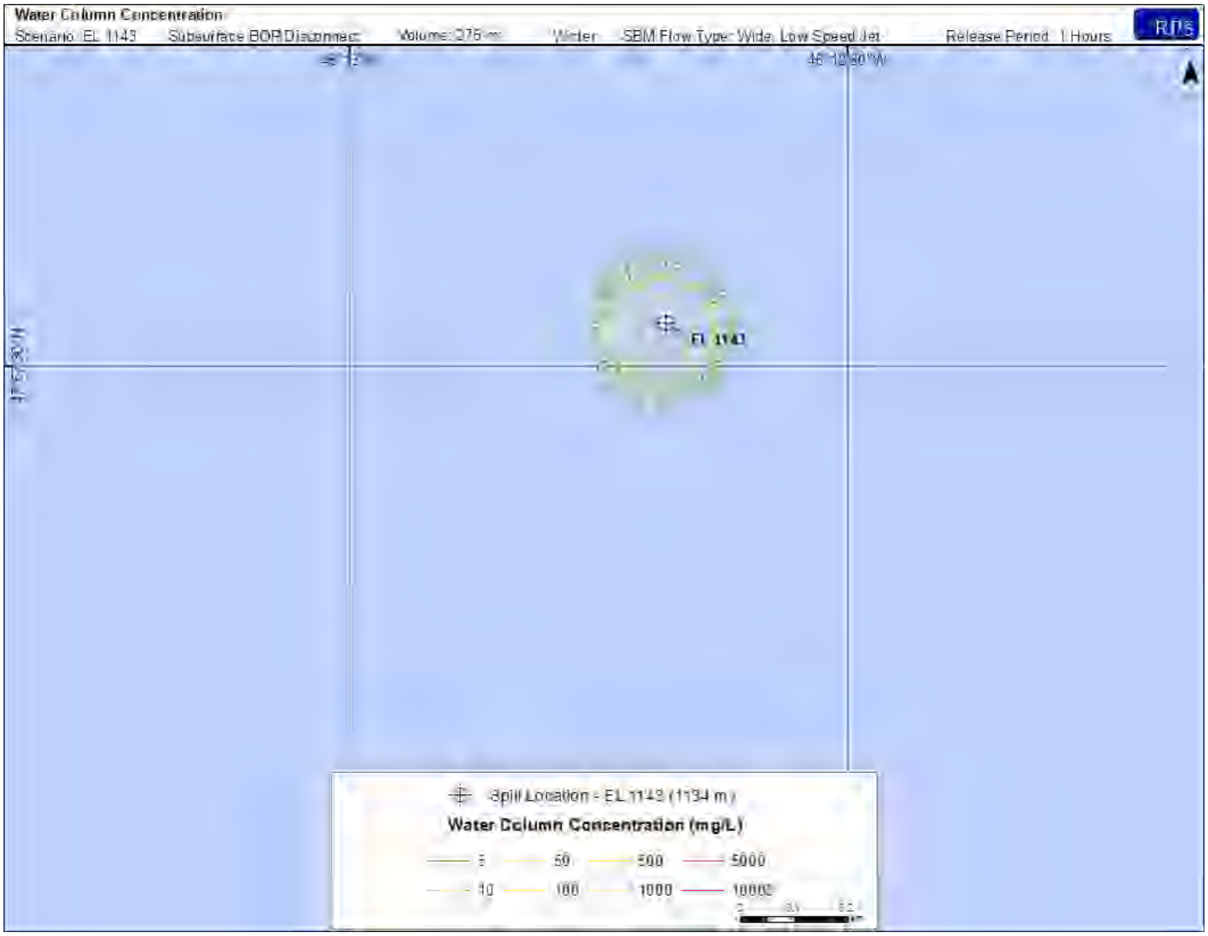


Figure 16-52 Predicted water column concentration from a BOP disconnect accidental seabed release 275 m³ at Site 1 (Winter)

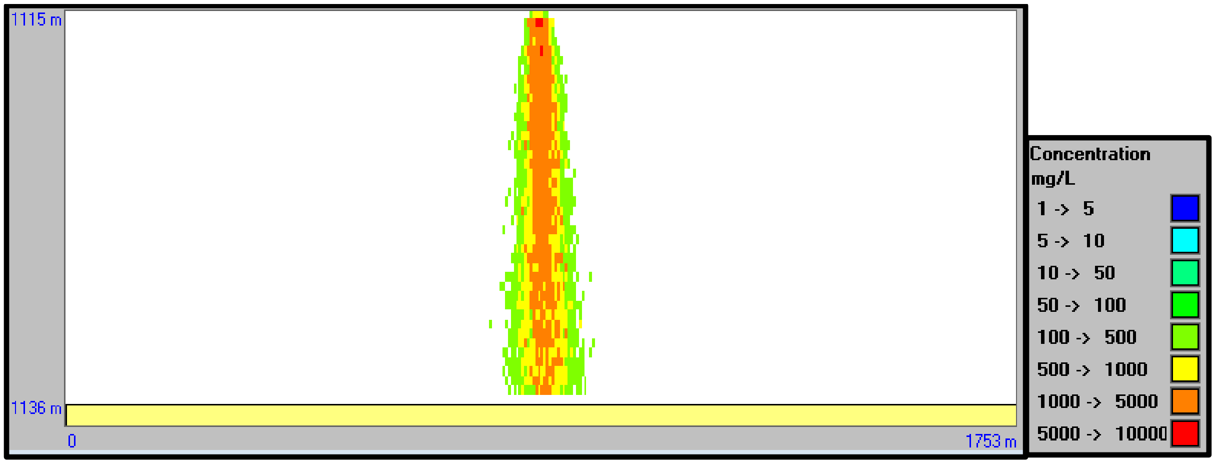


Figure 16-53 Cross-sectional view of predicted water column concentration from a BOP disconnect accidental seabed release 275 m³ at Site 1 (Winter)

Table 16.31 Areal Extent of Water Column Concentration (by concentration interval) for Site 1 Simulations

Water Column Concentration (mg/L)	Cumulative Area Exceeding (km²)					
	Surface Tank Spill (Fall)	Surface Tank Spill (Winter)	Flex Joint Failure (Fall)	Flex Joint Failure (Winter)	Subsea BOP Disconnect (Fall)	Subsea BOP Disconnect (Winter)
5	0.0623	0.1059	0.23984	0.2465	0.02121	0.02126
10	0.02704	0.04861	0.23984	0.2465	0.02121	0.02126
50	0.00377	0.00347	0.23984	0.2465	0.01431	0.0145
100	0.00103	0.0013	0.08369	0.08862	0.01197	0.01194
500	0	0	0.01087	0.01097	0.00511	0.00515
1,000	0	0	0.00677	0.0071	0.00321	0.00304
5,000	0	0	0.00093	0.00101	0.00041	0.00042
10,000	0	0	0.00019	0.00025	0.00004	0.00004

Table 16.32 Maximum Distance of Water Column Concentration Contours (distance from release site) for Site 1 Simulations

Deposition Thickness (mm)	Maximum extent from release site (km)					
	Surface Tank Spill (Fall)	Surface Tank Spill (Winter)	Flex Joint Failure (Fall)	Flex Joint Failure (Winter)	Subsea BOP Disconnect (Fall)	Subsea BOP Disconnect (Winter)
10	0.2	0.4	0.48	0.56	0.11	0.11
100	0.03	0.03	0.27	0.32	0.07	0.08
1,000	0	0	0.05	0.06	0.04	0.04
10,000	0	0	0.01	0.01	0	0

16.5.2 Site 2

16.5.2.1 Predicted Seabed Deposition

MUDMAP was used to predict seabed deposition at Site 2 from potential accidental releases of SBM for each scenario. Figures 16-54 to 16-56 present seabed deposition associated with the release of each of the accidental SBM release simulations. Table 16.33 summarize the areal extent of seabed deposition resulting from the modelled releases. Table 16.34 summarize the maximum distance seabed deposition extends from the release sites.

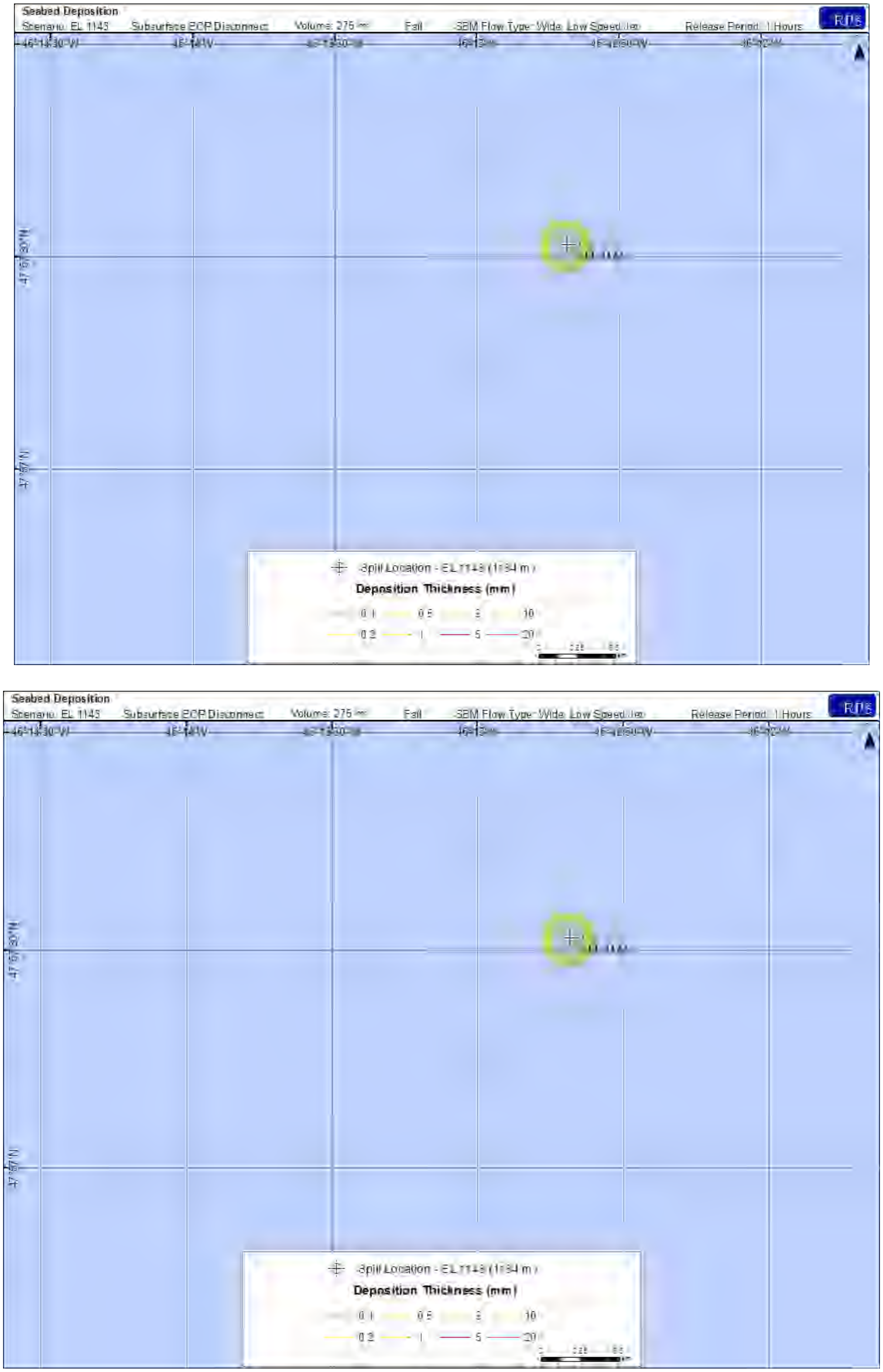


Figure 16-54 Predicted thickness from an accidental surface release of 60 m³ at Site 2 release site in Fall (top) and Winter (bottom)

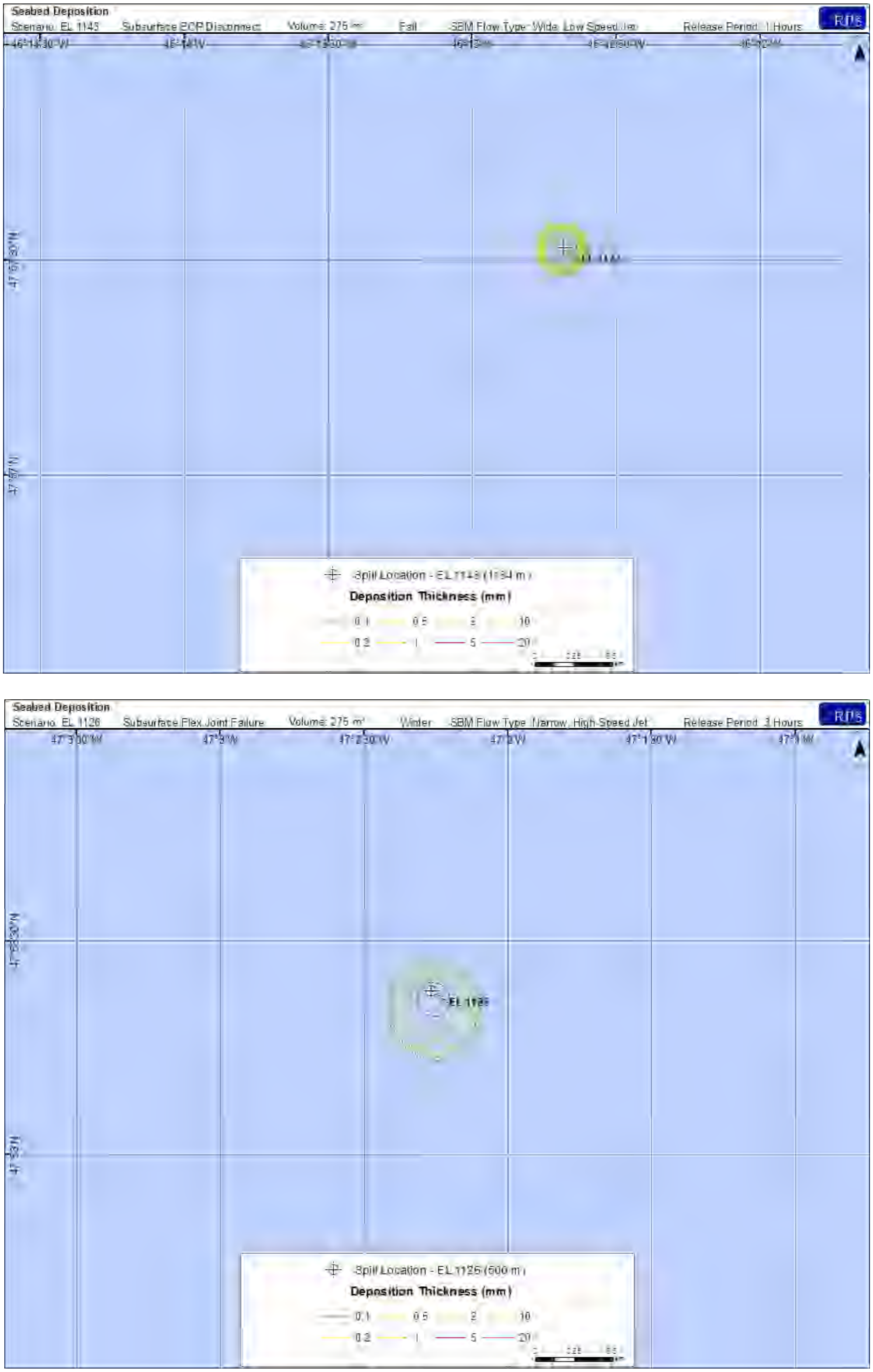
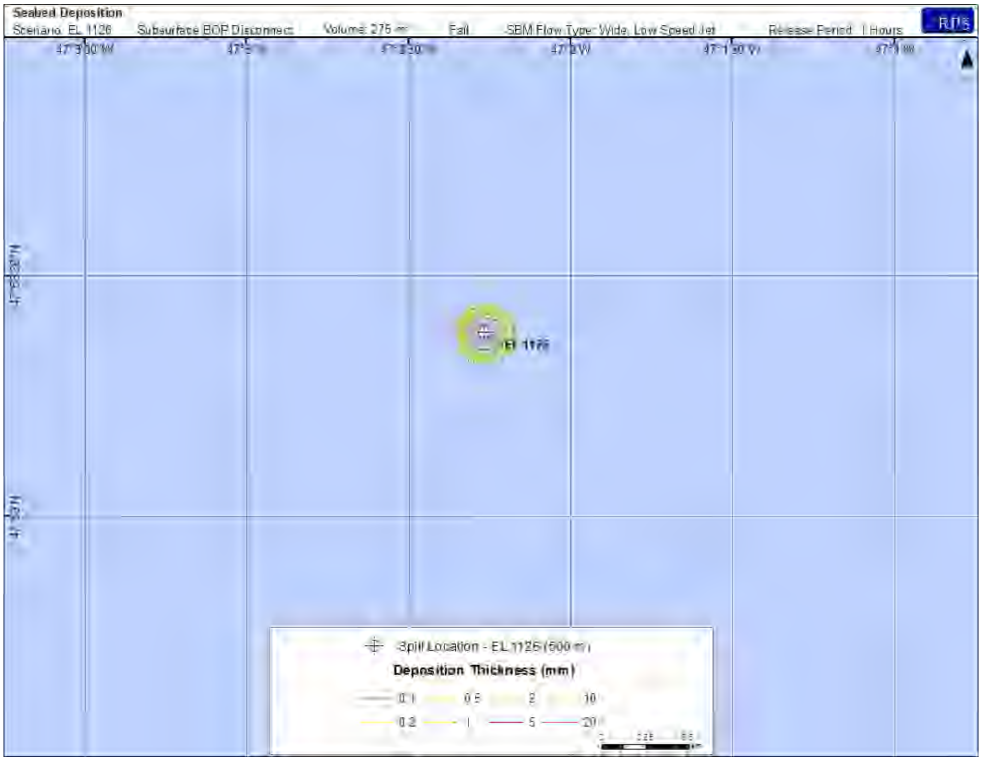


Figure 16-55 **Predicted thickness from a flex joint failure accidental seabed release 275 m³ at the Site 2 release site in Fall (top) and Winter (bottom)**



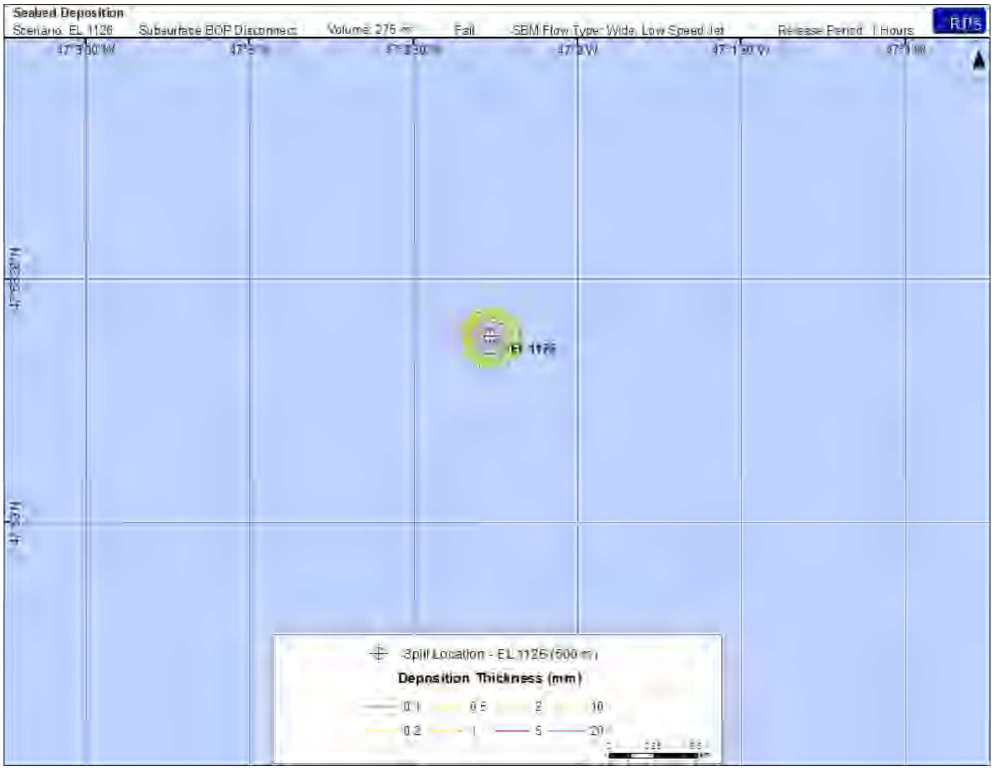


Figure 16-56 Predicted thickness from a BOP disconnect accidental seabed release 275 m³ at the Site 2 release site in Fall (top) and Winter (bottom)

Table 16.33 Areal Extent of Seabed Deposition (by thickness interval) for Site 2 Simulations

Deposition Thickness (mm)	Cumulative Area Exceeding (km²)					
	Surface Tank Spill (Fall)	Surface Tank Spill (Winter)	Flex Joint Failure (Fall)	Flex Joint Failure (Winter)	Subsea BOP Disconnect (Fall)	Subsea BOP Disconnect (Winter)
0.1	0.16856	0.16823	0.12602	0.13114	0.03549	0.03525
0.2	0.09827	0.09815	0.09858	0.10378	0.03212	0.03226
0.5	0.00838	0.00602	0.06827	0.07189	0.02576	0.02585
1	0	0	0.05106	0.05145	0.02174	0.02187
2	0	0	0.03428	0.0343	0.01778	0.01785
5	0	0	0.01606	0.01598	0.01214	0.01219
10	0	0	0.00396	0.00372	0.00809	0.00824
20	0	0	0	0	0.00424	0.00419

Table 16.34 Maximum Distance of Thickness Contours (distance from release site) for Site 2 Simulations

Deposition Thickness (mm)	Maximum extent from release site (km)					
	Surface Tank Spill (Fall)	Surface Tank Spill (Winter)	Flex Joint Failure (Fall)	Flex Joint Failure (Winter)	Subsea BOP Disconnect (Fall)	Subsea BOP Disconnect (Winter)
0.1	0.32	0.59	0.28	0.35	0.14	0.15
1	0	0	0.16	0.2	0.1	0.1
10	0	0	0.06	0.07	0.06	0.07

16.5.2.2 Predicted Water Column Concentrations

MUDMAP was also used to evaluate concentrations of TSS in the water column as a result of accidental releases of SBM for the 12 scenarios. Figures 16-57 through 16-68 present maximum water column concentrations associated with the release of each accidental SBM release simulations. As described for Site 1 (Section 16.5.1.2) each figure pair includes a top-down view as well as a cross-section of the release. These figures do not represent any instantaneous snapshot of water column concentrations, but instead depict the maximum, time-integrated TSS within the study domain for each modelled release. Table 16.35 summarizes the areal extent of water column concentrations resulting from the modelled releases. Table 16.36 summarizes the maximum distance water column concentrations extend from the release sites.

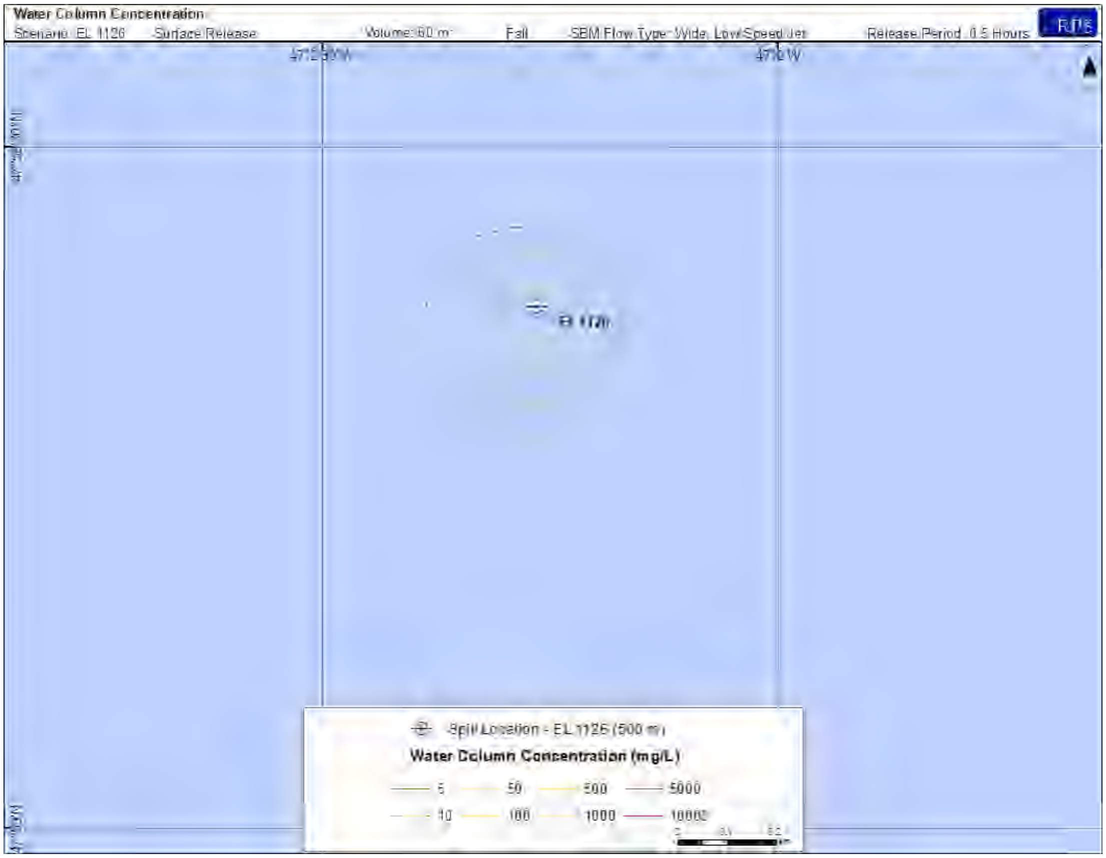


Figure 16-57 **Predicted water column concentration from an accidental surface release of 60 m³ at Site 2 (Fall)**

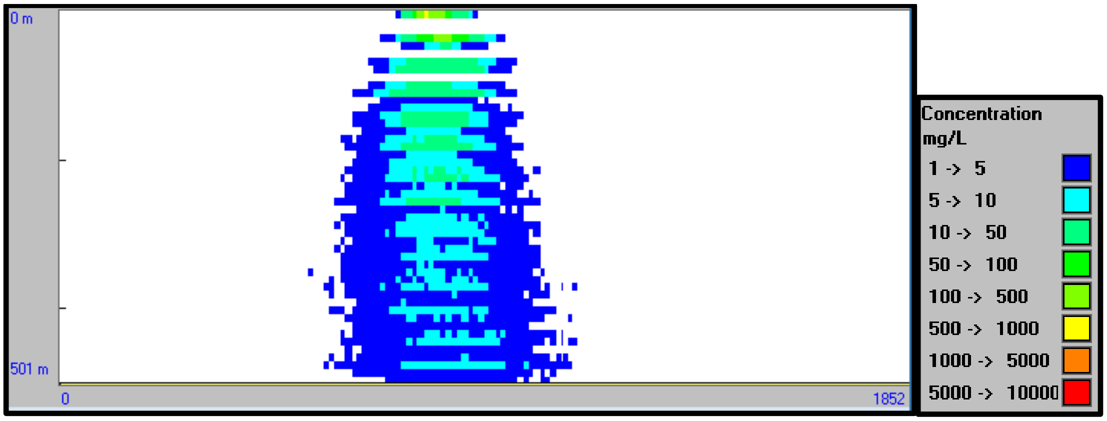


Figure 16-58 **Cross-sectional view of predicted water column concentration from an accidental surface release of 60 m³ at Site 2 (Fall)**

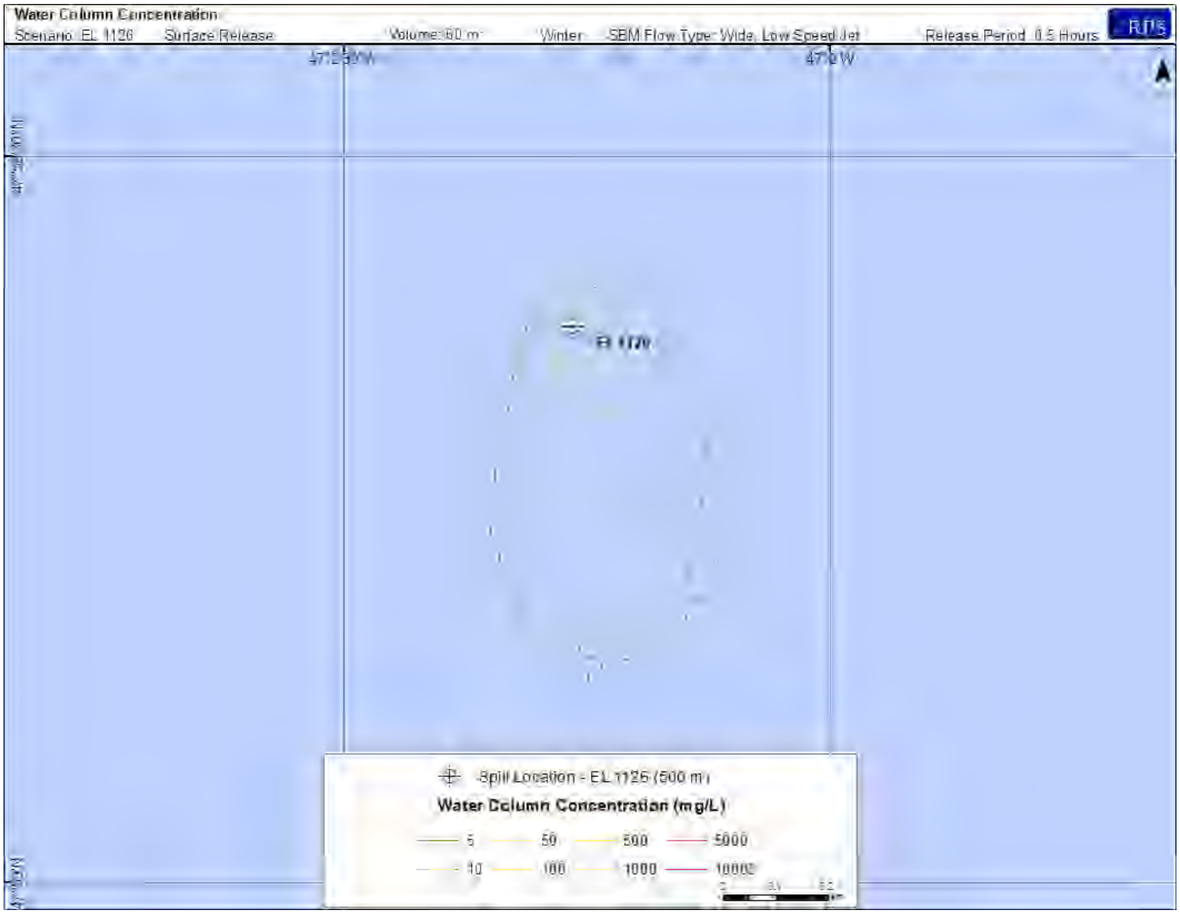


Figure 16-59 **Predicted water column concentration from an accidental surface release of 60 m³ at Site 2 (Winter)**

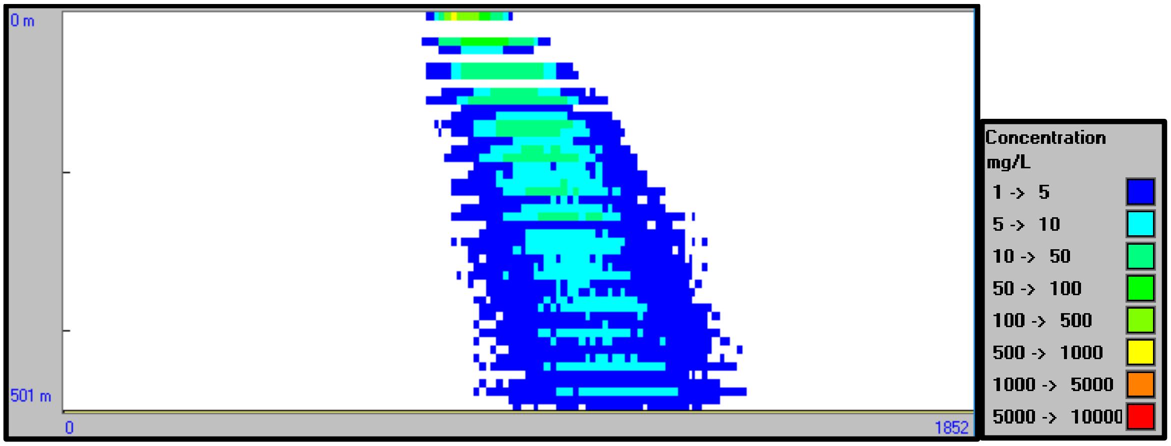


Figure 16-60 **Cross-sectional view of predicted water column concentration from an accidental surface release of 60 m³ at Site 2 (Winter)**

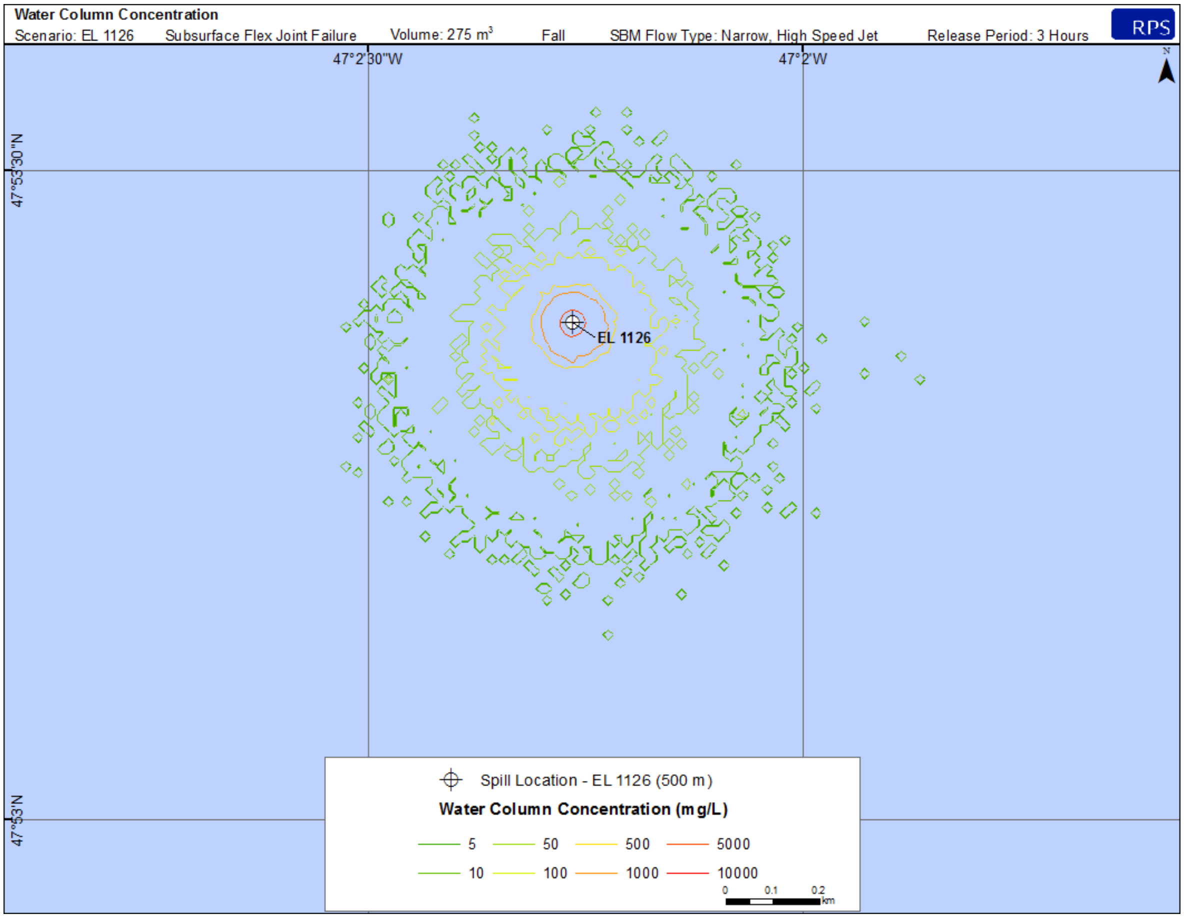


Figure 16-61 **Predicted water column concentration from a flex joint failure accidental seabed release 275 m³ at Site 2 (Fall)**

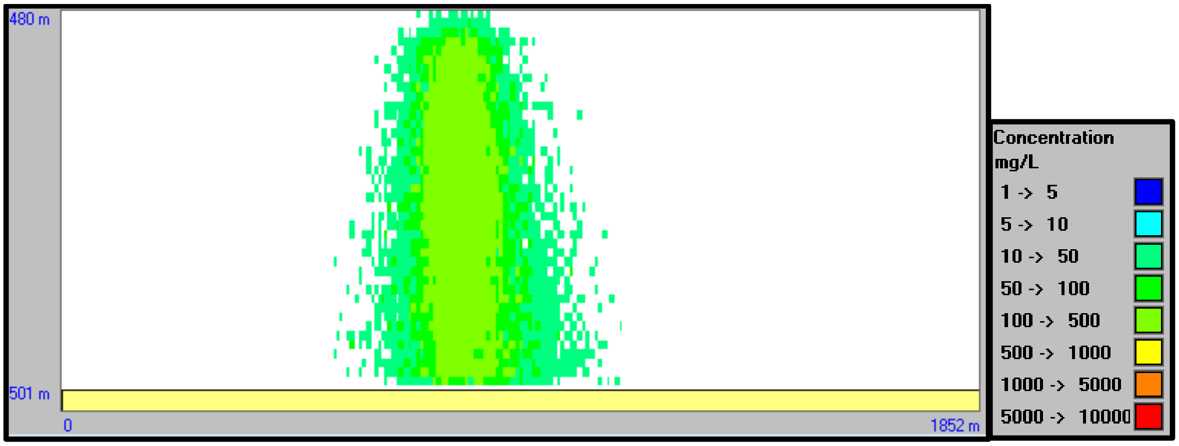


Figure 16-62 **Cross-sectional view of predicted water column concentration from a flex joint failure accidental seabed release 275 m³ at Site 2 (Fall)**

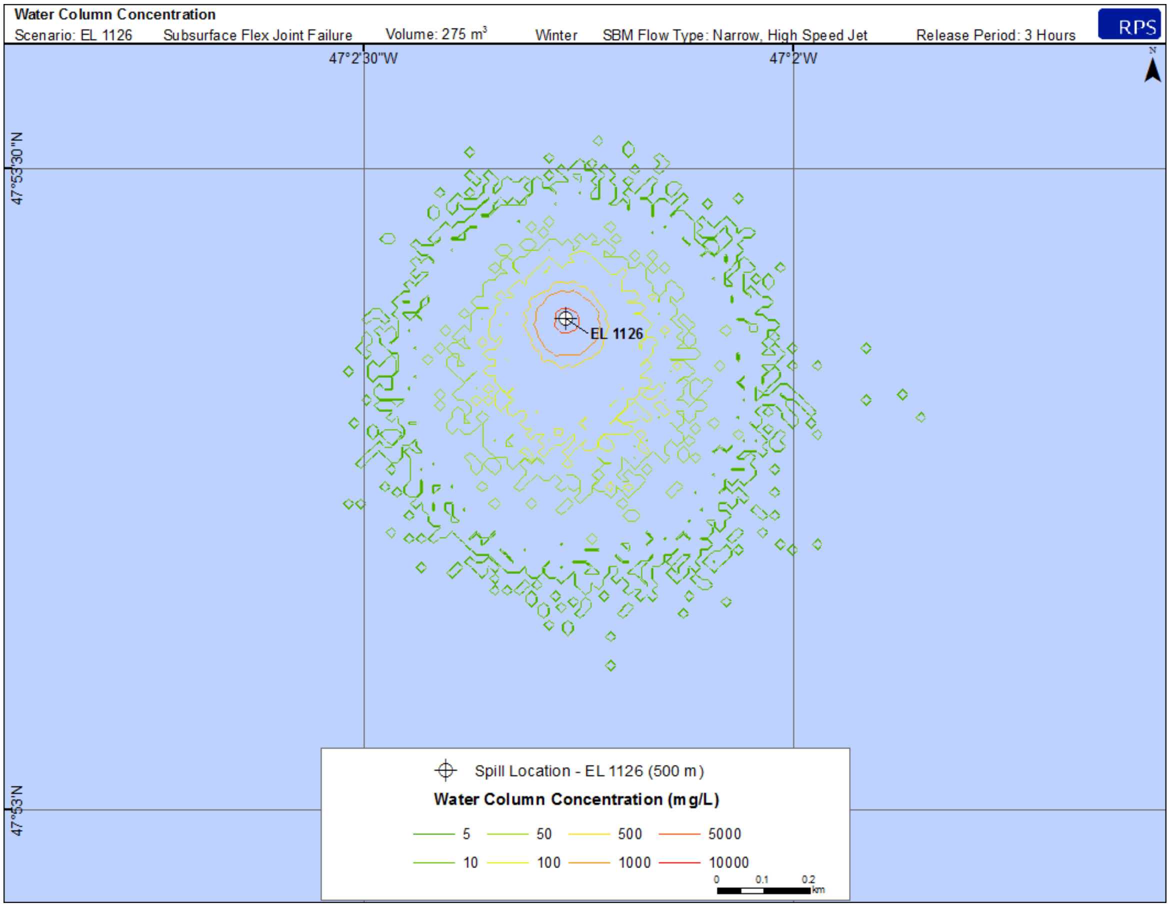


Figure 16-63 **Predicted water column concentration from a flex joint failure accidental seabed release 275 m³ at Site 2 (Winter)**

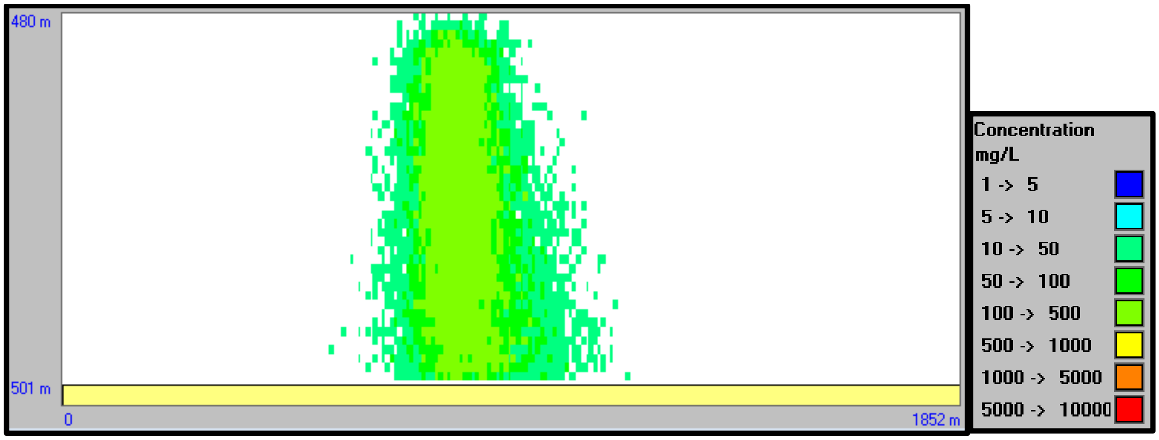


Figure 16-64 **Cross-sectional View of predicted water column concentration from a flex joint failure accidental seabed release 275 m³ at Site 2 (Winter)**

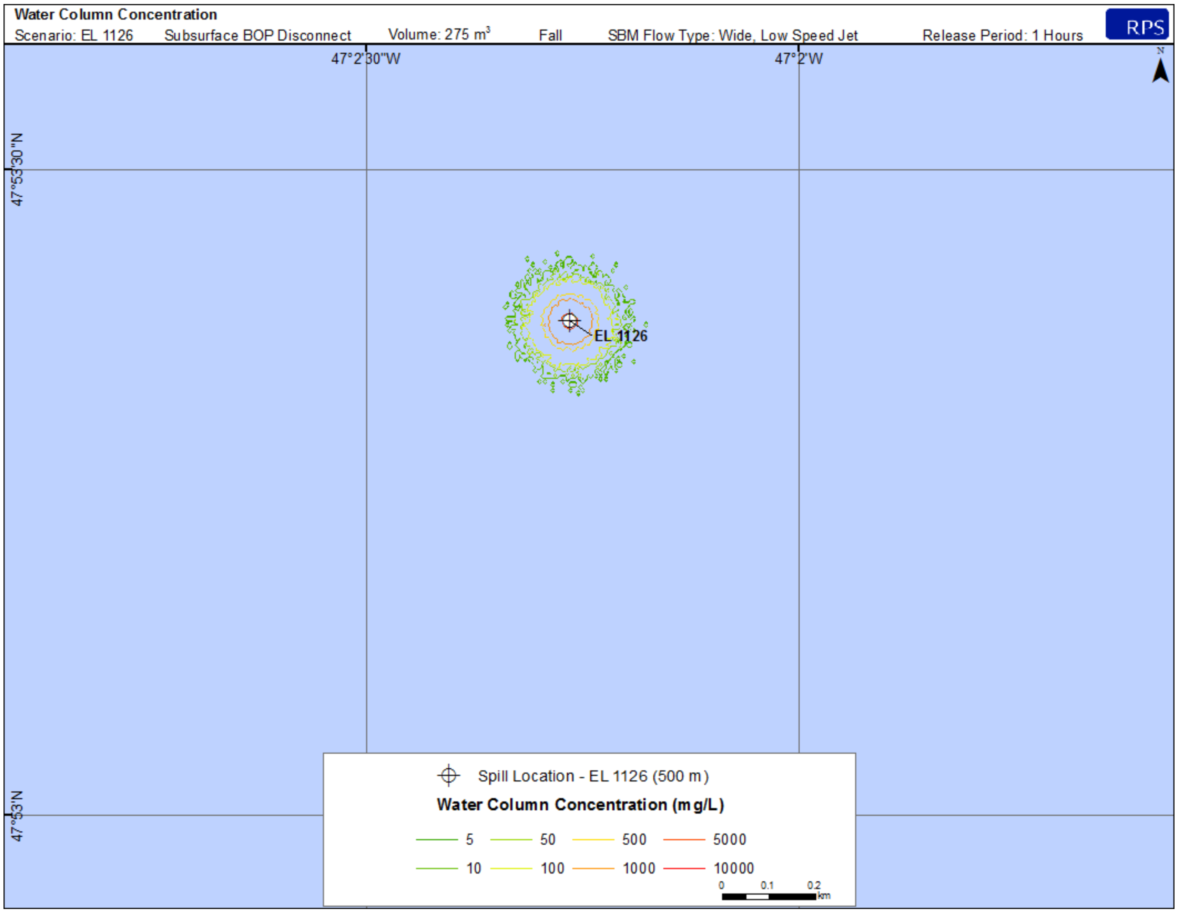


Figure 16-65 Predicted water column concentration from a BOP disconnect accidental seabed release 275 m³ at Site 2 (Fall)

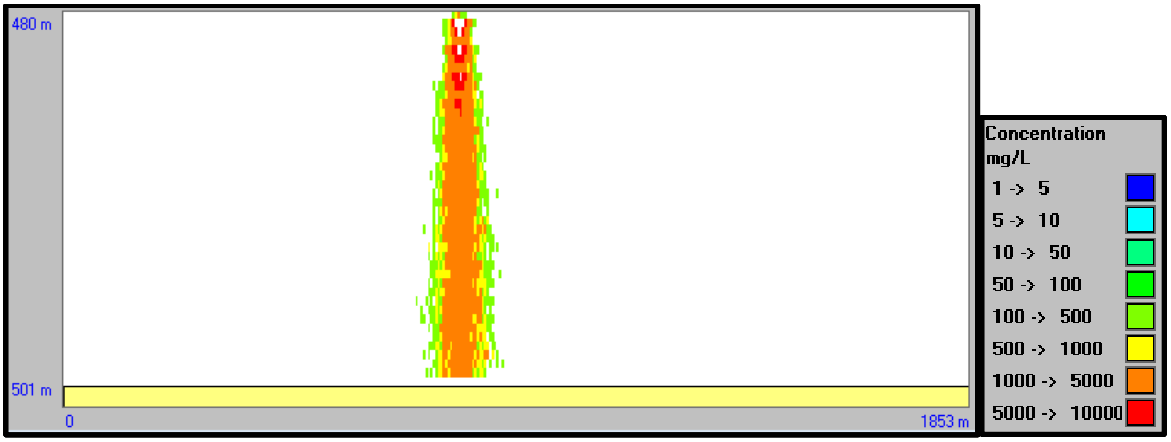


Figure 16-66 Cross-sectional view of predicted water column concentration from a BOP disconnect accidental seabed release 275 m³ at Site 2 (Fall)

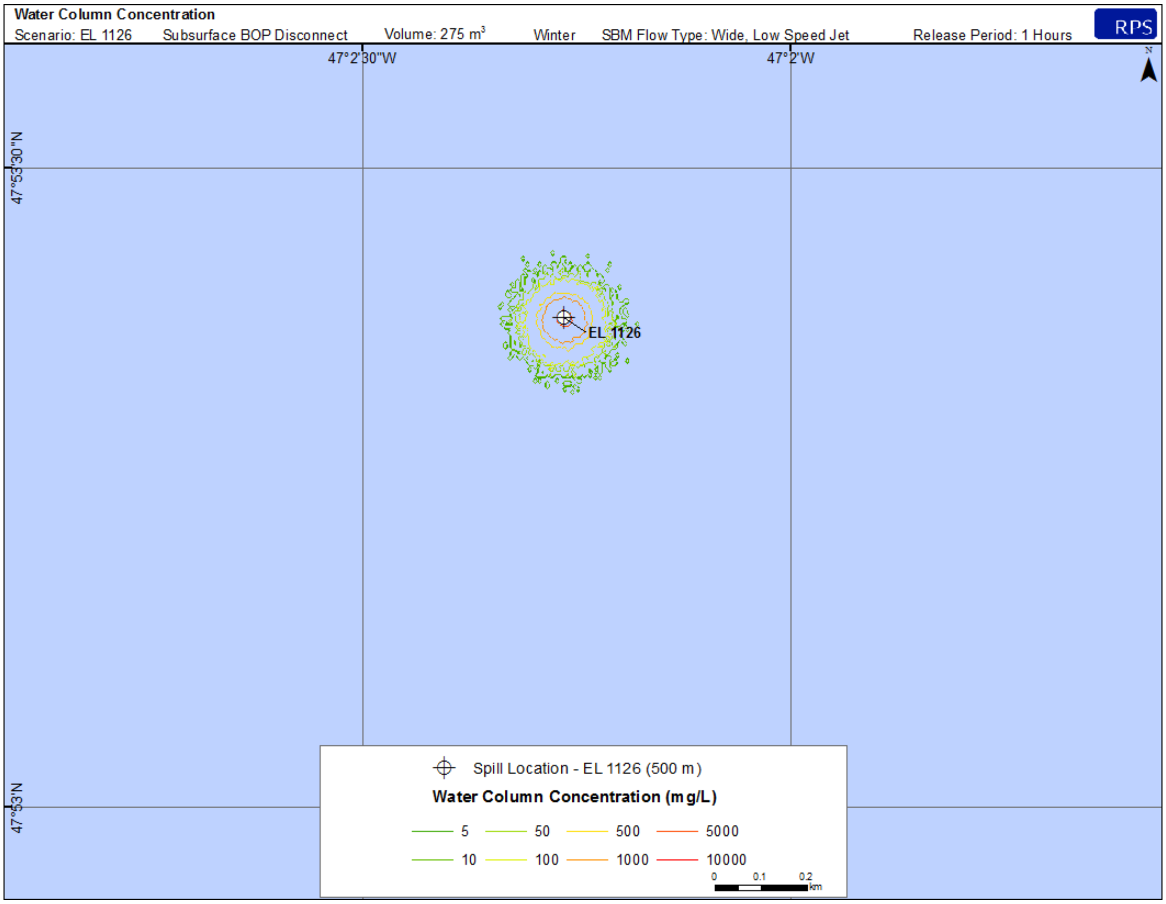


Figure 16-67 Predicted water column concentration from a BOP disconnect accidental seabed release 275 m³ at Site 2 (Winter)

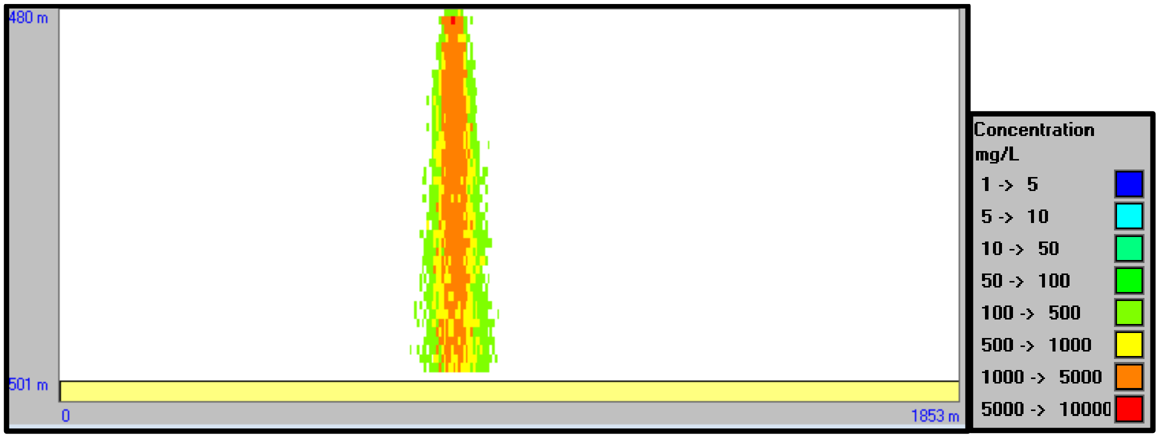


Figure 16-68 Cross-sectional view of predicted water column concentration from a BOP disconnect accidental seabed release 275 m³ at Site 2 (Winter)

Table 16.35 Areal Extent of Water Column Concentration (by concentration interval) for Site 2 Simulations

Water Column Concentration (mg/L)	Cumulative Area Exceeding (km²)					
	Surface Tank Spill (Fall)	Surface Tank Spill (Winter)	Flex Joint Failure (Fall)	Flex Joint Failure (Winter)	Subsea BOP Disconnect (Fall)	Subsea BOP Disconnect (Winter)
5	0.06277	0.10505	0.24469	0.25215	0.02114	0.0213
10	0.03508	0.05157	0.24469	0.25215	0.02114	0.0213
50	0.0088	0.01073	0.08584	0.0902	0.01449	0.01458
100	0.00341	0.00455	0.04306	0.04656	0.01191	0.01192
500	0.00014	0.00015	0.01087	0.01102	0.00501	0.00503
1,000	0	0	0.00662	0.00686	0.00322	0.00321
5,000	0	0	0.00101	0.00109	0.0004	0.00037
10,000	0	0	0.00022	0.00015	0.00004	0.00006

Table 16.36 Maximum Distance of Water Column Concentration Contours (distance from release site) for Site 2 Simulations

Deposition Thickness (mm)	Maximum extent from release site (km)					
	Surface Tank Spill (Fall)	Surface Tank Spill (Winter)	Flex Joint Failure (Fall)	Flex Joint Failure (Winter)	Subsea BOP Disconnect (Fall)	Subsea BOP Disconnect (Winter)
10	0.13	0.3	0.51	0.52	0.11	0.11
100	0.06	0.08	0.19	0.27	0.07	0.08
1,000	0	0	0.06	0.06	0.04	0.04
10,000	0	0	0.01	0.01	0.01	0.01

16.5.3 Uncertainties

The hypothetical accidental releases modelled in this study are not intended to predict a specific future event, but rather are to be used as a tool in environmental assessments to predict potential area of interaction. The results presented in this document demonstrate that there are a range of potential trajectories that could result if a release of synthetic based drilling mud were to occur. The specific trajectories vary for each release based upon the nature of the release, the environmental conditions, and the properties of the fluids. While each accidental release is unique and therefore uncertainties exist, the results of this modelling study suggest that if SBM were to be released in the Project Area, there is the potential for seabed deposition to extend up to1.5 km from the spill site. In addition, there is the potential for water column concentrations to exceed 10,000 mg/L within 10 m of the spill locations.

16.5.4 Summary of Modelling Results

Surface releases of SBM would be expected to result in seabed deposition extending farthest from the spill location, due to intensified currents at the surface, slower settling time, and a greater depth over which to settle. At Site 1, the maximum extent of deposition thickness of 0.1 mm was predicted to be within 1.5 km of the spill location from a surface tank loss; whereas in Site 2, a surface tank loss resulted in a deposition thickness of 0.1 mm within 590 meters of the spill site. The depth of each release site had the greatest potential to increase the extent of deposition but also generally reduced the predicted total thicknesses of the deposit. In the simulation results, the extent of deposition from surface releases was intensified by prevailing currents during winter conditions. Subsurface releases occurring from a BOP disconnect or flex joint failure near the seafloor would be expected to result in thicker deposition over a smaller area than from surface releases, due to the faster settling time of particles released from a wide, low velocity flow incident. For a flex joint release, the 10 mm deposition thickness was between 60 to 80 m from the release site. Deposition thickness of 10 mm for a BOP spill was within 60 to 70 m of the release location.

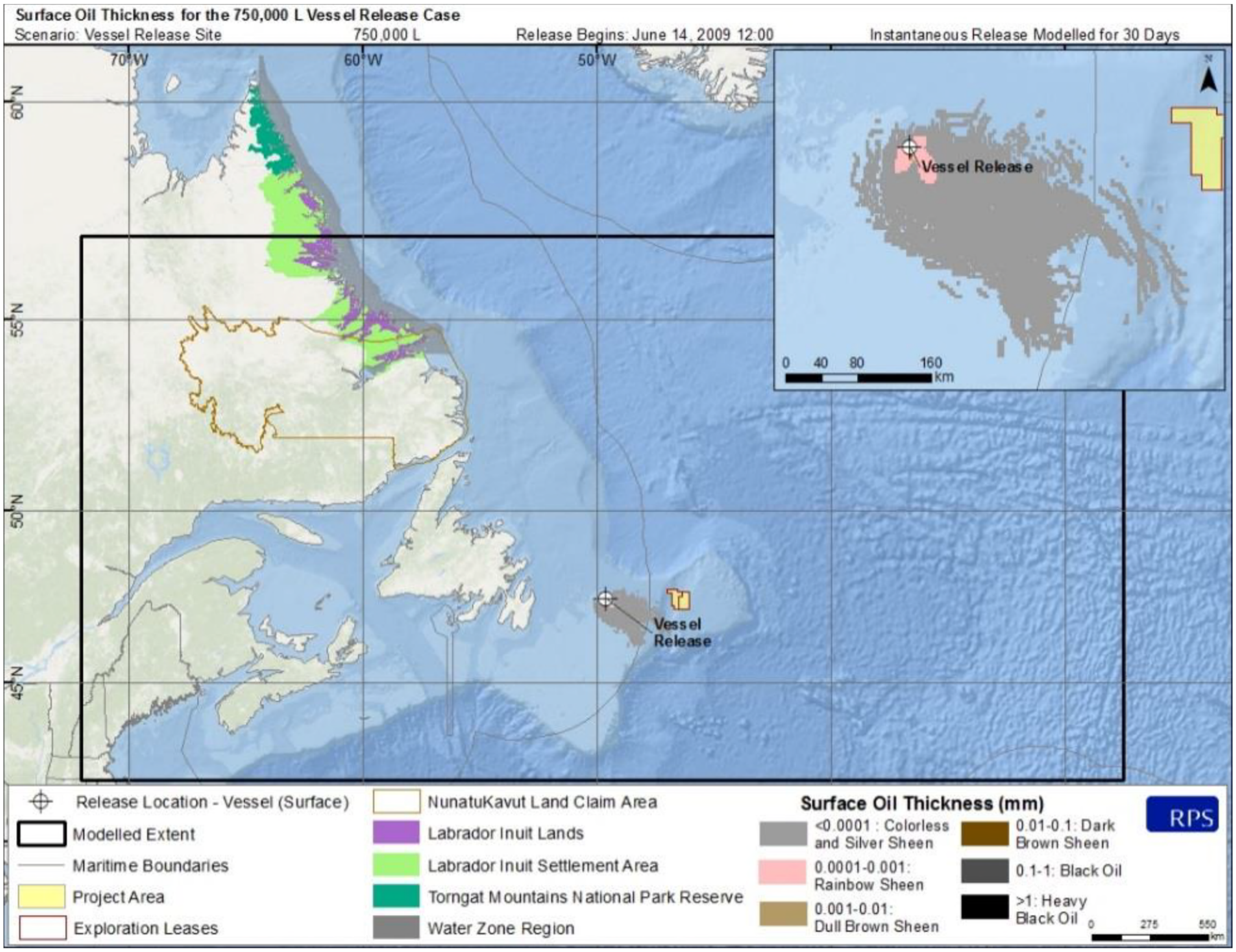
The variance in results between simulations was due to three main differences including: 1) release height relative to the seabed, 2) settling velocity associated with low versus high velocity releases, and 3) local current (i.e., hydrodynamics). Releases resulting from accidental mud tank spillage and BOP disconnect occur at a lower flow rate, and thus were predicted to have faster settling times and thicker deposition in regions close to the spill site. Flex joint failure releases typically result in increased flow rate, making particles much smaller and decreasing settling rates, allowing for particles to travel further before depositing on the seafloor.

The releases modelled in this study may be considered representative of other potential releases in the project area. The water depths at Site 1 and Site 2 (1,134 and 500 m, respectively) are similar in depth to other potential drilling locations in the area.

16.6 Vessel Collision

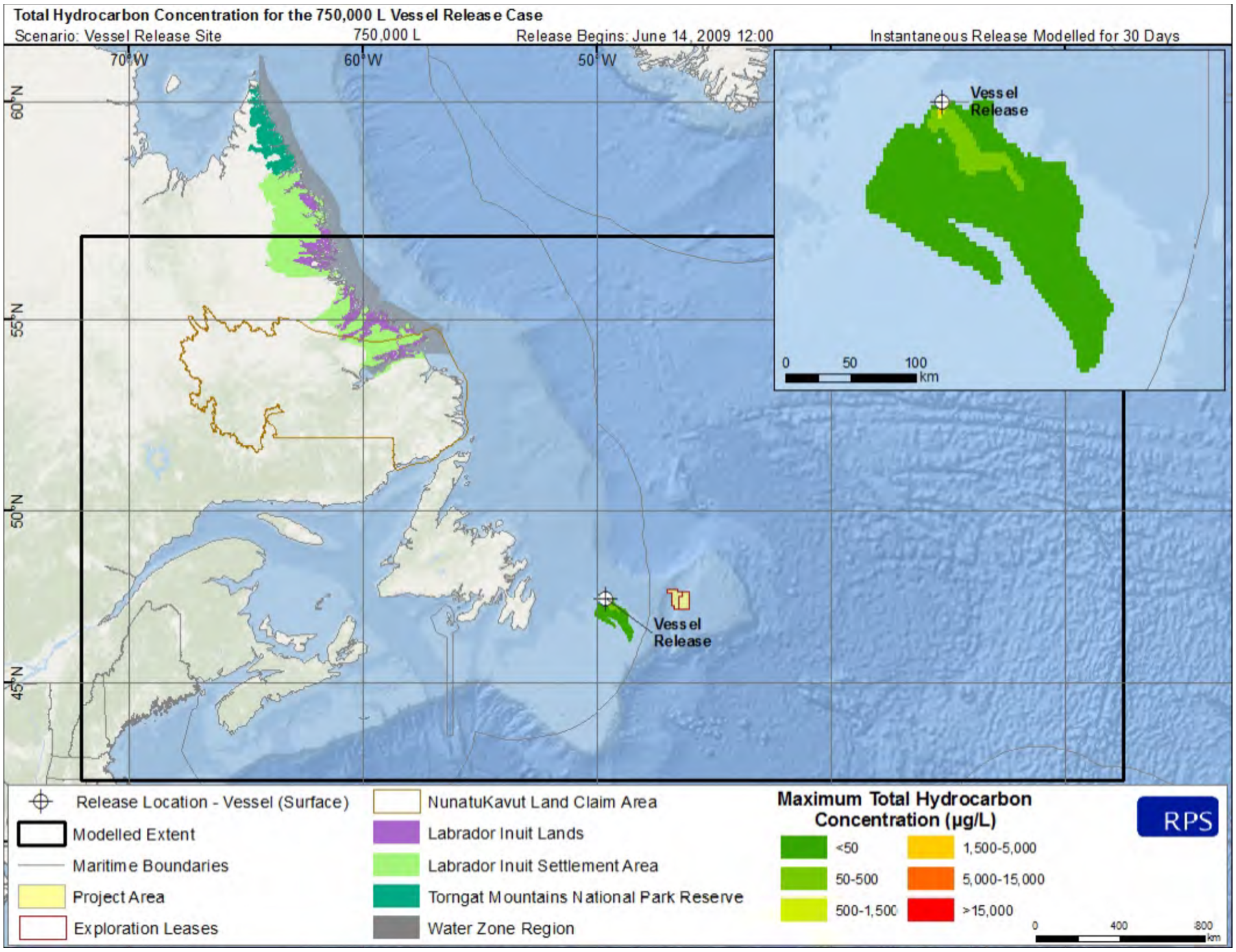
In the Flemish Pass Exploration Drilling Project EIS, Nexen Energy ULC (2018) modelled a 750 m^3 litre spill from a vessel-to-vessel collision between St. John's, NL and their proposed project area in the Flemish Pass. The model results indicated that the release migrated to the east and did not result in oil coming in contact with the shoreline. In addition, the release would be discontinuous and patchy surface sheens, with a 40-km rainbow sheen that would transition to the colorless and silver sheen. A surface oil exposure area of 13 km^2 and 925 km^2 for the 10 μm ecological threshold and 0.04 μm socioeconomic threshold, respectively, was predicted (Nexen Energy ULC 2018).

Based on the results of the Nexen diesel model (Nexen Energy ULC 2018), Equinor Canada did not undertake a vessel-to-vessel spill model. If this scenario was undertaken, the model would have used the same scenario – volume and reference location – along the vessel traffic route, using the RPS model. The modelling results would be similar to the those presented by Nexen (2018) (see Figures 16-69 and 16-70).



Source: Nexen 2018

Figure 16-69 Surface Oil Thickness Resulting from a Release of 750,000 L of Marine Diesel from a Vessel Collision



Source: Nexen 2018

Figure 16-70 Maximum Total Hydrocarbon Concentration at Any Depth in the Water Column resulting from Vessel Collision Release of 750,000 L

In addition to the Nexen Energy ULC (2018) model, the Risk Management Research Institute (RMRI) prepared the *Quantitative Assessment of Oil Spill Risk for the South Coast of Newfoundland and Labrador (Phase 1)* for Transport Canada (RMRI 2006) (herein referred to as the RMRI Report). The RMRI Report designated five zones of interest, including Zone 5 which included the St. John's port and its approaches. A spill location was determined for each Zone, with Zone 5 being located approximately 8 km east of St. John's. The RMRI Report, however, did not provide specifics regarding the size of the spill or scenario, however, due to prevailing wind and sea conditions it was concluded that oil from the spill would move to the east and not contact the shoreline (RMRI 2006), which aligns with the model completed by Nexen Energy ULC (2018).

Based on the vessel collision model results outlined above, marine diesel is predicted to migrate to the east, and it is not anticipated to contact the shorelines of coastal communities. This EIS uses the results of Nexen's vessel-to-vessel spill model and RMRI model results in the effect assessment sections that follow.

16.7 Accidental Events - Environmental Effects Assessment

This section provides an assessment of the potential environmental effects that may occur, such as an extremely unlikely subsurface blowout or a batch / instantaneous spill.

The assessment is based on the spill modelling conducted for this Project, as summarized in Sections 16.4 and 16.5 above and described in further detail in Appendices E and F, respectively. Modelling was conducted based on a credible worst-case, unmitigated approach (i.e., no preventative or spill response measures were applied), for a range of scenarios that are representative of spill types and volumes. In addition, the location for the subsurface blowout and subsea releases of SBM is within a fisheries closure area (FCA), a special area as discussed in Section 6.4.

The relevant VCs identified and assessed for the effects assessment for routine Project components are also assessed for potential the accidental events environmental effects:

- Marine Fish and Fish Habitat
- Marine and Migratory Birds
- Marine Mammals and Sea Turtles
- Special Areas
- Fisheries and Other Ocean Uses
- Indigenous Peoples

16.7.1 VC-Specific Context

The environmental effects assessment for each VC considers the potential spill events (as modelled) in the context of the characteristics of the particular VC and its known spatial and temporal distributions (see Chapters 9 to 14). Figure 16.71 provides an illustration of the RSA and the LSAs, Project Area, Core BdN Development Area as referenced throughout this assessment.

The spill trajectory modelling included two analyses – stochastic and deterministic (refer to Section 16.4.1). The accidental events environmental effects assessment for each VC uses the representative worst-case from all subsurface blowout modelling scenarios, which is the representative deterministic 95th percentile for surface oiling, water column exposure and contact with shoreline, as described in Section 16.4.3.2. The 95th percentile case is selected from 171 or 172 model runs (36-d or 115-d scenarios, respectively) that capture the seasonal and annual variability in currents, winds, and ice cover. While the stochastic analysis provides insight into the probable behavior of oil releases given historic wind and current data for the Project Area, the deterministic analysis provides individual trajectory, oil weathering information, expected concentrations or thicknesses of oil contamination, mass balance, or other information related to a single release at a given location and time. Therefore, the data provided by the deterministic modelling is more representative of the potential extent of a spill and is therefore used in the effects assessment. As noted in Section 16.3.1, only 41 percent of blowouts involve the release of any oil, as opposed to brine, water, or gas. The majority of surface blowouts from wells last less than five days.

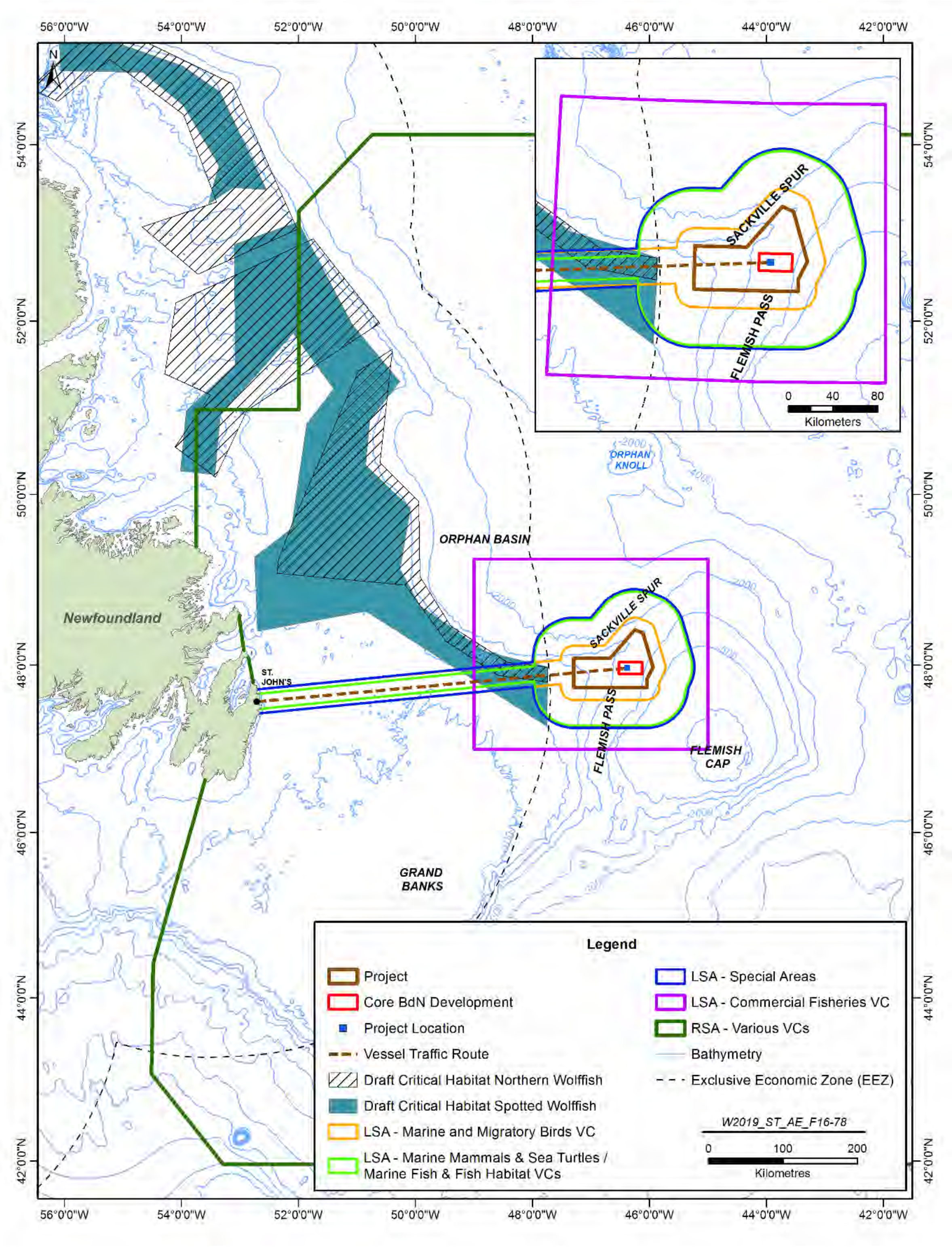


Figure 16-71 Valued Component RSA and LSAs

The RSA (see Figure 16-71) as defined in Section 4.3.1.2, considers the maximum cumulative surface oil thickness for the 95th percentile surface oil exposure case at the ecological threshold of 10 g/m² (0.01 mm). Where interactions associated with a spill occurs within the RSA, which were not considered part of routine operations, updates to these VCs have been included (e.g., describing nearshore commercial fisheries, shorebird species).

Table 16.37 identifies the most relevant deterministic cases (i.e., the worst case) in context of the environmental effects assessment for each VC.

Table 16.37 VCs and Corresponding Relevant Modelling Results for Subsurface Blowouts

VC	Potential Interaction[1]			Relevant Deterministic Model Results	Effect Pathway
	Sea Surface[2]	Water Column[3]	Shoreline / Sediment[4]		
Marine Fish and Fish Habitat	L	H	H	95th percentile Water Concentration 95th percentile Shoreline / Sediment Exposure	• Water column and sediments are fish habitat • Fish occupy the water column
Marine and Migratory Birds	H	M	H	95th percentile Surface Oil Thickness 95th percentile Water Concentration 95th percentile Shoreline Exposure	• Birds rest on water surface • Diving birds interact with water column • Coastal birds along shoreline
Marine Mammals and Sea Turtles	H	H	L	95th percentile Surface Oil Thickness 95th percentile Water Concentration	• Marine mammals spend most of their time in the water column • Surface contact when marine mammals surface to breathe
Special Areas	H	H	H	95th percentile Surface Oil Thickness 95th percentile Water Concentration 95th percentile Shoreline Exposure	• Designation of special areas due to ecological importance and therefore potential interactions with water surface/column and shoreline/sediment
Commercial Fisheries and Other Ocean Uses	H	M	L	95th percentile Surface Oil Thickness 95th percentile Water Concentration 95th percentile Shoreline Exposure	• Fishing gear interaction with surface oiling • Fish contamination in water column • Fishing in nearshore/coastal areas

Table 16.37 VCs and Corresponding Relevant Modelling Results for Subsurface Blowouts

VC	Potential Interaction[1]			Relevant Deterministic Model Results	Effect Pathway
	Sea Surface[2]	Water Column[3]	Shoreline / Sediment[4]		
Indigenous Peoples	H	M	L	95th percentile Surface Oil Thickness	- Fishing gear interaction with surface oiling - Interaction with current use of lands and resources for traditional purposes - Fishing in nearshore/coastal areas
				95th percentile Water Concentration	
				95th percentile Shoreline Exposure	

[1] High (H), Medium (M), and Low (L) is the relevance of that component in terms of interaction with the VC
[2] Surface Threshold - 0.04 g/m² (socioeconomic); 10 g/m² (ecological)
[3] Water column threshold - 1.0 g/m² (socioeconomic); 100 g/m² (ecological)
[4] shoreline / sediment threshold - 1 ppb dissolved PAH or 100 ppb THC (socioeconomic and ecological)

The assessment uses the same VC-specific definitions used for routine Project components and activities to make a determination of the significance of the effects, with the exception of geopgraphic extent. For the effects assessment of spills, the largest extent of the spill, as predicted by modelling are the boundaries of the RSA. Therefore, descriptors for geographic extent will use the following:

- Localized – geographic exent of the spill is less than 10 km^2
- PA - geographic extent of the spill is within the Project Area
- LSA – geographic extent of the spill is within the LSA
- RSA - geographic extent of the spill is within the RSA

For spills of SBM, the effects assessment considers the following effects thresholds:

- Sedimentation effects: mortality of 5 percent of benthic organisms (including mollusks, polychaetes, and crustaceans) would occur at burial depths of 1.5 to 6.5 mm and mortality of 50 percent would occur at burial depths of 54 mm (Smit et al. 2008).
- Turbidity and total suspended solids effects: Increased turbidity decreases the light availability for phytoplankton in the water column (IOGP 2016). Suspended sediment concentrations of approximately 10 mg/L bentonite clay and 1000 mg/L barite have been shown to adversely affect phytoplankton (Smit et al. 2008). A transient exposure to drilling fluids as they pass through the water column is unlikely to be toxic to mobile pelagic organisms.

While modelling was undertaken for spills where response measures and other mitigations were not applied, the effects assessment incorporates spill prevention and response procedures and mitigations described in Section 16.1 and below, as may be applicable for a VC.

16.7.2 Summary of Key Mitigation Measures – Accidental Events

Equinor Canada will implement multiple preventative measures to manage risks of incidents occurring and mitigate potential effects. Section 16.1 provides information on Equinor Canada's approach to spill prevention, contingency planning and emergency response measures. Well control measures are outlined in Section 2.6.3.

As stated in Section 16.1.2.3, Equinor Canada will undertake a SIMA as part of the OSRP during the OA approval process with the C-NLOPB. The SIMA is a structured process that evaluates benefits and drawbacks of different response tactics, considering feasibility and effectiveness of implementation in different spill scenarios and prevailing conditions, compared to no action. The SIMA will inform the selection of overall spill response strategy for the BdN Development.

Equinor Canada will develop and implement a compensation program for damages resulting from Project activities, including spill events. This compensation program will be developed in consideration of the C-NLOPB Compensation Guidelines Respecting Damages Relating to Offshore Petroleum Activities (2017) and will be aligned with the Best Practices Document for Compensation Processes and Procedures that One Ocean is currently preparing.

In the unlikely event of an accidental event such as a significant spill or a blowout, event-specific environmental monitoring programs may be required, which will be developed and implemented in consultation with the appropriate regulatory agencies.

16.7.3 Spill Modelling Summaries

16.7.3.1 Subsurface Blowouts – Model Summary

As described above, the worst case 95th deterministic unmitigated cases are used for the effects assessment for each VC. The following is a summary of the results of the representative 95th percentile cases for surface oiling, water column exposure and shoreline/sediment exposure on which the effects assessment is based.

The extremely unlikely and unmitigated subsurface blowouts at Sites 1 and 2 are predicted to result in large areas where hydrocarbons at the surface are predicted to exceed the conservative ecological and socioeconomic thresholds. For the unmitigated spill event, these areas are predicted to extend to the Flemish Pass, Flemish Cap, Orphan Basin, southern Grand Banks and associated slope waters. Modelling results indicate that the areas with THC water column concentrations exceeding the ecological threshold are predicated includes the slopes of the Grand Banks, the Flemish Pass, the Flemish Cap and areas northeast of the release site. At the end of the 160-day modelling simulations, it was predicted that most of the remaining oil evaporated (47 to 51 percent) and degraded (29 to 36 percent). Approximately 0.3 to 8 percent was predicted to remain at the surface, 1 to 3 percent remained entrained in the water column, 0 to 2 percent was predicted to make contact with the shore, and less than 0.01 percent remained in the sediment. Between 9 to 15 percent left the model domain.

BdN modelling predicted that between 5.6 percent and 22.92 percent of the total release volume could leave the model domain. Based on stochastic modelling (with 171 or 172 individual trajectories throughout the year and over multiple years), it always took greater than 25 days, and typically greater than 50 days for oil to leave the model domain. At this time, the oil would be highly weathered (i.e., the more toxic components of oil are the lighter more volatile ends that would have evaporated, dissolved, and degraded over time) thereby reducing the toxicity of the residual oil. It would be present as patchy and discontinuous emulsified oil and tarballs. At the end of 160 days, oil outside the model domain would be dispersed to the point that average thicknesses over this area would be at a level of dull brown sheen (0.001 to 0.01 mm) or thinner.

Upon review of comparable spill modelling in recent EIS reports in which the model domain included areas to the east of the BdN spill model domain, the predictions on the fate and effects of BdN crude for areas to the east of the BdN model domain can be made. A recent EIS submitted by CNOOC (CNOOC 2018) regarding exploration drilling used a larger model domain, extending from 35°N to 60°N and 72°W to 15°W, capturing the same areas as the BdN spill model domain as well as northern Labrador, additional portions of New England in the US, the southern tip of Greenland, and the Azores to the south east. The CNOOC EIS used the same modelling methodology (unmitigated subsurface blowouts simulated for 160 days), similar release depths (roughly 400-500 m and 1,100 m releases) and the same BdN crude oil type for their assessment. Although there are differences in the simulated releases between CNOOC and BdN, to a first order they are similar enough to draw general conclusions. Both studies demonstrate the general eastward motion of surface oil based upon prevailing winds and currents. CNOOC noted a much higher potential for oil making contact with shorelines (70-77% in their modelling study) when compared to BdN (maximum of approximately 20-25%) due to the locations predicted to be affected. In the CNOOC assessment, highly weathered oil was predicted to continue being transported to the east of the BdN model domain with the potential for oil to reach the Azores in an even more weathered state after 50 days. Using the results of the CNOOC model, the following predictions can be made regarding surface oiling and oil reaching shores that are outside the BdN model domain, namely the Azores.

The CNOOC EIS predicted the highest probability of oil reaching the Azores where shoreline exceeded the 1 gm/2 was 70 and 77 percent (depending on scenario) in the summer months. The modelled 95th percentile representative deterministic shoreline scenario predicted a minimum time for oil to reach the Azores at was between 80 days and 111 days, depending on the spill site. Therefore, oil that is predicted to make shore would be highly weathered, patchy and discontinuous. Surface oiling is predicted to occur to the areas to the east of the spill sites at thicknesses >0.04 μm in areas beyond NAFO division 3LMN.

For the representative worst-case scenarios for shoreline oiling, less than one percent of the total volume released was predicted to make contact with the shoreline of Newfoundland and Labrador. Most of the oil that was predicted to make contact occurred on the Avalon Peninsula and localized areas of the Burin Peninsula. First contact with shoreline occurred within 14 to 15 days (115-d scenario) or at day 45 (36-d scenario). In both cases, oil would be highly weathered (i.e., lighter and more toxic components would have evaporated, dissolved, and degraded thereby reducing the toxicity of the residual oil), patchy and discontinuous (RPS 2018). In these extremely low probability cases, the total hydrocarbon concentration on shore was predicted to exceed 500 g/m^2, which was above the socio-economic (1 g/m^2) and ecological (100 g/m^2) thresholds.

The subsurface releases were predicted to result in both dissolved and total hydrocarbon concentrations in the water column that exceeded the identified thresholds. Concentrations of dissolved and total hydrocarbons were predicted to be highest around the release site, with concentrations exceeding the threshold for THC (100 µg/l) remaining offshore and in a much smaller areal extent than for surface oil. While the highest concentrations of THC are predicted near or at surface, the majority of the predicted THC concentrations within the cumulative footprint are within tens of metres of the surface. This is due to the majority of the predicted THC being the result of entrained oil from wind-induced surface-breaking waves forcing surface oil into the water column. Concentrations dissipated as the oil was transported away from the release location. The footprints of these predicted concentration exceedances are very similar to the surface oil trajectories, with the largest portion of the oil predicted to be transported towards the east.

16.7.3.2 Batch Spills – Model Summary

The results from the modelling of unmitigated batch spills show that the potential spatial area that may be affected is much smaller than from the modelled unmitigated subsurface releases.

For the unmitigated batch spills at the FPSO location (8,300 m^3 FPSO surface release and 1,000 m^3 offloading) it was predicted to result in 37-39 percent of the released volume evaporating to the atmosphere, 29 percent remaining on the water surface, 22 percent to 24 percent degraded, 10 percent to 11 percent remaining entrained in the water column, 0.01 percent on sediments and 0 percent contacted the shore at the end of the 30 day model simulations. These batch spills resulted in cumulative maximum surface oil of >0.04 um threshold extending approximately 200 to 300 km to the east of the release location (Figure 16-33). Thicker dark brown sheens (0.01 to 0.1 mm) were predicated within 100 km or less of the release location, while thinner dull brown sheens (0.001 to 0.01) were predicted to extend approximately 375 km to the southeast from the release site. The areas where concentrations of THC in the water column were predicted to exceed 500 µg/L were in the immediate vicinity of the release site for both spill scenarios. There was no shoreline oiling predicted from the batch spills; all oil remained offshore.

The unmitigated seafloor flowline release of 500 m^3 of crude was predicted to result in a primarily dull brown sheen (0.001 to 0.01 mm) that extended approximately 300 km to the southwest from the release location. At the end of the 30-day simulation, 42 percent of the total release volume was predicted to evaporate, 32 percent to remain on the water surface, 20 percent degraded, while, 6 percent entrained, and no oil was predicted to be found on sediments or shorelines. The model simulation was predicted to result in in-water THC concentrations up to 100 µg/L within 250 km from the release site (Figure 16-36). Shoreline oiling as not predicted.

For the marine diesel batch spill, 58 percent of the total release volume was predicted to evaporate, 30 percent degraded, 12 percent entrained n the water column and less than one percent remained at the water surface. Surface oiling was predicted to result in a patchy and discontinuous distribution of colorless or silver sheen of oil < 0.0001 mm (0.1 µm) close the release location. The marine diesel batch spill resulted in the smallest volume of water exposed to THC concentrations exceeding 1 µg/L, where concentrations were generally less than 5 µg/L in an area within 200 km of the release site (Figure 16-38).

The model results indicated that the release migrated to the east and did not result in oil coming in contact with the shoreline. In addition, the release would be discontinuous and patchy surface sheens, with a 40-km rainbow sheen that would transition to the colorless and silver sheen (Nexen Energy ULC 2018).

16.7.3.3 SBM Spills – Model Summary

For surface loss of SBM, the maximum extent of deposition thickness of 0.1 mm was predicted to be within 1.5 km of the spill location at Site 1 and within 590 meters at Site 2. The depth of each release site had the greatest potential to increase the extent of deposition but also generally reduced the predicted total thicknesses of the deposit. In the simulation results, the extent of deposition from surface releases was intensified by prevailing currents during winter conditions. Subsurface releases occurring from a BOP disconnect or flex joint failure near the seafloor would be expected to result in thicker deposition over a smaller area than from surface releases, due to the faster settling time of particles released from a wide, low velocity flow incident. For a flex joint release, the 10 mm deposition thickness was between 60 to 80 m from the release site. Deposition thickness of 10 mm for a BOP spill was within 60 to 70 m of the release location.

16.7.4 Marine Fish and Fish Habitat – Accidental Events Effects Assessment

16.7.4.1 Introduction

Fish and invertebrate species of commercial, cultural and/or ecological value including species at risk, are known to occur in the RSA (See Section 6.1) and could therefore be affected by an accidental event. The extent of the RSA (Figure 16-71) includes the shelf and slope regions of the Grand Bank and Flemish Cap, the Flemish Pass, and abyssal areas east of the Flemish Cap. It includes various habitat types in the intertidal zone, the subtidal zone of the shelf of the Grand Bank, the deeper zone associated with the continental slope, and the very deep abyssal regions. Special areas that have been designated within the RSA (Figure 16.71) based on their importance to Marine Fish and Fish Habitat include critical habitat for wolffish species (see Figure 16.71), several Ecologically or Biologically Significant Areas (EBSAs), Vulnerable Marine Ecosystems (VMEs), and North Atlantic Fisheries Organization Fisheries Closure Areas (NAFO FCAs) (See Section 16.7.7).

The effects of the release of hydrocarbons into the marine environment on Marine Fish and Fish Habitat are largely dependent on a variety of biotic (e.g., species, life histories, behaviour, resistance) and abiotic factors (e.g., oceanographic conditions, exposure duration, oil type, oil response / treatment methods). The extent of the potential effects depends on how the spill trajectory and various components of the VC overlap spatially and temporally.

16.7.4.2 Potential Issues and Interactions

The potential environmental effects on Marine Fish and Fish Habitat used in the assessment of effects of routine activities (Chapter 9) were:

- Change in habitat availability and quality
- Change in food availability and quality

- Change in fish and invertebrate mortality, injury, health
- Change in fish and invertebrate presence and abundance (behavioural effects)

These potential effects are relevant to the assessment of accidental events, although the mechanisms or pathways of effects may be different. The extent of the potential effects on Marine Fish and Fish Habitat depends largely on the level and timing of exposure to the toxic components of the oil. Subsurface blowouts, batch spills, and SBM spills represent potential accidental events that involve varying degrees of interaction between hydrocarbons and Marine Fish and Fish Habitat.

The primary hydrocarbon spill exposure pathway for marine biota is via the upper water column where the most acutely toxic compounds (i.e., PAHs) are dissolved in the water (French-McCay 2009). Exposure studies using the dissolved fraction of the oil found lethal and sublethal levels for fish in the range of 0.3 to 60 µg/L dissolved PAHs (0.03-11 mg/L total petroleum hydrocarbons (TPH)) (Lee et al. 2015). Similar reviews focusing on cold water species indicated comparable ranges of lethal values for fish (i.e., 0.7 – 4.0 mg/L TPH) (AOSRT-JIP 2014). Therefore, the very conservative ecological threshold of 1.0 µg/L of dissolved PAHs (corresponding to approximately 100 µg/L THC) serves as a threshold to predict the effects of the various spill scenarios on marine species. The effects assessment, therefore, focuses on the in-water concentration of oil resulting from subsurface blowouts, batch spills and SBM spills.

Species at Risk

Thirty-one species with conservation designations may occur within the RSA (refer to Table 6.31 in Section 6.1.9). This includes species identified as species at risk that occur in the Project Area and eleven additional species at risk found in the RSA. Species designated as having low conservation status (i.e., Least Concern, Not at Risk) are not included in the assessment. COSEWIC listed species are included in this assessment. Therefore, there are six with either Endangered or Threatened (either NL ESA or SARA legislation) that may be present in the RSA. SARA listed species include white shark (Endangered), Inner Bay of Fundy Atlantic Salmon (Endangered), northern wolffish (Threatened), spotted wolffish (Threatened), striped wolffish (Species of Concern). American eel (Vulnerable) is listed under NL ESA. Although species-specific areas of relatively high aggregation have been identified in the Northwest Atlantic, critical habitats have only been designated for northern wolffish and spotted wolffish (Section 6.1.9.1). The eleven additional species at risk (Table 16.38) found within in the RSA include Atlantic sturgeon, marlins (blue and white), sharks (common thresher, Greenland, Portuguese dogfish, ocean sunfish, queen triggerfish, silver hake, spinytail skate, and yellowtail flounder. The distributions of the Queen Triggerfish and the Blue Marlin overlap the edge of the RSA and are likely rare visitors to RSA waters.

Table 16.38 Marine Fish Species at Risk that are Known to or May Occur within the RSA

Species	Status / Designation [1,2]	Status / Designation [1,2]	Relevant Population (Where Applicable)
Atlantic sturgeon	*Acipenser oxyrinchus*	NT	Global (IUCN)
Blue marlin	*Makaira nigricans*	V	Global (IUCN)
Common thresher shark	*Alopias vulpinus*	V	Global (IUCN)

Table 16.38 Marine Fish Species at Risk that are Known to or May Occur within the RSA

Species	Status / Designation [1,2]	Status / Designation [1,2]	Relevant Population (Where Applicable)
Greenland shark	*Somniosus microcephalus*	NT	Global (IUCN)
Ocean sunfish	*Mola mola*	V	Global (IUCN)
Portuguese dogfish	*Centroscymnus coelolepis*	NT	Global (IUCN)
Queen triggerfish	*Balistes vetula*	NT	Global (IUCN)
Silver hake	*Merluccius bilinearis*	NT	Global (IUCN)
Spinytail skate	*Bathyraja spinicauda*	NT, V	Global, Northwest Atlantic (IUCN)
White marlin	*Kajikia albida*	V	Global (IUCN)
Yellowtail flounder	*Pleuronectes ferruginea*	V	Global (IUCN)

16.7.4.3 Effects of Hydrocarbons on Marine Fish and Fish Habitat

Potential effects of hydrocarbons on Marine Fish and Fish Habitat are primarily derived from laboratory studies. As there have not been any large-scale hydrocarbon spill events in the Northwest Atlantic, information on the potential effects of hydrocarbons on Marine Fish and Fish Habitat is available from *in situ* scientific studies conducted after recent large-scale oil spills in the Gulf of Mexico. Effects information generated by studies done after the Gulf of Mexico Deepwater Horizon Spill (DWH) is supplemented with information in recently completed comprehensive reviews of oil spills in Arctic marine environments, including laboratory studies on ecotoxicology using more relevant cold-water species (AOSRT-JIP 2014). Information from other regions and species are included as the effects of hydrocarbon exposure is comparable for certain exposures in temperate and Arctic species (Olsen et al. 2011). Responses by plankton, fishes, coral and sponge species, and other invertebrates to potential accidental events are highlighted below.

It is generally accepted that developmental stages of fish and invertebrates are more sensitive to oil than adult stages (Lee et al. 2015; Sørensen et al. 2017). Laboratory exposure studies, in general, have shown more severe effects than measurements taken *in situ* during and after actual spills. However, effects on larval stages do not necessarily result in significant effects on adult populations (Gallaway et al. 2017; Carroll et al. 2018).

Plankton and Microbes

Since plankton represent a key component of primary and secondary production in oceanic environments, potential effects on these organisms may have implications for biota in higher trophic levels. The responses of plankton and microbial communities to oil spills are diverse and largely dependent on exposure specifics and species (Bretherton et al. 2018). In general, plankton and microorganisms do not exhibit an avoidance response to contaminants because their movements are controlled by oceanographic conditions. Certain taxa of coastal and estuarine copepods are an exception to this generality since they are able to detect and avoid small patches (1-7 cm) of hydrocarbon contaminated water (Seuront 2010).

Exposure of phytoplankton to oil may result in altered productivity and growth, with possible population-level effects on abundance and community composition (Buskey et al. 2016). Laboratory studies using Arctic phytoplankton have shown similar results with observed inhibited growth for two diatom species found in and around sea ice (Van Baalen and O'Donnell 1984) where crude oil concentrations exceed 50 mg/L. The responses to hydrocarbon exposure are also taxa specific as evidenced by certain diatoms showing growth inhibition while green flagellates show increased growth after exposure to water with a hydrocarbon concentration of 10 mg/L (Hsiao et al. 1978). Exposures to crude oil concentrations of 1, 5, and 25 µl/L reduced abundances of phytoplankton grazers, disrupting predator-prey controls and result in increased concentration of blooming dinoflagellates (Almeda et al. 2018). Conversely, Arctic field studies on diatoms found no decreases in cell densities, chlorophyll *a* concentrations or productivity in ice algal communities exposed to a field release of dispersed weathered oil (Cross et al. 1987).

Changes to phytoplankton communities may be confounded by the species-specific reactions to hydrocarbon exposure. Changes in both plankton population (biomass) and community assemblages after the DWH spill where characterized by a shift from ciliates and phytoflagellates to diatoms and cyanobacteria (Parsons et al. 2015; Li et al. 2017). Although remote sensing of chlorophyll *a* after the DWH spill indicated a strong but short-lived stimulation in regional phytoplankton after the spill, there was an overall reduction in photosynthetic capacity in near-surface waters that likely had a negative population effects on phytoplankton (Ozhan et al. 2014). Laboratory experiments with Gulf of Mexico phytoplankton species exposed to crude oil (10-100 µl/L) indicated that some species were resistant (i.e., no effects on growth rates), while other species were sensitive as shown by declines in growth rate and biomass (Bretherton et al. 2018). The laboratory experiments showed that one phytoplankton species was positively affected as evidenced by its increased biomass after hydrocarbon exposure (Bretherton et al. 2018).

Laboratory exposure studies have shown lethal and sublethal effects of oil on zooplankton (Seuront 2010; Almeda et al. 2013; AOSRT-JIP 2014). Zooplankton may take up oil components passively through ingestion of hydrocarbon exposed phytoplankton, or actively through direct ingestion of crude oil droplets (Almeda et al. 2014, 2016). Lethal concentrations of dispersed oil based on observations after the DWH spill are estimated to be approximately 27 ppm (Almeda et al. 2014, 2016). The types of sublethal effects range from physiological, feeding-associated, fecundity-associated, and behavioural related to predator avoidance (Almeda et al. 2013). Exposure experiments studying the effects of exposure to water soluble fractions of hydrocarbons (1.93 µg/L and 20.11 µg/L) on *C. finmarchicus* and *C. hyperboreus* did not observe any effects on hatching success rates (Utne 2017). However, nauplii of *C. hyperboreus* exposed to polycyclic aromatic hydrocarbons (PAHs) showed increased oxygen consumption and metabolism with temperature treatments (3-10^{o}C) (Utne 2017) with potential negative implications for development.

Comparison of fresh crude oil with weathered oil indicated that the latter was generally considered less toxic to zooplankton due to the loss of volatile fractions (Almeda et al. 2013). Laboratory exposure studies found that an Arctic copepod species, *Calanus glacialis*, was less sensitive to oil exposure compared to a temperate-boreal copepod species (*C. finmarchicus*) due to higher lipid content and slower hydrocarbon uptake in cold water (Hansen et al. 2011; Gardiner et al. 2013).

Microbes also serve an important role in moving oil from the surface waters into the deep ocean. As they do with other sources of organic matter, microbes degrade hydrocarbons into marine ‘snow’ that serves as a flocculating method to shuttle the oil to the deep-sea, where it will continue to degrade (Passow et al. 2012; Daly et al. 2016). Approximately 7 percent (3.19 Mbbl) of unrecovered oil from the DWH spill was estimated to have reached the seafloor as marine snow (Stout and German 2018). Flocculated hydrocarbon material may also be ingested by zooplankton as it settles and then subsequently expelled in fecal pellets, further enhancing settling of hydrocarbon material to benthic environments (AOSRT-JIP 2014; Almeda et al. 2016). This natural mechanism is an important link between benthic and pelagic environments that brings important nutrients and organic matter from the surface waters to the deep sea. However, during spill events, this mechanism may serve to contaminate deep sea corals and benthic communities (Rabalais 2014). Based on laboratory and field studies, similar mechanisms of microbial degradation of oil have been shown for the Arctic (Prince et al. 2013), although at slower rates than in more temperate environments (AOSRT-JIP 2014). Gelatinous zooplankton, such as jellyfish, may also help move oil from surface waters to the water column through increased production and shedding of mucous under the physiological stress of oil exposure (Gemmell et al. 2016). However, the increased growth rates of oil degrading bacteria associated with contaminated mucous may increase the amount of hydrocarbon degraded and reduce the overall amounts of hydrocarbons transported to benthic environments (Gemmell et al. 2016).

Seasonal plankton blooms typically coincide with increased concentrations of ichthyoplankton (fish eggs and larvae) that use increased food levels in the water column. Exposure to oil has potentially lethal and sublethal effects on these sensitive early life history stages (Lee et al. 2015; Sørensen et al. 2017; O’Shaughnessy et al. 2018). Similar to zooplankton, ichthyoplankton have limited avoidance capabilities. Laboratory experiments that exposed Atlantic herring larvae to total PAH concentrations of 0.129-6.019 µg/L for 12 days observed higher mortalities in the treatment groups compared to control groups (Ingvarsdóttir et al. 2012). Although there were no significant differences in mortality between treatment and control groups during a two-month recovery period, increased deformities and reduced growth were observed in the exposed larvae (Ingvarsdóttir et al. 2012). Early life stages of capelin have also shown sensitivities to hydrocarbons. Lethal effects on capelin larvae have been observed at exposures to total PAH concentrations ranging between 1.3-7.1 mg/L (Paine et al. 1992). and increased egg mortality rates and decreased hatching success at 40 µg/L crude oil (Frantzen et al. 2012). Similarly, exposure of embryos of Atlantic cod and Atlantic haddock to dispersed crude oil (concentration range of 10-600 µg/L) resulted in heart and craniofacial deformities (Sørensen et al. 2017). Exposures of bay anchovy to varying levels of weathered oil indicated that the more highly weathered oil had a greater toxic effect on embryonic and hatching stages (O’Shaughnessy et al. 2018). Exposure to polyaromatic hydrocarbons has also been shown to result in reduced growth rates and various developmental impairments in southern bluefin and yellowfin tuna eggs and larvae (Incardona et al. 2014). Responses to hydrocarbon exposure is species-specific as demonstrated by ichthyoplankton surveys before and after the DWH spill where no changes in body condition of larval Spanish mackerel were documented but negative effects on the body condition of larval red snapper were observed (Hernandez et al. 2016; Ransom et al. 2016). Ransom et al. (2016) suggest that the resilience of the Spanish mackerel and its phytoplankton food sources to the harmful effects of the oil spill may account for the different responses to the spill. While changes in body condition were noted, ichthyoplankton abundances of both species were not significantly different between pre- and post-DWH spill surveys (Hernandez et al. 2016; Ransom et al. 2016). Experimental exposure of larval echinoderm and bivalve invertebrate species to oil from the DWH spill indicated that while weathered oil had no effect on survival and development, fresh oil caused adverse effects (Stefansson et al. 2016). Gallaway et al. (2017) indicated the resulting larval mortality from a hypothetical large-scale oil spill that resulted 71 million m^3 of water above acute toxicity thresholds would be low relative to the overall potential reproductive output of Arctic cod populations. Therefore, while potential effects on larval stages have been identified, overall reductions may not necessarily have population-level negative effects on adult populations (Gallaway et al. 2017; Carroll et al. 2018).

The potential longer-term effects of plankton and microbe mortality due to exposure to hydrocarbons is twofold: (1) they are an important food source for higher trophic levels (e.g., fish and invertebrates), and (2) since most fish and invertebrate species have one or more life stages in a planktonic phase, there is potential effect on recruitment into the adult fish and invertebrate population and connectivity among areas. Depending on the persistence of hydrocarbons in the environment, effects on the planktonic phase of fishes and invertebrates may also limit distributions, recovery, and recolonization.

Plants and Macroalgae

The response of macroalgae and seagrass species to oil spills is variable and dependant on the degree and length of exposure. Experimental releases of oil and dispersants in the Canadian Arctic showed that low oil concentrations (3-30 mg/L) have either no discernable effect or, in some species, cause a mild stimulation of growth (Cross et al. 1987). Similar results were found in Northern Spain in relation to the *Prestige* oil spill in 2002, with negligible differences observed between years in terms of algal cover, richness, or diversity (Díez et al. 2008). They concluded that these results were likely due to relatively low levels of spilled oil resulting from dispersion over a wide area. However, coastal species that already exist in stressful environments (i.e., subject to wave action, intermittently out of water) have been shown to respond poorly to oil spills. *Fucus* species are abundant in the intertidal shores of NL. Following the *Exxon Valdez* oil spill, a closely related *Fucus* species was heavily impacted. Macroalgae at the upper boundary of the intertidal zone, where desiccation and wave action are significant stressors, did not recover during the five years post-spill (Stekoll and Deysher 1996). This was due to a disruption in the recruitment process, as mature algae are critical to protecting young recruits from desiccation and dislodgement. Remediation efforts using artificial turf were successful in protecting new recruits, and within a year, juvenile *Fucus* had recolonized barren areas. Algae present in the Gulf of Mexico were heavily impacted by the DWH oil spill, with the loss of about 83 percent of species at a deep (55-75 m) site west of the oil well (Felder et al. 2014). This loss of algal cover impacted the associated assemblage of crustaceans, including commercially valuable species. In this area, rhodoliths (free-living balls of calcareous algae), which are widespread along the coast of NL, acted as a seed bank for the subsequent re-recruitment of fleshy algal species (Felder et al. 2014).

Potential effects on seagrasses may include incorporation of sub-lethal quantities that reduce tolerance to other stress factors and smothering by stranded oil resulting in mortality. Based on exposure studies of eelgrass to the Exxon Valdez oil spill, oil primarily affected flowering (Dean et al. 1998 in Ralph et al. 2007). The effects on flowering are suggested to not likely to affect well established meadows as seagrasses have other ways of propagation (Dean et al. 1998 in Ralph et al. 2007). One year after the Exxon Valdez oil spill Dean et al. (1998 in Ralph et al. 2007) indicated that there were no differences among oiled and reference eelgrass sites and that there was no overall impact on seagrass biomass, density, flowering or seed production. Seagrasses at deeper waters are considered to be able to recovery better than smothered intertidal seagrasses (Ralph et al. 2007).

Invertebrates and Fish

Acute, short-term exposures (1-96 hours) would be more representative of exposure in a discrete diesel batch spill event. The ecological risks associated with this kind of exposure are less than those associated with a subsurface blowout of crude since the more toxic components of the crude oil, the lower molecular weight compounds (LMW), evaporate and dilute rapidly (Lee et al. 2015). There are, however, some sublethal effects which include reduced feeding (Lari et al. 2016) and larval deformities (Mager et al. 2014). Potential lethal effects (associated with the LMW) include a variety of responses by lipid membrane receptors collectively termed narcosis. Continued exposure may result in symptoms that range from depression in respiratory-cardiovascular activity, tissue hypoxia and ultimately respiratory paralysis (death). Again, these effects are short-term as the LMW evaporate from the oil in a matter of days (Lee et al. 2015).

Chronic, long-term exposures (i.e., more than 96 hours) also cause potential effects ranging from genetic and molecular responses of cells to impacts on reproduction, growth, disease, and survival (Lee et al. 2015). The various uptake pathways include respiratory uptake, direct contact, diet, and maternal transfer to eggs (Lee et al. 2015). Studies on finfish have shown that the dissolved oil components can travel across respiratory membranes in gills (Lee et al. 2015). As PAHs weather, they become enriched in phenanthrenes and become proportionally more toxic to fish hearts (Brette et al. 2017). Brette et al. (2017) showed that mackerel and juvenile tuna heart exposure to phenanthrene resulted in cardiac contractile failure and abnormal contractile rhythm. Exposure to PAHs (1-15 µg/L total PAH) has also been shown to result in reduced growth rates, and various developmental impairments in southern bluefin and yellowfin tuna eggs and larvae (Incardona et al. 2014). Direct effects of PAHs on adult tuna are less understood (Hazen et al. 2016), however, preliminary work has indicated that toxic metals and contaminants can cause reproductive alterations in large pelagic fishes such as Atlantic bluefin tuna (Fossi et al. 2002). Studies on other fish species have also shown that hydrocarbon exposure to adult fish has led to reduced swimming performance (Stieglitz et al. 2016), reduced immune defences (Bayha et al. 2017; Suzuki et al. 2018), higher susceptibility to parasite loading (Khan et al. 1990), and increased physiological stress (Klinger et al. 2015). Chronic exposure to dietary crude oil through contaminated food sources may also have effects on reproductive cycles of fish. Boreal cod exposed to moderate levels of dietary crude oil (0.57 µg crude oil/g fish/d) in experimentally contaminated *Calanus* sp. copepods had lower sperm motility compared to control fish (Bender et al. 2016). However, none of the concentrations tested (0.11, 0.57, 1.14 µg crude oil/g fish/d) had effects on health indices (gonad and liver size) and sex steroid levels (Bender et al. 2016).

Invertebrate species exposed to crude oil have been shown to be sublethally affected in similar ways as fish. Sensitivity to PAHs and crude oil are also comparable in invertebrates (i.e., bivalves, gastropods, and crustaceans) from polar and temperate regions (de Hoop et al. 2011; Olsen et al. 2011). Hazardous concentrations that would potentially affect 50 percent of species (fish and invertebrates) for crude oil ranged from 2,200-4,300 µg/L for polar and temperate species (de Hoop et al. 2011). Krill exposed to moderate crude oil concentrations of 0.10 mg/L showed higher occurrences of gut abnormalities (27-80 percent) than individuals exposed to lower oil concentrations (0.01 mg/L) (Moodley et al. 2018). Effects of oil exposure is also species specific and dependent on avoidance capabilities. For example, benthic and sedentary invertebrates may potentially be exposed to PAHs bound to sediments after the oil has been dispersed (Dupuis and Ucan-Marin 2015, Osse et al. 2018). Bivalves exposed to dietary PAHs and contaminated sediments showed accumulation primarily in the gonads, resulting in reproductive delays (Frouin et al. 2007). Increased DNA damage in mussels and sea urchins has also been demonstrated after exposure to various concentrations of oil (0.015 mg/L, 0.06 mg/L, and 0.25 mg/L) (Taban et al. 2004).

Although community and population-level effects from the DWH spill on regional fisheries were observed (Felder et al. 2014; Murawski et al. 2016), impacts on the productivity of the region's fisheries lasted only a few years (Murawski et al. 2016). This recovery, however, was largely influenced by fisheries closures (Murawski et al. 2016). These findings are in general agreement with population modelling studies on Arctic cod that predicted that even if large mortalities of Arctic cod juvenile and eggs were to occur due to a hypothetical spill event (as the early life stages are potentially the most susceptible to a spill), the effects on the regional cod population would be insignificant (Gallaway et al. 2017; Carroll et al. 2018). Species-specific population structure would be an important consideration as in the case of Arctic cod where diverse age distributions would help mitigate effects of single year recruitment reductions to the adult population (Carroll et al. 2018). Post-spill studies associated with the DWH spill during 2010-2012 also showed strong declines in species richness and diversity in the decapod crustacean community compared to earlier surveys (2004-2006) (Felder et al. 2014). It has been theorized that hydrocarbon exposure may have caused localized mortalities, reduced the fecundity of surviving females and/or reduced recruitment (Felder et al. 2014). The number of lesions observed on deep-water shrimp species surveyed after the spill increased nearly threefold (Felder et al. 2014). For example, severe reductions in benthic invertebrate abundance (-30.2 percent) and community diversity (-38.3 percent) was observed up to 3 km from the Macondo well, with moderate effects (invertebrate abundance: 17.6 percent and diversity: -4.5 percent) observed up to 17 km from the well (Montagna et al. 2013, Buskey et al. 2016). Baguley et al. (2015) measured meiofaunal (i.e., small benthic invertebrates) abundance, diversity, and nematode to copepod ratio with distance from the DWH wellhead as indicators of change. It was found that nematode diversity increased significantly near the wellhead which may have been due to the organic enrichment whereas copepod abundance decreased which may have been due to hydrocarbon toxicity (Montagna et al. 2013; Baguley et al. 2015). Based on nematode to copepod ratios, hydrocarbon effects on meiofauna were estimated to occur over approximately 310 km² around the wellhead with patchy effects observed up to 45 km (Montagna et al. 2013; Baguley et al. 2015; Cordes et al 2016).

Unlike plankton and microorganisms, adult stages of fish and invertebrates are generally motile and have higher capability to avoid oiled areas in the event of an accidental spill (Lee et al. 2015). *In situ* experiments indicate that salmon species can likely detect hydrocarbon concentrations about 10 percent of those shown to cause mortality, and subsequently avoid the contaminated water (Barnett et al. 1977; Weber et al. 1981; Pineiro et al. 1996; Stagg et al. 1998). Atlantic bluefin tuna, which are capable of long-distance travel (approximately100 km / week), may be able to avoid prolonged exposure to oil (Hazen et al. 2016). Although some flatfish species have been shown to detect and avoid oiled sediments, others would still occupy the oiled area in favour of preferred substrate type (Moles et al. 1994). Deep-sea fishes and invertebrates are likely to be more sensitive to anthropogenic disturbance as they typically have lower metabolisms, slower growth rates, and longer life spans indicating that recruitment and recovery to disturbances such as oil spills would be slower than shallow water counterparts (Cordes et al. 2016).

Deep-Sea Corals and Sponges

Corals and sponges have an important functional role, acting as nurseries, refugia, and spawning and breeding grounds for many aquatic species (Beazley et al. 2013; DFO 2015). In the deep sea that is largely characterized as having flat and featureless soft-bottom areas, corals and sponges serve as ecosystem engineers creating complex three-dimensional features that are critical habitat to other taxa (Beazley et al. 2013; Ragnarsson et al. 2017). In general, their life histories (planktonic larvae, slow growing, long life spans, and slow recovery) and feeding mechanisms (suspension feeding) make them susceptible to accidental events (Fisher et al. 2014; Cordes et al. 2016). Sessile adult and planktonic larvae of corals and sponges also have no known mechanisms to avoid exposure to oil in the event of a spill. Responses of coral and sponges to oil spills has been studied since the DWH oil spill and provide context on the potential ecological effects of a spill on similar coral and sponge taxa found in the Flemish Pass and northwest Atlantic. Cold water corals and sponges may recover slower than tropical species, however, regeneration rates would species specific and dependent on environmental factors (i.e., food availability, temperature).

The effects of hydrocarbons on corals are typically assessed *in situ* using visual indicators of stress (White et al. 2012). Visual indicators of coral stress related to the DWH spill include partial tissue loss, excessive mucus production, retracted polyps, partial coverage of brown flocculant sourced to the spill, and death (Buskey et al. 2016; Prouty et al. 2016; Ragnarsson et al. 2017). Follow-up studies on the DWH spills have shown a patchy distribution of the effects of the spill which are highly site specific. Hsing et al. (2013) surveyed an area located 11 km southwest of DWH five times over a 17-month span after the DWH spill to quantify the impacts and recovery of gorgonian corals that were partially covered in brown flocculant material. The corals that were not covered in flocculent material seemed to recover more quickly. Signs of hydroid colonization of the corals (a sign of coral deterioration) was first observed in the second survey conducted five months after the capping of the DWH spill. Fisher et al. (2014) found similar results with hydroid colonization on the areas of the corals that were previously covered with flocculent patches at sites located 6 and 22 km from the DWH spill site, indicating that the spill caused effects at greater distances and depths than originally thought. Corals at the site located 6 km from the DWH spill site were more highly impacted with 90 percent of the corals showing visible signs of being affected by the spill. Corals at both sites still showed visible signs of impact 16 months after the DWH spill was capped. Some recovery had occurred 16 months after the spill (e.g., the brown flocculent was no longer observed) but the dead areas on the corals had been colonized by hydrozoans (Fisher et al. 2014). Similarly, 86 percent of corals showed signs of injuries that included brown flocculent patches at a location 11 km southwest of DWH eight months after the spill (Hourigan et al. 2017). Most of the research associated with DWH and corals has focused on deep sea coral reefs, but mesophotic reefs (65 m to 90 m depth) were also studied in terms of DWH effects (Hourigan et al. 2017; Silva et al. 2015). Six sites with mesophotic reefs around 100 km from DWH spill site were observed and sampled via remotely operated vehicle (ROV) (Silva et al 2015). Detectable petroleum hydrocarbons were found in corals and visual stress indicators ranging from biofilms covering the sea fan branches (most common indicator) to bare coral skeletons and broken branches (uncommon) (Silva et al 2015).

The results from these monitoring studies were used to parameterize and validate an annual, impact-dependent, state-structured matrix model for estimating the time to recovery for each coral colony (Girard et al. 2018). The model predicted that the majority of corals that were impacted would be fully recovered within a decade with the more heavily impacted corals taking up to three decades to reach a state where all remaining branches appear healthy (Girard et al. 2018). Assessments of *Paramuricea biscaya* that were affected by the DWH spill were conducted during 2011-2017. They indicated that recovery was highly dependent on the initial impact of hydrocarbon exposure on the coral colonies (Girard and Fisher 2018). Adverse effects, including branch loss and lack of recolonization, were observed on coral colonies seven years after the initial oil spill (Girard and Fisher 2018). The presence of healthy tissues on corals is important for recovery and the initial damage to the colony may have reduced recovery capability by isolating healthy branches (Girard and Fisher 2018).

Exposure to hydrocarbons and PAHs also causes sublethal effects on early life stages of corals by diminishing larval health, metamorphosis success, and settlement (Negri et al. 2016; Overmans et al. 2018). The PAH anthracene was observed to result in tropical coral larvae mortality, reduced metamorphosis success, and strong phototoxic effects (Overmans et al. 2018). Considering the long development times (Baillon et al. 2015) and slow growth in cold-water corals, these adverse effects on early life stages can lower recruitment and potentially slow recovery of coral recolonization in areas affected by accidental events. Regeneration and recovery from injury may also lead to sublethal effects including reduced growth, impaired reproduction processes, and decreased predation defence due to reallocation of energetic and cellular resources (Henry and Hart 2005). Recovery of corals from accidental events may also be slowed through loss of connectivity (Kenchington et al. 2019) from potential adverse effects on larvae or adults.

Sponges have been shown to have relatively high bioaccumulation capabilities for PAH compounds (Batista et al. 2013, Gentric et al. 2016; Pedrete et al. 2017). However, sponges exposed to hydrocarbons may exhibit highly variable accumulations as they may alter their filtering behaviours in response to contaminants (Kutti et al. 2015). Sponges show potential for recovery from short-term exposure as demonstrated by *Hymeniaciadon heliophila* that were able to expel PAHs that had been accumulated up to two weeks when introduced to uncontaminated water (Pedrete et al. 2017). In short exposure experiments, altered feeding behaviours allowed sponges to cope with exposure to oil and dispersant contaminated sediments (Vad and Duran 2017). The PAH benzo(a)pyrene, a type of carcinogen, has been observed to be strongly bioaccumulated in sponges (Gentric et al. 2016) with potential damage to sponge DNA (Zahn et al. 1983). Hydrocarbon-contaminated sediments may also delay sponge recovery given the suggestion that deep-sea sponges may feed on resuspended matter (Vad et al. 2018). While the available information on the effects on sponge communities after DWH is more limited (Vad et al. 2018), there are indications that diversity and abundances of many taxa, including sponges, were less at sites within the trajectory of the subsea plume associated with the spill (Valentine and Benfield 2013). Sponge larval distribution may also be affected with experimental studies showing disrupted development and decreased larval settlement in the presence of hydrocarbons (100, 500, and 11,000,000 ng/L PAH) (Cebrian and Uriz 2007; Negri et al. 2016).

16.7.4.4 Effects of Dispersants on Marine Fish and Fish Habitat

Chemical dispersants do not remove oil from the environment but rather help disperse oil from the sea surface to the water column, resulting in accelerated microbial degradation of spilled oil (Lee et al. 2013; AOSRT-JIP 2014; Coelho et al. 2017). Dispersant use after a spill has the potential to increase exposure in the water column (i.e., plankton, pelagic fish) and at the seabed (demersal fish, benthic invertebrates) (Ramachandran et al. 2004). The dispersant serves to shear the oil slick into small droplets and mix them in the water column, thereby making them more accessible to the marine microbes that metabolize and degrade the hydrocarbons (Gemmell et al. 2016). Although it is generally agreed that dispersants increase the availability of the oil to the microbes in the water column, there still remains some debate regarding effects on oil degradation rates (Brakstad et al. 2014, 2015; Kleindienst et al. 2015; Seidal et al. 2016). For example, certain concentrations and ratios of oil to dispersant (10:1) have been shown to reduce the effectiveness of certain degradation pathways related to the formation of microbial marine snow (Passow 2016; Seidel et al. 2016).

Chemical dispersants are of toxicological concern due to the interaction and effects of chemically dispersed oil on Marine Fish and Fish Habitat (DeLeo et al. 2016). The use of dispersants increases the concentration of the more toxic components of the oil (i.e., PAHs) in the water column, thereby putting taxa occupying the water column at risk (Pace et al. 1995). Chemically dispersed oil has more pronounced effects on the early life stages of fish and invertebrates compared to the adult stage, specifically eggs and larvae (Cordes et al. 2016, DeLeo et al. 2016). For example, chemically dispersed oil is known to reduce larval settlement, and cause abnormal development and tissue degradation in sessile invertebrates (Cordes et al. 2016). Laboratory studies on Atlantic herring eggs showed an increase rate of deformities and mortalities for those exposed to dispersed oil (1 mg/L total hydrocarbons; up to 14-day exposure) (Greer et al. 2012). Capelin sperm fertilizing activity was lower in fish exposed to chemically dispersed oil compared to that of capelin exposed to either undispersed oil or dispersant alone (Beirão et al. 2018). Modelling of the effects of chemically dispersed oil on Arctic cod indicated that lethal and sublethal effects on juvenile fish may not necessarily have any effects on regional fish populations (Gallaway et al. 2017). This study predicted that even if large mortalities of Arctic cod juvenile and eggs (the life stages most susceptible to a spill) were to occur due to a hypothetical spill event, the effects on the regional cod population would be insignificant (Gallaway et al. 2017). Mussel responses to dispersed oil include increased movement, increased shell closure, and reduced respiration (Redmond et al. 2017). Laboratory studies on deep-sea coral from the Gulf of Mexico indicate that dispersed oil solutions were more toxic to the coral than untreated oil solutions (DeLeo et al. 2016). These studies used three initial oil concentrations (250 μM (high), 150 μm (medium), and 50 μM (low)) with total initial dispersant concentrations of 176.7 mg/L (high), 106.0 mg/L (medium) and 35.3 mg/L (low). Like other invertebrates, the most dramatic effects on the early coral life stages included decreased settling abilities and post-settlement survival (DeLeo et al. 2016). While responses to dispersed oil are species-specific, there is evidence that relative sensitivity to dispersed oil is similar among Arctic, temperate, and tropical fish and invertebrate species (Olsen et al. 2011; Bejarano et al. 2017).

16.7.4.5 Effects of Whole SBM on Marine Fish and Fish Habitat

As discussed in Section 9.2.3, synthetic based mud (SBM) is a heavy, dense fluid used for drilling. An SBM spill would have the potential to result in seabed disturbance (creation of anoxic sediments), chemical toxicity, and bioaccumulation (uptake of contaminants by invertebrates or fish, and the presence or perception of taint). As discussed in detail in Chapter 9, the acute toxicity of SBMs is considered relatively low (Still et al. 2000; Tsvetnenko et al. 2000; Hamoutene et al. 2004; Paine et al. 2014; Tait et al. 2016) and below environmental guidelines, and therefore adverse contamination effects on marine biota or habitats would be low. Petro-Canada Puredrill IA-35LV, the SBM fluid typically used by offshore operators in Atlantic Canada, is a component of the whole mud system Paradrill. The SBM fluid is paraffin based, composed of aliphatic hydrocarbons in the fuel range >C10-C21, and contains no aromatic hydrocarbons (Fefer 2001; DeBlois et al. 2014). Due to the flotation properties of paraffin, it is suggested that Pure Drill IA-35 may be distributed farther in ocean currents than other types of SBM (Lee et al. 2011). Puredrill IA-35LV is rated as a Category E product (least hazardous) in the Offshore Chemical Notification Scheme (OCNS) and is readily biodegradable under aerobic conditions in the environment (Li et al. 2009; DeBlois et al. 2014). Toxicity experiments with fish indicated that acute toxicity of SBMs was generally low (96-h LC50 toxicity of >30,000 mg/L, Jagwani et al. 2011), but there were potential health effects with chronic exposure to SBM associated cuttings (Jagwani et al. 2011; Gagnon and Baktyar 2013; Vincent-Akpu 2013).

In the water column, suspended solids and associated turbidity may decrease phytoplankton abundance (Pabortsava et al. 2011; Smit et al. 2008; IOGP 2016) due to decreased light penetration, thereby limiting light availability for phytoplankton. Suspended sediment concentrations of approximately 10 mg/L bentonite clay and 1000 mg/L barite have been shown to adversely affect phytoplankton (Smit et al. 2008). Sinking organic and inorganic aggregates comprised of living and dead cells of phytoplankton, zooplankton, microbial communities, and detritus, transport nutrients and material to the seabed (Pabortsava et al. 2011). Phytoplankton aggregate size and sinking rates have been observed to increase in the presence of hydrocarbon containing drill cuttings (35 mg/L and 175 mg/L), making delivery of drill cuttings to the seafloor more rapid than models based on particle size and density suggest. Once on the seafloor, these aggregates are more difficult to resuspend after settling and may have localized effects on food dynamics in the benthic environment (Pabortsava et al. 2011).

The nature and magnitude of SBM-associated drill cuttings' effects on benthic invertebrates and their habitats are linked to the thickness and extent of the associated cuttings pile (Smit et al. 2006; Schaanning et al. 2008; Stout and Payne 2017). Assessment of large quantities (greater than 2,200 barrels) of SBMs discharged in the Gulf of Mexico during the DWH blowout indicated that SBM-derived olefins persisted in the environment for at least four years (Stout and Payne 2017). An unrelated former drill site approximately 62 km away from the Macondo well showed persistence of weathered SBM-derived olefins for more than 13 years suggesting it would be detected at the Macondo well for at least the same amount of time (Stout and Payne 2017). The degradation of organic components in SBMs by bacteria increases local oxygen demand resulting in low oxygen or anoxic environments in areas of cuttings piles (Schaanning et al. 2002, 2008; Trannum et al. 2010, IOGP 2016). Similar to deposition of water-based muds (WBMs), the area of biological effect is generally limited to less than one kilometre from the SBM discharge source (Deblois et al. 2014; Tait et al. 2016). Deblois et al. (2014) also did not detect any biological effects in Icelandic scallop or American plaice collected one kilometre from the Terra Nova oil development after ten years of SBM discharge. A spill of spent WBMs (i.e., mix of WBM drill muds and cutting) would be similar in terms of extent and duration to the effects of drill mud cuttings during normal operations, where a localized increase in total suspended solids would be expected.

Benthic organisms have a range of tolerances to sediment deposition and burial depending on avoidance capabilities, local adaptations, particle size, and sediment clearing mechanisms. Smit et al. (2008) estimated that burial depths of 6.3 mm (3.1-10.6 mm) would result in mortality of 5 percent of benthic invertebrates, while burial depths of 54 mm (37-79 mm) would result in mortality of 50 percent of benthic invertebrates. The predicted no effect threshold (PNET), 6.5 mm of non-toxic sedimentation, has been established based on benthic invertebrate species tolerances to burial, oxygen depletion and change in sediment grain size (Kjeilen-Eilertsen et al. 2004; Smit et al. 2006, 2008). As the PNET was derived based on average tolerances, the authors suggest 1.5 mm as a conservative PNET level (Kjeilen-Eilertsen et al. 2004). However, burial effects on invertebrates are predicted to occur between 1.5 mm to 6.5 mm sediment thickness, as evidenced by injury to *Lophelia pertusa* coral observed with sedimentation of less than 6.3 mm (Larsson and Purser 2011), and reduced sediment reworking by invertebrates with a deposition thickness of WBM drill cuttings of 2.5 mm (Trannum 2017). Therefore, for effects assessment, the threshold for potential burial effects on sensitive species is 1.5 mm, and the threshold for potential burial effects on less sensitive benthic organisms is 6.5 mm. Recent SBM spills in the Gulf of Mexico and in Atlantic Canada have also shown limited environmental effects with partial recovery within weeks or months of release and full recovery within a few years (USDOI MSS 2004; CNSOPB 2005; 2018 a,b).

16.7.4.6 Residual Environmental Effects Assessment and Evaluation

The potential residual environmental effects of an oil spill, that is the effects remaining after the implementation of emergency response and mitigations measures (see Section 16.1) should it occur, are assessed in the following sections. The assessment is conservative as it assumes there will be a temporal and spatial overlap).

Subsurface Blowout

The likelihood, magnitude, geographic extent and duration of potential effects of a subsurface blowout will depend on the nature of the spill and its trajectory and how the spill trajectory and Marine Fish and Fish Habitat overlap in space and time.

An extremely unlikely subsurface blowout has the potential to result in a change in habitat availability and quality, fish mortality, injury and health, and fish presence and abundance. In the extremely unlikely event of a subsurface blowout, there could be potential effects in the water column, which could affect habitat availability and quality. Dissolved oil fractions in the water column constitute a physical and chemical change to the water column, especially in the upper few metres (Appendix E). Shoreline oil may also have effects on macroalgae and associated coastal nursery areas for fish species. Depending on the timing of the spill, shoreline contact may also have adverse effects on beaches where capelin spawn (Trenkel et al. 2014). While the spilled oil itself is not predicted to interact with sediments, interactions with benthic fish habitat are likely with flocculation and sinking events associated with plankton and microbial pathways. In the unlikely event of an oil spill reaching a shoreline, it will be weathered patchy and discontinuous; given this and the application of mitigation and response measures, it is unlikely that the overall abundance, distribution, or health of affected coastal areas would be significantly affected.

Fish health and mortality may also be affected by an unmitigated spill event. The effects on fish would vary depending on the timing of the spill event as some fish exhibit seasonal migrations or seasonally timed life stages. In particular, oil spill events during or soon after seasonal spring and fall phytoplankton blooms are likely to interact with early life stages of various fish and invertebrates whose times of occurrence typically coincide with the plankton blooms. Adult demersal and pelagic fish could potentially avoid the spill area, but juvenile and early life stages of fish and benthic invertebrates in the immediate areas of the spill could experience the sublethal and lethal effects already described in the event of a batch spill over a greater area. Overall, these effects are predicted to be medium in magnitude

Fish presence and abundance could also be affected by this unmitigated scenario as mobile fish species may temporarily avoid the oiled water. Local reductions in plankton due to injury or mortality from hydrocarbon exposure from surface or the water column may also reduce foraging opportunities for fish, especially if an accident were to occur during the spring and fall phytoplankton bloom. Further potential effects of a large oil spill on fish and fish habitat could exacerbate decreases in populations of fish that are already in decline.

Modelling results from the 95th percentile scenario for in-water exposure indicate that the areas reaching or exceeding the ecological threshold for in-water concentration of hydrocarbons from an unmitigated subsurface blowout, are predicted to include the Newfoundland Shelf, slopes of the Grand Banks, the Flemish Pass, the Flemish Cap and areas east of the release site (Section 16.4.3). Areas of the southern Grand Banks are important spawning areas and nursery areas for species including Atlantic cod, yellowtail flounder and American plaice (Templeman 2007; DFO 2016). The Flemish Cap is a spawning area for Atlantic cod and redfish (Borovkov et al. 2007). Concentrations of dissolved and total hydrocarbons based on the 95th percentile scenario were predicted to be highest around the release site, including Flemish Pass and the Flemish Cap. Oil concentrations dissipated as it was transported away from the release location through mixing within the water column, evaporation from the water surface, volatilization from the water column, and degradation, thus reducing the total amount of contaminants present (RPS 2018).

In the selected 95th percentile scenario for surface oil exposure releases surface oil was predicted to be thickest closest to the release location. Maximum thicknesses corresponded to a visual appearance of black oil within a few kilometres of the release site with the majority of footprints predicted to have a maximum thickness closer in appearance to dark brown to dull brown sheens (0.01-0.1 mm). Dark brown to dull brown sheens predicted to overlap with areas of high chlorophyll *a* concentrations, a proxy for phytoplankton biomass (See Section 9.2.2), around the Flemish Cap, and along the slopes and shelf of the Newfoundland Shelf, the Orphan Basin and off the Labrador shelf in winter to spring. The application of mitigation and response measures would reduce the magnitude, duration and geographical extent of the spill.

Less than one percent of total oil released was predicted to make contact with shoreline and most of the oil that was predicted to make contact occurred on the Avalon Peninsula and localized areas of the Burin Peninsula. Since the time for oil to make first contact ranged between 14 and 45 days, the oil would be highly weathered, patchy and discontinuous (RPS 2018). Depending on the timing of the spill, shoreline contact may also have adverse effects on beaches where capelin spawn (Trenkel et al 2014). Capelin have great ecological importance as they are a primary prey species of predatory fish, marine mammals, and seabirds (Davoren and Montevecchi 2003; Dawe et al 2012; Maxner et al 2016) and adverse effects to this forage fish species would have implications for higher trophic levels. While shoreline oil has the potential to interact with coastal spawning areas for fish species including Atlantic cod, cunner, American plaice, capelin, herring, and sand lance (Templeman 2007; Snelgrove et al. 2008; DFO 2016), the oil would be highly weathered (i.e., lighter and more toxic components would have evaporated, dissolved, and degraded thereby reducing the toxicity of the residual oil). The Placentia Bay area is established as an Ecologically and Biologically Significant Area (EBSA) for the high concentration of early life history stages for various fish species in the area (See Section 6.4.2) (Templeman 2007; DFO 2016). Scheduled Atlantic salmon rivers, where adults migrate to spawn, are distributed along the Avalon and Burin Peninsula (DFO 2018a) within the potential shoreline contact footprint. As indicated by the modelling, an unmitigated spill is extremely unlikely to reach the shoreline and the application of mitigation and response measures would further reduce potential effects.

The distribution of hydrocarbons on the seabed sediment is predicted to be focused at the release site, along the Flemish Pass and the slope of the Grand Bank. However, less than 0.01 percent of the oil is predicted to adhere to the sediment and estimated concentrations on the sediment were low (less than 0.01 g/m², below the ecological threshold). Natural mechanisms such as flocculation that transport nutrients to the deep sea may also transport hydrocarbons (i.e., Passow et al. 2012; AOSRT-JIP 2014). Dispersal and overall concentrations that may reach the seabed are dependent on degradation rates, oceanographic processes, flocculant composition, and other factors that influence shuttling oil to the deep sea (Passow et al. 2012; Daly et al 2016). This suggests that benthic organisms including corals and sponges may be exposed to hydrocarbons from a subsurface blowout. Hydrocarbon exposure would likely be localized to areas around release site with lower potential exposure with increasing distance.

Sediments within northern and spotted wolfish critical habitats (DFO 2018b) have low potential for hydrocarbon exposure based on subsurface blowout modelling, suggesting a low potential effect on adults and nesting habitat. While a subsurface blowout could potentially affect wolffish larvae inhabiting near surface waters (DFO 2018b), the oil would be patchy and discontinuous reducing potential population effects. The application of mitigation and response measures would further reduce potential effects on wolffish critical habitat.

Forty-two fish species designated as SAR or SOCC are known to occur in the in the LSA and/or RSA. In the extremely unlikely event of an unmitigated subsurface blowout these species have the potential to be adversely affected if the timing of the spill occurs at the same time of fish presence. Potential effects will be similar to those described above for secure species. The likelihood, however, of a blowout occurring is extremely low. There is a one in 6200 chance that a blowout of any size could occur during development drilling in the Core BdN Development Area. For the modelled blowout scenarios, there is between a one in 207,000,000 to one in 414,000,000 chance that this subsurface blowout scenario would occur.

Based on modelling results in the CNOOC EIS (CNOOC 2018), it is predicted the highest probability of oil reaching the Azores where shoreline exceeded the 1 gm/2 was 70 and 77 percent (depending on scenario) in the summer months. The modelled 95th percentile representative deterministic shoreline scenario predicted a minimum time for oil to reach the Azores at was between 80 days and

111 days, depending on the spill site. Therefore, oil that is predicted to make shore would be highly weathered (i.e., lighter ends would have evaporated, dissolved, and degraded) thereby reducing the toxicity of the residual oil, patchy and discontinuous emulsified oil and tarballs. Surface oiling is predicted to occur to the areas to the east of BdN model domain at thicknesses >0.04 μm in areas beyond NAFO division 3LMN and in the surface waters surrounding the Azores. With the application of mitigation and response measures, as noted above, it would further reduce potential for effects on Fish and Fish Habitat.

Effects from an unmitigated low probability subsurface blowout on Marine Fish and Fish Habitat are predicted to be adverse, as described above and reversible. As the probability of a subsurface blowout of any size is 1.61×10^{-4}, effects are not likely to occur. Effects would be medium- to long-term in duration depending on time for recovery. The geographic extent of effects, based on the representative deterministic 95th percentile for surface oiling, would be within the RSA. As noted, these changes in habitat availability and quality, fish mortality, injury and health, and fish presence and abundance would likely be beyond the range of natural variability, but are not expected to have effects on a population level due to temporary avoidance responses and weathering and degredation of oil as it moves into different horizontal and vertical environments. Therefore, the magnitude of effect is predicted to be medium. These predictions are made with a moderate to high level of confidence based on scientific literature and the experience and professional judgement of the EIS Team. Geographic extent is based on spill trajectory modelling. Modelling is a predictive tool providing an estimate of the zone of influence hydrocarbon spills, therefore there is some uncertainty regarding the overall spatial extent of the movement of hydrocarbons in the water. Based on this uncertainty there is a moderate level of confidence in the prediction of geographic extent. In an actual event, emergency response measures would reduce the magnitude, duration, and extent of the spill, and therefore reduce the potential impacts on Marine Fish and Fish Habitat.

In summary, with spill prevention plans and response procedures in place, the residual effects of a subsurface blowout on Marine Fish and Fish Habitat are predicted to be adverse, medium in magnitude, medium to long-term in duration, within the RSA, not likely to occur, and reversible. This was determined with a moderate to high level of confidence.

Batch Spills and Vessel Collision

Modelling results of batch spills (surface and subsea loss of crude; surface loss of diesel) indicate that the size and persistence of the area where effects on Marine Fish and Fish Habitat may be expected are much smaller than for subsurface blowouts.

For the crude batch spills, both surface and at seafloor, surface oiling (thinner dull brown sheens [(0.01 to 0.1 mm]) was predicted at a maximum to extend approximately 375 km from the spill location during the worst-case environmental conditions for surface oiling (i.e., calmest wind-speed period during the summer/ice-free conditions, which would result in the largest amount of oil on the water surface). In water THC concentrations were predicted to be confined to the spill location for surface batch spills and out to approximately 250 km for the seafloor flowline release. For the surface release of 6 m^3 diesel, surface oiling and in-water concentrations were predicated to be confined to the areas near the release location. The marine diesel batch spill resulted in the smallest volume of water exposed to THC concentrations exceeding 1 μg/L relative to other batch spills. THC concentrations were generally less than 5 μg/L within 200 km of the release site with a maximum THC concentration ranging from 1-5 µg/L (Figure 16-38 in Section 16.4.4). None of the hydrocarbons released during modelled batch spill scenarios were predicted to reach shore. For the spill of marine diesel from a vessel to vessel collision nearshore, the release would likely result in a rainbow sheen (0.0001-0.001 mm) for approximately 40 km before transitioning to the colourless and silver sheen (less than 0.0001 mm). No shoreline contact was predicted.

The probability of batch spills ranges from one in 46 (spills less than 159 litres) to one in 75,000 (spills greater than 1,590 m^3).

The results above suggest that both the potential for exposure and the likelihood of adverse effects on Marine Fish and Fish Habitat from batch spills of either crude or marine diesel are low. Although fishes, invertebrates, and plankton within 375 km of the release may be exposed (during the worst-case environmental conditions for spill trajectory), the change in habitat availability and quality will be of low magnitude, based on dissipation rates. Only fish in the immediate vicinity near the surface at the time of the spill would be exposed, and at the concentrations predicted, change in fish habitat availability and quality will likewise be of low magnitude. While batch spills would decrease water quality around the spill site, it would be short-term since the surface slick naturally disperses through surface wave action in the offshore environment. The geographic extent would vary depending on the batch spill. The geographic extent of batch spills during bunkering are predicted to be within the Project Area, batch spills from a seafloor release would be within the LSA, whereas the vessel to vessel collision would have a geographic extent of the RSA. Overall, effects predictions of hydrocarbons on fish and fish habitat are made with a moderate to high level of confidence based on scientific literature and the experience and professional judgement of the EIS Team. As noted above, geographic extent is based on spill trajectory modelling, in which there are some uncertainties and therefore there is a moderate level of confidence for geographic extent.

In summary, while the probability of smaller batch spills occurring is higher than for larger batch spills, with spill response procedures in place, potential effects of a batch spills on Marine Fish and Fish Habitat are predicted to be adverse, low magnitude, with a geographic extent between the Project area to the RSA, short-term in duration, not likely to occur to sporadically occurring, and reversible. These predictions are made with a moderate to high level of confidence

SBM Whole Mud Spill

A drill mud spill has the potential to result in a change in habitat availability and quality, fish mortality, injury and health, and fish presence and abundance. In the event of an accidental spill of SBM whole muds, there could be increases in turbidity and TSS which could affect habitat availability and quality in the water column. Suspended solids near the surface would decrease phytoplankton abundance due to decreased light availability and increase aggregation and sinking of phytoplankton. Increased turbidity would likely promote temporary avoidance of the area by mobile species. Suspended solids near the seabed would also reduce feeding in filter feeding species and potentially result in injury and mortality depending on the duration and levels of suspended solids. Sediment deposition and burial would result in injury and mortality of sessile or low mobility species. The degradation of organic components in the drilling fluids would promote localized eutrophication and creation of anoxic environments on the sediment surface. Injury or mortality in corals and sponges may result from exhaustion due to sediment cleaning or expelling mechanisms, depending on the duration and levels of discharged fluids.

For the surface release of SBM, it is predicted that the maximum extent of deposition thickness of 0.1 mm was approximately 550 m for the shallower Site 2 and approximately 1,500 m for the deeper water Site 1. Predicted concentrations of SBM in the water column were highest at the surface and decreasing with distance down through the water column and would be low near the seabed (less than or equal to 10 mg/L). Although higher concentrations in the water column near the surface, as high as 178 mg/L, may induce phytoplankton aggregation and sinking, the overall extent of the discharge in the water column would be localized within 130 m to 400 m from the discharge site. The probability of a the modelled SBM whole mud spills is one in 100.

Accidental SBM discharges from subsea releases are predicted to result in a maximum deposition thickness between 10 mm and 49.3 mm. Potential burial effects (above 1.5 mm and 6.5 mm thresholds) would occur between 200 m to 220 m of the release site. Although SBM in the water column would result in TSS concentrations greater than 10,000 mg/L, these concentrations would be limited to within 10 m of the discharge site. The maximum TSS concentrations in the water column are estimated to be between approximately 14,700 mg/L and 16,900 mg/L. Potential adverse effects on benthic organisms due to suspended drill mud concentrations greater than 10 mg/L would be between 110 m to 560 m from the release site, depending on season and location. As the discharge site is relatively close to the seabed, it is predicted that these accidental SBM discharges will not likely affect plankton communities. Given the small footprint for the potential deposition of spilled drill muds, the effect is likely to be within the range of natural variability and of low magnitude. These predictions are made with a high level of confidence based on scientific literature and the experience and professional judgement of the EIS Team.

In summary, with spill prevention plans and response procedures in place, the potential effects of accidental SBM discharges on Marine Fish and Fish Habitat are predicted to be adverse, low in magnitude, short-term in duration, localized, not likely to occur to sporadically occurring (depending on size of spill), and reversible. This was determined with a high level of confidence.

16.7.4.7 Summary

Table 16.39 provides a summary of predicted residual environmental effects of accidental event scenarios for Marine Fish and Fish Habitat. Effects predictions were made using a conservative approach for the spill modelling and considered the implementation of mitigation measures to prevent and reduce effects from a spill.

Table 16.39 Summary of Residual Accidental Event-Related Environmental Effects on Fish and Fish Habitat

Accidental Event Scenario	Residual Environmental Effects Characterization						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Confidence
Potential Effects: Change in habitat availability and quality; Change in food availability and quality; Change in fish and invertebrate mortality, injury, health; Change in fish and invertebrate presence and abundance (behavioural effects)							
Site 1 - 36-Day Subsurface Blowout - 10,500 m^3/d	A	M	RSA	M-L	N	R	M-H
Site 1 - 115-Day Subsurface Blowout - 10,500 m^3/d	A	M	RSA	M-L	N	R	M-H
Site 2 -36-Day Subsurface Blowout - 10,500 m^3/d	A	M	RSA	M-L	N	R	M-H
Site 2 - 115-day Subsurface Blowout - 10,500 m^3/d	A	M	RSA	M-L	N	R	M-H
FPSO Surface Release - 8,300 m^3	A	L	RSA	S	N	R	M-H
Offloading Surface Release - 1,000 m^3	A	L	RSA	S	N	R	M-H
Production Flowline Seafloor Release - 500 m^3	A	L	LSA	S	N	R	M-H
Bunkering Surface Release - 6 m^3	A	L	PA	S	S	R	M-H
Vessel/vessel collision - 750 m^3	A	L	RSA	S	N	R	M-H
Site 1 - SBM Whole Mud Spill - 60 m^3 surface spill	A	L	L	S	S	R	H
Site 1 - SBM Whole Mud Spill - 275 m^3 flex joint failure subsurface release	A	L	L	S	N	R	H
Site 1 - SBM Whole Mud Spill - 275 m^3 BOP disconnect subsurface release	A	L	L	S	N	R	H
Site 2 - SBM Whole Mud Spill - 60 m^3 surface spill	A	L	L	S	S	R	H
Site 2 - SBM Whole Mud Spill - 275 m^3 flex joint failure subsurface release	A	L	L	S	N	R	H
Site 2 - SBM Whole Mud Spill - 275 m^3 BOP disconnect subsurface release	A	L	L	S	N	R	H

KEY

Nature / Direction of Effect:

P	Positive
A	Adverse
N	Neutral (or No Effect)

Magnitude of Effect:

N	Negligible
L	Low
M	Medium
H	High

Confidence Level in Predictions:

L	Low level of confidence
M	Moderate level of confidence
H	High level of confidence

Duration:

S	Short-Term - less than 12 months (1 year)
M	Medium-term - 1 to 5 years
L	Long-term - more than 5 years

Frequency of Effect:

N	Not likely to occur
O	Occurs once
S	Occurs sporadically
R	Occurs on a regular basis
C	Occurs continuously

Reversibility:

R	Reversible (will recover to baseline)
I	Irreversible (permanent)

Geographic Extent of Effect:
L - localized
PA – within Project Area
LSA – within LSA
RSA – within RSA

N/A Not Applicable

Note: Batch spills / SBM whole mud spill / vessels / vessel collision are considered instantaneous releases; therefore, total volume is provided

16.7.4.8 Determination of Significance

In consideration of the known effects of spills on Fish and Fish Habitat, the results of spill modelling exercises, and with the implementation of mitigation measures, it is predicted that the accidental events associated with the Project will not result in significant residual adverse effects on Marine Fish and Fish Habitat.

In the very unlikely event of a subsurface blowout, some degree of residual adverse effects to Marine Fish and Fish Habitat in the area at the time of the accident or malfunction are expected. The degree of exposure and thus the type and level of any such effects would depend on the type and size of spill, time of year, and the number, location, and species of animals within the affected area. Although there is the potential for effects on fish and their habitats in the RSA, these are, with appropriate mitigations, not likely to result in an overall detectable decline in overall fish abundance or change in the spatial and temporal distribution of fish populations in the overall RSA for multiple generations. Similarly, while any affected individuals could conceivably be part of a species at risk, it is unlikely that the overall abundance, distribution or health of any such species and its eventual recovery will be negatively affected. For the length of accidental offshore oil release, there will be reduction in availability or access to fish habitat. Model predictions indicate minimal interactions with benthic habitats, therefore it is expected there will be limited residual adverse effects on fish habitat and benthic species including sensitive coral and sponge species. However, eventual break down of oil material in marine environments may become transported to benthic habitats through microbial and plankton pathways through sinking and flocculation. In the context of applied mitigations, these adverse environmental effects are considered unlikely and therefore not predicted to have any significant effects on fish habitat. Spill prevention techniques and response strategies will be incorporated into the design and operations for all Project activities as part of contingency planning, which will further help to ensure that effects do not occur, and in the unlikely event they did, that these would likely not result in significant adverse environmental effects to fish populations and fish habitats in the RSA.

16.7.5 Marine and Migratory Birds - Accidental Events Effects Assessment

16.7.5.1 Introduction

A variety of avifauna species occur within the marine and coastal environments off eastern NL at various times of the year, including seabirds and other avifauna that inhabit the region for breeding, feeding, migration and other activities according to their individual life histories and habitat requirements, and could therefore be present in the RSA at the time of an accidental event.

Seabirds, waterfowl and divers, and shorebirds are the most vulnerable to perturbation as they spend much of their life in the marine environment. Some land bird species may also be affected, particularly those associated with coastal habitats and any that migrate nocturnally over offshore waters. The timing of occurrence varies considerably depending on the species, with some taxa abundant year-round (such as large gull species and kittiwake, some alcid species, and fulmar) while some are more likely to be present in the winter (ivory gull, waterfowl) or the nesting and migration seasons (Leach’s storm-petrel). Several important habitats for birds have also been identified at locations along the coastline of NL. Although not in the Project Area itself but within the RSA, there are several

IBAs, Migratory Bird Sanctuaries (MBSs) and breeding sites around coastal NL, as well as EBSAs in the Northwest Atlantic designated in part due to their importance to seabirds (see Figure 12.2).

The accidental release of hydrocarbons in the marine environment can adversely affect Marine and Migratory Birds and their habitat present in the offshore and potentially the nearshore environment. The extent of the potential effects depends on how the spill trajectory and the VC overlap in both space and time.

16.7.5.2 Potential Issues and Interactions

The potential environmental effects on Marine and Migratory Birds used in the assessment of effects of routine activities (Chapter 10) were:

- Change in mortality / injury level and health of individuals or populations
- Change in avifauna presence and abundance (behavioural effects)
- Change in habitat availability and quality
- Change in food availability or quality

These potential effects remain relevant to the assessment of accidental events, although the mechanisms or pathways of effects may be different.

Accidental events such as oil spills can have important, adverse consequences for marine-associated birds, leading to potential changes in the presence, abundance, distribution and/or health of marine birds (individuals and populations). Exposure to accidental oil spills from drilling or production installations or vessels may affect individuals (through physical exposure, ingestion), important habitats and food sources. Marine birds are amongst the biota most at risk from oil spills, as they spend much of their time upon the surface of the ocean (LGL Limited 2005; Barron 2012; Boertmann and Mosbech 2011). In the event of a spill, and depending upon project and area specific factors, coastal birds may also be at risk on beaches and in intertidal zones.

Species at Risk

There are 14 marine and migratory bird species at risk that are likely to occur within the marine areas of the RSA and/or coastal regions of RSA (Section 6.2.4). Species designated as having low conservation status (i.e., Least Concern) are not included in this assessment of effects on SAR. As indicated in Chapters 6 and 10, there is a low potential for these SAR (listed in Table 10.4 in Section 10.4) to interact with the routine Project-related activities due to their low densities in the Project Area, LSA and overall RSA, and because there are no critical habitats or nesting sites of SAR or SOCC in the RSA. However, as with secure bird species, at risk marine and migratory birds are at risk from oil spills.

16.7.5.3 Effects of Hydrocarbons on Marine and Migratory Birds

An accidental release of hydrocarbons can result in the direct physical exposure of birds to oil within the affected area. Accidental discharges of hydrocarbons, and even routine operational discharges from vessels and platforms may lead to sheens of crude oil and other substances on the water's surface, to which avifauna (especially pelagic seabirds) may be exposed (Wiese and Robertson

2004; O’Hara and Morandin 2010; Morandin and O’Hara 2016). There would be an increased risk of mortality for individual birds that encountered the sheen (particularly for diving birds and those that spend large amounts of time on the water), as well as potential sublethal toxicity effects (metabolic rate and chick growth) to species such as Leach’s storm-petrel. Chicks and eggs are more susceptible to negative effects of exposure to oil (even at very low levels). The possible physical effects of oil exposure on birds include changes in thermoregulatory capability (hypothermia) and buoyancy (drowning) due to feather matting (Clark 1984; Montevecchi et al. 1999), as well as physiological effects of oil ingestion from excessive preening (Hartung 1995). Even small amounts of oil from sheens have been shown to affect the structure and function of seabird feathers (O'Hara and Morandin, 2010), which has the potential to result in water penetrating plumage and displacing the layer of insulating air, resulting in loss of buoyancy and hypothermia. This can cause a heightened metabolic rate (increased energy expenditure) and potential starvation due to increased energy needs to compensate for heat loss resulting from oiling and loss of insulation (Peakall et al. 1980; 1982; MMS 2001). Greater heat loss has been documented in a species of marine bird, accompanied by an increase in food consumption (Cunningham et al. 2017). A decrease in body temperature from plumage oiling has been documented in another marine bird species (Maggini et al. 2017c). External oiling (applied experimentally to homing pigeons released to fly 50, 80, or 100 miles) also alters birds’ flight paths, increases flight duration, and increases flight distance, and reduces the ability to regain body weight between flights (Perez et al. 2017a, 2017b). Plumage oiling can also lead to behavioural changes such as increased time spent preening at the expense of foraging and breeding, and potentially death (Morandin and O’Hara 2016).

The potential for toxic effects from ingesting small amounts of oil are not as clear as the effects of plumage oiling but may have greater effects on bird populations than acute mortality (Bursian et al. 2017b). While acute toxic effects from exposure to sheens are considered unlikely (Morandin and O’Hara 2016), some studies have shown effects of exposure to low levels of oil on adult birds (Miller et al. 1980; Trivelpiece et al. 1984; Butler et al. 1986, 1988; Alonso-Alvarez et al. 2007). Ingested oil can cause lethal and sublethal effects (McEwan and Whitehead 1980), including damage to the liver (Khan and Ryan 1991), pneumonia (Hartung and Hunt 1966), brain damage (Lawler et al. 1978), immunotoxic effects (Barron 2012). Oxidative injury to cytoplasmic hemoglobin (anemia) causing fatigue and reduction in energy available for metabolic energy due to oil ingested through diet and through preening has been documented in six species of marine birds and results consistent with hemolytic anemia were found in a seventh species (Bursian et al. 2017a; Dean et al. 2017; Harr et al. 2017c; Horak et al. 2017; Maggini et al. 2017c; Pritsos et al. 2017; Fallon et al. 2018). These effects have the potential to reduce survival and fitness. Species-specific differences were found in this effect, potentially due to physiology, foraging strategies, habitat preferences, and behaviour (Fallon et al. 2018). This hemolytic anemia can have its greatest effects during migration, when metabolic oxygen requirements are very high (Bursian et al. 2017b). Increases in liver and kidney weights have been found in two species (Harr et al. 2017a; Horak et al. 2017). Lesions in kidney, liver, heart, and thyroid gland were found in one species (Harr et al. 2017a). Impaired heart function has also been noted in one species of marine bird (Harr et al. 2017b). Experimentally applying a light oiling to the plumage of a marine bird reduces takeoff speed by 30 percent and increases flight energy cost by 20-45 percent (Maggini et al. 2017a, b). Birds that feed on organisms from affected areas are also at heightened risk of contamination from their food sources (Engelhardt 1983). Other studies have, however, found little or no effects from exposure to low doses of oil on adult seabirds (Ainley et al.1981; Stubblefield et al. 1995; Alonso-Alvarez et al. 2007; Camphuysen 2011).

Morandin and O'Hara (2016) reviewed several short and long-term studies of marine oil spills and reinforced that these effects can result in increased mortality rates, physiological impairment, reduced reproductive success and in severe cases, possible long-term population declines. Bird species at greatest risk are those that spend a considerable time resting or foraging on the water surface, i.e., alcids, waterfowl, and divers (Wiese and Roberston 2004; Boertmann and Mosbech 2011). The long-lived nature of many bird species and small clutch size (one egg in most species) also suggests that oil-related effects can have long-term population effects (Esler et al. 2002; Wiese and Roberston 2004). While the primary potential for exposure and thus for direct effects on seabirds occurs within the spatial extent of the spill itself, the ecological effects of oiled areas may also be transferred away from the affected site due to the migratory nature of some marine-associated avifauna (Henkel et al. 2012).

The possible effects of oil exposure on birds vary between species, as well as with different types of oil (Gorsline et al.1981), weather conditions, times of year, variation in distribution and abundance of prey, migratory patterns, and other activities (Wiese et al. 2001; Montevecchi et al. 2012), making the effects on population difficult to predict. Mortality rates and potential changes in bird populations due to accidental releases of oil are poorly known, but this is often cited as the main risk to marine birds from the offshore oil and gas industry (Fraser et al. 2008; Ellis et al. 2013). As noted above, seabirds have a life history strategy that depends on low annual adult mortality to compensate for very low annual reproductive rates. Consequently, a significant increase in mortality of adults of reproductive age results in a significant decrease in the number of juveniles recruited into a population, resulting in long-term effects on population size (Esler et al. 2002; Wiese and Robertson 2004). In years of poor food availability, nesting birds may abandon reproductive attempts, resulting in massive die-offs of chicks but preserving fitness of adult birds to reproduce in subsequent years. Although the volume of oil spilled and number of seabirds oiled is weakly correlated (Burger 1993), it is clear that the timing, location of a given spill (and not just its size) has an important influence on avifauna mortality and injury rates resulting from that spill due to the influence of variation in seabird abundance at a given location and of the effect of weather at the time on the dissipation of the slick (Wiese et al. 2001). As a result, the effects of a spill on seabird populations cannot be predicted with a high degree of confidence.

16.7.5.4 Effects of Dispersants on Marine and Migratory Birds

The use of dispersants, which enhances the natural microbial degradation, may be beneficial for marine and migratory birds within a spill area by reducing the exposure to floating oil on the sea surface. Application of chemical dispersants reduces the risk of adverse effects on marine and migratory birds at the water's surface, and results in a far greater rate of biodegradation of oil to a matter of weeks rather than of years (Baelum et al. 2012). This relatively rapid rate of degradation greatly reduces the chance of accidentally released oil reaching shorelines, where it could potentially cause great harm to shorebirds and adversely affect seabird nesting colonies (Prince 2015). Conversely, a majority of studies on the effects of dispersants on biodegradation suggest that dispersants inhibit microbial degradation of oil (Fingas 2017). The effects of dispersants and surfactants on biodegradation was most dependant on the characteristics of the dispersant itself, perhaps due to toxicity of specific components to microbial degraders (Fingas 2017). In addition, the use of dispersants results in increased oil in the water column, potentially resulting in exposure of food sources (fish and water column invertebrates) to oil, and exposure of diving birds near the dispersed oil (Fingas 2017). The measured toxicity of dispersants themselves to birds varies among studies. Prince (2015) found very low toxicity. Fiorello et al. (2016) found that common murre, a species that forages underwater, exposed to Corexit EC9500a, crude oil, develops conjunctivitis and is at higher risk of corneal ulcers. Preliminary studies of dispersant use during the Deepwater Horizon blowout show that dispersants enhance oil's toxicity to early life stages of coastal waterbirds (Beyer et al. 2016). The dispersed oil has similar effects to that of oil, as presented earlier, but the size of the slick and exposure concentrations would be lower than untreated oil. Hence, dispersant mitigates the potential adverse effects of oil on birds compared to untreated oil. A study of the effect of dispersant use on feather structure, waterproofing, and buoyancy of common murres showed no significant difference between the effects of oil alone and the effects of a mixture of dispersant and oil (Whitmer et al. 2018). In both cases the effect was dose-dependent and resolved over two days. A high concentration of dispersant alone caused an immediate, life-threatening loss of waterproofing and buoyancy, which resolved within two days.

16.7.5.5 Effects of Whole SBM on Marine and Migratory Birds

An SBM spill from the surface would likely result in a surface sheen similar to what has been described above but more limited in nature. The possible physical effects of SBM exposure on birds would be similar to other hydrocarbons and would include changes in thermoregulatory capability (hypothermia) and buoyancy (drowning) due to feather matting (Clark 1984; Montevecchi et al. 1999), as well as potential toxicity effects from oil ingestion through excessive preening (Hartung 1995). Birds that feed on organisms from affected areas are also at heightened risk of contamination from their food sources (Engelhardt 1983). Similar to exposure to other hydrocarbons, the primary potential for exposure, and resulting direct effects, on seabirds would occur within the spatial extent of a spill; the ecological effects of oiled areas may be transported from the affected site due to the highly mobile nature of marine-associated avifauna (Henkel et al. 2012). SBMs, however, are heavy, dense fluids that sink rapidly (Section 16.7.3.2) and the effects on the water's surface would be limited compared to marine diesel or crude oil spills.

16.7.5.6 Residual Environmental Effects Assessment and Evaluation

The potential residual environmental effects of an oil spill, i.e., the effects remaining after the implementation of emergency response measures and mitigations (see Section 16.1), should it occur, are assessed in the following sections. The assessment is conservative as it assumes there will be a temporal and spatial overlap.

Subsurface Blowout

The likelihood, magnitude, geographic extent and duration of potential effects of a subsurface blowout will depend on the nature of the spill and its trajectory and how the spill trajectory and Marine and Migratory Birds overlap in space and time. In the extremely unlikely scenario of a subsurface blowout, there is the potential to result in a change in mortality or injury level and bird health, change in avifauna presence and abundance, change in habitat availability and quality, and change in food availability or quality. Once birds are exposed to oil, and even with rescue and cleaning efforts, the chances of survival in the past were often quite low (French-McCay 2009). In recent years, however, the percent of African penguins successfully released after de-oiling has often been over 90 percent (Wolfaardt et al. 2009). If direct exposure to spilled oil equated to near 100 percent mortality of affected birds, the key factor in predicting mortality for marine birds would therefore be the probability of exposure. This probability is largely dependent on both the fate and behaviour of the spilled oil, but also the distribution and behaviour of the taxa involved. For example, an aerial species that is migrating through an area with a spill is less likely to become oiled than a species that frequently uses the area for foraging. As described in French-McCay (2009), a species' behaviour affects its likelihood of being oiled; for example, the amount of time spent on water, exhibiting diving behaviour, and having extended flightless periods (e.g., moulting) or roosting on the water can result in increased oiling if a slick is present. Oiled birds are generally assumed to have a very low survival rate (approximately 0 – five percent). French-McCay 2009 calculated vulnerability scores (i.e., the combined probabilities of a) encountering oil and b) mortality once oiled) which are, in effect, the mortality rate of a bird in the area of an oil slick. These scores were calculated for various wildlife groups which were then applied to species, i.e., surface diving seabirds and waterfowl (99 percent combined probability of oil encounter and mortality once oiled), nearshore aerial divers (35 percent combined probability), and aerial seabirds (5 percent combined probability). The vulnerability scores from French-McCay (2009) are:

- 99 percent mortality – birds that sit on the surface are most vulnerable (e.g., dovekie, puffin, murre species, to which moulting fulmars and shearwaters should be added)
- 35 percent mortality – birds that are mostly in flight but dive frequently for prey (e.g., non-moulting fulmarine petrels and shearwaters, gadfly petrels, storm-petrels, gannet)
- 5 percent mortality – birds that are mostly in flight (migratory birds in transit)

As part of this assessment, the ecological risk to marine birds was assessed by using these metrics in combination with the threshold concentrations for marine birds for the oil floating on the surface (10 g/m^2, 10 µm thickness) and shoreline oil (100 g/m^2).

The key implications for seabirds would include seabird-oil interactions when birds are occupying their foraging grounds. Although stochastic modelling shows the probability of oil from a blowout coming into contact with the Avalon Peninsula is very low, and the representative 95th percentile shoreline exposure case predicted less than one percent of the total volume of oil released would contact shore, contact during the breeding season has the potential to affect species' populations because of the large concentrations of birds nesting in colonies (see Section 6.2.2). However, the greatest risk of adverse seabird interactions with an oil spill generally occurs in the winter months when conditions are colder, and thermoregulation is most difficult, increasing the likelihood of mortality for affected birds (Morandin and O'Hara 2016). The species at greatest risk of interactions with an oil spill vary with the species' abundance in the area, which depends on the season, weather, and on prey distribution, which at short time scales is dependent on weather and currents.

Leach's storm-petrel is at greatest risk during the nesting season, when adults nesting at Baccalieu Island and Great Island commute to foraging areas in the deep waters off the Grand Banks including the Project Area (Hedd et al. 2018), and therefore breeding adults may be exposed to hydrocarbon emissions while foraging within the affected area and transfer oil from their breast plumage to eggs or nestlings. This species is also at risk of exposure during the fall when fledglings depart the colonies for those feeding grounds. Northern gannet, black-legged kittiwake, and great black-backed gull are at greatest risk in the fall, when young fledglings depart the colony for rich offshore feeding grounds. Although northern gannet is known to make extensive multi-day foraging trips during the nesting season, they forage almost exclusively in coastal areas during the nesting season (Garthe et al. 2007). Fledgling common murre, thick-billed murre, and Atlantic puffin are also vulnerable at this time of year, as chicks are flightless for a period of one to two months as they are accompanied by their male parent to foraging areas.

The waters off Atlantic Canada provide the core wintering area for Iceland's population of great skua. Globally important numbers of dovekies, black-legged kittiwakes and thick-billed murres overwinter over the shelf edge and the waters off Eastern Newfoundland. Fulmars and common murres also winter in relatively large numbers in this area, including the Project and Core BdN Development Areas. Most of the world's great shearwaters and large numbers of sooty shearwater are found in the Northwest Atlantic during the summer months. These birds breed in our winter months in the Southern Hemisphere and forage in the productive offshore waters of the Northwest Atlantic in their non-breeding season.

Modelling results for unmitigated subsurface blowouts predicted surface oiling to extend to the Flemish Pass, Flemish Cap, Orphan Basin, southern Grand Banks and associated slope waters, where hydrocarbons at the surface are predicted to exceed the conservative ecological threshold thickness of 10 µm for effects on marine and migratory birds. In the selected 95th percentile scenario for surface oil exposure releases surface oil was predicted to be thickest closest to the release location. Maximum thicknesses corresponded to a visual appearance of black oil within a few kilometres of the release site with the majority of footprints predicted to have a maximum thickness closer in appearance to dark brown to dull brown sheens (0.01-0.1 mm). Areas where in-water concentrations of dissolved and THC are predicted to exceed the ecological threshold from the 95th percentile scenario for in-water exposure include the slopes of the Grand Banks, the Flemish Pass, the Flemish Cap and areas northeast of the release site. The application of mitigation and response measures would reduce the magnitude, duration and geographical extent of the spill.

Based on the vulnerability indices (French-McCay 2009), the mortality rate from the unmitigated spill event would range from 35-99 percent for birds that come in contact with the slick in the 0.01-0.1 mm thickness range. Murre species, dovekies, and moulting shearwaters (Hedd et al. 2012), which spend most of their time sitting on the water's surface, are most vulnerable (estimated 99 percent mortality), while species that dive or feed at the water's surface for their prey but otherwise spend little time on the water, including Leach's storm-petrel, non-moulting shearwater species, non-moulting fulmars and great skua, are predicted to have a lower mortality rate of 35 percent. Black-legged kittiwake and northern gannet, which often sit on the water but spend more time in the air than alcids (murres and dovekies), would therefore be expected to have a mortality rate of between 35 and 99 percent.

For the representative worst-case scenarios for shoreline oiling, less than one percent of total oil released was predicted to make contact with shoreline and most of the oil that was predicted to make contact occurred on the Avalon Peninsula and localized areas of the Burin Peninsula. First contact with shoreline occurred within 14 to 15 (115-d scenario) or at day 45 (36-d scenario). In both cases, oil would be highly weathered, patchy and discontinuous. In these extremely low probability cases, the total hydrocarbon concentration on shore was predicted to exceed the ecological (100 g/m²) threshold. In the extremely unlikely event of shoreline oiling, particularly at or near the seabird colonies of the Avalon Peninsula and for coastal seabird ecological reserves on the Avalon, such as Cape St. Mary's and Witless Bay Islands, there is potential for marine and migratory birds present and breeding in these areas to experience an increase in mortality, injury or health effects due to ingestion of hydrocarbons during preening, loss of insulation and/or buoyancy associated with oiled plumage, and/or potential ingestion of oiled prey. It is probable that only a small proportion of local populations would be affected. As stated above, by the time oil made contact with the shoreline, it would be patchy, discontinuous and weathered. The magnitude and extent of potential effects would be reduced with the application of spill response measures noted above, therefore the risk of adverse effects on secure and at-risk to shoreline marine and/or migratory birds would be reduced.

Based on modelling results in the CNOOC EIS (CNOOC 2018), it is predicted the highest probability of oil reaching the Azores where shoreline exceeded the 1 gm/2 was 70 and 77 percent (depending on scenario) in the summer months. The modelled 95th percentile representative deterministic shoreline scenario predicted a minimum time for oil to reach the Azores at was between 80 days and 111 days, depending on the spill site. Therefore, oil that is predicted to make shore would be highly weathered (i.e., lighter ends would have evaporated, dissolved, and degraded) thereby reducing the toxicity of the residual oil, patchy and discontinuous emulsified oil and tarballs. Surface oiling is predicted to occur to the areas to the east of BdN model domain at thicknesses >0.04 µm in areas beyond NAFO division 3LMN and in the surface waters surrounding the Azores. With the application of mitigation and response measures, including shoreline response measures, it would further reduce potential for effects on Marine and Migratory Birds.

As noted in Section 10.4, there are six marine-associated avian SAR species that are known to occur in the in the LSA and/or RSA. In the extremely unlikely event of a subsurface blowout, these species have the potential to be adversely affected, if the timing of the spill occurs at the same time of presence of marine-associated avian SAR species. Potential effects will be similar to those described above. The likelihood, however, of a blowout occurring is extremely low. There is a one in 6200 chance that a blowout of any size could occur during development drilling in the Core BdN Development Area. For the modelled blowout scenarios, there is between a one in 207,000,000 to one in 414,000,000 chance that the modelled subsurface blowout would occur.

Effects from an unmitigated low probability subsurface blowout on Marine and Migratory Birds are predicted to be adverse, as described above and reversible. The probability of a subsurface blowout of any size is 1.61×10^{-4} and therefore not likely to occur. Effects would be medium-term in duration. The geographic extent of effects, based on the representative deterministic 95th percentile for surface oiling, would be within the RSA Based on mortality estimates, as noted above, depending on bird species present, mortality estimates could range from 35 to 95 percent. Therefore, the change in mortality would be considered beyond the range of natural variability. The degree to which the viability of the population is considered to be affected would depend on species present at the time of a spill and the level of mortality and/or injury that may occur and therefore the degree of change would range between medium to high magnitude. These predictions are made with a moderate to high level of confidence based on scientific literature and the experience and professional judgement of the EIS Team. Geographic extent is based on spill trajectory modelling. Modelling is a predictive tool providing an estimate of the zone of influence hydrocarbon spills, therefore there is some uncertainty regarding the overall spatial extent of the movement of hydrocarbons in the water. Based on this uncertainty there is a moderate level of confidence in the prediction of geographic extent. There is also a moderate level of confidence in the magnitude of effect as it would depend on species present offshore as well as the percentage of birds that could be affected by surface oiling. In an actual event, emergency response measures would reduce the magnitude, duration and geographic extent of the spill, and therefore reduce the potential impacts on Marine and Migratory Birds.

With spill prevention plans and response procedures in place, the residual effects of a subsurface blowout on Marine and Migratory Birds are predicted to be adverse, potentially medium to high in magnitude, medium-term in duration, within the RSA, not likely to occur and reversible in nature. This was determined with a moderate to high level of confidence.

Batch Spills and Vessel Collision

Modelling results of batch spills (surface and subsea loss of crude; surface loss of diesel) indicate that the size and persistence of the area where effects on Marine and Migratory Birds may be expected are much smaller than for subsurface blowouts. None of the hydrocarbons released during modelled batch spill scenarios are predicted to reach shore.

For the crude batch spills, both surface and at seafloor, surface oiling by thicker dark brown sheens (0.01 to 0.1 mm) were predicted within 100 km or less of the release location, while thinner dull brown sheens (0.001 to 0.01 mm) were predicted to extend approximately 375 km from the release site during the worst-case environmental conditions for surface oiling (i.e., calmest wind-speed period during the summer/ice-free conditions, which would result in the largest amount of oil on the water surface). In water THC concentrations were predicted to be confined to the spill location for the surface batch spills and out to approximately 250 km for the seafloor flowline release. For the surface release of diesel, surface oiling and in-water concentrations were predicated to be confined to the areas near the release location. None of the hydrocarbons released during modelled batch spill scenarios were predicted to reach shore. The probability of batch spills ranges from one in 46 (spills less than 159 litres) to one in 75,000 (spills greater than 1,590 m^3). For the larger surface batch spills, the model predictions suggest that both the potential for exposure and the likelihood of adverse effects on mortality/injury and health of individual marine and migratory birds would be low to medium in magnitude. Underwater habitat within 250 km of the release may be exposed to in-water concentrations exceeding the 1 ug/L threshold, therefore a change in habitat availability and quality will be of low to medium magnitude. For the smaller crude batch spills, the modelling results suggest that only marine and migratory birds in the immediate vicinity near the surface at the time of the spill may be exposed, and at the concentrations predicted, change in habitat availability and quality and effects on health will likewise be of low magnitude. For small batch spills of marine diesel, there is minimal chance that Marine and Migratory birds will be negatively affected (via changes in health and habitat quality/use), particularly since these animals are likely to avoid the immediate area around vessels. While any batch spill would decrease water quality around the spill site, it would be short-term since the surface slick naturally disperses through surface wave action in the offshore environment.

For the modelled spill of marine diesel from a vessel to vessel collision nearshore, the release would likely result in a rainbow sheen (0.0001 to 0.001 mm) for approximately 40 km before transitioning to the colourless and silver sheen (less than 0.0001 mm). No shoreline contact was predicted. In-water concentrations of THC are predicted to be highest in the immediate vicinity of the release location. These results suggest that both the potential for exposure and the likelihood of adverse effects on marine and migratory bird habitat from a vessel collision diesel release are low. Only birds in the immediate vicinity near the surface at the time of the spill may be exposed, and at the concentrations predicted, change in bird habitat availability and quality will likewise be of low magnitude.

Sheening

Observations of sheens in Atlantic Canada are industry-reported to C-NLOPB. Overall, the average number of reported sheens off platforms in the Grand Banks is 24 per year (Morandin and O'Hara 2016). Thicker sheens may persist for a day or more; data from ERIN Consulting Ltd and OCL Services Ltd (2003) for example showed that sheens of 1 µm persist for up to 24 h, while thinner (0.1 µm) sheens tended to disperse in less than an hour. Based on the perceived colour of sheens observed in the Grand Banks, the thickness was estimated to be in the range of 0.07 to 1 µm for sheens for which qualitative descriptions were provided, and it is thought that thicker sheens are rare in offshore operations (Morandin and O'Hara 2016). If a sheen was produced from a Project-related batch spill or operational discharges (i.e., produced water), it would be temporary (likely less than 24 hours) and limited in size, affecting only birds in the immediate area of the spill itself. As discussed above, nesting Leach's storm-petrels forage in the Project Area and Core BdN Development Area during the breeding season and therefore breeding adults may be exposed to surface hydrocarbons while foraging within the affected area within 24 hours of the spill. This also has the potential to result in changes in avifauna presence and abundance (behavioral effects), as hydrocarbon exposure could influence the occurrence and success of key life history stages of the species.

In summary, while the probability of smaller unmitigated batch spills occurring is higher than for larger batch spills with spill prevention response procedures in place, potential effects of a batch spill on Marine and Migratory Birds are predicted to be adverse, low to medium in magnitude, short-term in duration, with a geographic within the Project Area (i.e., batch spill during bunkering), not likely occur to sporadically occurring (depending on size of spill) and reversible. Overall, effects predictions of hydrocarbons on marine birds are made with a moderate to high level of confidence based on scientific literature and the experience and professional judgement of the EIS Team. As noted above, geographic extent is based on spill trajectory modelling, in which there are some uncertainties and therefore there is a moderate level of confidence for geographic extent. There is also a moderate level of confidence in the magnitude of change as it would depend on species present offshore as well as percentage that could be affected by surface oiling.

SBM Whole Mud Spill

A spill of SBM whole muds can potentially result in similar effects described for a marine diesel spill. SBMs, however, are heavy, dense fluids that sink rapidly, potentially leaving a sheen (Morandin and O'Hara 2016) so the effects on the water's surface would be more limited than diesel or crude oil spills as it sinks through the water column. Potential effects of a drill mud spill on Marine and Migratory Birds are predicted to be adverse, low in magnitude, short-term in duration, localized not likely to occur to sporadically occurring and reversible. Overall, effects predictions of hydrocarbons on marine birds are made with a moderate to high level of confidence based on scientific literature and the experience and professional judgement of the EIS Team. As noted above, geographic extent is based on spill trajectory modelling, in which there are some uncertainties and therefore there is a moderate level of confidence for geographic extent of surface sheening for surface spills.

16.7.5.7 Summary

Table 16.40 provides a summary of predicted residual environmental effects of accidental event scenarios for Marine and Migratory Birds. Effects predictions were made using a conservative approach for the spill modelling and considered the implementation of mitigation measures to prevent and reduce effects from a spill.

Table 16.40 Summary of Residual Accidental Event-Related Environmental Effects on Marine and Migratory Birds

Accidental Event Scenario	Residual Environmental Effects Characterization						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Confidence
Potential Effects: Change in mortality / injury level and health of individuals or populations; Change in avifauna presence and abundance (behavioural effects); Change in habitat availability and quality; Change in food availability or quality							
Site 1 - 36-Day Subsurface Blowout - 10,500 m³/d	A	M-H	RSA	M	N	R	M-H
Site 1 - 115-Day Subsurface Blowout - 10,500 m³/d	A	M-H	RSA	M	N	R	M-H
Site 2 - 36-Day Subsurface Blowout - 10,500 m³/d	A	M-H	RSA	M	N	R	M-H
Site 2 - 115-Day Subsurface Blowout - 10,500 m³/d	A	M-H	RSA	M	N	R	M-H
FPSO Surface Release - 8,300 m³	A	L	RSA	S	N	R	M-H
Offloading Surface Release - 1,000 m³	A	L-M	RSA	S	N	R	M-H
Bunkering Surface Release - 6 m³	A	L	PA	S	S	R	M-H
Production Flowline Subsurface Release - 500 m³	A	L-M	RSA	S	N	R	M-H
Vessel/vessel collision - 750 m³	A	L	RSA	S	N	R	M-H
Site 1 - SBM Whole Mud Spill - 60 m³ surface spill	A	L	L	S	S	R	M-H
Site 1 - SBM Whole Mud Spill - 275 m³ flex joint failure subsurface release	A	L	L	S	N	R	H
Site 1 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release	A	L	L	S	N	R	H
Site 2 - SBM Whole Mud Spill - 60 m³ surface spill	A	L	L	S	S	R	M-H
Site 2 - SBM Whole Mud Spill - 275 m³ flex joint failure subsurface release	A	L	L	S	N	R	H

Table 16.40 Summary of Residual Accidental Event-Related Environmental Effects on Marine and Migratory Birds

Accidental Event Scenario	Residual Environmental Effects Characterization						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Confidence
Site 2 - SBM Whole Mud Spill - 275 m^3 BOP disconnect subsurface release	A	L	L	S	N	R	H

KEY

Nature / Direction of Effect:
P Positive
A Adverse
N Neutral (or No Effect)

Magnitude of Effect:
N Negligible
L Low
M Medium
H High

Duration:
S Short-Term - less than 12 months (1 year)
M Medium-term - 1 to 5 years
L Long-term - more than 5 years

Geographic Extent of Effect:
Less 1 km^2
Less than 10 km^2
Less than 100 km^2
Less than 1,000 km^2
Less than 10,000 km^2
Greater than 10,000 km^2

Frequency of Effect:
N Not likely to occur
O Occurs once
S Occurs sporadically
R Occurs on a regular basis
C Occurs continuously

Reversibility:
R Reversible (will recover to baseline)
I Irreversible (permanent)

Confidence Level in Predictions:
L Low level of confidence
M Moderate level of confidence
H High level of confidence

N/A Not Applicable

16.7.5.8 Determination of Significance

In consideration of the known effects of oil spills on marine-associated avifauna, the result of spill modelling exercises, and with the implementation of mitigation measures, a precautionary conclusion is drawn that residual environmental effects from an extremely low probability occurrence subsurface blowout on Marine and Migratory Birds are predicted to be significant depending on the specific occurrence, the nature and degree of the event, and the presence of certain species of birds, but extremely unlikely to occur. Infrequent batch spills and SBM releases are predicted to affect a smaller number of individuals and be reversible at the population level, therefore would not cause a detectible decline in overall abundance or change in distribution over more than one generation. Therefore, it is predicted that batch spills and accidental SBM releases associated with the Project will not result in significant residual adverse effects on Marine and Migratory Birds.

In the extremely unlikely event of a subsurface blowout, some degree of residual adverse effects to marine and migratory birds present in the area at the time of the accident or malfunction are expected based on estimated mortality rates. The degree of exposure and thus the type and level of any such effects would depend on the type and size of spill, time of year, and the number, location, and species of marine and migratory birds within the affected area. For the blowout scenarios, these environmental effects could, however, be significant if it leads to a detectable decline in overall bird abundance or change in the spatial and temporal distribution of bird populations in the overall RSA for multiple generations. Again, this is considered extremely unlikely given the very low probability of a subsurface blowout to occur and the response mitigations that will be implemented.

16.7.6 Marine Mammals and Sea Turtles - Accidental Events Effects Assessment

16.7.6.1 Introduction

Numerous species of marine mammals and sea turtles, including several SAR/SOCC, are known to occur in the RSA seasonally or year-round (see Section 6.3.7), and could therefore be present at the time of an accidental event. While some species of marine mammals occur in the waters off NL year-round, abundance and diversity are generally highest from late spring to autumn. There is no designated critical habitat for marine mammals or sea turtles within or near the Project Area; however, there are several EBSAs in the RSA, some of which have been identified as important to marine mammals and sea turtles (see Section 6.4.2.5). The Northeast Shelf and Slope EBSA (see Section 6.4.2.5) overlaps with the Project Area and has been noted as having concentrations of cetaceans and phocids. With respect to their relevance to marine mammals and sea turtles, most EBSAs and the RMA in the region (Table 6.73 in Section 6.4.7) serve as feeding aggregation areas, with some of the coastally-located areas also providing migration corridors or breeding and whelping areas for seals.

The potential for interaction of different species of marine mammals or sea turtles with an accidental event such as a hydrocarbon release will vary based on the timing, location, duration, and extent of the spill. For example, small-toothed whale, dolphin, and porpoise species are expected in both coastal and offshore waters of the RSA, whereas sperm whales and beaked whales primarily occur in slope waters and basin areas. The most common baleen whale species in the RSA are humpback, minke, and fin whales. Harbour seals primarily occur in coastal areas, while grey, harp, and hooded seals are more widespread and can be found in deeper waters of the RSA when not breeding or whelping on land or pack ice. Within the RSA, leatherback sea turtles are considered most likely to be observed over the continental slope areas off the Grand Banks and south of the Flemish Cap. The likelihood of loggerhead and Kemp's ridley sea turtles occurring anywhere in RSA is considered low.

16.7.6.2 Potential Issues and Interactions

The potential environmental effects on the Marine Mammal and Sea Turtle VC used in the assessment of effects of routine activities (Chapter 11) were

- Change in injury level (underwater sound)
- Change in mortality / injury levels (ship strikes)
- Change in habitat quality or use (behavioural effects)
- Change in prey availability or quality
- Change in health (contaminants)

These potential effects remain relevant to the assessment of accidental events, although the mechanisms or pathways of effects may differ. Marine mammals and sea turtles may experience a change in mortality or injury (acute or immediate effects) if directly exposed to accidentally-released hydrocarbons or associated volatiles and aerosols. They may experience a change in health (sublethal effects) from direct contact with hydrocarbons (including volatiles and aerosols) or consumption of contaminated prey. There may be a change in habitat (marine water or shoreline / haul-out) quality and/or use due to oiling and associated response measures. The availability and quality of food (prey items) may also be adversely affected by an accidental release event; effects to prey species are discussed in detail in Section 16.7.4.3. An overview of the effects of an accidental release of hydrocarbons on marine mammals and sea turtles is provided below.

Species at Risk

Nine marine mammal species and two sea turtle SAR have been identified as having the potential to be present off eastern NL: blue whale, North Atlantic right whale, bowhead whale, fin whale, northern bottlenose whale, Sowerby's beaked whale, killer whale, beluga whale, harbour porpoise, leatherback sea turtle, and loggerhead sea turtle (see Section 6.3.7).

16.7.6.3 Effects of Hydrocarbons on Marine Mammals

Although some studies suggest that cetaceans can detect oil spills, they do not appear to consistently avoid contact with most types of oil (Geraci et al. 1983; St. Aubin et al. 1985; Harvey and Dahlheim 1994; Matkin et al. 1994; Smultea and Würsig 1995). There is some evidence that dolphins decrease their respiration rate and increase their dive duration in the presence of surface oil, which should minimize exposure to surface oil (Smultea and Würsig 1995). Oil has little effect on thermoregulation since cetaceans and pinnipeds rely on a subcutaneous layer of blubber for insulation (Geraci 1990). The exception is seal pups that have not yet developed insulating blubber and polar bears (Kooyman et al. 1976 *in* Helm et al. 2015). It is assumed that exposure of the eye to oil may result in temporary or permanent damage (St. Aubin 1990). Oil can coat the baleen of mysticetes and reduce filtration, thereby reducing feeding efficiency (Geraci 1990). This effect is considered reversible once adherent oil is removed (Geraci 1990). Inhalation of volatiles and aspiration of aerosolized oil compounds from an oil spill or blowout can result in inflammation of the mucous membranes and absorption of hydrocarbons into the bloodstream (Geraci 1990). Whales may ingest oil with water or by consuming contaminated prey. Species such as harbour porpoise and harbour seals that feed in more restricted areas (e.g., bays) are likely at greater risk of ingesting oil (Würsig 1990) should spilled substances extend to the shorelines. Ingested oil that is not excreted in vomit or feces can be absorbed into the tissues and have toxic effects (Geraci 1990), although it has been reported that ingested oil may be removed from an animals' system after returning to uncontaminated waters (Engelhardt 1978, 1982, 1983). Bence and Burns (1995) reported that only small traces of oil were found in the blubber of a grey whale and the liver of a killer whale exposed to oil from the *Exxon Valdez* spill.

Following the DWH spill in the Gulf of Mexico in 2010, there has been increased study of the effects of oil spills on marine mammals. Although initial avoidance of slicks by cetaceans had been observed (except in the case of sheens) (Sidorovskaia et al. 2016), several species have been seen swimming through, and feeding in, large slicks (see Helm et al. 2015; Wilkin et al. 2017). Although oil could coat the baleen of mysticete whales and reduce filtration efficiency, this effect is considered reversible (Geraci 1990). Oil from the DWH spill has been observed adhering to the skin of 11 species of cetaceans (Aichinger Dias 2017), persisting for at least two years after blowout for some species. As discussed above, oil from such spills can have negative effects on cetacean health. Atlantic bottlenose dolphins oiled during the DWH spill revealed respiratory abnormalities, impaired stress response (hormonal), and elevated adrenal hormone levels (Schwacke et al. 2014; Balmer et al. 2015; Lane et al. 2015; Venn-Watson et al. 2015; Smith et al. 2017). These effects persisted for at least four years after the blowout (Smith et al. 2017). In addition, immune function in these individuals was consistent with bacterial infection (De Guise et al. 2017). Annual survival in these populations was significantly lower than that in an unoiled area (McDonald et al. 2017; Mullin et al. 2017), and dead-stranding rates were up to four times greater in the areas with heaviest oiling (Kellar et al. 2017). The reproductive success rates in dolphins in oiled areas were reduced by more than two-thirds (Kellar et al. 2017), while the percentage of pregnant females giving birth to viable calves was reduced by 75 percent (Lane et al. 2015). Most of the pregnant females that failed to give birth to viable calves had previously been diagnosed with lung disease coinciding with the blowout.

Extremely large oil spills can also have negative effects on cetaceans at the population level. Bottlenose dolphin populations impacted by the DWH blowout were significantly reduced in size (McDonald et al. 2017). These populations were very susceptible to the effects of this particular spill event because the small size of pod home ranges resulted in continuous exposure to the oil (Wells et al. 2017). Killer whale pods in Prince William Sound that were photo-identified before the *Exxon Valdez* oil spill, lost 33 percent to 41 percent of their members in the first year (Matkin et al. 2008). The loss of adult females suppressed reproduction so that pod size failed to recover to pre-spill levels or declined during 16 years of follow-up monitoring (Loughlin 1994; Peterson et al. 2003; Matkin et al. 2008).

Mortality has been reported in seals fouled with oil, particularly in seal pups in colder waters who have yet to develop adequate blubber (St. Aubin 1990). Exposure of seals to oil can result in conjunctivitis (Spraker et al. 1994), corneal abrasion and swollen nictitating membranes, or permanent eye damage (St. Aubin 1990) and therefore reduced foraging ability (Levenson and Schusterman 1997). Heavily fouled seals can experience reduced locomotion and even drowning (Davis and Anderson 1976; Sergeant 1991). Harbour seals observed immediately after oiling appeared lethargic and disoriented, a response that may be attributed to lesions observed in the thalamus of the brain (Spraker et al. 1994). Seals may ingest oil by consuming contaminated prey or by nursing contaminated milk. Once ingested, oil absorbed into the tissues can result in minor kidney, liver, or brain lesions (Geraci and Smith 1976; Spraker et al. 1994). However, Spraker et al. (1994) found lesions characteristic of hydrocarbon toxicity in the brains of oiled seals collected several months after the *Exxon Valdez* spill.

16.7.6.4 Effects of Hydrocarbons on Sea Turtles

Sea turtles may be more susceptible to the effects of exposure to hydrocarbons than marine mammals because they do not respond with avoidance behaviour, exhibit indiscriminate feeding, and take large pre-dive inhalations (Milton et al. 2010; Vander Zanden et al. 2016). Effects of exposure to oil in sea turtles include reduced lung capacity, decreased oxygen uptake, reduced digestion efficiency, and damaged eyelid and nasal tissues (Lutz and Lutcavage 1989). Ingestion of oil is particularly deleterious to sea turtle health (Camacho et al. 2013). Loggerhead sea turtles have presented with skin lesions after exposure to oil, although effects were reversed ten days post-exposure (Bossart et al. 1995). Sea turtles are often found heavily oiled after a spill and approximately 1 percent of sea turtle strandings in the US are associated with oil (Lutcavage et al. 1997 in Milton et al. 2003). Many of the surface-pelagic juvenile sea turtles oiled during the DWH blowout in 2010 showed physiological derangements (Stacy et al. 2017), and visibly oiled sea turtles found dead or dying had elevated levels of polycyclic aromatic hydrocarbons (Ylitalo et al. 2017). NMFS (2014) documented over 600 dead sea turtles after the DWH spill, 75 percent of which were Kemp's Ridley sea turtles and at least 18 individuals of which were visibly oiled. An additional 450 oiled sea turtles were rescued, rehabilitated, and released; 95 percent of these were loggerhead sea turtles (NMFS 2014).

16.7.6.5 Effects of Dispersants on Marine Mammals and Sea Turtles

In general, dispersed oil is predicted to reduce potential adverse environmental effects on marine mammals and sea turtles. Marine mammals are susceptible to floating oil due to the fact they need to surface at regular intervals to breathe. The use of dispersants may be beneficial for marine mammals within a spill area by reducing the exposure to floating oil on the sea surface. The dispersion of oil, however, may expose swimming or feeding marine mammals to the consumption of contaminated plankton, skin/fur contamination, and potentially the clogging of baleen (Lee et al. 2015). Hydrocarbons consumed by marine mammals through contaminated prey can be metabolized and excreted. Some hydrocarbons, however, may be stored in blubber and other fat deposits which may be released into circulation during periods of physiological stress (low prey availability, migration, lactation) and may be bioavailable and toxic to a fetus or newborns (Lee et al. 2015).

16.7.6.6 Effects of Whole SBM on Marine Mammals and Sea Turtles

The possible physical effects of SBM exposure on marine mammals and sea turtles would be similar to other hydrocarbons described above. SBMs, however, are a heavy, dense fluid which sinks rapidly so the effects on the water's surface and water column would be limited compared to other hydrocarbon spills.

16.7.6.7 Residual Environmental Effects Assessment and Evaluation

The residual effects of an oil spill, that is the effects remaining after the implementation of emergency response measures (see Section 16.1), should it occur, are assessed in the following sections.

Subsurface Blowout

The likelihood, magnitude, geographic extent and duration of potential effects of a subsurface blowout will depend in large part on the occurrence and distribution of marine mammals and sea turtles at the time of the blowout, as well as the duration and extent of oil release (i.e., potential severity of effects will be dependent on the potential for exposure). Given that marine mammals and sea turtles are known or expected to occur throughout the RSA, the magnitude of effects may be higher for subsurface releases of larger scale and extended duration, as was observed during the DWH spill in the Gulf of Mexico (e.g., Takeshita et al. 2017). Depending on the exact nature, extent, and duration of a spill, marine mammals and sea turtles may be exposed to oil via a combination of pathways (inhalation, ingestion, aspiration, and adsorption). Marine mammals and sea turtles that are closer to the site of the blowout are more likely to be exposed to a more constant flow and higher concentrations of recently released oil, as compared to species that are more prevalent in the nearshore.

In the selected 95th percentile scenario for surface oil exposure releases, surface oil was predicted to be thickest closest to the release location. Maximum thicknesses corresponded to a visual appearance of black oil within a few kilometres of the release site with the majority of footprints predicted to have a maximum thickness closer in appearance to dark brown to dull brown sheens (0.01 to 0.1 mm). Dark brown to dull brown sheens were predicted to overlap with areas around the Flemish Cap, and along the slopes and shelf of the Newfoundland Shelf and the Orphan Basin. The application of mitigation and response measures would reduce the magnitude, duration and geographical extent of the spill.

Modelling results from the 95th percentile scenario for in-water exposure indicate that the areas reaching or exceeding the ecological threshold for in-water concentration of hydrocarbons from an unmitigated subsurface blowout, likely include the Newfoundland Shelf, slopes of the Grand Banks, the Flemish Pass, the Flemish Cap and areas east of the release site (Section 16.4.4). Concentrations of dissolved and total hydrocarbons based on the 95th percentile scenario were predicted to be highest around the release site, including Flemish Pass and the Flemish Cap. Oil concentrations dissipated as it was transported away from the release location through mixing within the water column, evaporation from the water surface, volatilization from the water column, and degradation, thus reducing the total amount of contaminants present (RPS 2018).

Less than one percent of total oil released was predicted to make contact with shoreline and most of the oil that was predicted to make contact occurred on the Avalon Peninsula and localized areas of the Burin Peninsula. Since the predicted time for oil to make first contact ranged between 14 and 45 days, the oil would be highly weathered, patchy and discontinuous (RPS 2018).

Based on modelling results in the CNOOC EIS (CNOOC 2018), it is predicted the highest probability of oil reaching the Azores where shoreline exceeded the 1 gm/2 was 70 and 77 percent (depending on scenario) in the summer months. The modelled 95th percentile representative deterministic shoreline scenario predicted a minimum time for oil to reach the Azores at was between 80 days and 111 days, depending on the spill site. Therefore, oil that is predicted to make shore would be highly weathered (i.e., lighter ends would have evaporated, dissolved, and degraded) thereby reducing the toxicity of the residual oil, patchy and discontinuous emulsified oil and tarballs. Surface oiling is predicted to occur to the areas to the east of BdN model domain at thicknesses >0.04 μm in areas beyond NAFO division 3LMN and in the surface waters surrounding the Azores. With the application of mitigation and response measures, including shoreline response measures, it would further reduce potential for effects on Marine and Migratory Birds.

It is possible that marine mammals and sea turtles that occur in offshore areas where predicted concentrations of surface or in-water hydrocarbons occurs above the ecological threshold levels from an unmitigated subsurface blowout could experience adverse changes in habitat quality and use, health, and in extreme cases increases in injury and mortality levels. As reviewed above, while some marine mammals seem to avoid oil spills, other marine mammals have been observed swimming through, and feeding in, large slicks (see Helm et al. 2015; Wilkin et al. 2017). Sea turtles may be more susceptible to the effects of exposure to hydrocarbons than marine mammals because they do not respond with avoidance behaviour, exhibit indiscriminate feeding, and take large pre-dive inhalations (see Milton et al. 2010; Vander Zanden et al. 2016).

The likelihood, however, of a subsurface blowout occurring is extremely low. The probability of a subsurface blowout of any size is 1.61 x 10^{-4}. In the unlikely event of a spill occurring, these effects to marine mammals and sea turtles would occur within the RSA and would be beyond the range of natural variability but would not likely result in an effect on the viability of a population, given avoidance behaviours of some species. Therefore, it is predicted to be of medium magnitude. In the unlikely event of shoreline oiling, it is possible harbour and grey seals that use haul-out sites sporadically on the Avalon and Burin Peninsula could be affected by an unmitigated subsurface release. Small numbers of seals may interact with hydrocarbons (albeit highly weathered oil that is patchy and discontinuous), conceivably experiencing a change in mortality or injury or a change in health; however, it is probable that only a small proportion of local populations would be affected. As stated above, by the time oil made contact with the shoreline, it would be patchy, discontinuous and weathered. As described in Section 6.3.7, there are nine marine mammal and two sea turtle Species at Risk that are known or expected to occur in the in the LSA and/or RSA. In the extremely unlikely event of a subsurface blowout to the marine environment, these species have the potential to be adversely affected, if the spill occurs when the Species at Risk is in the area. These predictions are made with a moderate to high level of confidence based on scientific literature and the experience and professional judgement of the EIS Team. Geographic extent is based on spill trajectory modelling. Modelling is a predictive tool providing an estimate of the zone of influence hydrocarbon spills, therefore there is some uncertainty regarding the overall spatial extent of the movement of hydrocarbons in the water. Based on this uncertainty there is a moderate level of confidence in the prediction of geographic extent. There is also a moderate level of confidence in the magnitude of effect as it would depend on species present offshore. In an actual event, emergency response measures would likely reduce the magnitude, duration and geographic extent of the spill, and therefore reduce the potential impacts on Marine Mammals and Sea Turtles.

With spill prevention plans and response procedures in place, effects from a low probability subsurface blowout on Marine Mammals and Sea Turtles are predicted to be adverse, medium in magnitude, medium to long-term in duration, with a geographic extent within the RSA, not likely to occur and reversible. These predictions are made with a moderate to high level of confidence.

Batch Spills and Vessel Collision

Modelling results of batch spills (surface and subsea loss of crude; surface loss of diesel) indicate that the size and persistence of the area where effects on Marine Mammals and Sea Turtles may be expected are much smaller than for subsurface blowouts. None of the hydrocarbons released during modelled batch spill scenarios are predicted to reach shore.

For the crude batch spills, both surface and at seafloor, surface oiling (thinner dull brown sheens[]) was predicted to have a maximum extent of approximately 375 km from the spill location during the worst-case environmental conditions for surface oiling (i.e., calmest wind-speed period during the summer / ice-free conditions, which would result in the largest amount of oil on the water surface). In water THC concentrations were predicted to be confined to the spill location for the surface batch spills and out to approximately 250 km for the seafloor flowline release. For the surface release of diesel, surface oiling and in-water concentrations were predicted to be confined to the areas near the release location. None of the hydrocarbons released during modelled batch spill scenarios were predicted to reach shore. The probability of batch spills ranges from one in 46 (spills less than 159 litres) to one in 75,000 (spills greater than 1,590 m³). Although marine mammals and sea turtles within 250 km of the release may be exposed, the change in habitat availability and quality as well as effects on health will be of low magnitude, based, in part, on dissipation rates. While batch spills would decrease water quality around the spill site, it would be short-term since the surface slick naturally disperses through surface wave action in the offshore environment.

For diesel batch spills, modelling of a surface loss of 6 m³ was predicted to result in a patchy distribution of colourless or silver sheens of oil (less than 0.0001 mm) close to the release location. The marine diesel batch spill resulted in the smallest volume of water exposed to THC concentrations exceeding 1 µg/L, where concentrations were generally less than 5 µg/L in an area within 200 km of the release site with a maximum THC concentration of 1 µg/L to 5 µg/L (Figure 16-38). For the spill of marine diesel from a vessel to vessel collision, the release would likely result in a rainbow sheen (0.0001 to 0.001 mm) for approximately 40 km before transitioning to the colourless and silver sheen (less than 0.0001 mm). No shoreline contact was predicted. These results suggest that both the potential for exposure and the likelihood of adverse effects on marine mammal and sea turtle habitat from exposure to diesel are low. Only animals in the immediate vicinity near the surface at the time of the spill may be exposed, and at the concentrations predicted, change in habitat availability and quality will be of negligible to low magnitude. While a batch spill would decrease water quality around the spill site, it would be short-term since the surface sheen evaporates and naturally disperses through surface wave action in the offshore environment. Overall, effects predictions of hydrocarbons on marine mammals and sea turtles are made with a moderate to high level of confidence based on scientific literature and the experience and professional judgement of the EIS Team. As noted above, geographic extent is based on spill trajectory modelling, in which there are some uncertainties and therefore there is a moderate level of confidence for geographic extent.

With spill prevention plans and response procedures in place, potential effects of a batch spills on Marine Mammals and Sea Turtles are predicted to be adverse, negligible low in magnitude, short- to medium-term in duration, with a geographic extent ranging from the PA to the RSA, not likely to occur to sporadically occurring, and reversible. This was determined with a moderate to high level of confidence.

SBM Whole Mud Spill

SBMs are a heavy, dense fluid which sinks rapidly so the effects on the water's surface and column would be more limited than diesel or crude oil spills. Potential effects of a drill fluid spill on Marine Mammals and Sea Turtles are predicted to be adverse, negligible to low in magnitude, short-term in duration, localized, not likely to occur to sporadically occurring, and reversible. This was determined with a high level of confidence based on scientific literature, modelling predictions and the experience and professional judgement of the EIS Team.

16.7.6.8 Summary

Table 16.39 provides a summary of predicted residual environmental effects of accidental event scenarios for Marine Mammals and Sea Turtles. Effects predictions were made using a conservative approach for spill modelling and considered the implementation of mitigation measures to prevent and reduce effects from a spill.

Table 16.41 Summary of Residual Accidental Event-Related Environmental Effects on Marine Mammals and Sea Turtles

Accidental Event Scenario	Residual Environmental Effects Characterization						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Confidence
Potential Effects: Change in Habitat Quality / Use; Change in injury or mortality level / health; Change in prey availability or quality							
Site 1 - 36-Day Subsurface Blowout - 10,500 m³/d	A	M	RSA	M-L	N	R	M-H
Site 1 - 115-Day Subsurface Blowout - 10,500 m³/d	A	M	RSA	M-L	N	R	M-H
Site 2 - 36-Day Subsurface Blowout - 10,500 m³/d	A	M	RSA	M-L	N	R	M-H
Site 2 - 115-Day Subsurface Blowout - 10,500 m³/d	A	M	RSA	M-L	N	R	M-H
FPSO Surface Release - 8,300 m³	A	L	RSA	M	N	R	M-H
Offloading Surface Release - 1,000 m³	A	L	RSA	M	N	R	M-H
Bunkering Surface Release - 6 m³	A	N	PA	S	S	R	H
Production Flowline Subsurface Release - 500 m³	A	L	LSA	S	N	R	M-H
Vessel/vessel collision - 750 m³	A	L	RSA	S	N	R	M-H
Site 1 - SBM Whole Mud Spill - 60 m³ surface spill	A	N	L	S	S	R	H
Site 1 - SBM Whole Mud Spill - 275 m³ flex joint failure subsurface release	A	L	L	S	N	R	H
Site 1 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release	A	L	L	S	N	R	H
Site 2 - SBM Whole Mud Spill - 60 m³ surface spill	A	N	L	S	S	R	H
Site 2 - SBM Whole Mud Spill - 275m³ flex joint failure subsurface release	A	L	L	S	N	R	H
Site 2 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release	A	L	L	S	N	R	H

KEY

Nature / Direction of Effect:
P Positive
A Adverse
N Neutral (or No Effect)

Magnitude of Effect:
N Negligible
L Low
M Medium
H High

Geographic Extent of Effect:
Less 1 km²
Less than 10 km²
Less than 100 km²
Less than 1,000 km²
Less than 10,000 km²
Greater than 10,000 km²

Duration:
S Short-Term - less than 12 months (1 year)
M Medium-term - 1 to 5 years
L Long-term - more than 5 years

Frequency of Effect:
N Not likely to occur
O Occurs once
S Occurs sporadically
R Occurs on a regular basis
C Occurs continuously

Reversibility:
R Reversible (will recover to baseline)
I Irreversible (permanent)

Confidence Level in Predictions:
L Low level of confidence
M Moderate level of confidence
H High level of confidence

N/A Not Applicable

16.7.6.9 Determination of Significance

In consideration of the known effects of spills on Marine Mammals and Sea Turtles, the results of spill modelling exercises, and with the implementation of mitigation measures, it is predicted that accidental events associated with the Project will not result in significant residual adverse effects on Marine Mammals and Sea Turtles.

In the very unlikely event of a large offshore oil release, some degree of residual adverse effects to Marine Mammals and Sea Turtles are expected. The degree of exposure and thus the type and level of any such effects would depend on the type and size of spill, time of year, and the number, location and species of animals within the affected area. Although there is the potential for effects on marine mammals, sea turtles and their habitat in the RSA, these are, with appropriate mitigations, not likely to result in a detectable decline in overall abundance or change in the spatial and temporal distributions of marine mammal and sea turtle populations in the overall RSA for multiple generations. Spill prevention techniques and response strategies will be incorporated into the design and operations for all Project activities as part of contingency planning, which will further help to ensure that effects do not occur, and in the unlikely event they did, that these would not have significant adverse effects on Marine Mammals and Sea Turtles.

This overall determination is generally made with a moderate to high level of confidence. There are several key uncertainties in predicting the effects of accidental events on marine mammals and sea turtles. There are limited baseline data on marine mammal and sea turtle use of the Project Area and larger RSA. Therefore, there is uncertainty as to whether the Project Area or certain portions of the RSA are regularly used and important foraging areas, migratory corridors, and/or breeding areas for marine mammals. There are some data to suggest that the Sackville Spur area may be important habitat for northern bottlenose whales, other odontocetes, and possibly fin whales (see Section 6.3.7). Another data gap is the lack of information on marine mammal and sea turtle response to oil spills; it is uncertain, particularly for marine mammals if they would avoid a spill. Recent studies of the DWH blowout have demonstrated that oil spills have more adverse effects on marine mammals and sea turtles than previous studies indicated.

16.7.7 Special Areas - Accidental Events Effects Assessment

16.7.7.1 Introduction

The following special areas intersect with the Project Area and Core BdN Development Area:

- Slopes of the Flemish Cap and Grand Bank (UNCBD) EBSA: Project Area and Core BdN Development Area
- Sackville Spur (Vulnerable Marine Ecosystem): Project Area
- Northwest Flemish Cap (10) (NAFO fisheries closure area): Project area and Core BdN Development Area

Special areas, or portions them, within the RSA including the vessel traffic route, could potentially interact with a Project-related accidental event. Special areas have been designated as protected or identified as being special or sensitive due to their biological or ecological characteristics and/or socio-cultural features. Special Areas may have associated provincial, federal or other regulatory mandates to protect ecological features, cultural or historical sites, or areas used for scientific research, education or recreation. These areas and their important characteristics may be vulnerable to an accidental event, as degradation of their conditions may affect their underlying integrity and value. Section 6.4 provides a description of special areas in the RSA.

16.7.7.2 Potential Issues and Interactions

The potential environmental effects on Special Areas used in the assessment of effects of routine activities (Chapter 12) were:

- Change in environmental features and/or processes
- Change in human use and/or societal value

These potential effects remain relevant to the assessment of accidental events although the mechanisms or pathways of effects may be different. The extent of the potential effects on Special Areas will depend on how the spill trajectory and the VC overlap in both space and time. Potential effects on Special Areas, in the unlikely event of an accidental release of hydrocarbons, includes potential degradation of the ecological integrity of the special area such that it is not capable of providing the same biological or ecological function for which it is designated. The Special Areas VC is therefore closely linked to other VCs considered in this assessment, particularly the biological VCs. The potential effects of accidental events on the biological VCs are discussed above in Sections 16.7.4 to 16.7.6 for marine fish and fish habitat, marine and migratory birds and marine mammals and sea turtles, respectively and are not repeated in this section. The assessment of effects on Special Areas is based on the effects assessment presented in Sections 16.7.4 to 16.7.6 and focusses on a change in environmental features and/or processes and change in human use of the Special Area and/or societal value of the Special Area."

16.7.7.3 Residual Environmental Effects Assessment and Evaluation

The potential residual environmental effects of an oil spill, that is, the effects remaining after the implementation of emergency response and mitigation measures (see Section 16.1), should such a spill occur, are assessed in the following sections. These results are based on the effects assessment conclusions in the preceding sections for Marine Fish and Fish Habitat, Marine and Migratory Birds and Marine Mammals and Sea Turtles. The assessment is conservative as it assumes there will be a temporal and spatial overlap between a spill and a special area.

Subsurface Blowout

The likelihood, magnitude, geographic extent and duration of potential effects of a subsurface blowout will depend on the nature of the spill and its trajectory and the spatial overlap of the spill trajectory with Special Areas. The extremely unlikely scenario subsurface blowout has the potential to result in a change in environmental features and/or processes, and changes in human use and/or societal value of Special Areas in the RSA. Given the potentially large amount of discharged oil that could conceivably be associated with such a blowout event, and the possibility for a spill to extend to adjacent areas and resources, an unmitigated subsurface blowout represents the accidental event with the most potential to affect special areas, and which would be the most widespread and thus of greatest environmental concern.

The modeling predicted that surface oil above the ecological threshold could potentially reach various special areas identified for marine and migratory birds (i.e., Canadian EBSAs, NL seabird ecological reserves, UNCBD EBSAs and IBAs). In-water concentrations of THC above the ecological thresholds, oil in the water column above ecological threshold could potentially reach special areas identified for the presence of marine fish, shellfish, mammals and sea turtles (i.e., Canadian and UNCBD EBSAs). Oil concentrations in sediment and/or shoreline and oil concentration above the ecological threshold in sediment and at shoreline could potentially reach special areas identified for benthic habitat, spawning grounds, and coastal bird areas. Table 16.42 summarizes the predicted overlap of special areas in the RSA with the 95th percentile deterministic results for the ecological thresholds for hydrocarbon surface exposure, in-water concentration and shoreline or seafloor sediment exposure as applicable to the primary reason for designation of the special areas (e.g., benthic habitat features, presence of marine species, etc.).

Table 16.42 Unmitigated Subsurface Blowout Potential Interactions above Ecological Thresholds with Special Areas

Special Area	Reason for Designation	95 Percentile Sea Surface				95 Percentile Water Column				95 Percentile Shoreline/Sediment			
		36 day Site #		115 day Site #		36 day Site #		115 day Site #		36 day Site #		115 day Site #	
		1	2	1	2	1	2	1	2	1	2	1	2
Marine Protected Areas (MPAs) and Areas of Interest (AOI)													
Eastport – Duck Islands MPA	Limits fishing to maintain a viable American lobster population and protect other threatened or endangered species.												
Eastport – Round Island MPA													
Canadian Ecologically and Biologically Significant Areas (EBSAs)													
Orphan Spur	High concentrations of corals. Presence of vulnerable fish species			X	X								
Notre Dame Channel	Cetacean feeding and migration. Several species of seabirds. Wintering harp seals.			X	X								
Fogo Shelf	Seabird breeding colonies. Capelin spawning areas. Important cetacean feeding areas. Marine mammal presence.			X									
Labrador Slope	Diversity of corals, sponges. Presence of vulnerable fish species.			X									
Northeast Slope	High aggregations of vulnerable fish species in spring. Concentrations of cetaceans, pinnipeds and corals.	X	X	X	X								
Virgin Rocks	High aggregations of capelin and other spawning groundfish. Seabird feeding areas.	X	X	X	X								

Table 16.42 Unmitigated Subsurface Blowout Potential Interactions above Ecological Thresholds with Special Areas

Special Area	Reason for Designation	95 Percentile Sea Surface				95 Percentile Water Column				95 Percentile Shoreline/Sediment			
		36 day Site #		115 day Site #		36 day Site #		115 day Site #		36 day Site #		115 day Site #	
		1	2	1	2	1	2	1	2	1	2	1	2
Lilly Canyon-Carson Canyon	Concentration, reproduction and feeding area for Iceland scallop. Aggregation and refuge/overwintering for cetaceans and pinnipeds.	X	X	X	X				X				
Southeast Shoal	High benthic biomass. Aggregation, feeding, breeding and/or nursery habitats for capelin, groundfish, cetaceans and seabirds.	X	X	X	X								
Eastern Avalon	Seabird feeding areas. Cetaceans, leatherback turtles and seals feed in the area from spring to fall.			X	X					X		X	X
Southwest Slope	Wide variety of seabirds. Pelagic seabird feeding area. Many marine mammals and leatherback sea turtles aggregate in summer.		X	X	X								
Haddock Channel Sponges	Largest sponge SBA on the shelf in the study area (DFO). Important aggregations of capelin and American plaice.			X	X								
St. Mary's Bay	Significant colonies and foraging area for common murre, northern gannet, razorbill and black-legged kittiwake. Aggregations of harlequin duck, salmon, capelin, common eider, Mysticetes functional group, hooded seal, leatherback turtle.									X	X	X	X

Table 16.42 Unmitigated Subsurface Blowout Potential Interactions above Ecological Thresholds with Special Areas

Special Area	Reason for Designation	95 Percentile Sea Surface				95 Percentile Water Column				95 Percentile Shoreline/Sediment			
		36 day Site #		115 day Site #		36 day Site #		115 day Site #		36 day Site #		115 day Site #	
		1	2	1	2	1	2	1	2	1	2	1	2
Bonavista Bay	Significant aggregations of eelgrass, salmon, killer whale, harbour seal, Mysticetes and duck functional groups. Important area for capelin and sea lamprey spawning. Significant foraging area for black-legged kittiwake and tern species.			X									
Baccalieu Island	Noted aggregations of killer whales, capelin, shrimp, plankpiscivores, spotted wolfish and seabird functional groups. Capelin spawning area. Important foraging area for Atlantic puffin, black-legged kittiwake and razorbill.			X	X								X
Marine Refuges													
Northeast Newfoundland Slope Closure	Aggregations of corals. Prohibitions for bottom contact fishing activities.	X	X	X	X	X			X				
Funk Island Deep Closure	Conserves seafloor habitat important to Atlantic cod. Bottom trawl, gillnet and longline fishing are prohibited.			X	X								
Gooseberry Island Lobster Area Closure	Key lobster spawning habitat. All lobster fishing is prohibited to increase lobster spawning and egg production.												

Table 16.42 Unmitigated Subsurface Blowout Potential Interactions above Ecological Thresholds with Special Areas

Special Area	Reason for Designation	95 Percentile Sea Surface				95 Percentile Water Column				95 Percentile Shoreline/Sediment			
		36 day Site #		115 day Site #		36 day Site #		115 day Site #		36 day Site #		115 day Site #	
		1	2	1	2	1	2	1	2	1	2	1	2
3O Coral Closure (portion inside EEZ)	Large and small gorgonian corals and sea pens. Presence of leatherback sea turtles, redfish and Atlantic cod. All bottom fishing activities prohibited to protect corals and sponges.	X		X	X								
Newfoundland and Labrador Shelves Bioregion Significant Benthic Areas													
Sea Pens	Modelling has determined high predicted presence probability of aggregations of sea pens, sponges, small gorgonian corals and large gorgonian corals.	X		X	X								
Sponges		X	X	X	X								
Large Gorgonian Corals		X	X	X	X								
Small Gorgonian Corals		X	X	X	X								
Canadian Fisheries Closures (FCA) within the EEZ													
Eastport Lobster Management Area	Fishing restrictions to protect prime lobster habitat. Two smaller areas are designated as MPAs under the Oceans Act												
Funk Island Deep Box	Bottom trawl, gillnet and longline fishing activities prohibited to conserve benthic habitat and Atlantic cod habitat.			X	X								
Gooseberry Island Lobster Area Closure	Key lobster spawning habitat. All lobster fishing is prohibited to increase lobster spawning and egg production.												

Table 16.42 Unmitigated Subsurface Blowout Potential Interactions above Ecological Thresholds with Special Areas

Special Area	Reason for Designation	95 Percentile Sea Surface				95 Percentile Water Column				95 Percentile Shoreline/Sediment			
		36 day Site #		115 day Site #		36 day Site #		115 day Site #		36 day Site #		115 day Site #	
		1	2	1	2	1	2	1	2	1	2	1	2
Snow Crab Stewardship Exclusion Zones													
Crab Fishing Area 5A (2 zones)	Snow crab fishing is prohibited.			X									
Crab Fishing Area 6A (2 zones)				X	X								
Crab Fishing Area 6B				X									
Crab Fishing Area – 8BX		X	X	X	X								
Crab Fishing Area – 9A (2 zones)					X								
Near Shore (2 zones)				X	X								
Coastal Provincial Ecological Reserves													
Witless Bay Seabird Ecological Reserve	Protects seabird breeding colonies. Large numbers of seabirds in area.			X								X	X
Baccalieu Island Seabird Ecological Reserve	Protects seabird breeding colonies. Large numbers and large colonies.												X
Mistaken Point Fossil Ecological Reserve	Protects fossils of oldest complex life forms. Also noted for seabirds.									X	X	X	X
Cape St. Mary's Seabird Ecological Reserve	Protects seabird breeding colonies. Large numbers of seabirds including overwintering waterfowl.											X	X

Table 16.42 Unmitigated Subsurface Blowout Potential Interactions above Ecological Thresholds with Special Areas

Special Area	Reason for Designation	95 Percentile Sea Surface				95 Percentile Water Column				95 Percentile Shoreline/Sediment			
		36 day Site #		115 day Site #		36 day Site #		115 day Site #		36 day Site #		115 day Site #	
		1	2	1	2	1	2	1	2	1	2	1	2
Coastal Provincial Parks and Protected Areas													
Chance Cove	Day use park. Natural or scenic attraction.									X		X	
Gooseberry Cove	Day use park. Natural or scenic attraction.									X			
UN Convention on Biological Diversity EBSAs													
Seabird Foraging Zone in the Southern Labrador Sea	Abundance of seabirds. Foraging habitat for overwintering and breeding seabirds.	X	X	X	X								
Orphan Knoll	Fragile and long-lived corals and sponges.		X	X	X								
Slopes of the Flemish Cap and Grand Bank	Aggregations of VME indicator species such as corals and sponges. A component of Greenland halibut fishery grounds. High diversity including threatened and listed species.	X	X	X	X	X	X	X	X				
Southeast Shoal and Adjacent Areas on the Tail of the Grand Bank	Offshore capelin-spawning ground, nursery ground for yellowtail flounder and spawning areas for depleted American plaice, depleted Atlantic cod and striped wolffish. Abundant forage fish. Important feeding area for a number of cetaceans, including humpback and fin whales, frequented by large numbers of seabirds.	X	X	X	X				X				

Table 16.42 Unmitigated Subsurface Blowout Potential Interactions above Ecological Thresholds with Special Areas

Special Area	Reason for Designation	95 Percentile Sea Surface				95 Percentile Water Column				95 Percentile Shoreline/Sediment			
		36 day Site #		115 day Site #		36 day Site #		115 day Site #		36 day Site #		115 day Site #	
		1	2	1	2	1	2	1	2	1	2	1	2
UN FAO Vulnerable Marine Ecosystems (VMEs)													
Sponge	Identified for sponges, sea pens and large gorgonian corals.	X	X	X	X	X	X	X	X				
Sea Pen		X	X	X	X	X	X	X	X			X	
Large Gorgonian Coral		X	X	X	X	X	X	X	X				X
NAFO Fisheries Closure Areas (FCAs)													
Tail of the Bank (1)	Closed to bottom fishing to protect concentrations of corals, sponges and seapens and/or seamounts.	X	X	X	X								
Flemish Pass/Eastern Canyon (2)		X	X	X	X	X	X	X	X				
Beothuk Knoll (3)		X	X	X	X				X				
Eastern Flemish Cap (4)		X	X	X	X			X	X				
Northeast Flemish Cap (5)		X	X	X	X			X	X				
Sackville Spur (6)		X	X	X	X	X	X	X					
Northern Flemish Cap (7)		X	X	X	X	X		X	X				
Northern Flemish Cap (8)		X	X	X	X	X		X	X				
Northern Flemish Cap (9)		X	X	X	X	X		X	X				
Northwest Flemish Cap (10)		X	X	X	X	X	X	X	X				
Northwest Flemish Cap (11)		X	X	X	X	X	X	X	X				
Northwest Flemish Cap (12)		X	X	X	X	X	X	X	X				
Beothuk Knoll (13)		X	X	X	X				X				
Orphan Knoll Seamount			X	X	X								
Newfoundland Seamounts		X	X	X	X								

Table 16.42 Unmitigated Subsurface Blowout Potential Interactions above Ecological Thresholds with Special Areas

Special Area	Reason for Designation	95 Percentile Sea Surface				95 Percentile Water Column				95 Percentile Shoreline/Sediment			
		36 day Site #		115 day Site #		36 day Site #		115 day Site #		36 day Site #		115 day Site #	
		1	2	1	2	1	2	1	2	1	2	1	2
Fogo Seamounts (1)				X	X								
30 Coral Area Closure		X	X										
Important Bird Areas (IBAs)													
Quidi Vidi Lake	Wintering area for seagulls and waterfowl. The IBA includes coastal areas.			X								X	X
Witless Bay Islands	Seabird breeding area. Waterfowl migration area.			X								X	X
Cape St. Francis	Wintering area for waterfowl. Presence of shorebirds in winter.												X
Baccalieu Island	Abundance and high diversity of seabirds including breeding colonies.												X
Grates Point	Wintering waterfowl and seabirds. Seabirds present in summer months.												X
Mistaken Point	Wintering area for waterfowl. Overwintering shorebirds. Nesting seabirds.				X					X			X
The Cape Pine and St. Shotts Barren	Migration area for shorebirds.									X		X	X
Placentia Bay	Summer seabird feeding area. Large numbers of breeding seabirds. Large numbers of seabirds and wintering waterfowl.									X			

Table 16.42 Unmitigated Subsurface Blowout Potential Interactions above Ecological Thresholds with Special Areas

Special Area	**Reason for Designation**	**95 Percentile Sea Surface**				**95 Percentile Water Column**				**95 Percentile Shoreline/Sediment**			
		36 day Site #		**115 day Site #**		**36 day Site #**		**115 day Site #**		**36 day Site #**		**115 day Site #**	
		1	2	1	2	1	2	1	2	1	2	1	2
Cape Freels Coastline and Cabot Island	Wintering waterfowl. Nesting seabirds.			X									
Cape St. Mary's	Significant numbers of breeding seabird populations. Large numbers of migrating waterfowl in winter, including species of Special Concern.									X		X	X
Wadham Islands and adjacent Marine Area	Wintering waterfowl. Nesting seabirds.			X									
UNESCO World Heritage Sites (WHSs)													
Mistaken Point Ecological Reserve	Protects fossil deposits.									X		X	
North East Atlantic Fisheries Commission (NEAFC) FCAs													
Middle Mid-Atlantic Ridge	Closed to bottom fishing to protect seamounts and fractures highly likely to contain VME indicator species such as corals and sponges.	X	X	X	X								
Note: X indicates special area intersects with area above ecological threshold													

Special Areas Identified for Biological VCs

Modelling results for unmitigated subsurface blowouts predict surface oiling on waters that intersect with Special Areas within the Flemish Pass, Flemish Cap, Orphan Basin, southern Grand Banks and associated slope waters and large areas where hydrocarbons at the surface are predicted to exceed the conservative ecological threshold thickness. In the selected 95th percentile scenario for surface oil exposure releases, surface oil was predicted to be thickest closest to the release location. Maximum thickness corresponded with a visual appearance of black oil within a few kilometres of the release site with the majority of footprints predicted to have a maximum thickness closer in appearance to dark brown to dull brown sheens (0.01 to 0.1 mm). Based on modelling, surface oil was predicted to exceed the ecological threshold in special areas identified for the presence of marine and migratory birds (Table 16.42). These include Canadian EBSAs (i.e., Notre Dame Channel, Fogo Shelf, Southeast Shoal, Eastern Avalon, Southwest Slope, Baccalieu Island, Virgin Rocks, Lilly Canyon-Carson Canyon, Bonavista Bay), Witless Bay Seabird Ecological Reserve, UNCBD EBSAs (i.e., Seabird Foraging Area in the Southern Labrador Sea, Southeast Shoal and Adjacent Areas on the Tail of the Grand Bank), and IBAs (i.e., Witless Bay Islands, Mistaken Point, Quidi Vidi Lake, Wadham Island and Adjacent Area, Cape Freels Coastline and Cabot Island). While any oil on the surface, as predicted by spill modelling, will not reach Quidi Vidi Lake itself, oil could intersect with a portion of the Quidi Vidi Lake IBA, which includes coastal areas. As described in Section 16.7.5, surface oiling would affect marine and migratory birds if they were in the area in the extremely unlikely event of a subsurface blowout. With the implementation of mitigation measures, the geographical extent and magnitude would be reduced and therefore the interaction of surface oiling with these special areas and marine and migratory birds would likely be reduced.

Modelling also predicted that surface oil in exceedance of the ecological threshold could reach special areas identified for the presence of marine mammals and sea turtles (Table 16.42). These include EBSAs (i.e., Notre Dame Channel, Fogo Shelf, Northeast Slope, Lilly Canyon-Carson Canyon, Southeast Shoal, Eastern Avalon, Southwest Slope, Laurentian Channel, St. Mary's Bay, Bonavista Bay, Baccalieu Island), and Southeast Shoal and Adjacent Areas on the Tail of the Grand Bank UNCBD EBSA. The 95th percentile scenario for in-water exposure indicate that areas reaching or exceeding the ecological threshold, which could change water quality and therefore could affect fish habitat availability and quality in special areas such as Lily Canyon-Carson Canyon EBSA, Slopes of the Flemish Cap and Grand Bank UNCBD EBSA and VMEs. For these areas identified as important features for fish species, marine mammals and sea turtles, effects from a subsurface blowout were assessed in Section 16.7.4 and 19.7.6 concluded that residual effects on these species would not be significant.

The 95th percentile deterministic modelling for shoreline contact predicted less than 0.1 percent of the total oil released making contact with areas of the Avalon Peninsula and isolated areas of the Burin Peninsula. Special Areas identified and/or protected for fish, marine mammals, marine and migratory birds, recreation and paleontological importance (i.e., fossils) could be affected by oil contacting shorelines. Since the time for oil to make first contact ranged between 14 and 45 days, the oil would be highly weathered, patchy and discontinuous (RPS 2018). Given the time to shore and with the application of mitigation and response measures, the magnitude and extent of effects would be reduced.

The modelling predicted the coastline of the Avalon Peninsula could potentially be affected by shoreline contact above ecological threshold. While shoreline oil has the potential to interact with coastal areas, the oil would be highly weathered (i.e., lighter and more toxic components would have evaporated, dissolved, and degraded thereby reducing the toxicity of the residual oil). As indicated by the modelling, an unmitigated spill is extremely unlikely to reach the shoreline and less than 0.01 percent of oil was predicted to remain in sediment after the 160-day simulation with TCH concentrations less than 0.01 g/m² (RPS 2018). With the application of mitigation and response measures would further reduce potential effects.

The modelling predicted a very low potential for oil exceeding ecological threshold to reach special areas on the coast of NL, which have been identified for the presence of marine and migratory birds. The special areas include Canadian EBSAs (i.e., Eastern Avalon, Placentia Bay, St. Mary's Bay, Baccalieu Island), Provincial ecological reserves (i.e., Witless Bay, Baccalieu Island, Mistaken Point and Cape St. Mary's), IBAs (i.e., Witless Bay Islands, Cape St. Francis, Baccalieu Island, Grate's Point, Mistaken Point, The Cape Pine and St. Shotts Barren, Placentia Bay, Cape St. Mary's), and VMEs for Sea Pens and Large Gorgonian Corals. As stated above, by the time oil made contact with the shoreline, it would be patchy, discontinuous and weathered. The magnitude and extent of potential effects would be reduced with the application of spill response measures, therefore the risk of adverse effects on secure and at-risk to shoreline marine and/or migratory birds would be reduced.

In the extremely low probability occurrence of shoreline oiling, it is possible seals using haul-out sites on the Avalon Peninsula could be affected. The Eastern Avalon EBSA is identified for the presence of seals. In the case of such an unlikely event, small numbers of seals may interact with hydrocarbons (albeit highly weathered oil that is patchy and discontinuous). Based on modelling, by the time oil would make contact with the shoreline, it would be patchy, discontinuous and weathered. The magnitude and extent of potential effects would be minimized with the application of spill response measures, therefore the risk of adverse effects to coastal marine mammals would be reduced.

Special areas, around the Flemish Pass, Flemish Cap and Grand Banks, designated due to their unique or sensitive benthic habitat features could be at risk of exposure to oil in sediment resulting from a subsurface blowout. The modelling location at Site 1 was chosen due to the presence of Northwest Flemish Cap (10) NAFO FCA, which is designated due to the presence of high concentrations of sea pens and sponges. The modelling predicted that less than 0.01 percent of the oil would adhere to sediment and estimated concentrations were low (less than 0.01 g/m²). This is well below the ecological threshold of 100 g/m². The change in environmental features and/or processes would be considered beyond natural variability, but without affecting the viability of the affected populations and therefore of medium magnitude. With the application of mitigation and spill response options, the magnitude and extent of the effects would likely be reduced. As concluded in Section 16.7.4, residual effects on sensitive benthic habitat features were predicted to be not significant.

Based on modelling results in the CNOOC EIS (CNOOC 2018), it is predicted the highest probability of oil reaching the Azores where shoreline exceeded the 1 gm/2 was 70 and 77 percent (depending on scenario) in the summer months. The modelled 95th percentile representative deterministic shoreline scenario predicted a minimum time for oil to reach the Azores at was between 80 days and 111 days, depending on the spill site. Therefore, oil that is predicted to make shore would be highly weathered (i.e., lighter ends would have evaporated, dissolved, and degraded) thereby reducing the toxicity of the residual oil, patchy and discontinuous emulsified oil and tarballs. Surface oiling is predicted to occur to the areas to the east of BdN model domain at thicknesses >0.04 μm in areas beyond NAFO division 3LMN and in the surface waters surrounding the Azores. With the application of mitigation and response measures, it would further reduce potential for effects.

As noted, modelling predictions indicate that in the unlikely case of an unmitigated subsurface blowout, a small percentage of oil could reach the shorelines of NL special areas. As noted, since the predicted time for oil to make first contact ranged between 14 and 45 days, the oil would be highly weathered, patchy and discontinuous. The effects on special areas would be beyond the range of natural variability but it not predicted to have an associated adverse effect on the viability of the defining ecological and /or sociocultural features of the special area. Therefore, the magnitude is predicted to be medium.

These predictions are made with a moderate to high level of confidence based on scientific literature and the experience and professional judgement of the EIS Team. Geographic extent is based on spill trajectory modelling. Modelling is a predictive tool providing an estimate of the zone of influence hydrocarbon spills, therefore there is some uncertainty regarding the overall spatial extent of the movement of hydrocarbons in the water. Based on this uncertainty there is a moderate level of confidence in the prediction of geographic extent. With the application of mitigation and response measures, it would further reduce potential for effects

In summary, with spill prevention plans and response procedures in place, potential effects from a low probability subsurface potential effects of a subsurface blowout on Special Areas identified biological VCs are predicted to be adverse, medium in magnitude, medium-term in duration, within the RSA, not likely to occur and reversible. This was determined with a moderate to high level of confidence.

Special Areas Identified for Human Recreation and Tourism

Special areas include coastal areas such as Chance Cove Provincial Park and Gooseberry Cove Provincial Park, which are used for outdoor recreation including hiking, camping and sightseeing. Detailed information on effects of accidental events on Marine Fisheries and Other Ocean Uses is including in Section 16.7.8. This section focuses on use of those provincial parks. There is a extremely low probability, without mitigation that oil may contact with the shoreline or encroach into the coastal areas, resulting in a predicted negligible magnitude. In these low probability events, coastal and recreation and tourism may be affected, especially if the event occurred in the summer months. Potential effects on recreation and tourism activities may include closure of marine areas or limited use. The level of effects will depend on the volume of oil released, the time of year, and the implementation of the mitigation and response measures as discussed above. The issuance of communications will provide timely notice of affected areas for recreational users and tourists. With the implementation of shoreline protection measures potential effects would likely be reduced.

Based on modelling results in the CNOOC EIS (CNOOC 2018), it is predicted the highest probability of oil reaching the Azores where shoreline exceeded the 1 gm/2 was 70 and 77 percent (depending on scenario) in the summer months. The modelled 95th percentile representative deterministic shoreline scenario predicted a minimum time for oil to reach the Azores at was between 80 days and 111 days, depending on the spill site. Therefore, oil that is predicted to make shore would be highly weathered (i.e., lighter ends would have evaporated, dissolved, and degraded) thereby reducing the toxicity of the residual oil, patchy and discontinuous emulsified oil and tarballs. Surface oiling is predicted to occur to the areas to the east of BdN model domain at thicknesses >0.04 μm in areas beyond NAFO division 3LMN and in the surface waters surrounding the Azores. While the model predicts surface oiling above the socio-economic threshold (0.04 μm), mitigations as noted below would reduce the overall effects to commercial fisheries. Harvesting areas where the socio-economic threshold is exceeded may be closed by DFO or international bodies. The issuance of Navigational Warnings and other communications will provide timely notice of closure areas for fishers enabling them to make alternative plans (i.e., alter fishing locations), thereby likely reducing effects on commercial harvesting success. Avoidance will also reduce potential gear/vessel fouling and the likelihood of any tainted product from entering the marketplace. A compensation program, as outlined above, will be implemented. The application of these mitigations and response measures identified in Section 16.1.2 would reduce the magnitude, duration and geographical extent of the spill and therefore the magnitude and extent of potential effects on commercial fisheries.

In summary, with spill prevention plans and response procedures in place, potential effects of a subsurface blowout on Special Areas identified for recreational and tourism use are predicted to be adverse, negligible in magnitude, medium-term in duration, occurring within the RSA, and reversible. This was determined high level of confidence based on scientific literature, modelling predictions and the experience and professional judgement of the EIS Team.

Batch Spills and Vessel Collision

Modelling results of batch spills (surface and subsea loss of crude; surface loss of diesel) indicate that the size and persistence of the area where effects Special Areas may be expected are much smaller than for subsurface blowouts. None of the hydrocarbons released during modelled batch spill scenarios are predicted to reach shore.

Special Areas overlapping with areas exceeding unmitigated oil concentration thresholds for surface oil, water column or sediment include the Slopes of the Flemish Pass and Grand Bank UNCBD EBSA, and Northwest Flemish Pass (10) NAFO FCA. These areas are identified and/or protected for sensitive benthic habitat (Table 16.42). The EBSA potentially includes the presence of vulnerable fish species. Based on the modelling results for the larger of the batch spills (8,300 m^3 surface loss of crude oil), approximately 0.01 percent of the total released volume was predicted to remain on the sediments. Therefore, the potential for the sensitive benthic habitat to be exposed to oil resulting from a batch spill is negligible.

For the spill of marine diesel from a vessel to vessel collision nearshore, the release would likely result in a rainbow sheen (0.0001 to 0.001 mm) for approximately 40 km before transitioning to the colourless and silver sheen (less than 0.0001 mm). No shoreline contact was predicted. Two Canadian EBSAs (i.e., Eastern Avalon and Baccalieu Island) intersect with the surface oil exposure area with the vessel to vessel batch spill. The Eastern Avalon is identified as a feeding area for seabirds, cetaceans and leatherback turtles. Baccalieu Island has been identified for aggregations of killer whales, capelin, shrimp, plankpiscivores, spotted wolffish as well as seabirds. In-water concentrations of THC are predicted to be highest in the immediate vicinity of the release. The potential for exposure and the likelihood of adverse effects on marine and migratory bird habitat from a vessel collision diesel release are low. Only birds in the immediate vicinity near the surface at the time of the spill may be exposed, and at the concentrations predicted, and at the concentrations predicted, change in bird habitat availability and quality will likewise be of low magnitude and short-term in duration (Section 16.7.5.6). For marine mammals, animals in the immediate vicinity near the surface at the time of the spill may be exposed, and at the concentrations predicted, change in habitat availability and quality will be of negligible to low magnitude. While a batch spill would decrease water quality around the spill site, it would be short-term since the surface sheen evaporates and naturally disperses through surface wave action in the offshore environment.

In summary, with spill prevention plans and response procedures in place, there are no residual effects from a batch spill on Special Areas, with the exception of the vessel to vessel batch spill. The potential residual effects of a vessel-vessel batch spill on Special Areas are predicted to be adverse, negligible to low in magnitude, short term in duration, within the RSA, not likely to occur and reversible. This was determined with a moderate to high level of confidence based on confidence levels noted for the Marine and Migratory Birds and Marine Mammals and Sea Turtles VCs.

SBM Whole Mud Spill

As discussed in Section 16.7.4.6, the results of modelling suggest that if SBM were to be released at these sites, there is the potential for seabed deposition. For a surface loss of SBM, deposition thickness of 0.1 mm was approximately 550 m for the shallower Site 2 and approximately 1,500 m for the deeper water Site 1 Accidental SBM discharges from subsea releases are predicted to result in a maximum deposition thickness between 10 mm and 49.3 mm. Potential burial effects (above 1.5 mm and 6.5 mm thresholds) would occur between 200 m to 220 m of the release site. In addition, there is potential for water column concentrations to exceed 10,000 mg/L within 10 m of spill locations. The following special areas are located within the relevant area of measurable seabed deposition and water column concentrations exceeding the identified threshold.

- UNCBD EBSA: Slopes of the Flemish Cap and Grand Bank
- NAFO FCAs: Sackville Spur (6), Northwest Flemish Cap (10)
- VME: Sponge and Sea Pen

These special areas have all been identified and/or protected due to the presence of high densities or corals and/or sponges. The effects of an SBM spill on Fish and Fish Habitat assessed in Section 16.7.4.6, would be the same for Special Areas, since the modelling for the SBM spill used a location within the NAFO FCA Northwest Flemish Cap (10).

In summary, with spill prevention plans and response procedures in place, the potential effects of accidental SBM discharges on Special Areas are predicted to be adverse, low in magnitude, short-term in duration, localized, not likely to occur to sporadically occurring (depending on size of spill), and reversible. This was determined with a high level of confidence based on scientific literature and the experience and professional judgement of the EIS Team.

16.7.7.4 Summary

Table 16.43 provides a summary of predicted residual environmental effects of accidental event scenarios on Special Areas. These summaries are based on the conservative approach that was used for the spill modelling and the implementation of mitigation measures to prevent and reduce effects from a spill.

Table 16.43 Summary of Residual Accidental Event-Related Environmental Effects on Special Areas

Accidental Event Scenario	Residual Environmental Effects Characterization						
	Nature	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Confidence**
Potential Effects: Change in environmental features and/or processes; Change in human use and/or societal value							
Site 1 - 36-Day Subsurface Blowout - 10,500 m³/d	A	M	RSA	M	N	R	M-H
Site 1 - 115-Day Subsurface Blowout - 10,500 m³/d	A	M	RSA	M	N	R	M-H
Site 2 - 36-Day Subsurface Blowout - 10,500 m³/d	A	M	RSA	M	N	R	M-H
Site 2 - 115-day Subsurface Blowout - 10,500 m³/d	A	M	RSA	M	N	R	M-H
FPSO Surface Release - 8,300 m³	N	N/A	N/A	N/A	N/A	N/A	H
Offloading Surface Release - 1,000 m³	N	N/A	N/A	N/A	N/A	N/A	H
Bunkering Surface Release - 6 m³	N	N/A	N/A	N/A	N/A	N/A	H
Production Flowline Subsurface Release - 500 m³	N	N/A	N/A	N/A	N/A	N/A	H
Vessel/vessel collision - 750 m³	A	N-L	RSA	S	N	R	M-H
Site 1 - SBM Whole Mud Spill - 60 m³ surface spill	A	L	L	S	S	R	H
Site 1 - SBM Whole Mud Spill - 275 m³ flex joint failure subsurface release	A	L	L	S	N	R	H
Site 1 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release	A	L	L	S	N	R	H
Site 2 - SBM Whole Mud Spill - 60 m³ surface spill	A	L	L	S	S	R	H
Site 2 - SBM Whole Mud Spill - 275m³ flex joint failure subsurface release	A	L	L	S	N	R	H

Table 16.43 Summary of Residual Accidental Event-Related Environmental Effects on Special Areas

Accidental Event Scenario	Residual Environmental Effects Characterization						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Confidence
Site 2 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release	A	L	L	S	N	R	H

KEY

Nature / Direction of Effect:
P Positive
A Adverse
N Neutral (or No Effect)

Magnitude of Effect:
N Negligible
L Low
M Medium
H High

Geographic Extent of Effect:
Less 1 km²
Less than 10 km²
Less than 100 km²
Less than 1,000 km²
Less than 10,000 km²
Greater than 10,000 km²

Duration:
S Short-Term - less than 12 months (1 year)
M Medium-term - 1 to 5 years
L Long-term - more than 5 years

Frequency of Effect:
N Not likely to occur
O Occurs once
S Occurs sporadically
R Occurs on a regular basis
C Occurs continuously

Reversibility:
R Reversible (will recover to baseline)
I Irreversible (permanent)

Confidence Level in Predictions:
L Low level of confidence
M Moderate level of confidence
H High level of confidence

N/A Not Applicable

16.7.7.5 Determination of Significance

It is predicted that accidental events associated with the Project will not result in significant residual adverse effects on Special Areas.

In the unlikely event of a subsurface blowout, some degree of residual adverse effects to the defining features of special areas that are within or near the zone of influence of the spill are expected. The degree of exposure and thus the type and level of any such effects would depend on the type and size of spill, time of year, the location relative to special areas (especially those that include important marine bird habitats) and other factors such as the numbers and types of species present during such an event.

For the extremely unlikely subsurface blowout scenarios, residual environmental effects are predicted to be not significant as there would not be a change in key characteristics and processes for which a special area is defined and valued by society. While there is the potential for effects on these special areas and their associated features, these effects are not likely to occur. Spill prevention techniques and response strategies will be incorporated into the design and operations for all Project activities as part of contingency planning, which will further help to ensure that effects do not occur, and in the unlikely event they did, that these would not have significant adverse effects on Special Areas.

16.7.8 Commercial Fisheries and Other Ocean Uses - Accidental Events Effects Assessment

16.7.8.1 Introduction

Commercial fishing activity for a variety of different species occurs within the RSA year-round in offshore NL and is most active during the summer months.

As discussed in Section 7.1, there is limited to no fishing within the Core BdN Development Area. In the unlikely occurrence of an accidental event, fisheries that could be affected would be those in the Project Area and some of those active within the RSA at the time of a spill. RSA fisheries that are not in the Project Area, that also may be affected by accidental events include the deep-sea clam fishery (southern 3L and 3N), small pelagic species fisheries (capelin and herring – nearshore and coastal bays), lobster (nearshore) and sealing. There are also aquaculture sites within coastal areas of the RSA, the closest currently being more than 400 km away from the Project Area. Based on the most recent information (DFLR 2018) there is currently one aquaculture site within the defined RSA. Recreational groundfish fisheries occur at designated times during the summer and fall, typically in nearshore areas and bays within the RSA.

16.7.8.2 Potential Issues and Interactions

The potential environmental effects on Commercial Fisheries and Other Ocean Uses used in the effects of routine activities (Chapter 14) were:

- Direct interference with fishing activity and other marine activities, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses
- Damage to fishing gear, vessels and other existing subsea infrastructure and associated loss of catch for harvesters
- Change in the abundance, distribution and quality of marine resources, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses

These potential effects are relevant to the assessment of accidental events, although the mechanisms or pathways of effects may be different. In the case of an accidental event such as a subsurface blowout or batch spill, the effects from any actual event would depend on the interaction of several factors, such as the location of the release, the duration of the release, the quantity and type of hydrocarbons released, the time of year, the timing and location of fisheries and other marine activities, and the prevailing environmental conditions at the time. These factors together would determine the magnitude and extent of any effects on fisheries.

As described in Section 16.4, the socioeconomic threshold used in the modelling scenarios is 0.04 g/m^2, or 0.04 µm, which would appear as a barely visible or scattered sheen (colorless or silvery/grey), or widely scattered patches of thicker oil. In terms of oil making contact with shorelines, 1.0 g/m² is considered a conservative socioeconomic threshold.

Effects of Hydrocarbon Spills on Commercial Fisheries and Other Ocean Uses

Depending on the size, nature and timing of the subsurface blowout, regulatory authorities may issue temporary closures of fish harvesting in the immediate vicinity of the spill. There is a potential for actual or perceived fish taint from a spill and this may affect marketability of affected commercial species. With respect to commercial fishing, these closures could translate into direct economic effects associated with a delay or cessation of fishing until the area reopens or movement to other fishing grounds that may be available, delaying harvesters' fishing schedules (European Union Parliament 2013). For example, after the DWH spill in 2010, short-term losses in the Gulf of Mexico included the closure of approximately 207,200 km² (80,000 square miles) of the United States EEZ to fishing activity (DFO 2013). The magnitude of these Project-related effects for the Project would depend on the size of area closed to commercial fishing, time of year, and the length of closure time. With respect to other ocean uses, the opportunity for and/or the quality of marine research could be affected through closure of survey areas, fouling research gear or vessels, or contaminating research results because of the presence of hydrocarbons on surface water or in the water column. Offshore training exercises such as military training activities could also be affected if areas are closed. Other marine traffic might also avoid affected areas.

Damage to fishing vessels and gear could result from fouling from contact with oil, which may then affect the quality of harvest for commercial fishers or cause them to stop fishing. Fouling could also affect commercial fish harvests and have direct economic effects on their operations if a spill ceases or delays fishing operations for a period of time (IPIECA 1997).

Consumer perceptions of, and confidence in, product quality may affect the price paid to harvesters and within the consumer marketplace (ITOPF 2004, 2014; IPIECA 1997; Cariglia 2017), or it may close markets altogether, for a time, if catches are tainted or otherwise deemed unfit (IPIECA 1997; Amec 2014; Cariglia 2017). Tainting occurs when fish species are exposed to hydrocarbons and absorb oil-derived substances into their tissues, which can cause unpleasant odours and flavours. Taint is usually removed through the normal processes of metabolism in fish species, and chemical analysis and sensory testing are usually conducted before a species is declared safe to consume. Even if an oil spill does not reach particular commercial fishing grounds and fish species are determined not to be tainted, accidental events can affect consumer perceptions of fish harvested in the surrounding area, potentially reducing market value of the product and subsequent economic returns. Market confidence, consumer behaviour, and resulting effects based on perceptions of products are difficult to predict and may only be measured after an event occurs (ITOPF 2014).

Although there are no aquaculture operations near the Project Area and only one within the RSA, if a spill were to reach the shoreline, effects on these operations could also occur (e.g., biophysical effects, equipment/facility fouling, public perception of taint). This could result in similar economic effects on aquaculture as on inshore commercial fisheries, with the exception that, unlike wild fisheries, there is no possibility to relocate business activities away from an affected area in the short or medium-term. Recreational fishing activities might be similarly restricted in affected areas until remediation is sufficiently complete. Depending on the time of year of an event, seal harvesting activities might be affected but likely to a lesser potential extent as they occur on marine ice flows building from the northwest.

Effects of Dispersants on Commercial Fisheries and Other Ocean Uses

As noted in Section 16.7.4, the use of chemical dispersants has the potential to affect fish and therefore, has the potential to indirectly affect commercial fisheries.

After the DWH spill, the USFDA conducted laboratory tests on the effects of a commonly used dispersant on Eastern oyster, blue crab, and red snapper and found little to no bioaccumulation; the dispersant was depurated from the organisms' tissues with 24 to 72 hours (Tjeerdema et al. 2013). Seafood species collected during the DWH spill detected dioctylsulfosuccinate sodium salt, a highly water-soluble component of dispersants, in 4 of 299 tissue samples and determined that it was unlikely to pose a risk to aquatic receptors due to low tissue concentrations, low bioaccumulation, and rapid depuration (Tjeerdema et al. 2013). It is anticipated that most free-swimming fish may be able to avoid interactions from a hydrocarbon release; however, if oil managed to reach the seafloor, some demersal, slow moving, or sessile organisms such as deep-sea clams or lobster could be exposed to hydrocarbons.

As assessed in Section 16.7.4, with the implementation of mitigation measures, it is not anticipated that there would be a long-term exposure of fish to hydrocarbons either at the surface or within the water column. Active fishing would not be expected to occur in areas where spill response activities were occurring and would this would allow time for exposed commercial species to recover.

Effects of Whole SBM on Commercial Fisheries and Other Ocean Uses

The possible effects of SBM on commercial fish are discussed in Section 16.7.4. With respect to surface oiling and in-water THC concentrations, SBMs, are a heavy, dense fluid which sinks rapidly so the effects on the water's surface and water column would be very limited compared to other hydrocarbon spills discussed above.

16.7.8.3 Residual Environmental Effects Assessment and Evaluation

The potential residual environmental effects of an oil spill, that is, the effects remaining after the implementation of emergency response measures and mitigations (see Section 16.1), should it occur, are assessed in the following sections. The assessment is conservative as it assumes there will be a temporal and spatial overlap.

A subsurface blowout, in comparison to a batch spill, is the scenario with greatest potential to interact with the Commercial Fisheries and Other Ocean Uses VC and therefore this assessment focuses on the potential interactions and effects from a subsurface blowout.

In addition to the mitigation and response measures detailed in Section 16.1, Equinor Canada will develop and implement a compensation program for damages resulting from Project activities. This compensation program will be developed in consideration of the C-NLOPB Compensation Guidelines Respecting Damages Relating to Offshore Petroleum Activities (2017) and will be aligned with the Best Practices Document for Compensation Processes and Procedures that One Ocean is currently preparing. This plan will outline compensation procedures for actual loss or damages to commercial fisheries, including commercial-communal fishers, attributable to the operator. Losses and damages include loss of income, future loss of income and, with respect to any Indigenous peoples of Canada, loss of harvesting, fishing, and gathering opportunities. Requirements from the C-NLOPB include the ability of an operator to demonstrate the financial resources to meet a liability obligation of $1 billion relating to damages, and to pay a deposit of $100 million for financial responsibility if an accidental event occurred. Equinor Canada will also provide timely issuance of Notices to Shipping if an accidental event that has occurred including the associated coordinates and undertake early and ongoing communication with commercial fishers and other industry stakeholders within the RSA.

Subsurface Blowout

The likelihood, magnitude, geographic extent and duration of potential effects of a subsurface blowout and its interaction with the Commercial Fisheries and other Ocean Uses VC will depend on the nature of the spill and its trajectory.

In the selected 95th percentile scenario for surface oil exposure releases, surface oil was predicted to be thickest closest to the release location. Maximum thicknesses corresponded to a visual appearance of black oil within a few kilometres of the release site with the majority of footprints predicted to have a maximum thickness closer in appearance to dark brown to dull brown sheens (0.01 to 0.1 mm). Considering the predicated spatial extent of surface oiling, fishing activities likely to be affected by a subsurface blowout include those being carried out in the NAFO NRA, particularly in the Sackville Spur, the Nose of the Grand Bands and the Flemish Cap. Year-round groundfish otter trawling, spring and summer snow crab harvesting and large pelagic longlining in these areas could be affected. In the eastern portions of the RSA, which is outside the NRA, little or no harvesting is known to occur. In the northwest areas of the RSA, in NAFO Divisions 2J and 3K, groundfish gillnetting (mainly Greenland halibut/turbot) is common during the spring through autumn periods, as is domestic groundfish and shrimp trawling potentially year-round. To the south in Division 3N, foreign and domestic groundfish harvesting may occur year-round, as does snow crab harvesting year in the summer. This area is also the primary location, along with southern Division 3L, for deep-sea clam harvesting. To the west of the Project Area and generally through many parts of the Grand Banks snow crab fishing predominates during the spring and summer. Science surveys within the RSA, and other marine activities, as with the fisheries described above may be affected, depending on the timing of activities in relation to a spill event.

Modelling results from the 95th percentile scenario for in-water exposure indicate that concentrations of dissolved and total hydrocarbons are predicted to be highest around the release site, including the Flemish Pass and the Flemish Cap. Oil concentrations are expected to dissipated as it is transported away from the release location through mixing within the water column, evaporation from the water surface, volatilization from the water column, and degradation, thus reducing the total amount of contaminants present (RPS 2018).

Less than one percent of total oil released was predicted to make contact with shoreline and most of the oil that was predicted to make contact occurred on the Avalon Peninsula and localized areas of the Burin Peninsula. Since the time for oil to make first contact range between 14 and 45 days, the oil would be highly weathered, patchy and discontinuous (RPS 2018). If oil were to make contact with shoreline or encroach into the coastal areas, coastal and nearshore fisheries may be affected. Lobster harvesting, recreational fishing and marine tourism may be affected, if the event occurred in the summer months or effects continued into those months. The only aquaculture operation within the RSA is in Trinity Bay and oil is not predicted to extend to this area; therefore, there will be no effect on aquaculture operations. As the potential for oil contacting the shoreline is low, and with the application of shoreline and nearshore response measures, it is unlikely that the nearshore fisheries or recreational activities would be affected.

Based on modelling results in the CNOOC EIS (CNOOC 2018), it is predicted the highest probability of oil reaching the Azores where shoreline exceeded the 1 gm/2 was 70 and 77 percent (depending on scenario) in the summer months. The modelled 95th percentile representative deterministic shoreline scenario predicted a minimum time for oil to reach the Azores at was between 80 days and 111 days, depending on the spill site. Therefore, oil that is predicted to make shore would be highly weathered (i.e., lighter ends would have evaporated, dissolved, and degraded) thereby reducing the toxicity of the residual oil, patchy and discontinuous emulsified oil and tarballs. Surface oiling is predicted to occur to the areas to the east of BdN model domain at thicknesses >0.04 µm in areas beyond NAFO division 3LMN and in the surface waters surrounding the Azores. With the application of mitigations and response measures as noted above, it would further reduce potential for effects.

While the model predicts surface oiling above the socio-economic threshold (0.04 µm), mitigations as noted below would reduce the overall effects to commercial fisheries. Harvesting areas where the socio-economic threshold is exceeded may be closed by DFO. The issuance of Navigational Warnings and other communications will provide timely notice of closure areas for fishers enabling them to make alternative plans (i.e., alter fishing locations), thereby likely reducing effects on commercial harvesting success. Avoidance will also reduce potential gear/vessel fouling and the likelihood of any tainted product entering the marketplace. A compensation program, as outlined above, will be implemented. The application of these mitigations and response measures identified in Section 16.1.2 would reduce the magnitude, duration and geographical extent of the spill and therefore the magnitude and extent of potential effects on commercial fisheries.

In the unlikely event of a subsurface blowout it is predicted that there will not be an effect on fish and fish habitat that would affect the viability of a population and there will be Navigational Warnings that would allow for avoidance of spills. Therefore, it is predicted that there will be a change in the distribution, intensity, function and/or value of Fisheries and Other Ocean Uses that is within the range of natural variability, with no associated adverse effect, or a low magnitude. These predictions are made with a high level of confidence based on historical fishing activity, scientific literature, and the experience and professional judgement of the EIS Team.

In summary, with spill prevention plans, response procedures and mitigation measures in place, the residual effects of a subsurface blowout on Commercial Fisheries and Other Ocean Uses are predicted to be adverse, low in magnitude, medium-term in duration, occur within the RSA, not likely to occur and reversible in nature. These predictions are made with a high level of confidence.

Batch Spills and Vessel Collision

As summarized in Section 16.7.3, modelling results of batch spills (surface and subsea loss of crude, surface loss of diesel, surface and subsea loss of SBM) indicate that the size and persistence of the area where effects may occur on marine species and commercial fisheries are much smaller than for subsurface blowouts. For crude batch spills, the maximum extent of surface oiling was predicted to extend approximately 375 km from the spill location during the worst-case environmental conditions for surface oiling (i.e., calmest wind-speed period during the summer/ice-free conditions, which would result in the largest amount of oil on the water surface). Surface releases of diesel were predicted to be confined to the areas near the release location. In all cases, it was predicted that hydrocarbons would not make contact with the shore. The probability of batch spills ranges from one in 46 (spills less than 159 litres) to one in 75,000 (spills greater than 1,590 m^3).

The modelled diesel batch of 6 m^3, cumulative surface oiling was to result in a patchy distribution of colourless or silver sheens of oil (less than 0.0001 mm) close to the release location, therefore there would be no effect on commercial fisheries. For the modelled spill of marine diesel from a vessel to vessel collision nearshore, the release would likely result in a rainbow sheen (0.0001-0.001 mm) for approximately 40 km before transitioning to the colourless and silver sheen (less than 0.0001 mm). No shoreline contact was predicted. In-water concentrations of THC are predicted to be highest in the immediate vicinity of the release location. Commercial fisheries and other ocean uses potentially affected by a spill from a vessel collision would depend on the timing of the spill and may affect snow crab harvesting and gillnetting (closer to shore), and recreational fisheries, especially if it occurred during summer months.

The geographic extent of these batch spills and their effects would be relatively localized to the spill location in comparison to the blowout scenarios. Depending on the size, nature and timing of the batch spill, regulatory authorities may issue temporary closures of fish harvesting in the immediate vicinity of the spill. Historically, this is typically implemented for significant batch spills. The fisheries and marine areas most likely to be affected by these batch spills are groundfish harvesting to the north and east (all months) and snow crab harvesting to the south, around the Nose of the Grand Banks spring and summer). Other harvesting in the areas affected might include large pelagic fisheries (e.g., for sharks or swordfish).

There is a potential for actual or perceived fish tainting from a spill and this may affect market conditions. With the implementation of response and mitigation measures, the geographic extent of a batch spill would be reduced. A change in the distribution or quality of marine resources, including commercial fish species, is considered unlikely, given that the oceanic conditions and mitigation measures would likely result in the spill being contained to a smaller area and for a shorter period of time.

In the event of a batch spill it is predicted that there will not be an effect on fish and fish habitat that would affect the viability of a population and there will be Navigational Warnings that would allow for avoidance of spills. These spills will be localized to the area of the source. Therefore, it is predicted that there will be a change in the distribution, intensity, function and/or value of Fisheries and Other Ocean Uses that is within the range of natural variability, with no associated adverse effect on fisheries, or a low magnitude. These predictions are made with a high level of confidence based on historical fishing activity, scientific literature, and the experience and professional judgement of the EIS Team.

With spill prevention plans and mitigations measures in place, potential effects of batch spill on Commercial Fisheries and Other Ocean Uses are predicted to be adverse, negligible to low in magnitude, short-term in duration, within the LSA (with the exception of a vessel collision, which might occur within RSA), not likely to occur and reversible. These predictions are made with a high level of confidence.

SBM Whole Mud Spill

The effects on commercial fish harvesting and other marine activities would be similar in nature to a small batch spill as described above in this section, except that SBMs are denser and would quickly sink to the seafloor. Any effects on harvesting opportunities would therefore be minimal, and the main issue would likely be market concerns about potential tainting. For other ocean uses, no effects would be expected

For batch spills of SBM, either surface or subsurface releases, the maximum extent of SBM deposition on the seafloor was 320 m for the shallower site and approximately 1,500 m for the deeper site. In-water concentrations of SBM were confined to within 400 m of the spill location. Sections 16.7.4 discuss potential effects of a of an accidental spill of SBMs on fish and fish habitat, concluding that effects are expected to be localized and low to medium in magnitude. Considering the relatively low levels of commercial harvesting typically conducted within the Project Area (particularly within in the Core BdN Development Area, Site 1), the availability of nearby alternative fishing grounds and transit routes, and with spill prevention plans and response procedures in place, the potential effects of a SBM spill on Commercial Fisheries and Other Ocean Uses are predicted to be adverse, negligible in magnitude, short-term in duration, localized, not likely to occur to sporadically occurring and reversible. These predictions are made with a high level of confidence based on historical fishing activity, scientific literature, and the experience and professional judgement of the EIS Team.

16.7.8.4 Summary

Table 16.44 provides a summary of predicted residual environmental effects of accidental event scenarios on the Marine Fisheries and Other Ocean Uses, with the implementation of mitigation and other response measures to prevent, reduce and compensate for effects from accidental events, as considered above.

Table 16.44 Summary of Residual Accidental Event-Related Environmental Effects on Commercial Fisheries and Other Ocean Uses

Accidental Event Scenario	Residual Environmental Effects Characterization						
	Nature	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Confidence**
Potential Effects: • Direct interference with fishing activity and other marine activities, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses • Damage to fishing gear, vessels and other existing subsea infrastructure and associated loss of catch for harvesters • Change in the abundance, distribution and quality of marine resources, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses							
Site 1 - 36-Day Subsurface Blowout - 10,500 m³/d	A	L	RSA	M	N	R	H
Site 1 - 115-Day Subsurface Blowout - 10,500 m³/d	A	L	RSA	M	N	R	H
Site 2 - 36-Day Subsurface Blowout - 10,500 m³/d	A	L	RSA	M	N	R	H
Site 2 - 115-Day Subsurface Blowout - 10,500 m³/d	A	L	RSA	M	N	R	H
FPSO Surface Release - 8,300 m³	A	L	RSA	S	N	R	H
Offloading Surface Release - 1,000 m³	A	L	L	S	N	R	H
Production Flowline Subsurface Release - 500 m³	A	N	LSA	S	N	R	H
Bunkering Surface Release - 6 m³	N	N/A	N/A	N/A	N/A	N/A	N/A
Vessel/vessel collision - 750 m³	A	L	RSA	S	N	R	H
Site 1 - SBM Whole Mud Spill - 60 m³ surface spill	A	N	L	S	S	R	H
Site 1 - SBM Whole Mud Spill - 275 m³ flex joint failure subsurface release	A	N	L	S	N	R	H
Site 1 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release	A	N	L	S	N	R	H
Site 2 - SBM Whole Mud Spill - 60 m³ surface spill	A	N	L	S	S	R	H
Site 2 - SBM Whole Mud Spill - 275m³ flex joint failure subsurface release	A	N	L	S	N	R	H
Site 2 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release	A	N	L	S	N	R	H

Table 16.44 Summary of Residual Accidental Event-Related Environmental Effects on Commercial Fisheries and Other Ocean Uses

Accidental Event Scenario	Residual Environmental Effects Characterization						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Confidence

KEY

Nature / Direction of Effect:
P Positive
A Adverse
N Neutral (or No Effect)

Magnitude of Effect:
N Negligible
L Low
M Medium
H High

Geographic Extent of Effect:
Less 1 km²
Less than 10 km²
Less than 100 km²
Less than 1,000 km²
Less than 10,000 km²
Greater than 10,000 km²

Duration:
S Short-Term - less than 12 months (1 year)
M Medium-term - 1 to 5 years
L Long-term - more than 5 years

Frequency of Effect:
N Not likely to occur
O Occurs once
S Occurs sporadically
R Occurs on a regular basis
C Occurs continuously

Reversibility:
R Reversible (will recover to baseline)
I Irreversible (permanent)

Confidence Level in Predictions:
L Low level of confidence
M Moderate level of confidence
H High level of confidence

N/A Not Applicable

16.7.8.5 Determination of Significance

In consideration of the present knowledge of commercial fishery and other marine in the RSA, the result of spill modelling exercises, and planned spill response and mitigation measures, it is predicted that accidental events associated with Project will not result in significant residual adverse effects on Commercial Fisheries and Other Ocean Uses.

Not only is subsurface blowout extremely unlikely, but its extent and duration will be reduced through response measures and affected fishers will be compensated in consideration of the C-NLOPB Compensation Guidelines Respecting Damages relating to Offshore Petroleum Activities, including compensation for lost and future lost income from an accidental event. Spill prevention techniques and response strategies will be incorporated into the design and operations for all Project activities as part of contingency planning, which will further help to ensure that effects do not occur, and in the unlikely event they did, that these would not result in significant adverse effects on Commercial Fisheries and Other Ocean Uses.

16.7.9 Indigenous Peoples - Accidental Events Effects Assessment

As described in Section 7.3, Equinor Canada has engaged with 41 Indigenous groups residing in Eastern Canada, including communities in NL, the Maritime provinces, and Quebec. The environmental effects assessment for the Project's components and activities has predicted no significant residual adverse effects on Indigenous Peoples (Chapter 13). Indigenous groups have expressed concerns regarding effects from accidental events on their interests and activities (Chapter 3). These concerns include, but are not limited to, adverse effects on the marine ecosystem, including fish and fish habitat, marine mammals and marine and migratory birds and associated effects on commercial-communal fishing activities as well as the current use of lands and resources for traditional purposes. Effects upon commercial-communal fisheries or on the current use of lands and resources could potentially result in effects upon Indigenous health and well being, socio-economic conditions, and cultural heritage. The extent of the potential effects depends on how the spill trajectory and various components of this VC overlap spatially and temporally.

16.7.9.1 Potential Issues and Interactions

The potential environmental effects on Indigenous Peoples used in the assessment of routine Project activities (Chapter 13) were specified in and required under CEAA 2012 section 5(1)(c). Of the matters referred to in section 5(1)(c), potential interactions with the Indigenous Peoples VC were identified in relation to:

- Change in commercial-communal fisheries
- Change in current use of lands and resources for traditional purposes

These potential effects remain relevant to the assessment of accidental events, although the mechanisms or pathways of effects may be different. While the assessment of routine Project activities concluded that there would be no potential for interaction with sites, structures or things of historical, archaeological, paleontological or architectural significance or for direct effects upon physical or cultural heritage or health and socio-economic conditions, these matters will also be considered in the assessment of accidental events.

The potential effects resulting from accidental events of offshore oil and gas activities on Indigenous Peoples may be direct or indirect in nature. An effect on species fished for traditional or commercial-communal purposes, a change in the marine habitat fished by Indigenous people, and/or area closures could affect the use of marine waters and resources. These effects could also potentially affect the economic, social, spiritual, and cultural value of the fishery to Indigenous groups.

As with non-Indigenous commercial fishers, accidental events could potentially directly affect fisheries and/or fishing activity (displacement from fishing areas, gear loss or damage, economic loss) that could result in an adverse effect upon the socioeconomic value of the commercial-communal fisheries. For some Indigenous communities, commercial-communal fishing activities are an important source of revenue generation; therefore, indirect socio-economic impacts are also qualitatively considered in this assessment. Although there is no current use of lands and resources for traditional purposes occurring in the LSA, accidental events could also result in effects on marine species used for traditional purposes that could potentially be migrating through or otherwise using the area within the zone of influence of the spill. Indirect impacts on the economic, social, spiritual, and cultural values associated with the current use of lands and resources for traditional purposes are therefore also considered in this assessment.

Indirectly, biophysical effects resulting from an accidental event such as an oil spill on marine fish or other resources that are used for traditional purposes could also potentially affect the physical health of human beings, through either direct exposure to contaminants or through consumption of affected fish and wildlife (see Section 15.5.6.2 for a discussion of potential effects related to tainting). These biophysical effects may also have consequences for the availability or quality of the marine resources (vegetation, fish, birds or marine mammals) used or harvested by Indigenous people, thereby potentially affecting the culture, quality of life and well-being of a community. There is also potential for an accidental event to create the perception of tainting on species harvested for commercial or traditional purposes. This perception may affect the marketability of species or restrict consumption of traditional foods, resulting in effects to the socio-economic conditions and mental and physical health and spiritual well-being of Indigenous peoples.

Section 16.7.4 describes potential environmental effects on marine fish and fish habitat, Section 16.7.5 describes potential effects on marine and migratory birds, Section 16.7.6 describes potential environmental effects on marine mammals and sea turtles, and Section 16.7.7 describes the potential environmental effects of the various spill scenarios on marine fisheries and other ocean uses. These sections help inform how the accidental release of hydrocarbons to the marine environment may adversely affect Indigenous groups, activities and communities.

16.7.9.2 Fish Species Used by Indigenous Groups

As described in Chapter 3, several fish species have been identified through Equinor Canada's Indigenous engagement program as being of cultural or economic importance to Indigenous groups (see Section 3.3.1.2) including Atlantic salmon, Atlantic cod, turbot / Greenland halibut, snow crab, American eel and swordfish. Table 16.45, as previously provided in Section 7.3.8.2, provides a list of fish species used by Indigenous groups. Additional species of importance are listed in the Desktop Indigenous Knowledge Study (Appendix H).

Table 16.45 Marine-Associated Species Used by Indigenous Groups

Group	Identified Species	
Newfoundland and Labrador		
Nunatsiavut Government	• Atlantic salmon • Arctic Char • Capelin • Cod • Mussels • Sea urchins • Sculpins • Snow crab	• Harbour seals • Ringed seals • Black ducks • Canada goose • Eider ducks • Loons • Murres • Mergansers

Table 16.45 Marine-Associated Species Used by Indigenous Groups

Group	Identified Species
Nunatsiavut Government	• Trout • Turbot • Winkles • Bearded seals • Grey seals • Sea ducks • Scoters • North Atlantic right whale
Innu Nation	• Atlantic salmon • Arctic char • Trout • American black duck • Black scoter • Blue-winged teal • Canada goose • Common loon • Eider duck • Harlequin duck • Long-tailed duck • Merganser • Murres • Northern pintail • Surf scoter
NunatuKavut Community Council	• Atlantic salmon • Arctic Char • Cod • Herring • Scallop • Trout • Whelk • Seals • Murres • Migratory birds (e.g., ducks and geese
Miapuwkek Mi'kamawey Mawi'omi	• Atlantic salmon • American eel • Atlantic cod • Crab • Herring • Lobster • Mackerel • Rainbow Trout • Redfish • Scallop • Harp seals • Grey seals
Qalipu Mi'kmaq First Nation	• Atlantic salmon • American eel • Pelagic fish • Groundfish • Trout • Shellfish • Seals • Migratory birds
Nova Scotia	
Not group specific	• Atlantic salmon • American eel • Blue shark • Blueback herring • Catfish • Capelin • Clams (e.g., bar, razor, soft-shell) • Cod • Crab • Flounder • Gaspereau • Groundfish • Haddock • Halibut • Herring • Lobster • Mackerel • Mussels • Oysters • Periwinkles • Perch • Pollock • Quahaug • Sea run trout • Sea urchins • Scallop • Shad • Squid • Tomcod • White sucker fish • Seals

Table 16.45 Marine-Associated Species Used by Indigenous Groups

Group	Identified Species
Prince Edward Island	
Not group specific	• Atlantic salmon • American eel • Clams • Gaspereau • Groundfish • Herring • Lobster • Mackerel • Mussels • Oysters • Quahaug • Rock crab • Scallops • Silversides • Toad crab • Seals
New Brunswick	
Not group specific	• Atlantic salmon • American eel • Alewives • Catfish • Chub • Clams • Gaspereau • Groundfish • Herring • Lamprey • Lobster • Mackerel • Mussels • Oysters • Perch • Quahaug • Rock crab • Scallops • Shad • Sturgeon • Sunfish • Seals • Right whale
Québec	
Not group specific	• Atlantic salmon • American eel • Cod • Crab • Herring • Lobster • Mackerel • Scallops • Shellfish • Waterfowl (e.g., ducks, geese and black guillemot) • Migratory birds and eggs (unspecified) • Seals

16.7.9.3 Effects of Hydrocarbons on Fish Species Used by Indigenous Groups

Additional information related to the potential effects of an unmitigated oil spill on these species is provided here.

As discussed in Section 6.1.9, Atlantic salmon and American eel have potential to migrate through the Project Area/LSA. Given the available data, there is likely low interaction with spring migration of adult salmon within and near the Project Area for the insular Newfoundland populations, Gulf of St. Lawrence populations, and eastern-southern Nova Scotia and Outer Bay of Fundy Populations. Since post-smolt and adult salmon from Labrador and Nunavik Populations generally feed and overwinter in the Labrador Sea, interaction of these populations with the Project Area would be considered negligible. Overwintering habitat for the iBoF is suggested to be off the Scotian shelf or the southern portion of the Gulf of Maine, therefore interaction with the Project Area does not occur.

In the spring, both grilse and multi-sea-winter (MSW) adults appear to congregate in two general locations; near the eastern slope of the Grand Bank of Newfoundland and approximately 480 km east of the Strait of Belle Isle (Reddin and Friedland 1993; Reddin 2006) prior to their spawning migrations back to their natal rivers. Migration routes from the overwintering areas to the east Grand Bank are not known and may include areas within and/or near the Project Area, particularly during time periods when sea-surface temperatures are favourable (over 4°C).

The effects of oil exposure on marine fish, including salmon, have principally been determined using laboratory studies with farm raised fish or caged fish that are unable to avoid oil exposure (e.g., Barnett and Toews 1977; Thomas and Rice 1987; Fraser 1992; Pineiro et al 1996; Zhou et al 1997; Stagg et al 1998; Meador et al 2006; Stieglitz et al 2016). Many of these studies showed effects on feeding, food conversion, or changes in enzyme levels based on exposure; however, returns to baseline were generally noted in 2-8 weeks (Fraser 1992; Stagg et al. 1998). It is noteworthy that many of the concentrations used in lab studies were high compared to the results of subsurface blowout modelling described above. For example, Stagg et al (1998) investigated the effects of the Braer oil spill on the Shetland Isles, Scotland. They characterized reference sites in the north of Shetland as having oil in water concentrations between 2 and 5 µg/L and regarded these as being typical background values for the local inshore environment. No effects on farmed salmon enzyme and protein levels were detected at these concentrations. Barnett and Toews (1977) observed no mortality in post-smolt Atlantic salmon during 96-hour acute lethal bioassays with concentrations up to 32 mg/L.

Few studies have been conducted on the avoidance behaviour of returning adult salmon to hydrocarbons in water under natural conditions. Weber et al (1981) conducted a behavioural study on adult Pacific salmon where hydrocarbons that closely approximated the water-soluble fraction of Prudhoe Bay crude oil were added in one of two fishways as salmon were migrating upriver. They found that migrating salmon substantially avoided (i.e., when 50 percent of fish which were expected to ascend a fishway avoided it) hydrocarbons in the water at concentrations of 3,200 µg/L. Concentrations used in the study ranged from 300 to 6,100 µg/L.

American eels are occasionally present in the LSA and RSA as adults migrate from coastal areas to the Sargasso Sea (Scott and Scott 1988). Migrations of adults and larvae generally follow continental shelf areas (Wang and Tzeng 1998). Like other fish, exposure to hydrocarbons has been shown to induce oil degrading enzymes like CYP1A (Schlezinger and Stegeman 2000) with a 5 mg/kg dose response, a sensitivity that is less than that of other fish. It has been speculated that this is due to the species' life history, as they spend a portion of their life in estuaries where they have increased chance of exposure to contaminants and therefore less sensitivity (Schlezinger and Stegeman 2000).

While Atlantic salmon and American eel are culturally important, Indigenous groups also harvest other species within the RSA (Section 7.3). These include swordfish, bluefin tuna, Atlantic cod, turbot, Greenland halibut, and snow crab. The distribution of and potential for hydrocarbon exposure, and where appropriate potential effects on, these species are discussed in the following paragraphs.

Effects of oil spills on large pelagic species such as swordfish and bluefin tuna populations are discussed in Section 16.7.4.3. Atlantic bluefin tuna spawn in open ocean areas east of the mid-Atlantic U.S. states, limiting any potential interaction with Project activities, including accidental events. Individual adult bluefin tuna or schools of tuna (fewer than 50 individuals) may have seasonal / intermittent presence in offshore Newfoundland as they migrate through the area in summer (Richardson et al. 2016). The general distribution and migration patterns of swordfish include most of the North Atlantic Basin (Dewar et al. 2011, Trenkel et al. 2014) with seasonal distribution in Canadian waters occurring in mid to late summer (movement from the Scotian Shelf to the Grand Banks). Spawning habitats for swordfish are also distant from the Project Area, occurring mainly in the Gulf of Mexico, Florida, the Caribbean and possibly off South America.

Atlantic cod have occasional presence in the LSA and occur in parts of the RSA, inhabiting offshore shelf areas in winter and nearshore areas in summer (Scott and Scott 1988). Resident offshore populations are distinct from inshore populations (Beacham et al. 2002). Rock cod are not expected to occur in the Project Area and LSA, and typically inhabit inshore regions (Scott and Scott 1988). Numerous studies have examined the effects of oil and dispersed oil on cod (e.g., Khan and Kiceniuk 1984, Kosheleva et al. 1997, Aas et al. 2000, Sturve et al. 2006, Skadsheim et al. 2009, Olsvik et al. 2010, 2011a, 2011b, 2012, Nordtug et al. 2011, Nahrgang et al. 2013). A number of studies have looked at sub-lethal effects of exposure such as transcriptional response to exposure in terms of gene expression (Olsvik et al. 2011), biomarkers (Aas et al. 2000), food assimilation (Nordtug et al. 2011), hematology and respiration. Similar to other marine fish, the long-term effects of an oil spill are generally thought to be relatively low for Atlantic cod with the exception of the more susceptible juvenile life stages (Olsvik et al. 2011). Modelling studies assessing the effects of cod larvae and eggs from a large-scale 90-day oil spill on the Grand Banks suggest that the effects on recruitment in terms of commercial fishing and adult cod populations would be negligible (Hurlbut et al. 1991). This conclusion is similar to modelling studies on other similar species such as Arctic cod (Gallaway et al. 2017). Those studies predicted that even if large mortalities of Arctic cod juvenile and eggs (the life stages most susceptible to the effects of a spill) were to occur due to a spill event, the effects on the regional cod population would not likely be significant (Gallaway et al. 2017).

Turbot / Greenland halibut occur within the LSA and RSA from shallow depth zones to deeper habitats, but mainly occur on the slopes of the Grand Banks and on shelf areas off Newfoundland (north of the Avalon). They are known to migrate between the Davis Strait and Eastern Newfoundland, indicating the potential for long distance migrations (Bowering 1984; Vis et al 1997). Mobile fish are likely to avoid an oil spill, and Greenland halibut are known to swim in shallow, mid, and deep waters (Jørgensen 1997).

Snow crab occur in parts of the LSA and RSA but have limited home ranges / movements by adult individuals (Puebla et al. 2008; Christian et al. 2010). The planktonic life stages are generally considered to be more susceptible to oil spill effects, and those within close proximity to a spill could be affected (Lee et al. 2015), although this would likely represent a small proportion of the planktonic population, minimizing overall effects to snow crab populations.

16.7.9.4 Residual Environmental Effects Assessment and Evaluation

The residual effects of a spill, that is the effects remaining after the implementation of spill response measures and mitigations (see Section 16.1), should it occur, are assessed in the following sections.

The likelihood, magnitude, geographic extent and duration of potential effects of a subsurface blowout and its interaction with the Indigenous Peoples VC will depend on the nature of the spill and its trajectory. A subsurface blowout, in comparison to a batch spill, is the scenario with greatest potential to interact with the Indigenous Peoples and therefore this assessment focuses on the potential interactions and effects from a subsurface blowout.

Subsurface Blowout

The modeled scenarios include unmitigated subsurface blowouts at two locations within the Project Area. The probability, of the extremely large blowout type incident modelled actually occurring is extremely low as there is between a one in 207,000,000 to one in 414,000,000 chance that it would occur. This type of event could potentially discharge a large volume of oil which could extend into the RSA, well beyond the LSA. For the unmitigated spill event, these areas are predicted to extend to the Flemish Pass, Flemish Cap, Orphan Basin, southern Grand Banks and associated slope waters, where surface hydrocarbon concentrations exceed the very conservative environmental and/or socioeconomic thresholds (see Section 16.4.4).

In the selected 95th percentile scenario for surface oil exposure releases surface oil was predicted to be thickest closest to the release location. Maximum thicknesses corresponded to a visual appearance of black oil within a few kilometres of the release site with the majority of footprints predicted to have a maximum thickness closer in appearance to dark brown to dull brown sheens (0.01 to 0.1 mm). Dark brown to dull brown sheens predicted to overlap with areas of high chlorophyll *a* concentrations, a proxy for phytoplankton biomass (See Section 9.2), around the Flemish Cap, and along the slopes and shelf of the Newfoundland Shelf, the Orphan Basin and off the Labrador shelf in winter to spring. The application of mitigation and response measures would reduce the magnitude, duration and geographical extent of the spill.

Modelling results from the 95th percentile scenario for in-water exposure indicate concentrations of dissolved and total hydrocarbons based on the 95th percentile scenario were predicted to be highest around the release site, including Flemish Pass and the Flemish Cap. Oil concentrations dissipated as it was transported away from the release location through mixing within the water column, evaporation from the water surface, volatilization from the water column, and degradation, thus reducing the total amount of contaminants present (RPS 2018).

For the representative worst-case scenarios for shoreline oiling, less than one percent of total oil released was predicted to make contact with shoreline and most of the oil that was predicted to make contact occurred on the Avalon Peninsula and localized areas of the Burin Peninsula. First contact with shoreline occurred within 14 to 15 days (115 d scenario) or at day 45 (36-d scenario). In both cases, oil would be highly weathered (i.e., lighter ends would have evaporated, dissolved, and degraded thereby reducing the toxicity of the residual oil), patchy and discontinuous (RPS 2018). In these extremely low probability cases, the total hydrocarbon concentration on shore was predicted to exceed 500 g/m², which was above the socio-economic (1 g/m²) and ecological (100 g/m²) thresholds.

Based on modelling results in the CNOOC EIS (CNOOC 2018), it is predicted the highest probability of oil reaching the Azores where shoreline exceeded the 1 gm/2 was 70 and 77 percent (depending on scenario) in the summer months. The modelled 95th percentile representative deterministic shoreline scenario predicted a minimum time for oil to reach the Azores at was between 80 days and 111 days, depending on the spill site. Therefore, oil that is predicted to make shore would be highly weathered (i.e., lighter ends would have evaporated, dissolved, and degraded) thereby reducing the toxicity of the residual oil, patchy and discontinuous emulsified oil and tarballs. Surface oiling is predicted to occur to the areas to the east of BdN model domain at thicknesses >0.04 µm in areas beyond NAFO division 3LMN and in the surface waters surrounding the Azores. With the application of mitigation and response measures noted in Section 16.7.8.2, it would further reduce potential for effects.

Based on the preceding modelling results and given its extremely unlikely occurrence, no direct effects of a subsurface blowout on physical or cultural heritage are predicted. Since there are no known sites, structures or things of historical, archaeological, paleontological, or architectural significance to Indigenous Peoples in the LSA and since the worst-case scenario for shoreline oiling does not extend to Indigenous communities, no direct effect on such resources of cultural importance is predicted.

A subsurface blowout may interact directly and indirectly with commercial-communal fishers. Depending on the size, nature and timing of the subsurface blowout, regulatory authorities may issue temporary closures of fish harvesting in the immediate vicinity of the spill location. There is a potential for actual or perceived fish tainting from a subsurface blowout and this may affect marketability of affected commercial species. There could be loss of access to fishing areas, resulting in potential economic loss. If fishing were occurring at the time of the spill, gear and/or equipment may be fouled. The potential interaction of a subsurface blowout and commercial fisheries is discussed in Section 16.7.8 and the identification and assessment of potential effects, both direct and indirect, is equally applicable to commercial-communal fishers. With the implementation of response and mitigation measures, the magnitude and geographic extent of a subsurface blowout would be reduced. The issuance of Navigational Warnings and other communications will provide timely notice of closure areas for fishers to make alternate plans, thereby likely reducing effects on commercial-communal harvesting success. Avoidance will also reduce potential gear/vessel fouling and the likelihood of any tainted product entering the marketplace. A compensation program, as outlined in Section 16.7.8, will be implemented.

With respect to the current use of lands and resources for traditional purposes, since no such activities occur in the Project Area or LSA and since the 95th percentile deterministic scenarios predict less than one percent of total oil released would make contact with shoreline, with most of the contact occurring on the Avalon Peninsula and localized areas of the Burin Peninsula, no direct effects are predicted.

There is potential for a subsurface blowout to indirectly affect such activities due to associated effects on marine-associated species. In the extremely unlikely event of an unmitigated subsurface blowout, migratory marine species have the potential to be adversely affected if the timing of the subsurface blowout occurs at the same time as species' presence in the area of the spill. Direct adverse effects on the availability, quantity or quality of such migratory species may have the potential to result in indirect effects on the current use of land and resources for traditional purposes, including indirect effects on health and well-being. As described in Sections 16.7.4 and 16.7.6, subsurface blowouts are not expected to result in significant residual adverse effects upon marine fish or mammals, including those currently used for traditional purposes. For marine and migratory birds, depending on the timing and presence of migratory birds, a significant residual adverse affect is predicted for certain species, however it has an extremely low probability of occurring. While it is obviously not possible to determine with absolute confidence whether any individual of a species used for traditional purposes by any group may be present in the affected area before moving to an area that is the subject of traditional harvesting activity, as noted in Section 7.3, there is limited potential for any degree of connection. While shoreline oil has the potential to interact with coastal spawning areas for fish species including Atlantic cod, cunner, American plaice, capelin, herring, and sand lance (Templeman 2007; Snelgrove et al. 2008; DFO 2016), the oil would be highly weathered (i.e., lighter and more toxic components would have evaporated, dissolved, and degraded thereby reducing the toxicity of the residual oil). Scheduled Atlantic salmon rivers, where adults migrate to spawn, are distributed along the Avalon and Burin Peninsula (DFO 2018) within the potential shoreline contact footprint. In the very low probability case of oil contacting the shoreline, given the time to reach the shoreline, the oil would be highly weathered, patchy and discontinuous. Response measures for shoreline protection would be implemented which would further reduce potential for effects.

The probability of a subsurface blowout occurring is extremely low, and in the event of a spill, species (individual fish, bird or marine mammal) would have to be present in the area at that time to be potentially affected. In an actual event, emergency response measures would likely be effective in limiting the magnitude, duration, and extent of the spill. Therefore, there is little potential for biophysical effects on marine-associated species in general (and individuals in particular) to adversely affect the presence, abundance, distribution, or quality of these marine resources and thus, their overall availability for resource use activities by Indigenous groups within traditional harvesting areas. As a result, there will be little or no potential for direct or indirect biophysical effects (should they occur) to translate into a detectable decrease in the overall nature, intensity, location, timing, quality or cultural value of these traditional activities by any Indigenous community or other aspects of their existing socio-economic or cultural conditions. Based on the 95th percentile modelling scenarios for shoreline exposure, it is predicted that oil will not make contact with shorelines in proximity to any Indigenous community. With the application of shoreline and nearshore response measures, it is unlikely that the nearshore traditional or recreational fisheries or access to traditional harvesting grounds would be affected. Consequently, no adverse effects on the exercise of asserted or established Aboriginal or treaty rights are predicted.

Similarly, adverse effects on the health and well-being of Indigenous Peoples are unlikely. While there is a possibility of taint due to the exposure of fish to hydrocarbons, this is unlikely to translate into an adverse effect upon health and well-being due to the factors outlined previously. A subsurface blowout is extremely unlikely and there is a limited potential for any degree of connection between an individual member of a marine-associated species harvested for FSC purposes to be in the area of a spill before moving to a traditional harvesting area. With the application of mitigation measures and spill response plans, no significant effects on marine-associated species are predicted and the imposition of closures around affected harvesting areas would further reduce the possibility of consumption of tainted species. While there may be the perception of taint even when results demonstrate safe exposure levels for consumption which can lead to avoidance of country foods, resulting effects based on perceptions of products are difficult to predict and may only be measured after an event occurs (ITOPF 2014) (see Indigenous Knowledge Study, Appendix H, for a discussion of the relationship between country foods and health, spiritual and cultural well-being). In the extremely unlikely event of a subsurface blowout, it will be important to communicate with communities and Indigenous groups, including providing information that may assist in understanding the incident and associated impacts, if any, including the perception of taint.

In summary, as concluded in Section 16.7.8, with spill prevention plans, response procedures and mitigation measures in place, the residual effects of a subsurface blowout on commercial-communal fisheries are predicted to be adverse, low in magnitude, medium-term in duration, with a geographic extent greater within the RSA, not likely to occur and reversible in nature. This conclusion has been reached with a high level of confidence based on scientific literature, modelling predictions and the experience and professional judgement of the EIS Team.

With respect to the current use of lands and resources for traditional purposes, with spill prevention plans in place and the implementation of response procedures and mitigations in place, the residual effects of a subsurface blowout on the current use of lands and resources for traditional purposes, including any associated health, socioeconomic or cultural conditions are predicted to be adverse, negligible in magnitude, short-term in duration, within the RSA, not likely to occur and reversible. This conclusion has been reached with a high level of confidence.

Batch Spills Vessel Collision

As summarized in Section 16.7.3, modelling results of batch spills (surface and subsea loss of crude, surface loss of diesel, surface and subsea loss of SBM) indicate that the size and persistence of the area where effects may occur on marine species and commercial-communal fisheries are much smaller than for subsurface blowouts. For crude batch spills, the maximum extent of surface oiling was predicted to extend approximately 375 km from the spill location during the worst-case environmental conditions for surface oiling (i.e., calmest wind-speed period during the summer/ice-free conditions, which would result in the largest amount of oil on the water surface). Surface releases of diesel were predicted to be confined to the areas near the release location. In all cases, it was predicted that hydrocarbons would not make contact with the shore. The probability of batch spills ranges from one in 46 (spills less than 159 litres) to one in 75,000 (spills greater than 1,590 m^3). For batch spills of SBM, either surface or subsurface releases, the maximum extend of SBM deposition on the seafloor was 320 m for the shallower site and 1,460 m for the deeper site. In-water concentrations of SBM were confined to within 400 m of the spill location.

The cumulative geographic extent (see Figure 16.33) of these batch spills and their effects would be relatively localized to the spill location in comparison to the modelled blowout scenarios and at a considerable range from any Indigenous communities or their known activities or interests. Therefore, no direct effects on Indigenous Peoples from batch spills are predicted. Moreover, as there are no known sites, structures or things of historical, archaeological, paleontological, or architectural significance to Indigenous Peoples in LSA, a batch spill will have no effect upon these cultural resources. As discussed in Chapters 7 and 14, there are no known Indigenous groups that have established or asserted Aboriginal or treaty rights to lands and waters of the Project Area or the LSA so a batch spill will have no direct effect upon the exercise of asserted or established rights. Since there is no current use by any Indigenous group of lands and resources for traditional purposes in the Project Area or LSA, a batch spill will not directly adversely affect traditional harvesting activities.

While there may be potential for indirect effects to Indigenous groups resulting from associated effects on marine-associated species of traditional importance, given the localized nature of a batch spill, no such adverse effects are predicted. The effects of a batch spill upon marine species (fish, birds and mammals) has been assessed and no significant adverse effects upon any of these species is predicted. As a result, there is almost no potential for the biophysical effects of a batch spill to adversely affect the presence, abundance, distribution, quality or availability for resource use activities by Indigenous groups in traditional territories or to otherwise affect social health and well-being.

The potential exists for interaction between a batch spill and commercial-communal fisheries. The potential direct and indirect effects of a batch spill upon commercial fisheries have been identified and assessed in Section 16.7.8 and would be equally applicable to commercial-communal fishers. As concluded in Section 16.7.8, with spill prevention plans and mitigations measures in place, the potential effects of batch spill on Indigenous Peoples would relate only to commercial-communal fisheries and are predicted to be adverse, low in magnitude, short-term in duration, within the LSA (with the exception of a vessel collision, which might occur within RSA), not likely to occur to sporadically occurring and reversible. This was determined with a high level of confidence based on scientific literature, modelling predictions and the experience and professional judgement of the EIS Team.

SBM Mud Spills

The potential interaction of SBM mud spills and commercial fisheries is discussed in Section 16.7.8 and the identification and assessment of effects upon commercial fisheries is equally applicable to commercial-communal fishers. As concluded in Section 16.7.8, considering that no domestic commercial-communal fishing currently takes place in the Core BdN Development Area and the relatively low levels of commercial harvesting within the Project Area, the availability of nearby alternative fishing grounds and transit routes, and with spill prevention plans and response procedures in place, the potential effects of a SBM spill on commercial-communal fishers, are predicted to be adverse, negligible in magnitude, short-term in duration, localized, not likely to occur. and reversible. This prediction is made with a high level of confidence based on scientific literature, modelling predictions and the experience and professional judgement of the EIS Team.

Given the localized nature of an SBM mud spill no adverse effects upon the current use of lands and resources for traditional purposes, physical or cultural heritage or the exercise of asserted or established Aboriginal or treaty rights are predicted.

16.7.9.5 Summary

Table 16.46 provides a summary of predicted residual environmental effects of accidental event scenarios for Indigenous Peoples. Effects predictions were made using a conservative approach for the spill modelling and considered the implementation of mitigation measures to prevent and reduce effects from a spill.

Table 16.46 Summary of Residual Accidental Event-Related Environmental Effects on Indigenous Peoples: Commercial-Communal Fisheries

Accidental Event Scenario	Residual Environmental Effects Characterization						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Confidence
Potential Effects: Change in commercial-communal fisheries; Change in current use of lands and resources for traditional purposes							
Subsurface Blowout	A	L	RSA	M	N	R	H
Batch Spills	A	L	RSA	S	N-S	R	H
SBM Spills	A	N	L	S	N-S	R	H

KEY

Nature / Direction of Effect:
P Positive
A Adverse
N Neutral (or No Effect)

Magnitude of Effect:
N Negligible
L Low
M Medium
H High

Geographic Extent of Effect:
Less 1 km²
Less than 10 km²
Less than 100 km²
Less than 1,000 km²
Less than 10,000 km²
Greater than 10,000 km²

Duration:
S Short-Term - less than 12 months (1 year)
M Medium-term - 1 to 5 years
L Long-term - more than 5 years

Frequency of Effect:
N Not likely to occur
O Occurs once
S Occurs sporadically
R Occurs on a regular basis
C Occurs continuously

Reversibility:
R Reversible (will recover to baseline)
I Irreversible (permanent)

Confidence Level in Predictions:
L Low level of confidence
M Moderate level of confidence
H High level of confidence

N/A Not Applicable

16.7.9.6 Determination of Significance

In consideration of the location of Indigenous communities and the activities undertaken by Indigenous groups within the RSA, the results of spill modelling exercises and proposed mitigation measures, is predicted that the accidental events associated with the Project will not result in significant residual adverse effects on Indigenous Peoples.

No Indigenous communities, or activities associated with the current use of lands and resources for traditional purposes are undertaken, within or near the Project Area itself. Indigenous communities range approximately 640 km to 2,000 km from the Project Area. The oil spill modelling completed for this EIS indicates that there is very limited potential for oil to reach the shoreline near any Indigenous community, making Project-related restrictions upon access to traditional harvesting areas extremely unlikely. Potential impacts upon commercial-communal fisheries in the LSA would be reduced by the application of prevention and response measures.

The potential for effects upon Indigenous Peoples would therefore be primarily indirect in nature and related to the possibility that marine-associated species harvested by Indigenous fishers in either the commercial-communal or traditional fishery could be affected by a spill. The degree of exposure and occurrence of effects upon marine-associated species would depend on the type and size of spill, time of year, location, and the types of marine species present within the affected area. As the preceding analysis demonstrates, there is limited potential for an accidental event to have an adverse effect on the presence, abundance, distribution or quality of marine species, and on the overall availability or sufficiency of the species for resource use activities, including the current use of lands and resources for traditional purposes.

As described in the preceding analysis, for each of the modelled releases, oil on the surface was most likely to move to the east due to the prevailing westerly winds and surface currents within the region. Based on deterministic modelling, there is no potential for any spill to reach and adversely affect any of the Indigenous communities listed in the EIS Guidelines. As there are no sites, structures or things of historical, archaeological, paleontological, or architectural significance in the LSA and no potential for oil to reach the traditional territories of any of the listed Indigenous groups, no direct effects on sites, structures, or things of historical, archaeological, paleontological, or architectural significance are predicted.

In terms of potential indirect effects due to associated biophysical changes resulting from such a spill, while it is not possible to determine with confidence whether a migratory individual of any species used for traditional purposes by any group may be present in the affected area before moving to an area that is the subject of traditional harvesting activity, as illustrated in Chapters 9 and14 there is limited potential for any degree of interaction. The probability of a subsurface blowout occurring is extremely low, and in the event of a spill, the species (individual fish, bird or marine mammal) would have to be present in the area at that time to be potentially affected. There is therefore little potential for any effects on marine-associated species in general (and individuals in particular) to translate into a detectable effect on the use of such species for traditional purposes by an Indigenous group in eastern Canada.

Consequently, there will be little potential for biophysical effects (should they occur) upon marine species resulting from a spill to translate into a detectable decrease in the overall nature, intensity, distribution (location and timing) and quality of either the commercial communal fishery or the current use of lands and resources for traditional purposes, including any associated health, socio-economic or cultural conditions. Spill prevention techniques and mitigation measures, including development of a fisheries compensation program will be incorporated into the design and operations for all Project activities as part of contingency planning, which will further reduce the potential for any effects to occur. Therefore, it is predicted that the residual effects of an accidental event upon Indigenous Peoples are not significant.

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17.0 EFFECTS OF ENVIRONMENT ON THE PROJECT

As required under Section 19(1)(h) of *Canadian Environmental Assessment Act, 2012* (CEAA 2012) and as specified in the EIS Guidelines (Part 2, Section 7.6.2; Appendix A), this chapter provides a discussion of the expected and potential effects of the environment on the Project design and Project activities, including production operations and drilling during life of field.

The physical environmental setting of an area is an important consideration in the planning, review and conduct of offshore oil and gas production activities. An appropriate understanding, and careful consideration, of environmental characteristics including winds, waves, currents, ice, precipitation, and other factors, such as seismicity, is required for offshore activities. The understanding of these environmental characteristics is important to enable the design and operations to occur in a manner that ensures human health and safety, as well as protection of the environment, and equipment and infrastructure. This includes avoiding or reducing the potential for incidents and accidents that may occur as a result of unplanned interactions between oil and gas operations and the physical environment of the marine area in question.

The information presented in herein is summarized from the more detailed description of the existing physical environment presented in Chapter 5 of this Environmental Impact Statement (EIS).

17.1 Summary of Mitigation Measures

The following sections provide an assessment and evaluation of the potential effects of environment on the Project. Mitigation measures to prevent or reduce adverse effects, as listed below, are identified and considered in an integrated manner within and throughout this chapter, as applicable.

- Design of the floating, production, storage and offloading (FPSO) such that it is capable of operating in deep water and in the environmental conditions prevalent in the Project Area and larger Regional Study Area (RSA).
- Selection criteria for drilling installation, offshore supply vessels (OSVs) and other vessels engaged in Project activities such that they can operate year-round at water depths and the environmental conditions prevalent in the Project Area and larger RSA.
- The Project will comply with Canadian regulations for engineering design and will adhere to international standards where applicable.
- Third-party certification, a Certificate of Fitness, for the FPSO, the drilling installation and subsea infrastructure, as required to obtain an Operations Authorization (OA) issued by the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB).
- Wells will be positioned to avoid geohazards; location, design, and/or operational plan will be adjusted to reduce the risk to an acceptable level.
- Physical environment data observations, weather forecasting, and reporting will be conducted in consideration with the Offshore Physical Environmental Guidelines (NEB et al. 2008).
- Radio communication systems will be in place to contact other marine vessels, shorebase and OSVs.
- Ability to quick disconnect the FPSO and/or drilling installation in event of an emergency.

- The FPSO will be designed in accordance with recognized standards to handle certain extreme icing loads, including the buildup of ice, should it occur.
- With regards to superstructure icing, which can occur under certain meteorological conditions, the installations will be monitored for icing conditions and accumulation rates, as applicable. Measures to reduce icing include removal and/or melting of the ice.
- Implementation of an ice management plan, which will outline ice and iceberg observations, and protocols for disconnection of the FPSO. Equinor Canada is evaluating options for iceberg detection, such as ice detection radar and use of satellite imaging data.
- The FPSO will be ice-strengthened and vessels and shuttle tankers will be capable of operating in ice-prone waters.
- Weather forecasting services to provide site specific forecasting for production and drilling operations.
- The FPSO, drilling installation and offshore vessels will have obstruction lights, navigation lights, and/or foghorns.
- Vessel captains, helicopter pilots and the Offshore Installation Managers of the FPSO or drilling installation are responsible and have the authority to suspend or modify respective operations in case of adverse weather or environmental conditions that could compromise the environmental integrity of operations.

17.2 Key Environmental Considerations

This section provides an overview of the key environmental factors that could potentially affect the Project, including:

- Seismicity and geohazards
- Climatology, weather and oceanographic conditions
- Sea ice and icebergs
- Climate change

17.2.1 Seismicity and Geohazards

The geology of the eastern Newfoundland Offshore Area is complex and dynamic. The seabed geomorphology is primarily a product of modern oceanographic processes and past glacial activity. Canada’s eastern continental margin is tectonically passive, and seismicity is relatively rare throughout much of the region. Natural Resources Canada (NRCan) indicates that the Core Bay du Nord (BdN) Development Area and the Project Area and surrounding areas have been classified as having a low seismic hazard (NRCan 2017a, 2017b). According to the National Earthquake Database (NRCan 2017c) there have been no seismic events recorded within the boundaries of the Project Area within the 1985 to 2018 period, with the closest recorded event having occurred over at least 300 km away.

Potential offshore geohazards in the Flemish Pass consist of geological phenomena including, but not necessarily limited to, submarine slides, venting of shallow gas, gas hydrates, and seismic events. Most continental margin sediments, except on slopes of more than a few degrees, are relatively stable and would require seismic accelerations associated with a large earthquake (magnitudes of five or greater) to fail (Nadim et al. 2005). NRCan analysis indicates that in any given area offshore eastern Canada, there is a risk of a landslide every 20,000 years and a minor one may occur every few thousand years (NRCan 2010). It is likely that most failures are earthquake triggered, with some seismicity induced by glacio-isostasy (Piper 2005).

The Flemish Pass area is a mid-slope basin bounded to the west by the Grand Banks of Newfoundland and Labrador (NL) and to the east by the isolated Flemish Cap (Piper and Campbell 2005). In this area, large, complex landslides have been mapped along a 65-km length of the northeast flank of the Flemish Pass. Failed sediments have run out as far as 20 km onto the floor of the Flemish Pass, forming mass transport deposits typically 50 m thick. These major sediment failures occurred 27,000 and 20,500 years ago and are believed to have been a result of earthquake triggers (Cameron et al. 2014). Piper and Campbell (2005) presented a brief regional geohazard assessment of the Flemish Pass area and suggested that most large debris flow deposits in the area are the result of earthquake triggered slumps on both flanks of the Flemish Pass. It would likely take a major earthquake in the northern Flemish Pass to trigger future landslides; Cameron et al. (2014) estimated such a quake could have a recurrence rate of approximately 10,000 years in a worst-case scenario. This is consistent with the findings of a review of existing geophysical and geotechnical data from the Flemish Pass region, used to develop a geohazard assessment (Fugro 2017). The results of a slope stability evaluation in the Project Area indicate that a triggering event of greater magnitude than the 3,000-year recurrence interval Abnormal Level Earthquake event is required for slope instability over large areas of the Flemish Pass flanks. This is consistent with the age estimates and observed recurrence intervals of the three basin-wide slope failure events / mass-transport deposits, the results of which indicate relatively low landslide likelihood across a large proportion of the Project Area (Fugro 2017).

Oil and gas activities have been conducted safely in areas where submarine landslides have occurred. Ormen Lange is a production (gas) field in 85 0 m to 1,100 m water in the Norwegian Sea and is located at the site of a submarine clay landslide. The submarine landslide occurred in approximately 300 m to 2,500 m of water approximately 8,200 years ago and was likely triggered by an extremely strong, low-probability earthquake (Kvalstad et al. 2005) combined with excess pore pressure (Leynaud et al. 2007). The slide area was approximately 90,000 m², moving a volume of 3,500 km³ approximately 800 km out into deep water (Solheim et al. 2005; Statoil 2011). The slide generated a tsunami approximately 10 m to 20 m high that made landfall on the Norwegian coast (Norsk Oljemuseum 2011), Scotland, and the Faeroes (Nadim et al. 2005). The Ormen Lange field development activities had negligible effects on stability and were determined to not trigger tsunami-generating slides, as a slide risk assessment indicated that only natural causes (i.e., extremely strong earthquake) are a realistic trigger mechanism. The annual probability of a slide with a run out of the Ormen Lange field development area is almost zero (Scandpower 2004). Hazards related to the Ormen Lange subsea processing facilities from landslide risks were determined to be negligible (Nadim et al. 2005); a separate case study for Ormen Lange indicated that transport, collision and landslide risks were negligible at less than 10^{-6} per year) (Lloyd’s Register Consulting 2013).

Shallow gas, and hydrate formation and melting, can lead to excess pore pressure in permeable strata such as silts and can be a preconditioning factor for submarine landsliding. Shallow sediments within the Project Area are generally interpreted to be primarily fine-grained and likely lack sufficient porosity for the development of massive hydrate zones. No direct hydrate encounters or issues related to hydrates have been recorded in regional cells or cores (Fugro 2017).

Generally, if a large natural slope failure did occur, it would likely be preconditioned by high pore pressure and triggered by earthquakes. Generally, in the Flemish Pass, the steep slopes, abundant shallow gas, make large landslides potentially more frequent, with a recurrence interval of approximately 10,000 years. This translates to approximately a 1 in 500 probability of a landslide occurring in a 20-year period (Cameron et al. 2014).

Tsunami hazard along the Atlantic coast of Canada is relatively low. Wave runup is the maximum vertical extent of a wave's sudden upward surge on a beach or structure above the still water level (Sorensen, 1997). Leonard et al. (2012) assessment of the outer Atlantics coastline indicates an expected recurrence of runup exceeding 1.5 m approximately every 300 to 1,700 years. Larger runup (> 3 m) would have a recurrence of approximately 600 to 4,000 years.

17.2.2 Climatology, Weather and Oceanographic Conditions

17.2.2.1 Air Temperature, Fog and Precipitation

According to the International Comprehensive Ocean-Atmospheric Data Set (ICOADS) (1960 to 2016), air temperatures in the Project Area exhibit strong seasonal variations, with mean temperatures ranging from -0.2°C in January to 13.3°C in August. The coldest observed air temperature on record (-13.0°C) was in February, while during the summer months the coldest observed temperatures range from 0.1°C in June to 4.1°C in August. Throughout the year the mean daily minimum and maximum temperatures generally stay within approximately 3°C of the mean temperature, due in part to the moderating effects of the ocean. Over the potential vessel and aircraft routes for the Project, conditions are on average fairly consistent with mean values between 0°C and 15°C year-round (Bowyer 1995).

The ICOADS also indicate that most of the observed precipitation events are in the form of rain (with precipitation occurring nine percent to 15 percent of the time for all months), snow and drizzle, while other precipitation types, such as mixed rain, freezing rain, and hail occur far less frequently. Freezing rain is relatively infrequent in this area, occurring less than one percent of the time during any given month, and typically does not occur at all between July and October. Thunderstorms, which can generate hail and lightning, occur with similarly low frequencies, however there is a year-round potential of occurrence.

The Project Area and surrounding areas have some of the highest occurrence rates of marine fog in North America, and fog can persist for days or weeks. This type of fog (advection fog) is most prevalent in spring and summer. Visibility is affected by the presence of fog, the number of daylight hours, as well as frequency and type of precipitation. Visibility within the Project Area varies considerably throughout the year. Annually, visibility is very poor 13.6 percent of time, poor 6 percent of the time, fair 19.6 percent of the time, and good (> 10 km) 60.9 percent of the time. The best visibility occurs during fall and winter when fair or good visibility occurs approximately 90 percent of the time. Visibility is poorest in summer with very poor visibility (< 500 m) occurring 25 percent of the time in June, 40 percent in July and 31 percent in August.

17.2.2.2 Winds

Based on Meteorological Service of Canada 50 (MSC50) hindcast data (Swail et al. 2006), the mean annual wind speed (1-hour averages, 10 m elevation) for the Project Area is approximately 9.0 m/s, while the maximum hourly wind speed is up to 35.3 m/s. The months with the highest mean wind speeds are typically January and February (ranging between 11.6 m/s to 12.0 m/s), which also have the highest maximum wind speeds (31.1 m/s to 35.3 m/s). The most frequent wind directions for mean and maximum winds are predominately westerly and south but range from northwesterly to southeasterly. The range of wind conditions experienced along the potential vessel and aircraft transit routes from shorebase to the Project Area are likely to be quite close to those experienced offshore, with the offshore winds being slightly higher than near St. John’s (1 m/s to 2 m/s higher average wind speeds, and 2 m/s to 3 m/s higher maximum wind speeds). The MSC50 M6013260 node data (closest to Bay du Nord) was used to characterize the Project site wind conditions. Exceedance values for wind speeds for various return periods are listed in Table 17.1 (see Section 5.3.1 for more details).

Table 17.1 Wind Speed Exceedance Values for Various Return Periods in the Project Area (MSC50 Node M6013260)

Return Period	1-year	10-year	50-year	100-year
Wind Speed	26.0 +/- 0.3	30.6 +/- 1.3	34.4 +/- 2.0	36.0 +/- 2.3

17.2.2.3 Waves

Based on MSC50 hindcast data (Swail et al. 2006), monthly mean significant wave heights in the Project Area range from approximately 1.8 m in July to 4.6 m in January, with an annual mean of 3 m. The most severe sea states occur in December through February when maximum significant wave heights exceed 14 m. The largest waves are from the southwest through northwest directions with associated peak periods in the 15 s to 17 s range. The maximum significant wave height at 7.1 m is lowest in July, with an associated peak period of 12 s. Annually, mean wave heights are approximately 2 m near St. John’s compared with 3 m to 3.5 m near the eastern portions of the Project Area. During fall and winter months, average wave heights in the Project Area can be expected to be 1.5 m higher than near St. John’s, while maximum wave heights can be expected to be at least 2 m higher. Exceedance values for significant wave heights for various return periods are listed in Table 17.2 below (see Section 5.4.1 for more details).

Table 17.2 Significant Wave Height Exceedance Values for Various Return Periods in the Project Area

Return Period	1-year	10-year	50-year	100-year
Wave Height	11.8 +/- 0.2	14.1 +/- 0.5	15.8 +/- 0.6	16.5 +/- 0.6

17.2.2.4 Currents

The offshore Labrador Current, which flows near the Project Area, has average speeds of approximately 40 cm/s, mainly between the 400 m and 1,200 m isobaths (Lazier and Wright 1993). Over areas of the Grand Banks with water depths less than 100 m, the mean currents are generally weak (<10 cm/s) and flow southward, dominated by wind-induced and tidal current variability (Seaconsult Ltd. 1988). In the vicinity of the Flemish Pass, the Labrador Current divides into two branches with the main branch flowing southwards as Slope Water Current and the side branch flows up to the east-northeast clockwise past the Sackville Spur and north-eastward around the Flemish Cap. The cores of the currents are located at an average depth of 100 m (Greenan et al. 2016).

Current statistics derived for Equinor Canada met-ocean monitoring program (2014 to 2016) in the BdN Field Metocean Design Basis (Statoil 2017a) from the full CM-2 deployment show that currents are largest near-surface with mean and maximum speeds of 21 cm/s and 112 cm/s respectively at 19 m. Speeds decrease steadily to approximately 200 m after which speeds are fairly uniform with depth reaching mean and maximum near-bottom speeds of 3 cm/s and 32 cm/s respectively (see Section 5.4.2 for more details).

The ocean current conditions encountered along the vessel traffic route to the Project Area will vary depending on distance offshore. Close to the Avalon Peninsula circulation will be dominated by the inshore branch of the Labrador Current flowing south with average speeds of approximately 15 cm/s. This inshore branch sometimes also spreads out farther out onto the Grand Banks where currents are generally weak (<10 cm/s) and southwards and dominated by wind-induced and tidal current variability (Seaconsult 1998). Once the Grand Banks are traversed, the offshore branch of the Labrador Current that flows along the outer edge of the Grand Banks will be encountered. The flow here is stronger than inshore with average speeds of approximately 20 cm/s as reported above.

17.2.2.5 Water Levels and Storm Surge

Water level variations due to tides in the Project Area are generally quite predictable. The water levels exhibit two high tides and two low tides per day, with one set of tides having a higher tidal range than the other. The highest and lowest astronomical tide (HAT, LAT) elevations at BdN, based on the NAO.99b tidal prediction system, as reported in the Flemish Pass Exploration Drilling EIS (herein referred to as the Drilling EIS) (Statoil 2017b) are 43 cm and -32 cm above and below mean sea level, respectively.

Storm surge amplitudes can be high in coastal areas, but surges with comparatively smaller amplitudes can also occur offshore. The expected storm surge levels range between 90 cm (100-year return period) and 1.2 m (10,000-yr return period), with an exceedance probability of 0.8 and 1 m respectively for the BdN Field (Seaconsult 1998; Bernier and Thompson 2006).

17.2.2.6 Superstructure Icing

A number of factors can contribute to vessel icing potential at any given time. These include environmental parameters such as air and sea temperature, wind speed, wave height and precipitation. The size, shape, and configuration of the vessel itself are also critical factors for icing potential. With sub-zero temperatures and strong winds common, especially in the northern parts of the Project Area, icing of the ships' superstructure can be an important consideration and risk. A few tens of centimetres of ice over a complex deck and superstructure represents many tonnes of loading. Vessel icing in this region is likely to occur in the period between November and May, with the highest frequency typically occurring in February (Amec 2014).

17.2.3 Sea Ice and Icebergs

Portions of the Project Area are subject to seasonal intrusions of sea ice and icebergs. Ice conditions experience interannual and spatial variability, depending on winter conditions over NL and the surrounding waters as well as seasonal wind patterns. Cold and dry westerly to northerly winds tend to move ice further offshore, while northeasterly winds drive the ice towards shore.

Information drawn from the Canadian Ice Service (CIS) Sea Ice Climatic Atlas for the East Coast 1981 to 2010 (CIS 2011) shows that a large variability in sea ice conditions can be experienced from year to year, as well as in any given year, on time scales of days to weeks and over comparatively small geographic scales of tens of kilometres (see Section 5.5.1). When sea ice is present, it is more likely of greater concentration and thickness in the western portions and less severe further offshore to the east. With passing weeks, as the sea ice advances, there is potential that thicker sea ice to the west and north will continue to drift farther offshore (south and east). There is potential for landfast ice (ice which forms and remains fast along the coast) nearshore which can extend from a few metres to several hundred kilometres offshore. This may pose a potential risk for potential vessel traffic routes near the coastline of eastern NL but is unlikely to be a factor in the Project Area itself.

Ice is typically present as early as mid- to late-January for the southwestern portion of the Project Area and covers most of the Project Area by the first week of February and as late as mid- to late-April. The latest ice is usually seen over only the southwestern portion of the Project Area. The frequency of sea ice is one percent to 15 percent, or approximately as frequent as every six or seven years, for most of the Core BdN Development Area and the northeastern half of the Project Area. Along the vessel traffic route, the greatest frequency of occurrence of sea ice is during the week of 19 March at approximately 16 percent to 33 percent (or every three to six years) though with the potential for a 34 to 50 percent likelihood at approximately one quarter and two thirds along the route from St. John's. The greatest risks are likely encountering areas of potentially high ice concentration of 9 to 9+/10 in late January at the eastern location along the vessel traffic route to the week of 23 April at the same location, and medium and thick first year ice (> 70 cm) from the end of March through the beginning of May.

The National Research Council (NRC) Program of Energy Research and Development (PERD) iceberg database (Sudom et al. 2014; NRC 2015) shows 74 icebergs for the Core BdN Development Area, 1,255 icebergs within the Project Area, and 1,433 and 1597 for the western and eastern portions of the vessel traffic route over the past 30 years. Sizes are known for approximately 95 percent to 98 percent of these observations. Of the icebergs in the Project Area, approximately eight percent are growlers or bergy bits (< 1 m in height, < 5 m in length and mass approximately 500 t), 55 percent are small or medium, 13 percent are large, and 0.5 percent are very large (< 100 m in height, < 200 m in length, and mass over 5 Mt). Icebergs can be present in the Project Area from January through September, with icebergs observed 27 percent of the time each in March and April.

A reduced time window was estimated for the Core BdN Development Area (February to August), and January to August at the vessel traffic route.

(IR-43) It is also noted that with the changing climate and shrinking Arctic sea ice cover the Arctic ice pack is more mobile. There is increased advection of pack ice from the Arctic Ocean to Baffin Bay (Barber et al 2018). This is via the Nares Strait from the Lincoln Sea, and Jones Sound and Lancaster Sound from the Canadian Arctic Archipelago (CAA). For example, Howell et al (2013) report on recent increases in the flow of multiyear ice (MYI) from the Arctic Ocean to the Queen Elizabeth Islands due to increased open water in the CAA that has allowed more inflow to occur. The pack ice in Baffin Bay makes its way south, via the West Greenland Current and Labrador Current, to coastal Labrador, the northeast coast of Newfoundland and the NL offshore area. The increased mobility of sea ice from the Arctic poses a potential added risk of increased MYI for these more southerly regions, as suggested by Barber et al. (2018) who report on an anomalous ice cover in spring 2017 off the northeast coast of Newfoundland with medium (100 to 500 m) and small (20 to 100 m) floes of old ice (second year or MY ice) in 3/10 concentration during the weeks of June 5th to 19th. Old ice was also reported in trace amounts just east of St. John’s for the week of April 3rd. Old ice is harder, stronger, and usually thicker than FYI: the presence of old ice represents an increased risk to navigation and should be avoided whenever possible. As reported in Section 5.6.1, old ice has been reported infrequently and at concentrations of 1/10 or less for the past 30 years for the Project Area (mid-March to early April in 1994 and one week in April 1995) and the vessel traffic routes (two weeks in March 1994 for the east route; one week in March 1992 for the west route, at 3/10 concentration). While difficult to quantify the timing, locations and magnitude, this increased mobility of the Arctic pack ice may pose added risk of increased MYI for the Project Area in the future. However, it should be noted that sea ice extent and ice thicknesses will be reduced in the future.

17.2.4 Climate Change

With a lifespan of 12 to 20 years for the Core BdN Development, and with Potential Future Development to increase the life of field to 30 years, it is likely that the physical environment in the Project Area will experience changes in climate beyond what is presently found in recent trends and interannual variability. Climate change will likely have some influence on the atmosphere, ocean, and cryosphere over time, although the magnitude and timing of these changes will vary regionally and across variables. On a global scale, there are three changes in climate for which long-term trends are already being observed and future projections are in general agreement and would likely be seen in the Project Area; these generally include temperature increase, arctic sea ice extent, and intensification of the hydrologic cycle. However, there remains substantial regional variability, including locations that exhibit trends counter to the global mean (Stocker et al. 2013). As Project activities may commence in the early 2020s with a projected life of field of several decades, recent trends and variability along with medium-term climate projections (to the middle of the 21st century) are presented.

Air temperatures have increased in coastal meteorological stations in eastern Canada over the 110-year record by 0.75 ± 0.34°C (Savard et al. 2016). Warming in the region has been found to be greater than or equal to global trends (IPCC 2013). This underlying trend is expected to continue and intensify over the coming decades. IPCC (2014) projects that for 50 to 70 percent of the years in the mid-21st century the Grand Banks (including the Flemish Pass) will experience a higher temperature greater than the maximum observed temperature between 1986 and 2005.

Cheng et al. (2014) found that the frequency of high-speed hourly wind gusts in Atlantic Canada is expected to increase under both medium and high greenhouse gas (GHG) emissions scenarios by the mid-21st century. However, a recent study (Amec Foster Wheeler 2017) in a region near the Project Area found that the median and maximum annual sustained (hourly average) wind speeds were projected to decrease slightly or remain unchanged over the coming decades along main transport / shipping routes adjacent to the Project Area.

It is projected that mean annual precipitation for the region (and the Project Area) will increase by up to 10 percent (IPCC 2014). The same report projected that the 20-year return value of annual precipitation extremes would increase by 5 to 10 percent by mid-century. This does not imply that there will be more precipitation events, but that the events that do occur are more likely to produce higher rates of precipitation. Precipitation is expected to increase in winter and spring but remain stable or decrease slightly in summer and fall (Savard et al. 2016). There is no expected increase in the frequency of tropical storms in the Project Area. However, the hurricanes that do occur in the Atlantic are expected to be stronger under climate change, with a higher percentage of Category 3, 4 and 5 storms (Bender et al. 2010). This, along with warmer waters, could suggest an increase in likelihood for large rainfall events traveling further north and reaching the Flemish Pass in the future.

Winter storms are projected to be affected by a shift northward of storm tracks and a shift in strength to the west-to-east jet stream, which exists over the Project Area. A well-defined west-to-east jet stream is correlated with more and stronger winter storms, while a relatively meandering jet stream associated with a weaker polar-equatorial temperature gradient will create blocking patterns and fewer winter storms. Furthermore, it has been suggested that the weaker polar-equatorial temperature gradient causes more persistent weather patterns in mid-latitudes (including the Flemish Pass), such as more extreme weather with prolonged droughts, flooding, cold spells, or heat waves, (Francis and Vavrus, 2012), however this is currently debated (Barnes 2013).

Projected changes to ocean conditions are less certain than the projections for atmospheric conditions (temperature and precipitation), however, a rise in sea level due to thermal expansion of the ocean and increased water amounts from melting ice sheets and glaciers (rising rate of 3.2 ± 0.4 mm/year from 1993 to 2009 (Church and White 2011). As sea levels around eastern NL are projected to rise on the order of 0.5 m to 1 m (or more) by the end of the 21st century (James et al. 2014), the rate of annual sea level rise will likely increase beyond present day trends and may reach multi-meter levels (Hansen et al. 2016). Other changes are less certain but extrapolating from existing relationships it has been projected that these may include further warming of surface waters, decreases of average significant wave heights, and possible changes in currents related to the melting of Greenland's ice sheet and the extent and duration of sea ice. There is medium confidence that a nearly ice-free Arctic Ocean in September before mid-century is likely for high GHG emissions scenarios (IPCC 2013). Based on these historical trends and projections for shrinking Arctic sea ice cover, it is likely that sea ice extent and ice thicknesses will be reduced in the future for offshore NL in general, including the Project Area. Projections indicate that there will be up to a 70 percent reduction in spring sea ice thickness by 2050 near the Project Area. The same projections also indicate a 10 percent decrease in sea ice extent for the corresponding dates and region. Warmer air temperatures could lead to an increase in iceberg calving rates and could lead to less obstructed routes from calving sites to the Project Area. While this would increase the number of icebergs in the waters off NL, the increased sea surface temperature and wave action (from reduced sea ice cover) would increase their melt and deterioration rates. The number of icebergs observed offshore NL varies widely from year to year, and so long-term trends may take multiple decades to become apparent.

In summary, increases are projected for air temperature and sea surface temperatures at the Project Area (with varied levels of confidence). Meanwhile, the frequency of high-speed hourly wind gusts is expected to increase slightly. Meanwhile, sustained (hourly average) wind speeds are projected to decrease slightly or remain unchanged. Annual precipitation volumes are projected to increase by up to 10 percent in the Flemish Pass. However, the number of precipitation events is projected to remain relatively unchanged (events are projected to be more intense). Most of the increase in annual precipitation volumes is projected to take place during the Winter months (with a decrease in summer and fall) and it is possible that fewer winter storms will occur due to a weaker jet stream (likely less but more intense winter storms). The number of topical storms is not projected to increase in the Project Area, however, there is an increased likelihood of hurricane-linked storm events occurring in the Project Area (due to anticipated increases in hurricane strength in the Atlantic and the warmer sea surface temperatures at the Flemish Pass). Sea level and its rate or rising is projected to increase. Due to increases in air and sea surface temperatures, it is likely that there will be a reduction in sea ice extent, thickness, and duration (possible ice-free Arctic Ocean in September by mid-century). There is great uncertainty on the future of icebergs; however, warmer air temperatures could lead to an increase in iceberg calving rates, but also lead to less obstructed routes from calving sites to the Project Area.

17.3 Assessing and Mitigating Potential Effects of the Environment on the Project

This section provides an overview of the hazards and mitigation measures to bring risk to acceptable levels, including:

- Seismicity and geohazards
- Climatology, weather and oceanographic conditions
- Sea ice and icebergs

Environmental conditions (including extreme events) play a key role in the design, planning and operations of offshore oil and gas production activities. This includes consideration of, and planning for, typical environmental conditions within the offshore area in question, as well as consideration of their seasonal and inter-annual variability and potential extreme events. The design of the FPSO and selection of drilling installations and vessels is based on a consideration of existing and anticipated conditions at site, including water depth, met-ocean conditions, and presence of sea ice and icebergs. Certain offshore activities, such as the deployment and use of geophysical or geotechnical, environmental equipment, have specific operational parameters and restrictions which require that they only be commenced and completed during specific environmental conditions. The potential for, and occurrence of, extreme meteorological and oceanographic conditions may also affect other project components, activities, and schedules, such as the scheduling of construction and installation activities, the timing of vessel movements and drilling activities.

The primary measures for mitigating risks associated with effects from the environment on the Project are engineering design that incorporates environmental criteria so that the physical conditions of the Project Area can be tolerated, and thorough planning that includes adherence to regulatory design and fitness standards. Design of the FPSO will adhere to applicable national and international standards and will consider site-specific normal and extreme physical environmental conditions. These national and international standards consider physical environmental criteria (e.g., temperature, wind, snow, waves, ice loading, drainage), as well as the life of the expected life of the design (i.e., choosing materials with sufficient durability and corrosion resistance). The selection of drilling installations and vessels will consider their ability of operate these environmental conditions. Similarly, the selection and procurement of OSVs and helicopters will require consideration of the operational requirements for such equipment, including weather and marine conditions.

The Project will require an OA from the C-NLOPB to commence operations. The OA, and the *Newfoundland Offshore Certificate of Fitness Regulations*, require an Operator obtain a Certificate of Fitness from an independent, third-party Certifying Authority (CA) for a FPSO and drilling installation. The CA must confirm that the installations meet the associated regulatory requirements, is fit for purpose, can function as intended, and remains in compliance with the regulations without compromising safety and polluting the environment. In addition, modifications/repairs to the installation that affects its strength, stability, integrity, operability, safety, or regulatory compliance need to be reviewed and accepted by the CA to ensure the continued validity of the certificate. Offshore installations must be designed, constructed, transported, and installed in accordance with Parts I to III of the *Newfoundland Offshore Petroleum Installations Regulations.*

17.3.1 Seismicity and Geohazards

The Project Area has been classified as having a relatively low seismic hazard (see Section 5.1.3.1). A seismic event could disrupt Project activities and increase the risk of potential accidental events. A seismic event could also contribute to sediment and seafloor instability.

Earthquakes significant enough to trigger submarine landslides or tsunamis are estimated to be magnitude six or greater, and these have not occurred within 1,000 km of the Project Area since the inception of NRCan's earthquake database in 1985. The closest significant earthquakes were a 7.2-magnitude event in 1929 (Laurentian Slope >800 km away from Project Area) as well as a 7.0-magnitude event in 1663 (Charlevois-Kamouraska, Quebec >1,800km away from Project Area), and 4.1-magnitude event in 2018 (292 km northeast from Bonavista >300km away from Project Area).

Given the life of field for the Project, the probability of a major seismic event (and resulting landslides or tsunamis) occurring during the life of the Project is very low. In accordance with the *Newfoundland Offshore Certificate of Fitness Regulations*, the FPSO and drilling installation(s) are required to have a Certificate of Fitness, which requires that the installation be designed with potential environmental loads imposed by earthquakes and other naturally occurring phenomena were taken into account. The FPSO and/or drilling installation(s) are capable of disconnection in a short period of time, if necessary.

The potential for shallow gas, large objects or other geohazards will be determined based on wellsite surveys or the interpretation of existing seismic data. Wells will be positioned to avoid geohazards; location, design, and/or operational plan will be adjusted to reduce the risk to an acceptable level.

17.3.2 Climatology, Weather and Oceanographic Conditions

Adverse weather and oceanographic conditions, such as high winds, large waves, low visibility or freezing precipitation may affect Project activities.

Poor visibility resulting from fog, heavy rain, or snow conditions can hinder helicopter transits, which could potentially delay supply and personnel movement to and from the Project. The potential for accidental events (e.g., a vessel or helicopter collision potentially resulting in a spill) could also increase due to poor visibility. There are set visibility requirements for helicopter flights; if these requirements are not met, flights will not occur. In addition, there are specific navigational lighting requirements on the FPSO and drilling installation helipad and exterior. Vessels can operate in most weather conditions, however, reduce visibility may result in slower speeds. Visibility forecasts will be used to inform personnel of expected conditions at scheduled departure, transit and arrival times. The FPSO, drilling installation and vessels will have obstruction lights, navigation lights, and/or foghorns. Radio communication systems will be in place to contact other marine vessels, shorebase and OSVs.

Severe and/or extreme weather conditions, such as high wind and wave conditions, have the potential of delaying cargo or personnel transit. Adequate food and water supplies are stored onboard the installations to accommodate such delays. Extreme wind and wave conditions could also result in accidental spills, suspension or delay of operations (production and/or drilling), evacuation of the installations, and in extreme cases, may lead to fatalities. Extreme weather conditions such as high wind, high waves and freezing precipitation can cause increased stress conditions on the FPSO and/or drilling installation superstructure, and vessels, and potentially result in impacts to the superstructure or, in extremely unlikely cases, failure or capsizing. To mitigate these risks, the Project will comply with Canadian regulations for engineering design and will adhere to international standards where applicable. For example, an OA and the requisite approvals for drilling are required from the C-NLOPB to conduct carryout production and/or drilling activities. Certificates of Fitness (from an independent third-party CA) for the FPSO and drilling installation are required in accordance with the *Newfoundland Offshore Certificate of Fitness Regulations*, prior to the offshore installation of the facilities and the start of production or drilling activities. These regulations require that offshore installations are designed, constructed, transported, and installed or established in accordance with the *Newfoundland Offshore Petroleum Installations Regulations*, requiring components of an installation be designed using good engineering practice, and taking into account the specific activities of the installation and the physical environment surrounding the installation. Engineering design is based on analyses, model tests, and/or simulations under foreseeable transportation, installation, and operating conditions. Pursuant to Parts I to III of the *Newfoundland Offshore Petroleum Installations Regulations*, engineering design of an installation must take into account (among other factors) the type and magnitude of loads imposed by ice, sea ice, snow, waves, currents, tides, wind, or by a combination of those phenomena, and operating ambient temperatures. The FPSO will be designed to safely operate in a range of environments including extreme conditions. Similarly, the selection of drilling installation and vessels will consider their operability in harsh environment. Floating installations will be classed by a recognized Classification Society, which ensures that flag state and international maritime rules are followed for the design and construction of the installation. These rule sets govern the stability and integrity of the installations for the physical environment in which they will be operating.

Superstructure icing can result from freezing precipitation or a combination of low ambient air temperature, low sea surface temperatures, and wind-induced sea spray. Superstructure icing can result in a raised centre of gravity, slower vessel speed, and maneuvering difficulty, as well as problems with cargo-handling equipment (DFO 2012). Delays from superstructure icing can result if operations are slowed (or suspended) to remove ice accumulations. The FPSO will be designed in accordance with recognized standards to handle certain extreme icing loads, including the buildup of ice, should it occur. Operating experience for other drilling and production facilities in the offshore area indicates that the observed icing is significantly less than allowed in the design of the facilities. However, if the meteorological conditions are present, visual monitoring for the buildup of icing will be carried out, and if required, the ice will be removed.

The collection and analysis of detailed and site-specific information on climatic and meteorological conditions (winds, waves, precipitation, and temperatures) and oceanographic characteristics (including waves, currents, sea ice and icebergs) are also typically part of an operator’s overall planning and design of operations offshore. Appropriate design and planning based on this information, such as in program scheduling, equipment selection and the development and implementation of appropriate operational procedures, helps to facilitate the safety of personnel, equipment, vessels, and the natural environment during the execution of offshore production and exploration activities. In addition to pre-commencement analysis and planning, meteorological and oceanographic monitoring programs will be implemented throughout Project activities to provide weather forecasts and respond to severe environmental conditions.

The Offshore Physical Environment Guidelines (NEB et al. 2008) require that offshore operators implement a physical environment monitoring program. This includes monitoring of meteorological conditions and onsite weather observation, ice management, and other met ocean and marine monitoring and forecasting. Meteorological condition monitoring includes winds, precipitation, temperature, and visibility, while oceanographic monitoring includes waves and currents. The information acquired through Equinor Canada’s previous metocean data collection and as summarized in the metocean design basis (Statoil 2017a) contribute to appropriate equipment selection, program scheduling, and the development of operational procedures, all of which are key factors to facilitate safe operations and reduced risks to personnel, environment, equipment and vessels.

In addition to pre-commencement analysis and planning, meteorological and oceanographic monitoring programs are implemented throughout offshore programs to forecast and plan for severe environmental conditions. In situ metocean monitoring and observations programs are essential to support weather and marine forecasting, which will be obtained from a contracted third-party forecaster. Environment and Climate Change Canada (ECCC) issues marine weather observations, forecast bulletins, special weather statements, watches, alerts, and warnings via the MSC’s Automated Telephone Answering Device, ECCC’s Graphical Forecast Area (GFA), weather radio (continuously broadcast over VHF or FM radio), and regional storm prediction centres. Furthermore, the NL weather office in Gander provides year-round marine weather and wave height information for waters around NL, out to approximately 250 nautical miles (NM) (DFO 2018). Equinor Canada will contract weather forecasting services, which will provide forecasts specific to the Project Area. Monitoring of these forecasts provides OSVs, helicopters, drilling installation, and the FPSO a forewarning of extreme weather conditions. Vessel captains, helicopter pilots and the FPSO/drilling installation Offshore Installation Managers will have the authority to suspend or modify operations in case of adverse weather that could compromise the safety of offshore supply vessel, helicopter, or production/drilling operations.

17.3.3 Sea Ice and Icebergs

The Project Area is subject to seasonal intrusions of sea ice and icebergs. Ice conditions pose a seasonal risk to operations offshore NL. Support vessel navigation and delivery of personnel and supplies can be hindered by the presence of sea ice and icebergs. Their presence in the area may also result in the need to suspend operations or move the FPSO and/or drilling installation to avoid collision. The primary risk from sea ice is at the ocean surface (e.g., vessel collision, impact with installations). Icebergs can pose a risk to subsea equipment, however with water depths in the Project Area ranging from 340 m to 1,200 m, there is no risk of iceberg scour.

Ice monitoring / observation and management is a vital component in the reduction of ice related risks and has been conducted and continuously improved offshore NL for several decades. In accordance with the Offshore Physical Environmental Guidelines (NEB et al. 2008) and as required under the C-NLOPB OA application process, operators are required to prepare and submit an ice management plan to the C-NLOPB. Equinor Canada’s Project-specific ice management plan will include procedures related to ice detection, monitoring and assessment as well as the physical management of icebergs, and will outline procedures for the implementation of disconnection and movement of the FPSO due to presence of an iceberg. The ice management plan will be submitted to the C-NLOPB for acceptance as part of the OA process. There is a proven coordinated ice management approach amongst the offshore oil and gas operators in NL, which facilitates sharing of information (including ice detection and monitoring) as well as physical management resources.

Various initiatives are in place to detect and monitor sea ice and icebergs in the region. Refer to Section 16.2.3 of the Drilling EIS (Statoil 2017b) for an overview of these initiatives. For the Project, monitoring and radar equipment will be installed on the FPSO. The FPSO will be ice-strengthened (refer to Section 2.5.1.1) and vessels and shuttle tankers will be capable of operating in ice-prone waters.

17.4 Residual Effects Summary

A significant adverse residual effect of the environment on the Project is defined as one that results in one or more of the following:

- Project infrastructure is damaged, causing harm to Project personnel or the public
- A substantial impact to the Project schedule delaying Project activities by more than one season or resulting in a shutdown of production or drilling operations for three months or more
- Project infrastructure is damaged, resulting in repairs that are not technically or economically feasible

The key environmental factors, as describe above, that may affect the Project include severe and/or extreme weather conditions, sea ice, icebergs, superstructure icing, oceanographic conditions, and geological stability and seismicity (unlikely due to low probability of occurrence).

Engineering design, operational procedures, and mitigation measures discussed in Sections 17.1 and 17.3 will reduce potential adverse effects to the Project.

Based on the significance criteria defined above, and with the application of the engineering and environmental design standards, operational procedures, offshore regulations (e.g., *Newfoundland Offshore Certificate of Fitness Regulations*, *Newfoundland Offshore Petroleum Installations Regulations*), flag state regulations, international codes, and Classification Society Rules, and adherence to the Offshore Physical Environmental Guidelines (NEB et al. 2008), it is predicted that there will be no significant adverse residual effects of the environment on the Project.

There is potential for effects of the environment on the Project to result in the Project having an accidental event or experiencing a malfunction. Potential environmental effects of Project-related accidents and malfunctions are assessed in Chapter 16.

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18.0 ENVIRONMENTAL ASSESSMENT SUMMARY AND CONCLUSIONS

This chapter provides a summary of the potential environmental interactions that may occur between the VCs identified for assessment for the Project, and the resulting residual environmental effects, including their predicted significance.

18.1 Summary of Potential Effects

As a first step in assessing the potential effects of the Project on the selected VCs, interactions between Project activities included in the scope of the EIS and each VC are identified. A summary of the potential interactions between the VCs and planned Project activities, which formed the basis for the effects analysis, are presented in Table 18.1.

18.2 Summary of Mitigation and Commitments

Mitigation is proposed to reduce or eliminate adverse environmental effects. Design features and mitigation measures have been incorporated into the Project to prevent or reduce potential environmental effects. These design-feature mitigation measures, in combination with VC-specific mitigation measures will reduce environmental effects to acceptable levels. A summary of mitigation and commitments set out in the EIS is provided in Table 18.2.

18.3 Residual Environmental Effects

The residual environmental effects (i.e., after mitigation has been applied) for each VC for planned Project-related interactions as well as for cumulative environmental effects are evaluated and presented in Chapters 8 to 15 of the EIS. Tables 18.3 and 18.4 summarizes the residual environmental effects determinations for each VC for the Project (Core Bay du Nord (BdN) Development Activities and Potential Future Development) and indicates the significance of these effects. Where an effect is predicted to be significant (refer to the specific VC-chapter of the EIS for predefined criteria for each VC), the likelihood of that effect occurring is also presented. With the implementation of proposed mitigation measures (refer to Table 18.2), residual adverse environmental effects of routine Project activities and components are predicted to be not significant for all VCs.

The residual environmental effects related to accidental events are presented in Chapter 16 of the EIS. Tables 18.5 and 18.6 summarize the residual effect findings for each VC and indicates the significance of these effects. Spill prevention techniques and response strategies, as described in Section 16.1 of the EIS, will be incorporated into the design and operations for Project activities as part of contingency planning.

Table 18.1 Potential Project-VC Interactions Summary

Potential Environmental Effects	Project Component / Activity Core BdN Development and Project Area Tiebacks					
	Offshore Construction and Installation, and Hook-up and Commissioning	Production and Maintenance Operations	Drilling Activities	Supply and Servicing	Supporting Surveys	Decommissioning
Marine Fish and Fish Habitat (including Species at Risk)						
Change in Habitat Availability and/or Quantity	●	●	●			●
Change in Food Availability and/or Quality	●	●	●	●	●	●
Change in Fish and Invertebrate Mortality, Injury, and/or Health	●	●	●		●	
Change in Fish and Invertebrate Presence and/or Abundance (Behavioral Effects)	●	●	●	●	●	●
Marine and Migratory Birds (including Species at Risk)						
Change in Habitat Availability and/or Quality	●	●	●	●	●	●
Change in Food Availability and/or Quality	●	●	●	●	●	●
Change in Avifauna Presence and Abundance (Behavioural Effects)	●	●	●	●	●	●
Change in Mortality/Injury Levels and/or Health of Individuals or Populations	●	●	●	●	●	●
Marine Mammals and Sea Turtles (including Species at Risk)						
Change in Injury and/or Mortality Levels		●	●	●	●	●
Change in Habitat Quality and/or Use	●	●	●	●	●	●
Change in Prey Availability and/or Quality	●	●	●	●	●	●
Change in Health		●				

Table 18.1 Potential Project-VC Interactions Summary

Potential Environmental Effects	Project Component / Activity Core BdN Development and Project Area Tiebacks					
	Offshore Construction and Installation, and Hook-up and Commissioning	**Production and Maintenance Operations**	**Drilling Activities**	**Supply and Servicing**	**Supporting Surveys**	**Decommissioning**
Special Areas						
Change in Environmental Features and/or Processes	●	●	●	●		●
Change in Human Use and/or Societal Value				●		
Commercial Fisheries and Other Ocean Uses						
Direct interference caused by the Project with fishing harvesting and other marine activities, resulting in a change in the distribution, intensity, function and/or value of Commercial Fishing and Other Ocean Uses	●	●	●		●	●
Damage caused by the Project to fishing gear, vessels, and other existing subsea infrastructure, and associated loss of incomes for harvesters or other marine operators	●	●		●	●	●
Change in abundance, distribution and/or quality of marine resources, resulting in a change in the distribution, intensity, function, and/or value of Commercial Fishing and Other Ocean Uses					●	

Table 18.1 Potential Project-VC Interactions Summary

Potential Environmental Effects	Project Component / Activity Core BdN Development and Project Area Tiebacks					
	Offshore Construction and Installation, and Hook-up and Commissioning	**Production and Maintenance Operations**	**Drilling Activities**	**Supply and Servicing**	**Supporting Surveys**	**Decommissioning**
Indigenous Peoples						
Change in Commercial-Communal Fisheries	●	●	●	●	●	●
Change in the Current Use of Lands and Resources for Traditional Purposes	●	●	●	●	●	●

Table 18.2 Summary of Mitigation and Commitments

No.	Equinor Canada Mitigations and Commitments
1.	Project activities will be undertaken in accordance with internal Equinor Canada's management systems, standards and policies.
2.	In consideration of the OWTG and regulatory discharge limits, for marine discharges associated with the Project, the use of best treatment practices that are commercially available and economically feasible will be implemented.
3.	The selection and screening of chemicals to be discharged, will be undertaken in consideration of the Offshore Chemical Selection Guidelines for Drilling and Production Activities on Frontier Lands (OCSG) and Equinor Canada's chemical selection and screening processes.
4.	Contractors shall be required to demonstrate conformance with the requirements that have been established, including HSSE standards and performance requirements.
5.	Base case is to treat produced water using best treatment practices that are commercially available and economically feasible and discharge to the marine environment
6.	Treated produced water and cooling water will be combined prior to discharge. Sampling ports downstream of last treatment unit for each discharge will be available to collect requisite compliance samples prior to comingling.
7.	Flaring on the FPSO will not occur during routine operations and excess gas will be re-injected into the reservoir.
8.	Low pressure flare gas (e.g., produced water degassing, cargo tank blanket gas) will be recovered, therefore no continuous flaring, which reduces air emissions and light emissions.
9.	Equinor Canada is evaluating flare pilot options – pilot flare vs pilotless flare.
10.	High efficiency burners (flare tip) will be used when flaring is required to reduce air emissions.
11.	The duration of non-routine flaring will typically be of short duration and will be governed by Equinor best practices to reduce overall flaring duration, thereby reducing light emissions from flaring
12.	A flaring and venting plan will be submitted to the CNLOPB for review and acceptance in in support of the application for Operations Authorization, which will outline planned non-routine flaring events. It is the understanding of Equinor Canada that a flaring and venting plan is required to be submitted annually for approval.
13.	The preferred option is for well clean up to be done through the FPSO. However, if required, the option is available to flare from the drilling installation during well clean-up and/or well flow testing.
14.	Best treatment practices that are commercially available and economically feasible will be utilized for treatment of drill cuttings.
15.	Synthetic-based mud (SBM)-related drill cuttings will be returned to the drilling installation and treated in consideration of the Offshore Waste Treatment Guidelines (OWTG) before being discharged to the marine environment.
16.	WBM-related drill cuttings will be discharged without treatment per the OWTG.
17.	Appropriate procedures will be implemented for the handling, storage, transportation, and onshore disposal of solid and hazardous waste
18.	Sewage and grey water will be treated in consideration of the OWTG and in accordance with Canadian and international regulatory requirements.
19.	Ballast water and hull fouling will be managed in consideration of applicable Canadian and international requirements to reduce the potential spread of invasive species.

Table 18.2 Summary of Mitigation and Commitments

No.	Equinor Canada Mitigations and Commitments
20.	Use of anti-fouling paint on hull of FPSO
21.	Marine discharges (e.g., bilge water) are will be treated in accordance with MARPOL and Canadian requirements prior to discharge
22.	Use of common vessel and aircraft travel routes for vessels and helicopters will be used where possible and practicable.
23.	Low-level aircraft operations will be limited or avoided where it is not required per Transport Canada protocols.
24.	A decommissioning plan will be submitted to the C-NLOPB for review and acceptance. The plan will be developed in consideration of regulatory requirements in place at the time of decommissioning, engagement with Indigenous groups, commercial fisheries and other stakeholders and likely effects on the environment.
25.	At the time of decommissioning a well, the well will be inspected in accordance with applicable regulatory requirements.
26.	At the time of decommissioning, all surface facilities (e.g. FPSO, turret, anchor lines) will be removed.
27.	Use of explosives will not be employed for removal of wellheads.
28.	Use of variable speed drive on equipment with high power consumption (e.g., gas compressors, water injection pumps) to optimize energy efficiency.
29.	Use of waste heat recovery units for energy optimization, capturing energy from engines/turbine exhaust stack to provide heat for systems on board the FPSO.
30.	Selection and use of high efficiency equipment for power generation.
31.	Air emission sources associated with vessels will adhere to applicable limits set out in the *Vessel Pollution and Dangerous Chemicals Regulations*.
32.	Sulphur content in diesel fuel associated with vessels will meet the *Sulphur in Diesel Fuel Regulations* and will comply with the sulphur limits in fuels for large marine diesel engines, per the *Vessel Pollution and Dangerous Chemicals Regulations* under the *Canada Shipping Act, 2001*.
33.	The Project will operate in accordance with the Canadian Environmental Protection Act, through the National Ambient Air Quality Objectives for specified criteria air contaminants, the Ambient Air Quality Standard for fine particulate ($PM_{2.5}$), and the IMO relevant regulations and emission limits under MARPOL, as applicable.
34.	With regards to subsea layout, well templates will not be placed over Lophelia pertusa corals
35.	Discharge locations for water-based cuttings, when cuttings transport system is used, will be determined based on the C-NLOPB requirements to avoid Lophelia pertusa complexes and / or assemblages of 5 or more corals in 100 m2 with heights greater than 30 cm within 100 m of the discharge location
36.	Where Project activities may affect fish habitat, and it is determined through DFO's "Request for Review" process pursuant to the *Fisheries Act* that a *Fisheries Act* Authorization is required, a habitat offsetting program will be developed in conjunction with DFO and in consultation with Indigenous Groups and stakeholders as a mitigation measure for the net loss of fish habitat resulting from the Project (See Appendix O).

Table 18.2 Summary of Mitigation and Commitments

No.	Equinor Canada Mitigations and Commitments
37.	Helicopter flight paths and offshore supply vessel (OSV) traffic routes will avoid passing within 300 m of established migratory bird nesting colonies during the nesting period (May 1 – Aug 31; Sept 30 for northern gannet colonies) and will adhere with NL *Seabird Ecological Reserve Regulations, 2015* and in consideration of federal guidelines in order to reduce disturbance to seabird colonies.
38.	Lighting on the FPSO will be reduced to the extent that worker safety and safe operations, per regulatory requirements, are not compromised. Lighting reduction options will be evaluated during detail design, and economically and technically feasible options, which do not compromise worker safety and safe operations, will be implemented. This may include, but not limited to shading, avoiding use of unnecessary lighting, and directional lighting (i.e., towards the deck and not out to sea). Equinor Canada will engage with ECCC on the results of the lighting engineering study(s) undertaken in the front-end engineering and design phase before proceeding to detailed design. The selection of technical and economic feasible lighting options will be undertaken at detail design, whereby Equinor Canada will again engage with ECCC on the selection of lighting options.
39.	With regards to stranded seabirds the following will be undertaken: • Routine systematic searches for stranded seabirds will be conducted on vessels engaged in construction and installation activities and HUC, the FPSO, drilling installation(s), stand-by vessels (SBVs), and during supporting surveys. Searches will be undertaken by vessel/installation crew, who have been trained in bird identification and handling. • Equinor Canada will work with ECCC to develop installation/vessel-specific protocols applicable to the Project with respect to the systematic searches for, and documentation of, stranded birds. • Appropriate programs and protocols for the collection and release of stranded seabirds will be implemented. The program will consider the following existing protocols: ECCCs “Procedures for handling and documenting stranded birds encountered on infrastructure offshore Atlantic Canada” (ECCC 2017). • If a Species at Risk is found alive (stranded) or dead on the FPSO, drilling installation or SBVs, a report will be sent to ECCC for identification.
40.	A Seabird Handling Permit will be obtained from ECCC-CWS annually.
41.	In accordance with ECCC requirements, an annual report, including all occurrence data will be submitted to ECCC which summarizes stranded and/or seabird handling in accordance with the Seabird Handling permit and seabird observation data.
42.	If a Leach’s storm-petrel is found deceased on the FPSO, drilling installation or SBVs, the carcass will be sent to ECCC for further evaluation.
43.	In consideration of the Geophysical, Geological, Environmental and Geotechnical Program Guidelines (C-NLOPB 2019), mitigation measures applied during the Project’s geophysical surveys where air source arrays are used will be consistent with those outlined in the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP) (DFO 2007). This includes implementing shut downs of the air source array(s) when SAR listed as Endangered or Threatened on Schedule 1 of SARA (as well as all beaked whale species) are detected within the safety zone during anytime air sources are active, including ramp up.
44.	Shut-down of air source arrays for all beaked whales when detected within safety zone

Table 18.2 Summary of Mitigation and Commitments

No.	Equinor Canada Mitigations and Commitments
45.	Consistent with International Regulations for Preventing Collisions at Sea, 1972 with Canadian Modifications, Rule 5, every vessel shall maintain a proper lookout at all times. Project vessels will alter course and/or reduce speed if a marine mammal(s) (or sea turtle) is detected ahead of the vessel
46.	Equinor Canada will develop a marine mammal and sea turtle observation program for 4D seismic surveys which will be provided to DFO for review and acceptance.
47.	Equinor Canada will communicate seismic survey plans to C-NLOPB and geophysical operators as early as possible to reduce concurrent seismic surveys and/or to maximize the separation distance between surveys to the extent possible.
48.	If Equinor Canada is aware of a Project vessel striking a marine mammal or sea turtle, Equinor Canada will inform DFO through their 24-hour emergency contact number (1-888-895-3003).
49.	Equinor Canada will, in accordance with its commitment to ongoing engagement with identified Indigenous groups throughout the EA process continue to review their inputs and perspectives as the planning and eventual implementation of the Project progresses. Equinor Canada will consider such input in its Project-related planning and decision-making as applicable and appropriate, including in the design of any monitoring and follow-up program in accordance with Section 9 of the EIS Guidelines.
50.	Equinor Canada will establish an anti-collision zone for the FPSO and drilling installation(s) pursuant to Transport Canada regulations. Pursuant to the Drilling and Production Regulations, a safety zone demarcating the extent of subsea infrastructure will be established.
51.	Equinor Canada will provide appropriate regulatory authorities the coordinates of the safety zone and/and or anti-collision zone for addition to marine navigational charts
52.	Equinor Canada is evaluating the need for subsea infrastructure protection. In determining the need for protection measures, the level and types of historical fishing effort in the Project and Core BdN Development Area will be considered. Options for trawl protection will be in consideration of Equinor's global experience.
53.	Ongoing communication with commercial fishers through One Ocean, FFAW-Unifor and seafood producers regarding planned Project activities, including notification of coordinates of safety and/or anti-collision zones.
54.	Ongoing communications with the NAFO Secretariat, through DFO as the Canadian representative, regarding planned Project activities, including communication of anti-collision and/or safety zones.
55.	Ongoing communication with regulatory agencies to share information regarding the timing and location of activities (e.g. DFO research surveys, DND offshore military exercises).
56.	Equinor Canada will engage with DND to determine appropriate communication protocols regarding project activities.
57.	Equinor Canada will develop and implement a compensation program for damages or losses in consideration of the C-NLOPB Compensation Guidelines Respecting Damages Relating to Offshore Petroleum Activities (2017) and aligned with the Best Practices Document for Compensation Processes and Procedures that One Ocean is currently preparing.
58.	In consideration with the One Ocean "Risk Management Matrix Guidelines", the need for a Fisheries Liaison Officer (FLO) and/or fisheries guide vessels during drilling installation movement from a NL port to its offshore location will be determined in consideration of the guidelines.

Table 18.2 Summary of Mitigation and Commitments

No.	Equinor Canada Mitigations and Commitments
59.	Equinor Canada will implement a standard marine communication protocol to promote safe practices between commercial fishing enterprises, other marine users and BdN operations. The protocol will be in accordance with the One Ocean "Protocols for Communication with Oil Installations on the Grand Banks," which outlines communication requirements upon approach to the safety zone.
60.	Issuance of Navigational Warnings (formerly Notices to Shipping) and Notices to Mariners (where appropriate) regarding planned Project activities.
61.	Upon final decommissioning, if applicable, the communication through Notices to Mariners and DFO for inclusion on nautical charts, of the locations of any subsea infrastructure that may be left in the Project Area.
62.	Design of the FPSO such that it is capable of operating in deep water and in the environmental conditions prevalent in the Project Area and larger Regional Study Area.
63.	Selection criteria for drilling installation, OSVs/SBVs and other vessels engaged in Project activities such that they are capable of operating year-round at water depths and the environmental conditions prevalent in the Project Area and larger Regional Study Area.
64.	Third-party certification, a Certificate of Fitness, for the FPSO, the drilling installation and subsea infrastructure, as required to obtain an Operations Authorization issued by the C-NLOPB.
65.	The Project will comply with Canadian regulations for engineering design and will adhere to international standards where applicable.
66.	Physical environment data observations, weather forecasting, and reporting will be conducted in consideration with the Offshore Physical Environmental Guidelines.
67.	Ability to disconnect the FPSO and/or drilling installation.
68.	With regards to superstructure icing, which can occur under certain meteorological conditions, the installations will be monitored for icing conditions and accumulation rates, as applicable. Measures to reduce icing include removal and/or melting of the ice.
69.	Implementation of an Ice Management Plan, which will outline ice and iceberg observations and protocols for disconnection of the FPSO. Equinor Canada is evaluating options for iceberg detection, such as ice detection radar and use of satellite imaging data.
70.	Weather forecasting services to provide site specific forecasting for production and /or drilling operations.
71.	Vessel captains, helicopter pilots and the Offshore Installation Managers of the FPSO or drilling installation are responsible and have the authority to suspend or modify respective operations in case of adverse weather or environmental conditions that could compromise the environmental integrity of operations.
72.	The use of obstruction lights, navigation lights, and foghorns on board the FPSO and drilling installation(s) and supply vessels
73.	Develop and implement an environmental effects monitoring program that reflects the final project design and considers the conclusions of the environmental effects assessment, and the requirements outlined in the EIS Guidelines. Equinor Canada will engage with regulatory agencies, Indigenous groups and key stakeholders for additional information or further input into EEM plans.

Table 18.3 Residual Environmental Effects Summary – Core Bay du Nord Development

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 "environmental effect")	Potential Environmental Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Confidence
Marine Fish and Fish Habitat (including Species at Risk)	s. 5(1)(a)(i)	• Change in Habitat Availability and Quality • Change in Food Availability and Quality • Change in Fish and Invertebrate Mortality, Injury and Health • Change in Fish and Invertebrate Presence and Abundance (Behavioural Effects)	Offshore Construction and Installation, and Hook Up and Commissioning	See Section 9.1.5.2 and Table 18.2	A	N - L	<1 km^2 - <10 km^2	S - M - L	S - R - C	R	M - H
			Production and Maintenance Operations		P - A	N-L	<1 km^2 - <10 km^2	L	N - S - R - C	R	M - H
			Drilling Activities		A	N-L	<1 km^2 - <10 km^2	S - M - L	N - S - R - C	R	M - H
			Supply and Servicing		A	N - L	<1 km^2	S - L	S - R - C	R	H
			Supporting Surveys		A	N - L	<1 km^2 <1,000 km^2 - <10,000 km^2	S	N - S	R	M - H
			Decommissioning		N - A	N	<1 km^2 - <10 km^2	L	O	N/A	M - H
Marine and Migratory Birds (including Species at Risk)	s. 5(1)(a)(iii)	• Change in Habitat Availability and Quality • Change in Food Availability and Quality • Change in Avifauna Presence and Abundance (Behavioural Effects) • Change in Mortality/Injury Levels and Health of Individuals or Populations	Offshore Construction, Hook Up and Commissioning	See Section 10.1.5.2 and Table 18.2	P - A	N - L	<1 km^2 - <1000 km^2	S	S - C - R	R	M - H
			Production and Maintenance Operations		P - A	N – L - M	<1 km^2 - <1000 km^2	L	N - S - C - R	R	M - H
			Drilling Activities		P - A	N – L - M	<1 km^2 - <1000 km^2	S - M	N - S - C - R	R	M - H
			Supply and Servicing		P - A	N - L	<1 km^2 - <1000 km^2	S - L	S - C - R	R	M - H
			Supporting Surveys		P - A	N - L	<1 km^2 - <1000 km^2	S	N - S - C - R	R	M - H
			Decommissioning		N - A	N	<1 km^2	S	O	N/A	H

Table 18.3 Residual Environmental Effects Summary – Core Bay du Nord Development

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 “environmental effect”)	Potential Environmental Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Confidence
Marine Mammals and Sea Turtles (including Species at Risk)	s. 5(1)(a)(ii) s. 5(1)(a)(ii)	• Change in Injury and/or Mortality Levels • Change in Habitat Quality and Use • Change in Prey Availability or Quality • Change in Health	Offshore Construction, Hook Up and Commissioning	See Section 11.1.5.2 and Table 18.2	A	N-L	<10 km2 to 100 km2 - 1,000 km2	S	C	R	M-H
			Production and Maintenance Operations		A	N – L - M	<1 km2 - <10 km2 - <1,000 km2	L	N - C	R	M-H
			Drilling Activities		A	N – L - M	<1 km^2 - <10,000 km^2	M - L	N - C	R	M-H
			Supply and Servicing		A	N-L	<10 km2 to 100 km2 - 1,000 km2	S - L	N - S - C - R	R	M-H
			Supporting Surveys		A	N – L - M	<1 km2 - <10 km2 - <10,000 km2	S - L	N - S - C	R	M-H
			Decommissioning		A	L	<10 km2 to 100 km2-1,000 km2	S	R	N/A	M-H
Special Areas	s. 5(1)(b)(i)	• Change in Environmental Features and/or Processes • Change in Human Use and/or Societal Value	Offshore Construction, Hook Up and Commissioning	See Section 12.1.5.2 and Table 18.2	A	L	<10 km^2	M - L	S - R	R	M - H
			Production and Maintenance Operations		P – A	L	<10 km^2	L	C	R	M – H
			Drilling Activities		A	L	<1 km^2	M - L	C	R	M - H
			Supply and Servicing		A	N – L	<1 km^2 - <1000 km^2	S - L	S - R	R	M - H
			Supporting Surveys		No Interaction						
			Decommissioning		A	N	<1 km^2 - <10 km^2	S - L	O	N/A	H

Table 18.3 Residual Environmental Effects Summary – Core Bay du Nord Development

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 "environmental effect")	Potential Environmental Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Confidence
Commercial Fisheries and Other Ocean Uses	s. 5(2)(b)(i)	• Direct interference caused by the Project with fishing activity and other marine activities, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses • Damage caused by the Project to fishing gear, vessels, and other existing subsea infrastructure, and associated loss of catch for harvesters • Change in abundance, distribution and quality of marine resources, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses	Offshore Construction, Hook Up and Commissioning	See Section 13.1.5.2 and Table 18.2	A	N	<10 km^2	S - L	S- C	R	H
			Production and Maintenance Operations		A	N	<10 km^2	L	S - C	R	H
			Drilling Activities		A	N	<1 km^2	M	C	R	H
			Supply and Servicing		A	N	<10 km^2	S	S	R	H
			Supporting Surveys		A	N	<1 km^2 and <1000 km^2 - 10,000 km^2	S - L	S - C	R	H
			Decommissioning		N - A	N	<10 km^2	L	O – S	N/A	H
Indigenous Peoples	s.5(1)(c)(i) s.5(1)(c)(iii)	• Change in Commercial-Communal Fisheries • Change in the Current Use of Lands and Resources for Traditional Purposes	Offshore Construction, Hook Up and Commissioning	See Section 14.1.5.3 and Table 18.2	N - A	N	<10 km^2	L	C	R	H
			Production and Maintenance Operations		N - A	N	<10 km^2	L	C	R	H
			Drilling Activities		N - A	N	<1 km^2	M	C	R	H
			Supply and Servicing		N - A	N	<10 km^2	S	S	R	H
			Supporting Surveys		N - A	N	<100 km^2 - <1000 km^2	S	C	R	H
			Decommissioning		N - A	N	<10 km^2	L	O	N/A	H

Table 18.3 Residual Environmental Effects Summary – Core Bay du Nord Development

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 "environmental effect")	Potential Environmental Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Confidence**
Key/Note: **Environmental Effects under CEAA, 2012:** 5(1) (a) a change that may be caused to the following components of the environment that are within the legislative authority of Parliament: (i) fish as defined in Section 2 of the *Fisheries Act* and fish habitat as defined in subsection 34(1) of that Act, (ii) aquatic species as defined in subsection 2(1) of the *Species at Risk Act*, (iii) migratory birds as defined in subsection 2(1) of the *Migratory Birds Convention Act*, 1994, and (iv) any other component of the environment that is set out in Schedule 2 of [CEAA, 2012]; (b) a change that may be caused to the environment that would occur (i) on federal lands, (ii) in a province other than the one in which the act or thing is done or where the physical activity, the designated project or the project is being carried out, or (iii) outside Canada; and (c) with respect to Aboriginal peoples, an effect occurring in Canada of any change that may be caused to the environment on (i) health and socioeconomic conditions, (ii) physical and cultural heritage, (iii) the current use of lands and resources for traditional purposes, or (iv) any structure, site or thing that is of historical, archaeological, paleontological or architectural significance. Certain additional environmental effects must be considered under Section 5(2) of CEAA, 2012 where the carrying out of the physical activity, the designated project, or the project requires a federal authority to exercise a power or perform a duty or function conferred on it under any Act of Parliament other than CEAA, 2012. 5(2) (a) a change, other than those referred to in paragraphs (1)(a) and (b), that may be caused to the environment and that is directly linked or necessarily incidental to a federal authority's exercise of a power or performance of a duty or function that would permit the carrying out, in whole or in part, of the physical activity, the designated project or the project; and (b) an effect, other than those referred to in paragraph (1)(c), of any change referred to in paragraph (a) on (i) health and socioeconomic conditions, (ii) physical and cultural heritage, or (iii) any structure, site or thing that is of historical, archaeological, paleontological or architectural significance.					Nature / Direction: A – Adverse P – Positive N – Neutral (or no effect) - = Rating not required because the effect is not expected to occur	Magnitude: N - Negligible L - Low M - Medium H – High - = Rating not required because the effect is not expected to occur or because the effect is neutral	Extent: • Less 1 km^2 • Less than 10 km^2 • Less than 100 km^2 • Less than 1,000 km^2 • Less than 10,000 km^2 • Greater than 10,000 km^2 - = Rating not required because the effect is not expected to occur or because the effect is neutral	Duration: S – Short-Term - less than 12 months (1 year) M – Medium-Term - 1 to 5 years L – Long-Term - more than 5 years - = Rating not required because the effect is not expected to occur or because the effect is neutral	Frequency: N – not likely to occur O - Occurs once S - Occurs sporadically R - Occurs on a regular basis C - Occurs continuously - = Rating not required because the effect is not expected to occur or because the effect is neutral	Reversibility: R – Reversible (will recover to baseline) I – Irreversible (permanent) - = Rating not required because the effect is not expected to occur or because the effect is neutral	Confidence in Predictions: L - Low level of confidence M - Moderate level of confidence H - High level of confidence

Table 18.4 Residual Environmental Effects Summary – Project Area Tiebacks

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 “environmental effect”)	Potential Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	**Magnitude**	**Extent**	**Duration**	**Frequency**	**Reversibility**	**Confidence**
Marine Fish and Fish Habitat (including Species at Risk)	s. 5(1)(a)(i)	• Change in Habitat Availability and Quality • Change in Food Availability and Quality • Change in Fish and Invertebrate Mortality, Injury and Health • Change in Fish and Invertebrate Presence and Abundance (Behavioural Effects)	Offshore Construction, Hook Up and Commissioning	See Section 9.1.5.2 and Table 18.2	A	N - L	<1 km^2; 10 km^2- 100 km^2	S - L	S - R - C	R	M - H
			Production and Maintenance Operations		P - A	N - L	<1 km^2 - <10 km^2	L	N - S - R - C	R	M - H
			Drilling Activities		A	N - L	< 1 km^2 - <100 km^2	S - M - L	N - S - R - C	R	M - H
			Supply and Servicing		A	N - L	<1 km^2	S - L	S - R - C	R	H
			Supporting Surveys		A	N - L	<1 km^2 <1,000 km^2 - <10,000 km^2	S	N - S	R	M-H
			Decommissioning		N - A	N	< 10 km^2 - <100 km^2	L	O	N/A - Y	M - H
Marine and Migratory Birds (including Species at Risk)	s. 5(1)(a)(iii)	• Change in Habitat Availability and Quality • Change in Food Availability and Quality • Change in Avifauna Presence and Abundance (Behavioural Effects) • Change in Mortality/Injury Levels and Health of Individuals or Populations	Offshore Construction, Hook Up and Commissioning	See Section 10.1.5.2 and Table 18.2	P - A	N - L	<1 km^2 - <1000 km^2	S	S - C - R	R	M - H
			Production and Maintenance Operations		P - A	N – L - M	<1 km^2 - <1000 km^2	L	N - S - C - R	R	M - H
			Drilling Activities		P - A	N – L - M	<1 km^2 - <1000 km^2	S - M	N - S - C - R	R	M - H
			Supply and Servicing		P - A	N - L	<1 km^2 - <1000 km^2	S - L	S - C - R	R	M - H
			Supporting Surveys		P - A	N - L	<1 km^2 - <1000 km^2	S	N - S - C - R	R	M - H
			Decommissioning		N - A	N	<1 km^2	S	O	N/A	H

Table 18.4 Residual Environmental Effects Summary – Project Area Tiebacks

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 "environmental effect")	Potential Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	**Magnitude**	**Extent**	**Duration**	**Frequency**	**Reversibility**	**Confidence**
Marine Mammals and Sea Turtles (including Species at Risk)	s. 5(1)(a)(ii) s. 5(1)(a)(ii)	• Change in Injury and/or Mortality Levels • Change in Habitat Quality and Use • Change in Prey Availability or Quality • Change in Health	Offshore Construction, Hook Up and Commissioning	See Section 11.1.5.2 and Table 18.2	A	N-L	<10 km2 to 100 km2 - 1,000 km2	S	C	R	M-H
			Production and Maintenance Operations		A	N – L - M	<1 km2 - <10 km2 - <1,000 km2	L	N - C	R	M-H
			Drilling Activities		A	N – L - M	<1 km² - <10,000 km²	M - L	N - C	R	M - H
			Supply and Servicing		A	N-L	<10 km2 to 100 km2 - 1,000 km2	S - L	N - S - C - R	R	M-H
			Supporting Surveys		A	N – L - M	<1 km2 - <10 km2 - <10,000 km2	S - L	N - S - C	R	M - H
			Decommissioning		A	L	<10 km2 to 100 km2-1,000 km2	S	R	N/A	M-H
Special Areas	s. 5(1)(b)(i)	• Change in Environmental Features and/or Processes • Change in Human Use and/or Societal Value	Offshore Construction, Hook Up and Commissioning	See Section 12.1.5.2 and Table 18.2	A	L	<100 km²	M - L	S - R	R	M - H
			Production and Maintenance Operations		P – A	L	<10 km²	L	C	R	M – H
			Drilling Activities		A	L	<100 km²	M - L	C	R	M - H
			Supply and Servicing		A	N – L	<1 km² - <1000 km²	S - L	S - R	R	M - H
			Supporting Surveys		No Interaction						
			Decommissioning		A	N	<1 km² - <10 km²	S - L	O	N/A	H

Table 18.4 Residual Environmental Effects Summary – Project Area Tiebacks

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 "environmental effect")	Potential Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	**Magnitude**	**Extent**	**Duration**	**Frequency**	**Reversibility**	**Confidence**
Commercial Fisheries and Other Ocean Uses	s. 5(2)(b)(i)	• Direct interference caused by the Project with fishing activity and other marine activities, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses • Damage caused by the Project to fishing gear, vessels, and other existing subsea infrastructure, and associated loss of catch for harvesters • Change in abundance, distribution and quality of marine resources, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses	Offshore Construction, Hook Up and Commissioning	See Section 13.1.5.2 and Table 18.2	A	N - L	<100 km²	S	S - C	R	H
			Production and Maintenance Operations		A	N - L	<10 km² - <100 km²	L	S - C	R	H
			Drilling Activities		A	N - L	<1 km²	M	C	R	H
			Supply and Servicing		A	N	10 km²	S	S	R	H
			Supporting Surveys		A	N	<1 km² and <1000 km² - 10,000 km²	S - L	S- C	R	H
			Decommissioning		N - A	N - L	<1 km² - <100 km²	L	O – S	R	H
Indigenous Peoples	s.5(1)(c)(i) s.5(1)(c)(iii)	• Change in Commercial-Communal Fisheries • Change in the Current Use of Lands and Resources for Traditional Purposes	Offshore Construction, Hook Up and Commissioning	See Section 14.1.5.3 and Table 18.2	N - A	N - L	<100 km²	S	C	R	H
			Production and Maintenance Operations		N - A	N	<10 km²	L	C	R	H
			Drilling Activities		N - A	L	<1 km²	M	C	R	H
			Supply and Servicing		N - A	N	<10 km²	S	S	R	H
			Supporting Surveys		N - A	N - L	<100 km² - <1000 km²	S	C	R	H
			Decommissioning		N - A	N - L	<100 km²	L	O	N/A	H

Table 18.4 Residual Environmental Effects Summary – Project Area Tiebacks

Valued Component	**Area of Federal Jurisdiction (CEAA, 2012 s.5 "environmental effect")**	**Potential Effect**	**Project Activity**	**Mitigation**	**Residual Effect Characterization**						
					Nature / Direction	**Magnitude**	**Extent**	**Duration**	**Frequency**	**Reversibility**	**Confidence**
Key/Note: **Environmental Effects under CEAA, 2012:** 5(1) (a) a change that may be caused to the following components of the environment that are within the legislative authority of Parliament: (v) fish as defined in Section 2 of the *Fisheries Act* and fish habitat as defined in subsection 34(1) of that Act, (vi) aquatic species as defined in subsection 2(1) of the *Species at Risk Act*, (vii) migratory birds as defined in subsection 2(1) of the *Migratory Birds Convention Act*, 1994, and (viii) any other component of the environment that is set out in Schedule 2 of [CEAA, 2012]; (b) a change that may be caused to the environment that would occur (iv) on federal lands, (v) in a province other than the one in which the act or thing is done or where the physical activity, the designated project or the project is being carried out, or (vi) outside Canada; and (c) with respect to Aboriginal peoples, an effect occurring in Canada of any change that may be caused to the environment on (v) health and socioeconomic conditions, (vi) physical and cultural heritage, (vii) the current use of lands and resources for traditional purposes, or (viii) any structure, site or thing that is of historical, archaeological, paleontological or architectural significance. Certain additional environmental effects must be considered under Section 5(2) of CEAA, 2012 where the carrying out of the physical activity, the designated project, or the project requires a federal authority to exercise a power or perform a duty or function conferred on it under any Act of Parliament other than CEAA, 2012. 5(2) (a) a change, other than those referred to in paragraphs (1)(a) and (b), that may be caused to the environment and that is directly linked or necessarily incidental to a federal authority's exercise of a power or performance of a duty or function that would permit the carrying out, in whole or in part, of the physical activity, the designated project or the project; and (b) an effect, other than those referred to in paragraph (1)(c), of any change referred to in paragraph (a) on (iv) health and socioeconomic conditions, (v) physical and cultural heritage, or (vi) any structure, site or thing that is of historical, archaeological, paleontological or architectural significance.					Nature / Direction: A – Adverse P – Positive N – Neutral (or no effect) - = Rating not required because the effect is not expected to occur	Magnitude: N - Negligible L - Low M - Medium H – High - = Rating not required because the effect is not expected to occur or because the effect is neutral	Extent: • Less 1 km^2 • Less than 10 km^2 • Less than 100 km^2 • Less than 1,000 km^2 • Less than 10,000 km^2 • Greater than 10,000 km^2 - = Rating not required because the effect is not expected to occur or because the effect is neutral	Duration: S – Short-Term - less than 12 months (1 year) M – Medium-Term - 1 to 5 years L – Long-Term - more than 5 years - = Rating not required because the effect is not expected to occur or because the effect is neutral	Frequency: N - Not likely to occur O - Occurs once S - Occurs sporadically R - Occurs on a regular basis C - Occurs continuously - = Rating not required because the effect is not expected to occur or because the effect is neutral	Reversibility: R – Reversible (will recover to baseline) I – Irreversible (permanent) - = Rating not required because the effect is not expected to occur or because the effect is neutral	Confidence in Predictions: L Low level of confidence M Moderate level of confidence H High level of confidence

Table 18.5 Summary of Residual Effects for Accidental Events

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 “environmental effect”)	Potential Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Confidence
Marine Fish and Fish Habitat (including Species at Risk)	s. 5(1)(a)(i)	• Change in Habitat Availability and Quality • Change in Food Availability and Quality • Change in Fish and Invertebrate Mortality, Injury and Health • Change in Fish and Invertebrate Presence and Abundance (Behavioural Effects)	Site 1 - 36-Day Subsurface Blowout - 10,500 m^3/day	See Section 9.1.5.2 and Table 18.2	A	M	RSA	M-L	N	R	M-H
			Site 1 - 115-Day Subsurface Blowout - 10,500 m^3/day		A	M	RSA	M-L	N	R	M-H
			Site 2 - 36-Day Subsurface Blowout - 10,500 m^3/day		A	M	RSA	M-L	N	R	M-H
			Site 2 - 115-Day Subsurface Blowout - 10,500 m^3/day		A	M	RSA	M-L	N	R	M-H
			FPSO Surface Release - 8,300 m^3		A	L	RSA	S	N	R	M-H
			Offloading Surface Release - 1,000 m^3		A	L	RSA	S	N	R	M-H
			Production Flowline Subsurface Release - 500 m^3		A	L	LSA	S	N	R	M-H
			Bunkering Surface Release - 6 m^3		A	L	PA	S	S	R	M-H
			Vessel/vessel collision - 750 m^3		A	L	RSA	S	N	R	M-H
			Site 1 - SBM Whole Mud Spill - 60 m^3 surface spill		A	L	L	S	S	R	H
			Site 1 - SBM Whole Mud Spill - 275 m^3 flex joint failure subsurface release		A	L	L	S	N	R	H
			Site 1 - SBM Whole Mud Spill - 275 m^3 BOP disconnect subsurface release		A	L	L	S	N	R	H
			Site 2 - SBM Whole Mud Spill - 60 m^3 surface spill		A	L	L	S	S	R	H
			Site 2 - SBM Whole Mud Spill - 275 m^3 flex joint failure subsurface release		A	L	L	S	N	R	H
			Site 2 - SBM Whole Mud Spill - 275 m^3 BOP disconnect subsurface release		A	L	L	S	N	R	H

Table 18.5 Summary of Residual Effects for Accidental Events

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 "environmental effect")	Potential Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Confidence
Marine and Migratory Birds (including Species at Risk)	s. 5(1)(a)(iii)	• Change in Habitat Availability and Quality • Change in Food Availability and Quality • Change in Avifauna Presence and Abundance (Behavioural Effects) • Change in Mortality/Injury Levels and Health of Individuals or Populations	Site 1 - 36-Day Subsurface Blowout - 10,500 m^3/day	See Section 10.1.5.2 and Table 18.2	A	M-H	RSA	M	N	R	M-H
			Site 1 - 115-Day Subsurface Blowout - 10,500 m^3/day		A	M-H	RSA	M	N	R	M-H
			Site 2 - 36-Day Subsurface Blowout - 10,500 m^3/day		A	M-H	RSA	M	N	R	M-H
			Site 2 - 115-Day Subsurface Blowout - 10,500 m^3/day		A	M-H	RSA	M	N	R	M-H
			FPSO Surface Release - 8,300 m^3		A	L	RSA	S	N	R	M-H
			Offloading Surface Release - 1,000 m^3		A	L-M	RSA	S	N	R	M-H
			Production Flowline Subsurface Release - 500 m^3		A	L-M	RSA	S	N	R	M-H
			Bunkering Surface Release - 6 m^3		A	L	PA	S	S	R	M-H
			Vessel/vessel collision - 750 m^3		A	L-M	RSA	S	N	R	M-H
			Site 1 - SBM Whole Mud Spill - 60 m^3 surface spill		A	L	L	S	N	R	M-H
			Site 1 - SBM Whole Mud Spill - 275 m^3 flex joint failure subsurface release		A	L	L	S	N	R	H
			Site 1 - SBM Whole Mud Spill - 275 m^3 BOP disconnect subsurface release		A	L	L	S	N	R	H
			Site 2 - SBM Whole Mud Spill - 60 m^3 surface spill		A	L	L	S	N	R	M-H
			Site 2 - SBM Whole Mud Spill - 275 m^3 flex joint failure subsurface release		A	L	L	S	N	R	H
			Site 2 - SBM Whole Mud Spill - 275 m^3 BOP disconnect subsurface release		A	L	L	S	N	R	H

Table 18.5 Summary of Residual Effects for Accidental Events

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 “environmental effect”)	Potential Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Confidence
Marine Mammals and Sea Turtles (including Species at Risk)	s. 5(1)(a)(ii)	• Change in Injury and/or Mortality Levels • Change in Habitat Quality and Use • Change in Prey Availability or Quality • Change in Health	Site 1 - 36-Day Subsurface Blowout - 10,500 m³/day	See Section 11.1.5.2 and Table 18.2	A	M	RSA	M-L	N	R	M-H
			Site 1 - 115-Day Subsurface Blowout - 10,500 m³/day		A	M	RSA	M-L	N	R	M-H
			Site 2 - 36-Day Subsurface Blowout - 10,500 m³/day		A	M	RSA	M-L	N	R	M-H
			Site 2 - 115-Day Subsurface Blowout - 10,500 m³/day		A	M	RSA	M-L	N	R	M-H
			FPSO Surface Release - 8,300 m³		A	L	RSA	M	N	R	M-H
			Offloading Surface Release - 1,000 m³		A	L	RSA	M	N	R	M-H
			Production Flowline Subsurface Release - 500 m³		A	L	LSA	S	N	R	M-H
			Bunkering Surface Release - 6 m³		A	N	PA	S	S	R	H
			Vessel/vessel collision - 750 m³		A	L	RSA	S	N	R	M-H
			Site 1 - SBM Whole Mud Spill - 60 m³ surface spill		A	N	L	S	S	R	H
			Site 1 - SBM Whole Mud Spill - 275 m³ flex joint failure subsurface release		A	L	L	S	N	R	H
			Site 1 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release		A	L	L	S	N	R	H
			Site 2 - SBM Whole Mud Spill - 60 m³ surface spill		A	L	L	S	S	R	H
			Site 2 - SBM Whole Mud Spill - 275 m³ flex joint failure subsurface release		A	L	L	S	N	R	H
			Site 2 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release		A	L	L	S	N	R	H

Table 18.5 Summary of Residual Effects for Accidental Events

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 "environmental effect")	Potential Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Confidence
Special Areas	s. 5(1)(b)(i)	• Change in Environmental Features and/or Processes • Change in Human Use and /or Societal Value	Site 1 - 36-Day Subsurface Blowout - 10,500 m³/day	See Section 12.1.5.2 and Table 18.2	A	M	RSA	M	N	R	M-H
			Site 1 - 115-Day Subsurface Blowout - 10,500 m³/day		A	M	RSA	M	N	R	M-H
			Site 2 - 36-Day Subsurface Blowout - 10,500 m³/day		A	M	RSA	M	N	R	M-H
			Site 2 - 115-Day Subsurface Blowout - 10,500 m³/day		A	M	RSA	M	N	R	M-H
			FPSO Surface Release - 8,300 m³		N	-	-	-	-	-	H
			Offloading Surface Release - 1,000 m³		N	-	-	-	-	-	H
			Production Flowline Subsurface Release - 500 m³		N	-	-	-	-	-	H
			Bunkering Surface Release - 6 m³		N	-	-	-	-	-	H
			Vessel/vessel collision - 750 m³		A	N-L	RSA	S	N	R	M-H
			Site 1 - SBM Whole Mud Spill - 60 m³ surface spill		A	L	L	S	S	R	H
			Site 1 - SBM Whole Mud Spill - 275 m³ flex joint failure subsurface release		A	L	L	S	N	R	H
			Site 1 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release		A	L	L	S	N	R	H
			Site 2 - SBM Whole Mud Spill - 60 m³ surface spill		A	L	L	S	S	R	H
			Site 2 - SBM Whole Mud Spill - 275 m³ flex joint failure subsurface release		A	L	L	S	N	R	H
			Site 2 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release		A	L	L	S	N	R	H

Table 18.5 Summary of Residual Effects for Accidental Events

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 "environmental effect")	Potential Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Confidence
Commercial Fisheries and Other Ocean Uses	s. 5(2)(b)(i)	• Direct interference caused by the Project with fishing activity and other marine activities, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses • Damage caused by the Project to fishing gear, vessels, and other existing subsea infrastructure, and associated loss of catch for harvesters • Change in abundance, distribution and quality of marine resources, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses	Site 1 - 36-Day Subsurface Blowout - 10,500 m³/day	See Section 13.1.5.2 and Table 18.2	A	L	RSA	M	N	R	H
			Site 1 - 115-Day Subsurface Blowout - 10,500 m³/day		A	L	RSA	M	N	R	H
			Site 2 - 36-Day Subsurface Blowout - 10,500 m³/day		A	L	RSA	M	N	R	H
			Site 2 - 115-Day Subsurface Blowout - 10,500 m³/day		A	L	RSA	M	N	R	H
			FPSO Surface Release - 8,300 m³		A	L	RSA	S	N	R	H
			Offloading Surface Release - 1,000 m³		A	L	L	S	N	R	H
			Production Flowline Subsurface Release - 500 m³		A	N	LSA	S	N	R	H
			Bunkering Surface Release - 6 m³		N	-	-	-	-	-	N/A
			Vessel/vessel collision - 750 m³		A	L	RSA	S	N	R	H
			Site 1 - SBM Whole Mud Spill - 60 m³ surface spill		A	N	L	S	S	R	H
			Site 1 - SBM Whole Mud Spill - 275 m³ flex joint failure subsurface release		A	N	L	S	N	R	H
			Site 1 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release		A	N	L	S	N	R	H
			Site 2 - SBM Whole Mud Spill - 60 m³ surface spill		A	N	L	S	S	R	H
			Site 2 - SBM Whole Mud Spill - 275m³ flex joint failure subsurface release		A	N	L	S	N	R	H
			Site 2 - SBM Whole Mud Spill - 275 m³ BOP disconnect subsurface release		A	N	L	S	N	R	H

Table 18.5 Summary of Residual Effects for Accidental Events

Valued Component	Area of Federal Jurisdiction (CEAA, 2012 s.5 "environmental effect")	Potential Effect	Project Activity	Mitigation	Residual Effect Characterization						
					Nature / Direction	Magnitude	Extent	Duration	Frequency	Reversibility	Confidence
Indigenous Peoples	s.5(1)(c)(i) s.5(1)(c)(iii)	• Change in health and socioeconomic conditions • Change in the current use of lands and resources for traditional purposes • Change in physical and cultural heritage • Change in any structure, site, or thing that is of historical, archaeological, paleontological or architectural significance	Subsurface Blowout	See Section 14.1.5.3 and Table 18.2	A	L	RSA	M	N	R	M
			Batch Spills		A	L	RSA	S	N-S	R	H
			SBM Spills		A	N	L	S	N-S	R	H

KEY:

Nature/Direction of Effect:
P Positive
A Adverse
N Neutral (or no-effect)

Magnitude of Effect:
N Negligible
L Low
M Medium
H High

Geographic Extent of Effect:
Less 1 km²
Less than 10 km²
Less than 100 km²
Less than 1,000 km²
Less than 10,000 km²
Greater than 10,000 km²

Duration:
S Short-term - less than 12 months (1 year)
M Medium-term - 1 to 5 years
L Long-term - more than 5 years

Frequency of Effect
N Not likely to occur
O Occurs once
S Occurs sporadically
R Occurs on a regular basis
C Occurs continuously

Reversibility:
R Reversible (will recover to baseline)
I Irreversible (permanent)

Confidence Level in Predictions:
L Low level of confidence
M Moderate level of confidence
H High level of confidence

N/A Not Applicable

18.4 Follow-Up and Monitoring

Equinor Canada will obtain the required permits, approvals, and authorizations for the Project, and Equinor Canada and its contractors will comply with these and relevant regulations and guidelines in planning and implementing the Project. This includes the mitigation measures summarized in the Section 18.2, the implementation of which will be directed, managed, and tracked in accordance with Equinor Canada's existing policies and procedures.

Monitoring is an important activity for measuring performance against regulatory, corporate and project requirements. Monitoring enables the assessment of progress against goals as well as the gathering of information to track the overall environmental performance throughout the BdN Project. Monitoring falls into two broad categories: compliance monitoring and follow-up monitoring.

18.4.1 Follow-up Programs

Under CEAA 2012, a follow-up program is defined as a program for "verifying the accuracy of the environmental assessment of a designated project" and "determining the effectiveness of mitigation measures". It is commonly referred to as environmental effects monitoring (EEM). In determining whether a follow-up program is required the following factors should be considered:

- Whether the project will impact environmentally sensitive areas / VCs or protected areas or areas under consideration for protection
- The nature of Indigenous and public concerns raised about the project
- The accuracy of predictions
- Whether there is a question about the effectiveness of mitigation measures, or the proponent proposes to use new or unproven techniques and technology
- The nature of cumulative environmental effect
- The nature, scale, and complexity of the program
- Whether there was limited scientific knowledge about the effects identified in the Project EIS

As stated throughout the EIS Section in the relevant VC chapters, Equinor Canada is committed to the development of a follow-up monitoring program as required by Section 9.2 of the EIS Guidelines. The design of the follow-up monitoring program will be undertaken following finalization of Project design, taking into account Agency guidance, the terms of the EIS Decision Statement and relevant regulatory requirements.

The follow-up monitoring program will be developed in consultation with the C-NLOPB and relevant government departments (e.g., DFO, ECCC). In addition, Indigenous groups and key stakeholders will be engaged, as appropriate. The design of EEM will take into consideration the results of other offshore environmental effects monitoring programs (both previous and ongoing) and utilize technology specifically suited to the monitoring of a production project at 1200 m water depths and utilize Equinor's global experience in EEM and ongoing research and new technologies. The EEM program design must be reviewed and accepted by the C-NLOPB in order to obtain an Operations Authorization (OA).

Consistent with the effects predictions contained in the EIS, the follow-up monitoring program will focus upon sensitive marine environments (e.g. VMEs / FCA in the Baccalieu area) and track such matters as drill cuttings dispersion, produced water dispersion and sound emissions.

The EEM program will be developed to achieve one or more of the following objectives:

- To provide a database against which short-term or long-term environmental effects of the project can be identified;
- To monitor the effectiveness of mitigation measures;
- Assess actual project impacts against those described in the impact assessment; to verify the predictions of environmental effects contained in the EIS;
- To validate the results of modelling (e.g. produced water, sound emissions, drill cuttings);
- To identify and implement remedial measures if unforeseen impacts occur.

EEM program results will be submitted to the C-NLOPB for review and acceptance. Where monitoring results fall outside of those predicted in the EIS, the appropriate regulatory authorities will be consulted to determine the necessary course of action (for example, the development of additional mitigation, adaptive management, or further follow-up or monitoring).

It is important to note that the follow-up program will change and evolve over the course of the Project life in consideration of: EEM results; new relevant academic and applied research; new and emerging technologies; and, evolving industry best practices, consistent with Equinor Canada’s commitment to continuous improvement.

18.4.2 Environmental Monitoring and Observations

As indicated in the relevant sections of the EIS, the Equinor Canada will undertake visual observation programs regarding presence of marine and migratory birds, and marine mammals and sea turtles. In particular, Equinor Canada will develop and implement a marine mammal and sea turtle observation program for 4D seismic survey programs. The Plan will include MMO requirements, shutdown and ramp-up procedures and reporting requirements. Frequency of reporting requirements will be developed in consultation with C-NLOPB and DFO and will, include documentation of marine mammal and sea turtle sightings.

The options for a marine bird observation program include technology-based observations though the use of equipment such as bird radar, or through dedicated seabird observation programs from supply vessels similar to those undertaken by ExxonMobil Canada Properties at the Hebron Production platform (LGL 2017). Other operations have investigated the use of technology-based observations (i.e., bird radar) and it is understood that there may be some technical limitations to the use of the equipment in an offshore environment. Equinor Canada will further investigate the use of equipment such as bird radar to determine if it can be incorporated into the design of the FPSO. Equinor Canada will work with ECCC to develop an observation program that meets the needs of the Project.

Routine systematic searches for stranded seabirds will be conducted on vessels engaged in construction and installation activities and HUC, the FPSO, drilling installation(s), stand-by vessels (SBVs), and during supporting surveys. Searches will be undertaken by vessel/installation crew, who have been trained in bird identification and handling. Equinor Canada will work with ECCC to develop installation/vessel-specific protocols applicable to the Project with respect to the systematic searches for, and documentation of, stranded birds. Appropriate programs and protocols for the collection and release of stranded seabirds will be implemented. The program will consider the following existing protocols: ECCCs "Procedures for handling and documenting stranded birds encountered on infrastructure offshore Atlantic Canada" (ECCC 2017). If a Species at Risk is found on the FPSO, drilling installation or SBVs, a report will be sent to ECCC for identification. In accordance with ECCC requirements, an annual report, including all occurrence data, will be submitted to ECCC that summarizes stranded and/or seabird handling occurrences.

For Marine Fish and Fish Habitat, upon completion of final subsea layout design, the area occupied by the final layout design will be compared against the layout used in the 2018 survey. Based on the final design, if there are areas where subsea infrastructure will be installed on the seafloor that were not captured by the 2018 survey, these areas will be surveyed to collect coral, sponge and/or sea pens data. The survey methodology and plan will be provided to DFO in advance of survey commencement date for review and acceptance. In addition, if DFO determines a *Fisheries Act* Authorization is required regarding the harmful alteration, disruption or destruction (HADD) of fish habitat resulting from Project activities, additional fish habitat data may be required in support of the authorization.

The environmental monitoring, observational, and follow-up initiatives outlined in relation to relevant components of the biophysical environment are equally applicable to Special Areas and Indigenous Peoples VCs. No additional and specific environmental monitoring or follow-up is considered necessary in relation to this VC, as no residual effects are anticipated.

Equinor Canada will, in accordance with its commitment to ongoing engagement with identified Indigenous groups, also continue to review these inputs and perspectives as the planning and eventual implementation of the Project progress and will consider them in its Project-related planning and decision-making as applicable.

18.4.3 Environmental Compliance Monitoring

Environmental compliance monitoring programs refers to activities used to ensure compliance with regulatory, corporate and Project requirements. Monitoring programs will be carried out to measure compliance with the terms of any permits, approvals or authorizations or otherwise measure the environmental performance of the Project. Requirements for compliance monitoring are outlined in the Drilling and Production Regulations. Equinor Canada's Environmental Protection Plan (EPP) for the BdN Project will detail the environmental compliance monitoring plans, procedures, and reporting requirements, consistent with the requirements of the OWTG and the Environmental Protection Plan Guidelines (NEB et al. 2011). Section 2.10 of the EIS provides an outline of some the compliance monitoring requirements for the Project. In compliance with the prescribed conditions of any permits/approvals/authorizations (including the CEAA Decision Statement), compliance monitoring results will be reported to the appropriate regulatory body in the required form and frequency and will be shared as required or appropriate.

The EPP must be reviewed and accepted by the C-NLOPB in order to obtain an Operations Authorization (OA).

In addition to reporting requirements outlined in the Equinor Canada's corporate plans and procedures, Equinor Canada will be responsible for various reporting to the C-NLOPB in accordance with the Drilling and Production Guidelines (C-NLOPB and CNSOPB 2017), Data Acquisition and Reporting Guidelines (C-NLOPB 2011) and the terms of the EIS Decision Statement. Incidents will be reported in accordance with the Incident Reporting and Investigation Guidelines (C-NLOPB and CNSOPB 2018).

In the event of a spill and depending on the size and nature of the spill, an EEM program may be required. This monitoring program will be developed in consultation with the C-NLOPB and other relevant regulatory authorities.

A summary of follow-up, compliance monitoring and observational programs is provided in Table 18.6.

18.5 Summary of Predicted Environmental Changes and Effects and their Relationship to Federal Jurisdiction and Decisions

This section provides an overview of the changes that may be caused by the Project on the components of the Environment listed in section 5(1)(a) and (b) and 5(2) of the CEAA 2012. These include:

- Changes to the components of the environment within federal jurisdiction, namely fish and fish habitat, aquatic species, and migratory birds.
- Changes to the environment that may occur on federal lands or transboundary lands
- Changes to the environment that are directly linked or necessarily incidental to these decisions

Table 18.7 provides a summary of changes that may be caused by the Project on the environment.

Table 18.6 Summary of Environmental Monitoring Programs for Routine Project Activities

Proposed Monitoring Program	Program Overview	Applicable VC(s)	Proposed Intervention / Adaptive Management	Reporting
Marine Environmental Effects Monitoring Program	• Program to determine effectiveness of mitigation measures and confirm EIS predictions. Options for this program will consider technology-based verses person-based sampling efforts	Marine Fish and Fish Habitat (including Species at Risk) Marine Mammals and Sea Turtles (and SAR)	Survey is for data gathering purposes and determining the effectiveness of mitigation measures and confirm EIS predictions For marine mammals, purpose is to confirm underwater sound transmissions predicted by modelling	• Reporting requirements will be determined in consultation with C-NLOPB and DFO
Seabird Observations	• Options for seabird observations are under development and may be technology-based or observer based. • Regular searches of vessel decks (FPSO, drilling installation, SBVs) will be undertaken and accepted protocols for the collection / handling of bird mortalities and release of birds that become stranded	Migratory and Marine Birds (including Species at Risk)	Survey is for data gathering purposes.	• Reporting requirements for the observational program will be determined in consultation with ECCC • If a Species at Risk is found, a report will be sent to ECCC for identification. • In accordance with the Seabird Handling permit, an annual report and all occurrence data summarizing stranded and/or seabird handling will be submitted to ECCC.

Table 18.6 Summary of Environmental Monitoring Programs for Routine Project Activities

Proposed Monitoring Program	Program Overview	Applicable VC(s)	Proposed Intervention / Adaptive Management	Reporting
Marine Mammal and Sea Turtle Observations	• Operational program for marine mammals during 4D seismic surveys may include the following elements. Specific details of the plan will be determined in consultation with DFO. • A trained MMO will be onboard to record marine mammal and sea turtle sightings during 4D seismic survey operations • A marine mammal and sea turtle monitoring plan will be submitted to the applicable regulators for review in advance of the commencement of the first geophysical survey • Visual monitoring for the presence of marine mammals and sea turtles within a pre-determined exclusion zone • Observational / shutdown procedures will follow the SOCP and will include baleen whales	Marine Mammals and Sea Turtles (including Species at Risk)	Survey is for data gathering purposes and reducing potential interactions	• Reporting requirements for the observational program will be determined in consultation with C-NLOPB and DFO. • Vessel strikes involving marine mammals or sea turtles will be reported to DFO.
Environmental Compliance Monitoring	• Environmental compliance monitoring is a requirement of the Drilling and Production Regulations. Monitoring and reporting of discharges identified in the EPP will be undertaken. It may include, but not limited to: - Produced water - Deck drainage - Drill cuttings	All		• In accordance with the OWTG, monthly compliance monitoring reports will be submitted to C-NLOPB • Other reporting requirements will be determined in consultation with C-NLOPB

Table 18.7 Summary of Changes that May be Caused by the Project on the Environment

Component	Change
Changes to the components of the environment within federal jurisdiction	
Marine Fish and Fish Habitat (including Species at Risk (SAR))	• Change in Habitat Availability and Quality • Change in Food Availability and Quality • Change in Fish and Invertebrate Mortality, Injury, Health • Change in Fish and Invertebrate Presence and Abundance (Behavioural Effects)
Marine and Migratory Birds	• Change in Habitat Availability and Quality • Change in Food Availability and Quality • Change in Avifauna Presence and Abundance (Behavioural Effects) • Change in Mortality / Injury Levels and Health of Individuals or Populations
Marine Mammals and Sea Turtles (including SAR)	• Change in Injury Levels (Underwater Sound) • Change in Mortality / Injury Levels (Ship Strikes) • Change in Habitat Quality or Use (Behavioural Effects) • Change in Prey Availability or Quality • Change in Health (Contaminants)
Changes to the Environment that would occur on Federal Lands	
Special Areas	• Change in Environmental Features and / or Processes • Change in Human Use and / or Societal Value
Commercial Fisheries and Other Ocean Uses	• Direct interference caused by the Project with fishing activity and other marine activities, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses • Damage caused by the Project to fishing gear, vessels, and other existing subsea infrastructure, and associated loss of catch for harvesters • Change in abundance, distribution and quality of marine resources, resulting in a change in the distribution, intensity and/or function of Commercial Fishing and Other Ocean Uses
Indigenous Peoples	• Change in Commercial-Communal Fisheries • Change in Current Use of Lands and Resources for Traditional Purposes
Changes to the Environment that are Directly Linked or Necessarily Incidental to Federal Decisions	
Accord Act Authorizations – Development Plan Approval, Operations Authorization	Development Plan Approval and Operations Authorization provide regulatory approval for the Project in its entirety. Therefore, the changes to the environment associated with the Project are directly linked or necessarily incidental to these approvals and authorizations
Authorization under Section 35(2) of the Fisheries Act (if applicable) Ocean Disposal Permit under the Canadian Environmental Protection Act (if applicable)	• A *Fisheries Act* Authorization may be required due to a change that constitutes serious harm to fish that are part of or support a commercial, recreational or Aboriginal fishery, associated with installation of subsea infrastructure. • An Ocean Disposal Permit may be required releasing of substances (e.g., dredged material, excavated material) into the marine environment from a ship, platform, or other structure.

Each of these factors are addressed in a comprehensive and fully integrated manner as part of the environmental effects assessment presented in preceding chapters of this EIS. Rather than repeat the detailed information and analysis provided throughout this EIS, the sections below provide a brief identification of the various environmental components, changes and effects that relate to each of these factors and requirements, and an indication of where and how these have been addressed.

18.5.1 Changes to Environmental Components with Federal Jurisdiction

Section 5(1) of CEAA 2012 requires consideration of changes that may be caused to the following components that are within federal jurisdiction: fish and fish habitat as defined in Section 2(1) of the *Fisheries Act*; aquatic species, as defined in Section 2(1) of the Species at Risk Act; and migratory birds as defined in section 2(1) of the *Migratory Birds Convention Act, 1994*.

As described in Chapter 9, offshore Project activities may affect Marine Fish and Fish Habitat, including SAR, through possible injury, mortality, or behavioral effects on fish and invertebrates due to underwater sound, effects to benthic communities through the alteration of marine habitats, and change in habitat quality from discharges or accidental events. Many of the offshore activities and associated disturbances that will occur as a result of this Project will be relatively localized at a specific location, or transient, though of a long-term nature. Over the life of the Project, the presence of subsea infrastructure, the FPSO, and drilling installation will have medium to long-term disturbances on benthic habitats. Overall the increase in hard structures may have localized positive effects on fish abundance and diversity through that would last for the length of the project activity. Operational marine discharges will be managed in accordance with regulatory requirements. Effects from produced water and drill cuttings discharges are predicted to be localized. Marine vessel and helicopter traffic servicing the Project will be transient in nature, reducing potential environmental effects associated with discharges, light and sound, to any one location. Underwater sound levels from the FPSO and/or drilling installation above behavioural effect threshold (150 dB re 1 μPa_{rms}) were predicted to be localized. Geophysical surveys within the Project Area, 4D seismic surveys, will likely cause behavioural effects on fish species. Given the complex bathymetry in the Project Area, behavioural effects, based on sound modelling results, could extend out to 50 km from the seismic source, depending on where the air sources are being discharged. With the implementation of mitigation measures outlined in this EIS, the Project is not predicted to result in significant adverse environmental effects on Marine Fish and Fish Habitat.

As described and assessed in Chapter 10, potential interactions with, and effects on, Marine and Migratory Birds as a result of the Project include the possible attraction and/or disorientation of the birds around the FPSO, drilling installation, and/or vessels due to artificial light sources. Underwater sound and marine discharges may also contribute to environmental effects. Operational marine discharges will be managed in accordance with regulatory requirements. Light from electrical lighting and flaring on the FPSO may result in injury or mortality in some species due to stranding, collisions, and predation. To reduce effects, lighting options will be examined during the design of the FPSO, and may include shading, avoiding use of unnecessary lighting, and directional lighting. Routine flaring will not occur. Vessel and aircraft traffic in nearshore environments may also have potential interactions due to disturbance effects, but they will be reduced through adherence to common traffic routes and avoidance of known bird colonies. Because such effects are anticipated to negligible to low, and spatially and temporally limited, and given the typically wide variation in marine bird presence and distribution in space and time throughout this large offshore area, the number of individuals affected by the Project is not expected to have population-level effects. With the implementation of mitigation measures outlined in this EIS, the Project is not predicted to result in significant adverse environmental effects on Marine and Migratory Birds.

As assessed in Chapter 11, the Project will interact with marine mammals and possibly sea turtles and may result in a change in injury and/or mortality levels, habitat quality and use, and prey availability or quality. Operational marine discharges will be managed in accordance with regulatory requirements. Marine mammals and sea turtles may experience injury and/or mortality if they are struck by a Project vessel, however, based upon a review of available information, the potential for this to occur in the Core BdN Development Area and along the transit route to/from the Core BdN Development Area is considered low and is further reduced by mitigation measures. Likewise, the assessment for potential auditory injury resulting from exposure to underwater sound from impulsive sound sources (i.e., air source arrays, MBES used during Supporting Surveys) and continuous sound sources (Project vessels including the FPSO and drillship) concluded that with mitigation measures (i.e., adherence to the SOCP) in place, auditory injury in marine mammals and sea turtles was considered unlikely to occur. Underwater sound generated by the Project was assessed as potentially resulting in localized and likely short-term avoidance of sound sources by marine mammals and sea turtles. Based on behavioural threshold criteria, acoustic modelling results and a review of the literature, the extent of this avoidance was predicted to be highest for activities using air sources (i.e., seismic surveys and to a lesser extent geohazard surveys and VSP) and for the FPSO and drillship which will employ DP thrusters. There is some uncertainty in how marine mammals (and sea turtles should they occur there) will respond to multiple sound sources from concurrent Project activities within the Core BdN Development Area. However, with the implementation of the mitigation measures outlined in this EIS, the Project is not predicted to result in significant adverse environmental effects on Marine Mammals and Sea Turtles.

An accidental event, such as a subsurface blowout could likely have adverse effects on each of the VCs, which would vary between each VC and would depend on the specific nature, magnitude and extent of the event and the presence of the VC during the accidental event. While for most VCs, it is predicted that such an accidental event would not likely result in significant adverse environmental effects, effects on Marine and Migratory Birds, while extremely unlikely to occur, could be significant depending on the amount of oil spilled, time of year, and types and numbers or birds present at that time in the affected area. As described in Chapter 16, a variety of oil spill prevention and response measures have been identified and are committed to in this EIS, which will help prevent such an accidental event from occurring, as well as responding to one in the unlikely event that it did, thereby reducing the potential magnitude, extent and duration of the potential effects. With the implementation of these mitigation measures, the Project is not likely to result in significant environmental effects on the above listed environmental components within federal jurisdiction, including both secure and at-risk species.

18.5.2 Changes to the Environment that Would Occur on Federal Lands, in Another Province, or Outside Canada

Section 5(1)(b) of CEAA 2012 states that the environmental effects that are to be considered in relation to a designated project include changes that may be caused to the environment that would occur on federal lands, in another province, or outside Canada.

As described in Section 1.2 of the EIS, Project activities are planned to take place within the offshore marine environment, which is considered “federal lands” under CEAA 2012. The Project Area includes all or part of ELs 1143, 1154 and 1156, and SDLs 1047, 1048, 1055, which constitutes federal land (see Section 1.2). Since the scope of the Project does not include any land-based activities or components, changes to the environment from routine Project activities are not anticipated to occur on terrestrial lands belonging to Her Majesty in right of Canada, or reserves, surrendered lands, or other lands that are set apart for the use and benefit of a band and are subject to the Indian Act.

Changes to marine fish and fish habitat, marine mammals and sea turtles and marine and migratory birds within federal waters may occur as a result of the Project. Chapters 9, 10 and 11 provide a detailed analysis of the potential environmental effects and summarized above in Section 18.5.1. This section, therefore, provides a summary of the VCs not considered above, namely, Special Areas, Commercial Fisheries and Other Ocean Uses and Indigenous Peoples.

Special Areas that intersect with the Core BdN Development area are the Slopes of the Flemish Cap and Grand Bank UNCBD EBSA, a VME identified for sea pens and Northwest Flemish Cap (10) NAFO FCA. Special Areas that intersect the Project Area are four VMEs: three identified for sponges and one for large gorgonian corals and the three noted for the Core BdN Development area. These special areas have been identified primarily for the presence of benthic habitats and therefore, the potential environmental effect of the Project on Special Areas would be a change in habitat quality. For Special Areas within the RSA that do not intersect the Project area, with the exception of the vessel traffic route, there will be no interaction with Project activities. Critical habitat areas (per SARA) for northern and spotted wolffish species do not overlap with the Project Area. As described for the various biophysical VCs (Chapters 9 to 11), the Project is not expected to result in significant adverse effects on marine fish, birds, mammals, sea turtles, species at risk, or their habitats. Therefore, it is not likely to adversely affect the ecological features, processes and integrity of marine or coastal locations that are designated as special areas, nor the human use and societal value of these areas. The Project is not likely to result in significant effects on the defining physical, biological, and socio-economic features these special areas. For the Special Areas that intersect or otherwise interact with planned Project activities, discharges and emissions, the overall and defining physical, biological, and socioeconomic environments within these areas will not be adversely affected by the Project. Project activities and resulting discharges and emissions are predicted to be localized though some will be of a long-term nature. With the implementation of mitigation measures, the Project is not likely to result in significant environmental effects on Special Areas.

For Commercial Fisheries and Other Ocean Uses, possible Project-induced changes may result from a loss of access due to the presence of the FPSO and/or drilling installation and associated anti-collision zones, potential interference between subsea infrastructure and fishing equipment, and biophysical changes to fish and fish habitat from Project activities that may affect the quality and availability of commercial fish resources. These interactions and potential effects may result in lost time, reduced catch volumes, lower economic returns on catches, and increased operational costs for fishers and other ocean uses in the area. Anti-collision zones where marine vessel traffic is prohibited, will be established for the FPSO (approximately 8.5 km²) and/or drilling installation(s) (1 km²). A safety zone demarcating the location of Project subsea infrastructure will be established. The anti-collision and safety zones will be communicated to fisheries and other ocean uses. With the implementation of mitigation measures outlined in this EIS, the Project is not predicted to result in significant adverse environmental effects on Commercial Fisheries or Other Ocean Uses.

Given the nature, location and timing of the various marine activities and associated Project-induced changes to the environment likely to occur as a result of this Project, it is not expected to have adverse effects on Indigenous Peoples. Project-related activities will take place in the offshore marine environment, hundreds of kilometres from land and thus at a considerable range from communities (Indigenous or otherwise). As associated emissions and other disturbances are expected to be quite localized and short-term in nature (Chapters 9 to 11), these activities are unlikely to extend to or affect the health (physical, mental or social) and well-being or socioeconomic conditions of Indigenous Peoples. There are also no other known aspects of the physical and cultural heritage of these groups, including any structure, site or thing that is of historical, archaeological, paleontological or architectural significance, located in proximity to, or which may otherwise be affected by, the Project. Equinor Canada is aware that a number of Indigenous groups hold commercial-communal licences, including swordfish/tuna licences, in NAFO areas 3L and 3M, which overlap the Project Area, including the Core BdN Development Area. To date, no Indigenous group has provided information that they actively fish in the Core BdN Development Area or Project Area for commercial-communal purposes at the current time. This does not mean that those Indigenous communities will not fish in these areas in the future. Given the nature of the Project, including its limited and localized environmental disturbances, it is not anticipated that there would be significant residual adverse effects to commercial-communal fishing activity, even if it did occur in the LSA over the course of the Project.

None of the Indigenous groups identified by the CEA Agency and listed in the EIS Guidelines has asserted or established Aboriginal or treaty rights protected by section 35 of Constitution Act, 1982 in or to the lands and waters of the LSA, including the Core BdN Development Area and the Project Area. Project activities will be located at a considerable distance (approximately 640 km to 2,000 km) from the traditional territories of the identified Indigenous groups. As determined through ongoing engagement with Indigenous groups and based on existing documentation, there is no current use by any Indigenous group of lands and resources for traditional purposes within or near the Core BdN Development Area, Project Area, or LSA. The environmental effects analysis indicates that few of the marine associated resources (species) that are known to be used by these Indigenous groups migrate through the Core BdN Development Area, Project Area, or LSA and are thus not likely to be affected by Project activities and disturbances. The implementation of the mitigation measures outlined throughout the EIS will serve to further address direct or indirect potential effects on these resources. There is therefore no potential for the availability or quality of resources that are currently used for traditional purposes by Indigenous groups to be reduced or negatively affected in other ways as a result of the Project, especially to a nature and to a degree that would alter the overall nature, intensity, frequency, distribution, quality or cultural value of traditional activities by Indigenous communities or the health, socio-economic conditions or heritage of Indigenous peoples. With the implementation of mitigation measures outlined in this EIS, the Project is not predicted to result in significant adverse environmental effects on Indigenous Peoples.

For all VCs in the EIS, an accidental event such as a large-scale subsurface blowout could possibly result in transboundary effects by extending to other provinces of Canada or outside an area of Canada's jurisdiction, as well as by affecting environmental components (such as migratory fish, birds, special areas, or marine mammals and sea turtles) that extend across or move both within and outside the areas under the jurisdiction of Canada (Chapter 16). A variety of oil spill prevention and response measures have been identified and are committed to in this EIS, which will help safeguard against such an accidental event occurring, as well as responding to one in the unlikely event it did, thereby reducing the potential magnitude, extent and duration of its potential effects. With the implementation of these mitigation measures, the Project is not likely to result in significant environmental effects upon any environmental component, in any jurisdiction.

18.5.3 Changes to the Environment that are Directly Linked or Necessarily Incidental to Federal Decisions

Section 5(2)(a)a of CEAA 2012 requires consideration of additional changes that may be caused to the environment that are directly linked or incidental to a federal authority's exercise of a power or performance of a duty or function that would permit the carrying out, in whole or in part, of the designated project.

The primary regulatory approvals necessary to develop the BdN field is a Development Plan Approval and an Operations Authorization pursuant to the Accords Act. A Fisheries Act Authorization may be required associated with the installation of subsea infrastructure which may result in serious harm to fish, as defined under the Fisheries Act. Depending on the method used to lay/install subsea infrastructure, an Ocean Disposal Permit may also be required. Table 1.1 in Chapter 1 provides a listing of various other federal legislation and regulations and potential permitting requirements that will or may be relevant to the Project. This section focuses on changes to the environment other than those addressed above in Sections 18.5.1 and 18.5.2.

As the above noted federal decisions and approvals would allow the various planned Project to proceed, each of the various potential environmental changes assessed and evaluated in this EIS (on all VCs) "would be directly linked or necessarily incidental to a federal authority's exercise of a power". These environmental components and predicted environmental changes and effects are identified and summarized in the preceding sections and are therefore not repeated here.

For completeness, Table 18.8 provides a summary of the Project's potential effects on several environmental components that are not addressed in the EIS, namely: 1) terrestrial environment; and 2) aquatic (freshwater) environment.

Table 18.8 Other Potential Environmental Changes Linked to the Exercise of Power or Performance of Duty or Function by a Federal Authority

Environmental Component	Potentially Applicable Federal Decisions or Actions	Summary of Potential Environmental Changes
Terrestrial Environment and Freshwater Environment	C-NLOPB licenses, approvals and authorizations (see Table 1.2)	• The Project is located in the marine offshore environment and will not involve the development and use of new on-land or nearshore infrastructure or Project-related expansions or modifications to existing infrastructure. • Project-related supply and support activities will take place at existing, established onshore industrial facilities operated by a third-parties, which have been previously approved under applicable regulatory processes and currently provide services to multiple offshore and other industrial operators. No Project-specific construction or expansion of such facilities or other onshore infrastructure is required or planned. • Support vessel and aircraft services and their transits to and from the Project Area from these supply bases will likewise be contracted from third-party suppliers. • Planned Project activities will therefore not interact with or adversely affect components of the terrestrial or aquatic environments. • The environmental effects assessment for accidental events in Chapter 16 assessed the potential for oil to reach land, and concluded that this is extremely unlikely to occur, particularly with the implementation of oil spill prevention and response measures.
Others	C-NLOPB approvals and authorizations (see Table 1.2)	• No other components of the biophysical or socio-economic environments have been identified as having the potential to be directly and adversely affected by the Project which would necessitate or justify their inclusion in the environmental effects assessment presented in this EIS.

18.6 Conclusion

A summary of the residual adverse effects for each VC from Project-related interactions, accidental events, and cumulative effects is provided in Table 18.9.

Table 18.9 Summary of Residual Environmental Effects for Routine Operations, Accidental Events, and Cumulative Effects

VC	Routine Operations	Accidental Effects		Cumulative Effects
	Significance of Residual Environmental Effect	Significance of Residual Environmental Effect	Likelihood of Significant Effect	Significance of Residual Environmental Effect
Marine Fish and Fish Habitat (including Species at Risk)	N	N	N/A	N
Marine and Migratory Birds (including Species at Risk)	N	S	Extremely unlikely	N
Marine Mammals and Sea Turtles	N	N	N/A	N
Special Areas (including Species at Risk)	N	N	N/A	N
Commercial Fisheries and Other Ocean Uses	N	N	N/A	N
Indigenous Peoples	N	N	N/A	N
Key: N = No significant residual adverse environmental effect S = Significant residual adverse environmental effect L = Low likelihood N/A = Not Applicable				

In conclusion, with the application of mitigation measures, the routine operations of the Project are not predicted to result in significant adverse residual environmental effects on the environment and will not cumulatively interact with other offshore activities in the Canada - NL Offshore Area, in a way that would cause significant environmental effects.

Under certain circumstances, a precautionary conclusion is drawn that residual environmental effects from an extremely low probability of occurrence accidental subsurface blowout on Marine and Migratory Birds are predicted to be significant depending on the specific occurrence, nature and degree of the event, and the presence of certain species of birds. However, with the implementation of spill prevention measures, significant residual adverse effects are extremely unlikely to occur.

18.7 References

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