EQUINOR CANADA LTD – EAST COAST OPERATIONS NEWFOUNDLAND AND LABRADOR OFFSHORE AREA

SPILL IMPACT MITIGATION ASSESSMENT

Sponsongroup

14 April 2020

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SPONSON GROUP TECHNICAL REPORT 20-01

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List of Abbreviations and Acronyms

API	American Petroleum Institute
bbl	Barrels of oil
bpd	Barrels per day
BdN	Bay du Nord crude oil
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
CEAA	Canadian Environmental Assessment Agency
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CRA	Comparative Risk Assessment
DOR	Dispersant-to-Oil Ratio
DWH	Deepwater Horizon
DFO	Fisheries and Oceans Canada (aka Department of Fisheries and Oceans)
EBSA	Ecologically and Biologically Significant Areas
ECRC	Eastern Canada Response Corporation
ECCC	Environment and Climate Change Canada
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EL	Exploration Licenses
EU	Environmental Unit
FCA	Fishing Closure Area
FSC	Food, Social and Ceremonial
GDS	Global Dispersant Stockpile
IBA	Important Bird Areas
ICS	Incident Command System
IOGP	International Oil and Gas Producers
IPIECA	International Petroleum Industry Environmental Conservation Association
ISB	In-Situ Burn
IUCN	International Union for Conservation of Nature
ITOPF	International Tanker Owners Pollution Federation Limited
km	kilometre
LC	Lethal Concentration
m	metre
m^3	cubic metre
mm	millimetre
µm	micrometre (also known as a micron)
NAFO	Northwest Atlantic Fisheries Organization
NEBA	Net Environmental Benefit Analysis
NASEM	National Academies of Sciences, Engineering, and Medicine
NL	Newfoundland & Labrador
NLDFA	Newfoundland and Labrador Department of Fisheries and Aquaculture
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OSAT	Operational Science Advisory Team
OSRL	Oil Spill Response Limited
PAH	Polycyclic Aromatic Hydrocarbon
ppb	parts per billion
ppm	parts per million

ROC	Resources of Concern
ROV	Remotely Operated Vehicle
RSA	Regional Study Area
RV	Research Vessel
SARA	Species at Risk Act
SEA	Strategic Environmental Assessment
SIMA	Spill Impact Mitigation Assessment
SIMAP	Spill Impact Model Application Package
SMART	Special Monitoring of Applied Response Technologies
SSDI	Subsea Dispersant Injection
THC	Total Hydrocarbons
TPH	Total Petroleum Hydrocarbon
USCG	United States Coast Guard
VOC	Volatile Organic Compound

PREFACE

This Spill Impact Mitigation Assessment (SIMA) has been prepared for Equinor Canada Ltd. as part of the contingency planning process for exploratory drilling on licences held by Equinor Canada in the Newfoundland & Labrador (NL) Offshore Area. SIMA is a process intended to be used as a spill response decision support tool. The guiding principle behind the selection of any response option, including the authority to permit the use of dispersants or in-situ burning, is to promote the best overall recovery of the environment on a holistic basis – not individuals, specific species, or economic interests.

The fundamental purpose of any SIMA is to: 1) guide planning and preparedness toward the objective of minimizing ecological damages and promoting the most rapid recovery of the overall ecosystem; 2) assist the relevant decision-makers to make the determination of net environmental benefit; and 3) serve as a planning tool to support, not replace, other aspects of the spill response decision-making process during both contingency planning and an actual spill event. This SIMA should be viewed as a process, not a product that promotes any given response option over another.

Understanding the Purpose of this SIMA

This SIMA "is":

- *A tool to support the development of contingency plans for Equinor Canada Ltd. exploratory drilling in the Flemish Pass*
- *A framework for selecting response options*
- *Designed with a matrix that can be rapidly adapted for actual spill conditions*
- *Intended to facilitate stakeholder involvement during a spill*

This SIMA "is not":

- *An EIS, but the EIS provides background information for this document*
- *A comprehensive review of response option tactics*
- *An academic review of dispersed oil fate and effects*
- *An endorsement of any given response option*

Should a spill occur in this region, it is highly unlikely that the actual spill conditions (volume, season, release location) would duplicate the hypothetical event considered in this document. However, the process presented here serves as a guide to conduct a real-time expedited SIMA during an actual incident. During a spill, the assessment must be conducted rapidly, by individuals and organizations possessing the most current real-time biological, environmental, oceanographic, and climatological information.

A SIMA for an actual spill would be generated 'real-time', using this document as a template. During an actual response, the SIMA process can be expedited by reviewing this existing contingency planning SIMA, conferring with local experts to determine what biological resources are in the region on that day (Section 4), updating the spill specifics and trajectories (Section 5), and then modifying the comparative risk matrix (Section 6.4) to inform the response option selection process. During a spill response, the expedited SIMA would incorporate the review and advice from the Environmental Emergencies Science Table (convened by the National Environmental Emergencies Center to provide technical and scientific environmental advice to the lead agency during an oil spill), as well as advice from response experts about real-time feasibility of various response options.

During the development of this SIMA, a draft version was distributed for review (in January 2020) by various agencies and organizations with purview over spill response in Eastern Canada. The authors of this document carefully considered reviewer suggestions and incorporated edits to this final SIMA, as appropriate. Many of the comments related to several core themes, and the author responses are summarized below:

Modelling and Scenarios: Oil spill modelling is a tool to help response experts understand, in general, where oil might go. There is uncertainty with any model, and in the case of subsea blowouts, modelers have one actual oil spill event (Deepwater Horizon) to validate the oil and dispersed oil algorithms. Despite a decade of research, there is uncertainty about the accuracy of these models to predict subsea fate, biodegradation, and effects of a blowout (whether unmitigated, or treated with subsea dispersants). No amount of scenario development or modelling will provide a definitive answer on how to “build” a response for a specific future oil spill. At best, a modelled worst-case scenario, like the one developed for this SIMA, can help the response community ensure that a broad range of strategies and equipment stockpiles are in place and available. If a spill occurs in the future, real-time incident conditions should be input into a model to provide the response team with a likely real-time trajectory. This real-time fate and trajectory modelling can then be used by relevant subject matter experts (e.g., response specialists, resource trustees, socio-economic decision-makers, etc.) to determine which resources should receive the highest priority for protection and then mobilize response strategies accordingly.

Resource and Species Data: The purpose of this SIMA is not to capture as much information as possible about available ecological resources – this information is already provided in the EIS. New data is always being generated to help resource trustees understand ever-changing ecological shifts. This SIMA identified general sources of information about various ecological and socio-economic resources in this region, based largely on the EIS, and response decision-makers understand that new information is becoming available every month. It is not feasible nor practical to revise this SIMA each time a new field study dataset becomes available. When an incident occurs, subject matter experts must rapidly convene to assess the resources that might be affected based on their local, current knowledge of the region.

In the event of an incident offshore NL, the most updated data for safety, ecological and socioeconomic compartments would be identified, evaluated and scored at the time of oil spill using “real-time” modelling results and expertise from the preparedness and response community. It is evidenced through decades of past spill responses that individual species cannot be protected solely through response mitigation. At best, response decisions are aimed at shifting oil into or out of environmental compartments (e.g., surface vs. water column).It must be understood that once a spill occurs, there will be some impacts to resources, and the SIMA helps facilitate the trade-off discussion that must occur at the onset of the incident.

Risk Analysis Scoring: It is not possible to protect an individual species during a large scale oil spill, so the goal is to protect ecological assemblages, habitats or populations. Response experts recognize that difficult decisions will need to be made by the resource trustees about protection priorities. Typically, resource experts will prioritize species protected by law, or those populations that are long-lived and will take the longest time re-establish after an oil spill.

Ultimately, there is no “correct” weighting factor, and there is no “correct” score, rather both of these values are assigned during a spill. These scores represent how subject matter experts (assembled during the response) apply best-available data to prioritize resource protection - these are professional judgement calls. The strength of the assigned scores is based largely on the degree of expertise in the room at the time the incident-specific risk matrix is completed. The scores and associated justification should include considerations such as: What species are present right now? Is the population already stressed? Is this a low recruitment year? These assessments are made in context of the actual spill that is occurring.

While the authors of this SIMA value the feedback received from the reviewers on suggested changes to various risk matrix scores, we have opted not to change any scores for this hypothetical score, since the scores in this contingency planning SIMA are NOT intended to be applied to any actual oil spill incident. As clearly stated above, the objective of this Newfoundland Labrador (NL) scenario based hypothetical oil spill SIMA is to provide a template, or starting point, that is customizable to generate “real time” analysis in the event of an exercise or an actual oil spill using the expert knowledge and judgement of the preparedness and response community. In summary, this community is comprised of government entities, potentially impacted stakeholders, potentially affected communities, scientific experts and the responsible party. During an actual event, this group can rapidly follow this qualitative approach to assess the feasibility of how a response option might mitigate or exacerbate key resources compared to providing no response (natural attenuation).

1 Spill Impact Mitigation Assessment

1.1 Background

This Spill Impact Mitigation Assessment (SIMA) has been prepared for Equinor Canada Ltd. (Equinor Canada) as part of the contingency planning process for exploratory drilling in the Newfoundland & Labrador (NL) offshore area. The reader is encouraged to review the Preface, which outlines the purpose of this SIMA and how it is intended to be used. In summary, the purpose of a SIMA is to evaluate logistically feasible response options that can aid in minimizing impacts from an oil spill and to promote rapid ecological, cultural and socio-economic recovery. The 2017 publication, *Guidelines on Implementing Spill Impact Mitigation Assessment* (Industry Environmental Conservation Association-American Petroleum Institute-International Oil and Gas Producers [IPIECA-API-IOGP], 2017), provides the strategy for assessing oil spill impacts and facilitating response option selection.

For this Equinor Canada SIMA, trajectory modelling for a Tier 3 subsea discharge due to a loss of source control at an offshore NL drilling location is evaluated. While there are other potential types of oil spills that could possibly occur, the Tier 3 scenario would likely represent the worst-case scenario requiring evaluation of all possible available response options for implementation by Equinor Canada using their response groups, Eastern Canada Response Corporation (ECRC) and Oil Spill Response Limited (OSRL). All response options determined to be both feasible and potentially effective in this offshore NL drilling location are evaluated in this SIMA.

The SIMA utilizes information provided in the following:

- *Flemish Pass Exploration Drilling Project and Eastern Newfoundland Offshore Exploration Drilling Project Environmental Assessment Report* (CEAA, 2019);
- *Newfoundland and Labrador Offshore Area 2019 Environmental Assessment Update (*Equinor Canada, 2019); and
- *Flemish Pass Drilling Project Environmental Impact Statement* (Statoil, 2017).

The IPIECA (2017) guidelines define the SIMA process in four stages:

1. **Compile and evaluate data** for relevant oil spill scenarios including fate and trajectory modelling, identification of resources at risk and determination of feasible response options.
2. **Predict the outcomes** for the ‘no intervention’ (or ‘natural attenuation’) option as well as the effectiveness (i.e. relative mitigation potential) of the feasible response options for each scenario.for the given scenario, to determine which techniques are effective and feasible.
3. **Balance trade-offs** by weighing and comparing the range of benefits and drawbacks associated with each feasible response option, including no intervention, for each scenario.
4. **Select the best response options** to form the strategy for each scenario, based on the combination of techniques that will minimize the overall ecological, socio-economic and cultural impacts and promote rapid recovery.

A high-level snapshot of the first two steps of the SIMA process is depicted in Figure 1. This information has been collated and presented in Sections 2 through 5 of this report. The third step of SIMA involves conducting an impact analysis for each response option and this analysis is presented in Section 6. Finally, recommendations for the most appropriate response options for the oil spill are summarized in Section 7. Before presenting detailed information for the Equinor Canada SIMA, a brief overview of the SIMA process and how it can be used to inform response plans are provided in Sections 1.2 and 1.3.

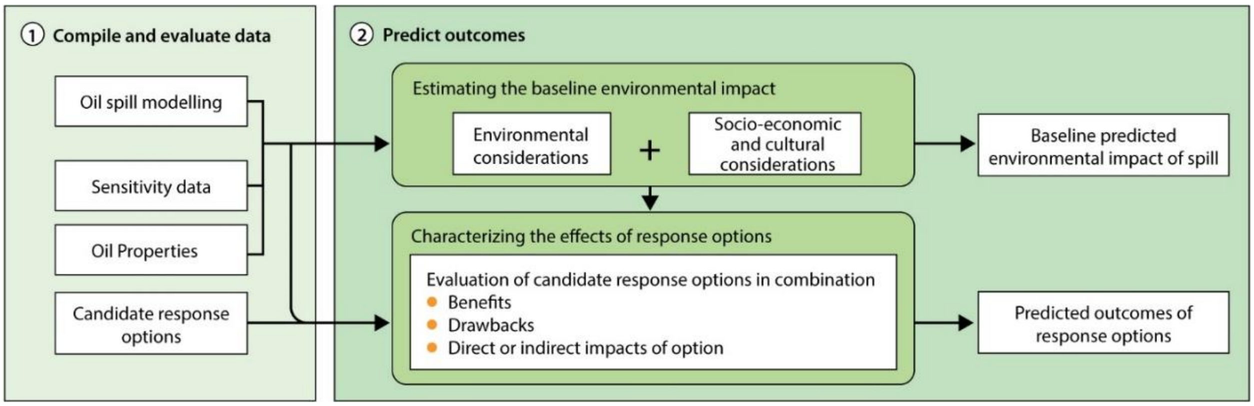


Figure 1 Types of data used to assist with characterization of response options. (IPIECA, 2015b)

1.2 Overview of SIMA

The term Net Environmental Benefit Analysis (NEBA) has been used to describe an approach used by the oil spill response community for guiding the selection of the most appropriate response option(s) to minimize the net impacts of spills on people, the environment and other shared resources. Given that the selection of the most appropriate response action(s) has in practice been guided by more than just 'environmental' considerations, the oil and gas industry has sought to transition to a term that better reflects the process, its objectives, and the suite of shared values which shape the decision-making framework. In 2016, SIMA was introduced as a simplified tool used to support the NEBA approach. The SIMA process encompasses ecological, socio-economic and cultural considerations, and this new term eliminates the perceptions associated with the word 'benefit'.

A report prepared for IUCN (Stevens and Aurand, 2008) entitled, Criteria for Evaluating Oil Spill Planning and Response Options, probably best summarizes the NEBA process as "…a holistic approach that considers all the potentially impacted resources, looks at how well they can be protected with the available response techniques under the conditions prevailing at the time of a spill, and seeks to implement the response that provides the best overall outcome to a spill."

IUCN is the International Union for Conservation of Nature, based in Switzerland.

The objective of a SIMA, when applied to oil spills, is to conduct an evaluation that will allow spill responders and stakeholders to choose the response options that will result in the best overall recovery of the ecological, socio-economic and cultural resources of concern, while maintaining safety of responders as the primary goal. In most spill scenarios, no single response option is likely to be completely effective.

Oftentimes, the best approach to minimize environmental impacts is to employ multiple response options.

A risk-based approach is implicit in all response planning; however, the required level of detail in determining and documenting the approach depends upon the type of incident and the circumstances. For example, a small 50-barrel surface spill in a harbour may only require a SIMA that simply compares and contrasts the possible impacts of shoreline booming and removal strategies. Weather, logistics and transportation delays are much less of a factor, and modelling is likely not needed in a SIMA for this small spill. In comparison, a continuous subsea release scenario dictates inclusion of appropriate offshore response operations, evaluation of more logistics and timing constraints because of considerable distances that must be traversed, and consideration of harsh offshore conditions. These complicating factors require a more robust SIMA document that involves predictive modelling, evaluation of metocean conditions, inclusion of offshore response options, etc.

The SIMA process recognizes that once oil has been spilled, some environmental impact will occur, no matter what spill response options are chosen. The goal of a successful response is to apply the response technique(s) that will be most effective at protecting locally identified resource priorities while also minimizing negative impacts and promoting overall recovery.

In 2013, IOGP-IPIECA in conjunction with API, developed an outreach presentation on SIMA that emphasized the focus on *local and regional priorities* (IPIECA, 2013). Later in 2015, IPIECA published a good practice guide for incident management and emergency response personnel, which continued to advocate that a SIMA should result in decisions based on *what is best for a specific location under a defined set of circumstances* (IPIECA, 2015a). More recently, IPIECA-API-IOGP (2017) developed guidelines for implementing SIMA, which serves as the approach for the process used here.

1.3 Using SIMA to Support Contingency Planning and Spill Response

The SIMA process supports many aspects of emergency management:

- **Contingency planning**: SIMA is an integral part of the contingency planning process used to ensure that response strategies for planning scenarios are well informed. It can be used to identify relevant scenarios and agree on the best response options for those scenarios. The use of SIMA in contingency planning offers opportunities for stakeholder involvement within the planning process.
- **Exercises or drills**: A SIMA that is developed during the contingency planning phase can be further tailored to a specific spill scenario or season.
- **Training:** The SIMA can familiarize the incident management team regarding the feasibility and effectiveness of response options in a specific locale or can be used to inform decision-makers on the 'resource trade-offs' that are inherent when selecting one response option in lieu of another.
- **Spill response:** The SIMA process is used during a response to ensure evolving conditions are understood, so that the response strategy can be adjusted as necessary to manage individual response actions and end points.

Importantly, SIMA is an iterative process that can be applied multiple times both before and during a spill to accommodate changing conditions. Its application during a response will differ to some degree from the contingency planning phase, depending on the similarity of the hypothetical scenario analyzed for the SIMA, compared to the conditions of the actual oil spill event. In either case, the primary objective is to maximize efficacy of the utilized response options and minimize overall harm to environmental, socio-economic, and cultural resources. An overview of the SIMA process both before a spill and during a spill is provided in Figure 2.

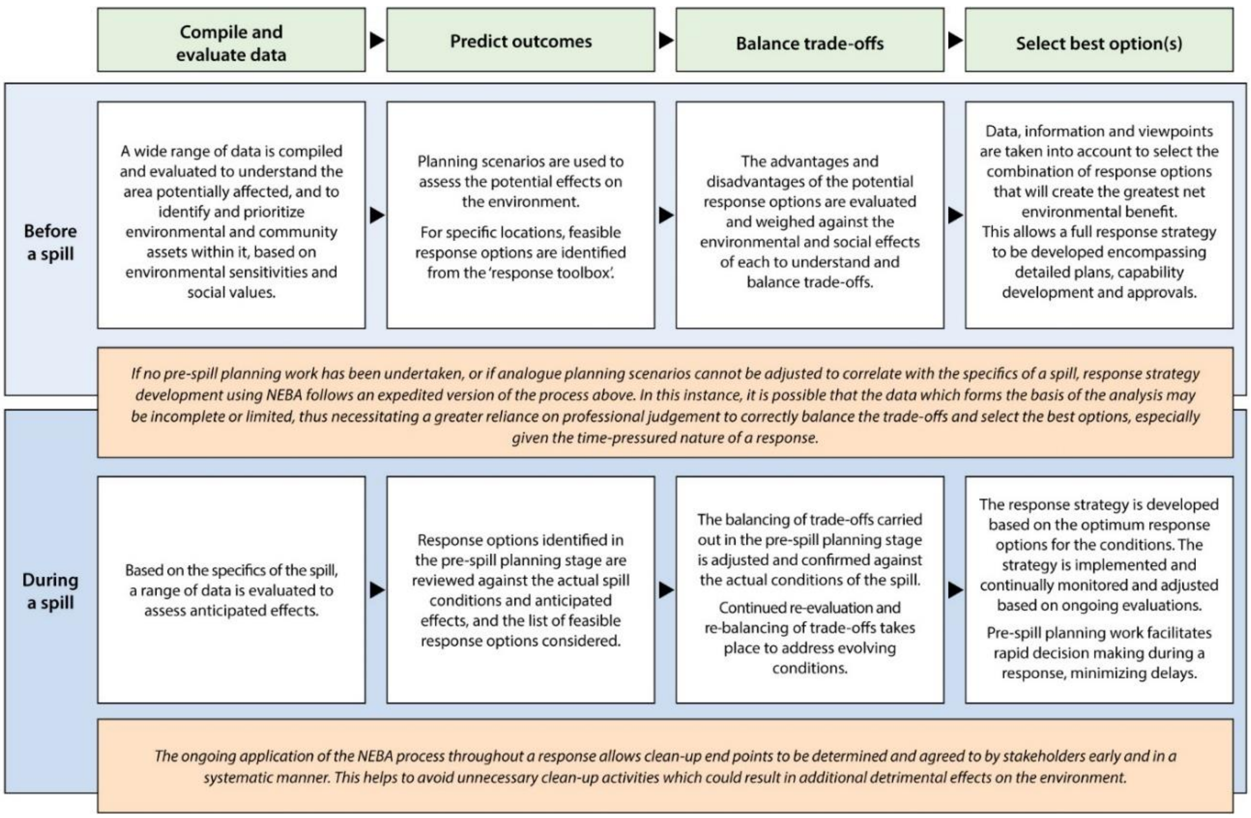


Figure 2 Applying SIMA before a spill (contingency planning) and during a spill. (IPIECA, 2015b)

History has shown that contingency planning trade-off analysis is invaluable during actual spill responses. For example, in the US Gulf of Mexico, two Ecological Risk Assessments were conducted in that region (Pond et al., 2000; Aurand, 2007) to support contingency planning for dispersant pre-authorization. When the 2010 *Deepwater Horizon* (DWH) spill occurred, these two trade-off analysis documents served, in part, as the justification for dispersant authorization and use during DWH. In the case where a trade-off analysis (e.g., SIMA) is performed prior to a spill, its principles can be utilized to frame and adapt the response as it is being executed, evaluated, and modified to fit the situation. During a spill, the SIMA process can work two ways. When the actual event mirrors closely pre-event planning, the contingency planning SIMA would be conducted by using Sections 6.4 to 7 as guidelines to evaluate scenario, response and resource specifics. During so-called "novel" events (i.e., the actual event does not align with the SIMA planning scenario), a situationally relevant SIMA is performed (often in a matter of hours) using an approach that relies heavily on expert judgment of the stakeholders and response subject matter experts.

One of the key advantages to the SIMA process is its transparency – it clearly shows and documents the assumptions and decisions that were used to arrive at the conclusions. No matter when the SIMA is conducted, the developers must assess carefully any assumptions that have been made when framing the scenario. Attention must be given to ensuring strategy selection is made with flexibility and adaptability in mind. This approach assists responders in shaping the response strategy as event-driven data is gathered and evaluated.

1.4 Intended Use of this SIMA During a Response

This SIMA process utilizes a single score for extent of exposure and duration of recovery and adds a weighting factor for resource values based on local priorities. The National Academies of Sciences, Engineering, and Medicine (NASEM, 2019) prepared a recent state-of-science consensus study report on the use of dispersants in marine oil spill response and recognized the benefits of a SIMA tool for supporting contingency planning (which is the purpose of this document).

However, the added benefit of using the SIMA process is that it is easily and rapidly modified during an actual spill response by assessing real spill conditions and informing the ongoing response strategies for the specific spill conditions observed. This process is frequently referred to as "conducting an expedited SIMA." Effective implementation of the expedited SIMA process is incumbent on the use of competent and knowledgeable experts to understand specific event conditions and local resources, and to make reasonable response trade-off decisions.

Equinor Canada's response actions are managed through use of the Incident Command System (ICS). The ICS provides a common, functional organizational structure, nomenclature and terminology, and is commonly used in industry. In this system, the development of an expedited SIMA would occur primarily within the Spill Management Team, more specifically by the Environmental Unit (EU). The EU would prepare a 'real-time' expedited SIMA, using this document as a template for modification in the following manner:

- Confer with local experts to determine what biological resources are in the region at the time the spill occurs, then revise Section 4 of this document to align with the spill location and timing;
- Document the spill event and expected trajectories with various response mitigation, then revise Section 5 with real-time information; and
- Modify the comparative risk matrix (Tables 16 and 17 in Section 6.4) by incorporating the review and advice from the Environmental Emergencies Science Table and response experts about real-time feasibility of various response options.

The resulting expedited SIMA would serve as an input to the selection of an agreed strategy for the overall spill response, ensuring a systematic assessment has been completed with input from appropriate stakeholders. Once finalized, the expedited SIMA would typically be included as part of a dispersant and/or in-situ burn application authorization process (if either response option is deemed appropriate for the spill conditions). During a prolonged spill response, the expedited SIMA process may be cyclical and adapted as needed to meet ongoing and changing spill conditions.

2 Newfoundland & Labrador Offshore Area Overview

This section provides a brief overview of the Geographical Area of Interest (Section 2.1), Physical Environment (Section 2.2) and Oil Spill Scenario (Section 2.3) for the Equinor Canada SIMA. Section 2 is intended purely as an overview of the relevant information that must be considered for this geographic area when weighing the trade-offs for the feasible oil spill response options. The reader should consult the Flemish Pass EIS if additional detail is desired (Statoil, 2017). This overview section, combined with the response option benefits and limitations (Section 3), Resources of Concern (ROC) in Flemish Pass (Section 4) and hypothetical spill modelling (Section 5) are collectively evaluated for this SIMA. Section 6 provides the risk analysis and assessment results for a large-scale spill in Flemish Pass, which are summarized in Section 7.

2.1 Geographical Area of Interest

The Flemish Pass is a mid-slope basin bounded to the west by the Grand Banks of Newfoundland and to the east by the isolated Flemish Cap. The drilling project area is located off eastern Newfoundland, outside Canada's 200 nm Exclusive Economic Zone (EEZ) on the outer continental shelf, encompassing water depths ranging from <100 m to >2,000 m. For this SIMA, the red oval region in Figure 3 depicts the geographical range for potential drilling locations in Equinor Canada's exploration licenses (ELs).

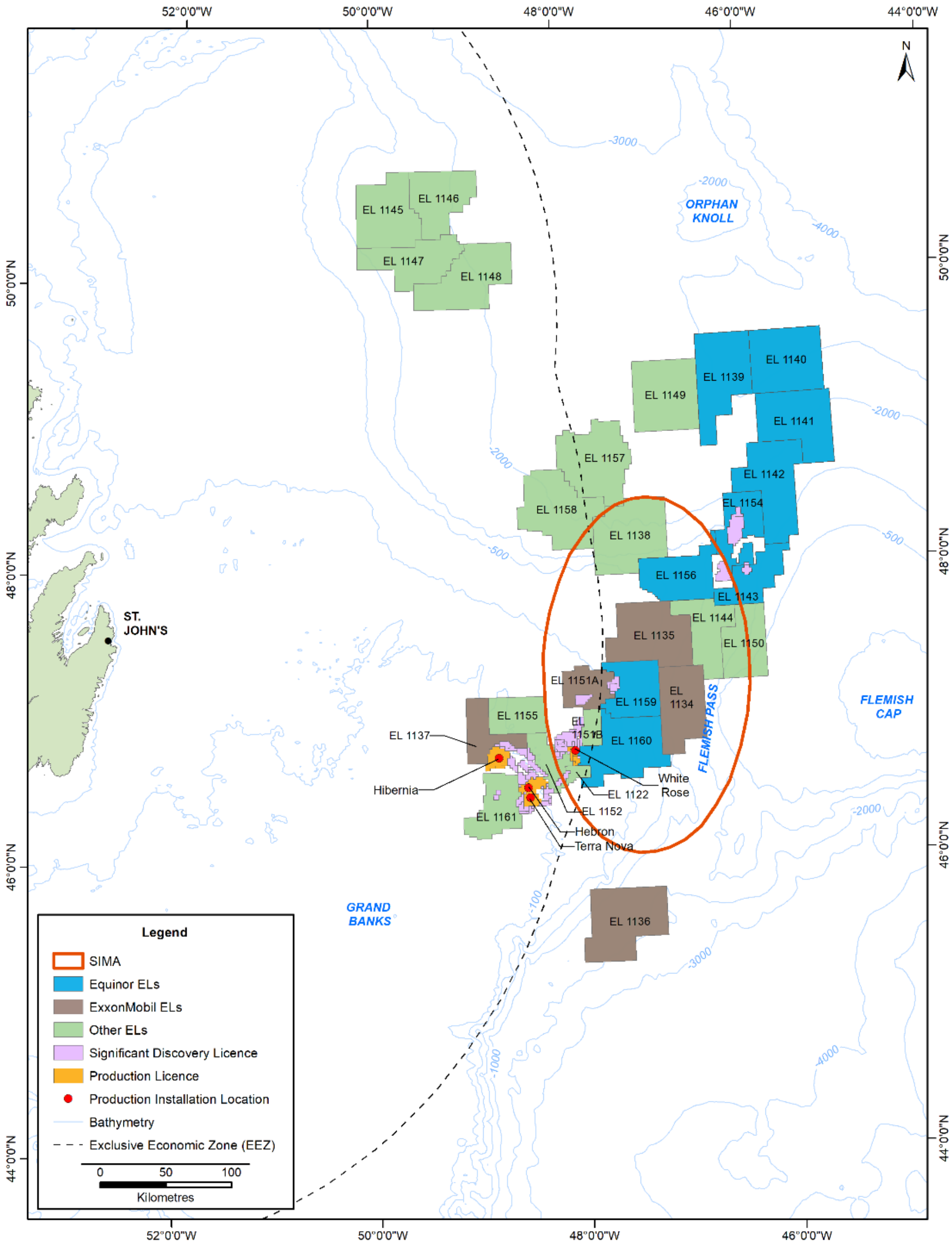


Figure 3 The red oval region depicts the geographical range for potential drilling locations in Equinor Canada's exploration licenses (ELs) used for this SIMA.

In Figure 4, for planned drilling events, the Flemish Pass EIS (Statoil, 2017) describes the regional study area (RSA) (yellow box) as the predicted zone of influence of a potential drilling event. This yellow box depicts the region where resources would have a greater potential for interactions with planned drilling projects. However, during an unplanned event, such as an oil spill, the RSA expands to include potential ecological and socioeconomic interactions with the hypothetical oil spill (described in Section 2.3 and Section 5) that may extend outside the area. More specifically, the RSA and beyond is defined as the maximum cumulative surface oil thickness for the 95th percentile surface oil exposure case, based on a hypothetical subsea blowout scenario, as modelled in the Flemish Pass EIS (Statoil, 2017,

Appendix E). Illustrating the extent with a modelling figure, Figure 4 depicts the RSA (yellow box) and beyond (surface oil extent), hereinafter referred to as “RSA”. This larger geographic extent allows for a more thorough evaluation of the fate and trajectory of an oil spill.

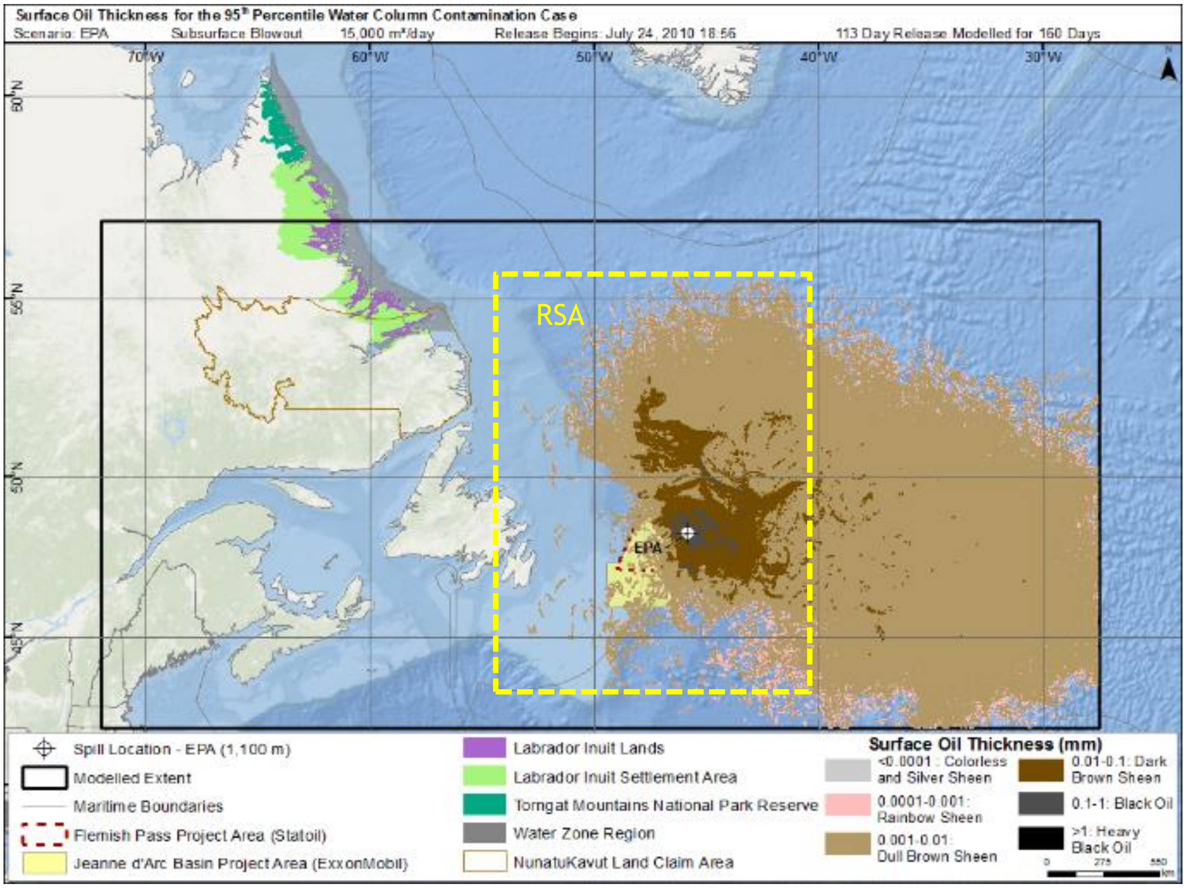


Figure 4 The geographic extent of the Equinor SIMA encompasses the RSA (yellow box) and the 95th percentile surface oil exposure case of a hypothetical oil spill event.
(Adapted from the Flemish Pass EIS (Statoil, 2017, Appendix E).

2.2 Physical Environment

The description of the physical environment for the Flemish Pass drilling project area (e.g., oceanography, climatology and meteorology) is described in detail in the Flemish Pass EIS (Statoil, 2017, Sections 5.2, 5.3 and 5.5). The relevant physical environmental parameters include:

- Day Length
- Visibility
- Wind and Waves
- Ocean Currents
- Bathymetry
- Ice Conditions
- Shoreline

For the purpose of this report, the two seasons analyzed are defined as: *summer* (June through August) and *winter* (December through February), which bracket seasonally mild or harsh weather conditions that factor into operational response activities. It is assumed that conditions in the spring and autumn lie somewhere between these two extremes of metocean conditions. Depending on the parameter, different sources provide the seasonal data that best illustrate the dynamic nature of the potential drilling project area and are described under each section.

Day Length (Civil Twilight Hours)

For this report, day length is based on civil twilight hours, which occur when the sun is less than 6 degrees below the horizon. This timeframe is when there is enough natural sunlight to carry out surface vessel-based or aviation-related activities. Note that day length is not relevant for subsea debris removal or subsea dispersant injection (SSDI) operations at the sea floor (1,100 m depth in this case), where remotely operated vehicles (ROVs) are equipped with integrated lighting and sonar to safely operate in the dark. The day length data for St. Johns, Newfoundland and Labrador, Canada is listed in Table 1 (Time and Date, 2017).

Table 1 Civil twilight hours for Saint Johns, Newfoundland Canada (2017).

St. Johns Newfoundland	Civil Twilight Hours*		Total Civil Twilight Hours*
	AM	PM	
Dec	7:06	4:46	9 hrs 40 min (9.7 hrs)
Jan	7:09	5:12	10 hrs 3 min (9.1 hrs)
Feb	6:34	5:56	11 hrs 22 min (11.3 hrs)
Mar	6:43	7:37	12 hrs 54 min (12.9 hrs)
Apr	5:40	8:23	14 hrs 43 min (14.7 hrs)
May	4:47	9:09	16 hrs 22 min (16.4 hrs)
Jun	4:22	9:41	17 hrs 19 min (17.3 hrs)
Jul	4:40	9:35	16 hrs 55 min (16.9 hrs)
Aug	5:23	8:46	15 hrs 23 min (15.4 hrs)
Sep	6:07	7:43	13 hrs 26 min (13.4 hrs)
Oct	6:49	6:43	11 hrs 54 min (11.9 hrs)
Nov	6:33	4:58	10 hrs 25 min (10.4 hrs)
*Based on the 15th of each month. Source: Time and Date, n.d.			

This SIMA defines the winter season to encompass December through February. Based on the civil twilight hours for the 15th of each of these three months, the average winter day length is approximately 10 hrs for the RSA. Similarly, this SIMA defines the summer season to encompass June through August. Based on the civil twilight hours for the 15th of each of these three months, the average summer day length is approximately 16.5 hrs for the RSA.

Visibility

Visibility information originates from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS), as summarized in the 2014 Strategic Environmental Assessment [(SEA), as cited in AMEC, 2014)] and in Table 2 below. Visibility is affected by the presence of fog, the number of daylight hours and the frequency and type of precipitation.

Table 2 Frequency of occurrence (%) of visibility state for the Flemish Cap

Flemish Cap (1950-2012)	Very Poor (<0.5 km)	Poor (0.5-2 km)	Fair (2-10 km)	Good (>10 km)
Dec	2.9	4.4	45.7	47.0
Jan	2.5	5.2	48.9	43.4
Feb	2.8	5.2	49.3	42.7
Mar	4.4	7.0	45.6	43.1
Apr	7.8	8.5	41.4	42.4
May	10.8	8.6	37.9	42.7
Jun	17.6	11.5	35.9	35.0
Jul	26.0	14.0	30.5	29.6
Aug	15.4	8.8	34.1	41.7
Sep	6.8	5.6	37.7	50.0
Oct	4.0	4.2	39.9	51.9
Nov	3.9	4.3	43.1	48.6
Source: Table 4.14 (AMEC, 2014)				

Visual Flight Rule conditions for aircraft operations specify a visibility minimum of 5 km. Consequently, a good visibility state (>10 km) for *winter* (December through February) exists 44% of the time. During *summer* (June through August), good visibility state occurs less frequently, on average 35% of the time. However, aircraft could operate during some of the periods listed as Fair, provided that a 5 km visibility minimum exists.

Wind and Waves

In the Flemish Pass EIS (Statoil, 2017, Section 5.5 Oceanography), MSC50 grid point locations were selected to provide a general illustration of oceanographic conditions over the RSA – M3012443, M6013912, M6013091, M6011605 and M6010089 (Figure 5).

Hourly wave and wind data from 53 years (1962 to 2015) were obtained from the five MSC50 Grid Points located in the RSA. This information is summarized for wind (Table 3) and waves (Table 4). Based on these two data tables, average winter wave data for December through February is 4.2 m wave height. Summer season wave data for June through August indicates an average summer wave height of 1.9 m.

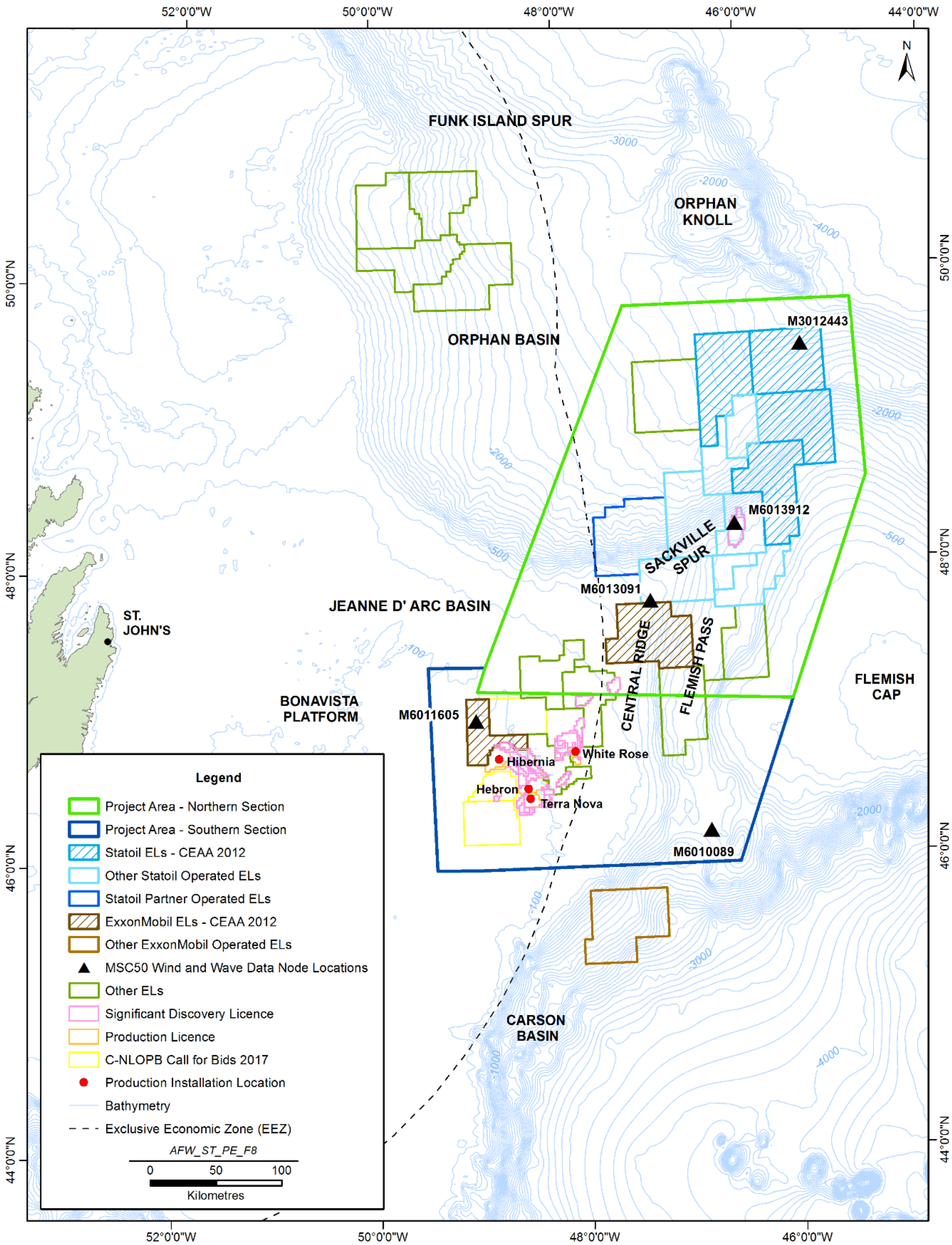


Figure 5 Location of the MSC50 grid points selected for wind/wave conditions in the RSA. (Statoil, 2017)

Table 3 Wind statistics for the RSA[1].

Month	Mean Wind Speed (m/s)	Most Frequent Direction[2]	Maximum Wind Speed (m/s)	Most Frequent Direction[2]
December	11.1	W	29.9	SW
January	11.6	W	29.4	W
February	11.4	W	31.1	W
March	10.2	W	29.1	W
April	8.6	SW	25.6	N/NW
May	7.4	SW	24.0	NW
June	6.9	SW	22.8	NW
July	6.3	SW	19.1	S/SW
August	6.7	SW	28.5	S
September	7.9	SW	27.6	S
October	9.3	W	28.0	W/NW
November	10	W	27.3	W/NW

[1] MSC50 wave hindcast data from 1962-2015 for five nodes in the RSA.
[2] Direction from which winds are blowing.

(Wind data provided in Flemish Pass EIS [Statoil, 2017, Table 5.3])

Table 4 Wave statistics for the RSA[1].

Month	Mean Wave Height (m)	Most Frequent Direction[2]	Maximum Wave Height (m)	Most Frequent Direction[2]
December	4.2	W	14.0	NW
January	4.4	W	13.7	W
February	4.0	W	14.6	SW
March	3.4	NW/SW	12.2	NW/SW
April	2.9	SW	11.1	N/NW
May	2.3	SW	10.9	NW
June	2.0	SW	10.1	NW
July	1.8	SW	6.5	S
August	1.9	SW	8.4	SW
September	2.5	SW	12.5	SW
October	3.1	NW	12.3	SW
November	3.5	NW	12.4	W

[1] MSC50 wave hindcast data from 1962-2015 for five nodes in the RSA.
[2] Direction from which winds are blowing.

(Wave data provided in Flemish Pass EIS [Statoil, 2017, Table 5.17])

Ocean Currents

Major ocean currents are depicted in Figure 6. The Labrador Current is a large-scale circulation offshore Newfoundland and Labrador consisting of two branches. The offshore branch flows over the upper Continental Slope and a sub-branch moves through the Flemish Pass. More information is provided in the Flemish Pass EIS (Statoil, 2017, Section 5.1.3.2).

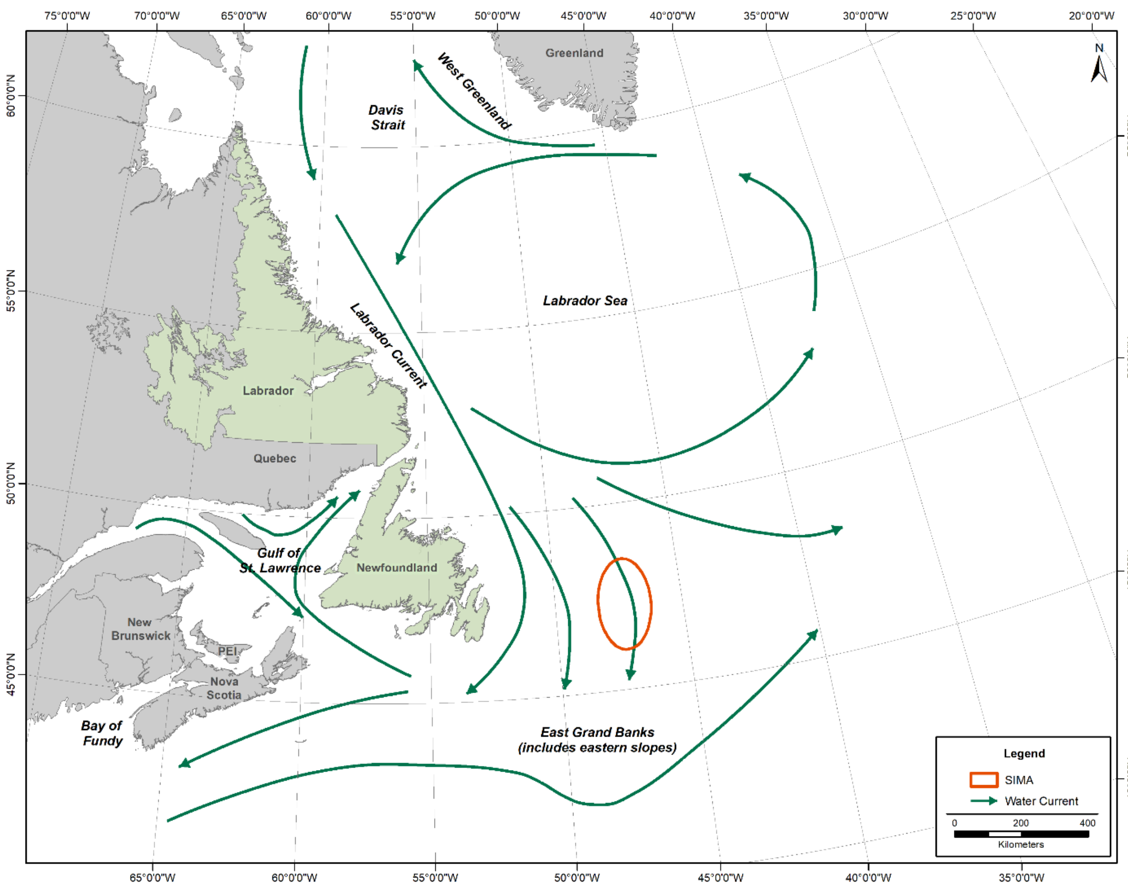


Figure 6 Overview of ocean currents in the RSA.
(Equinor Canada)

Bathymetry

Water depths in this region vary considerably, with shallow waters on the shelf and Flemish cap areas, rapidly increasing depths along the slope, and deep waters in the Flemish Pass. A bathymetry chart is provided in Figure 7.

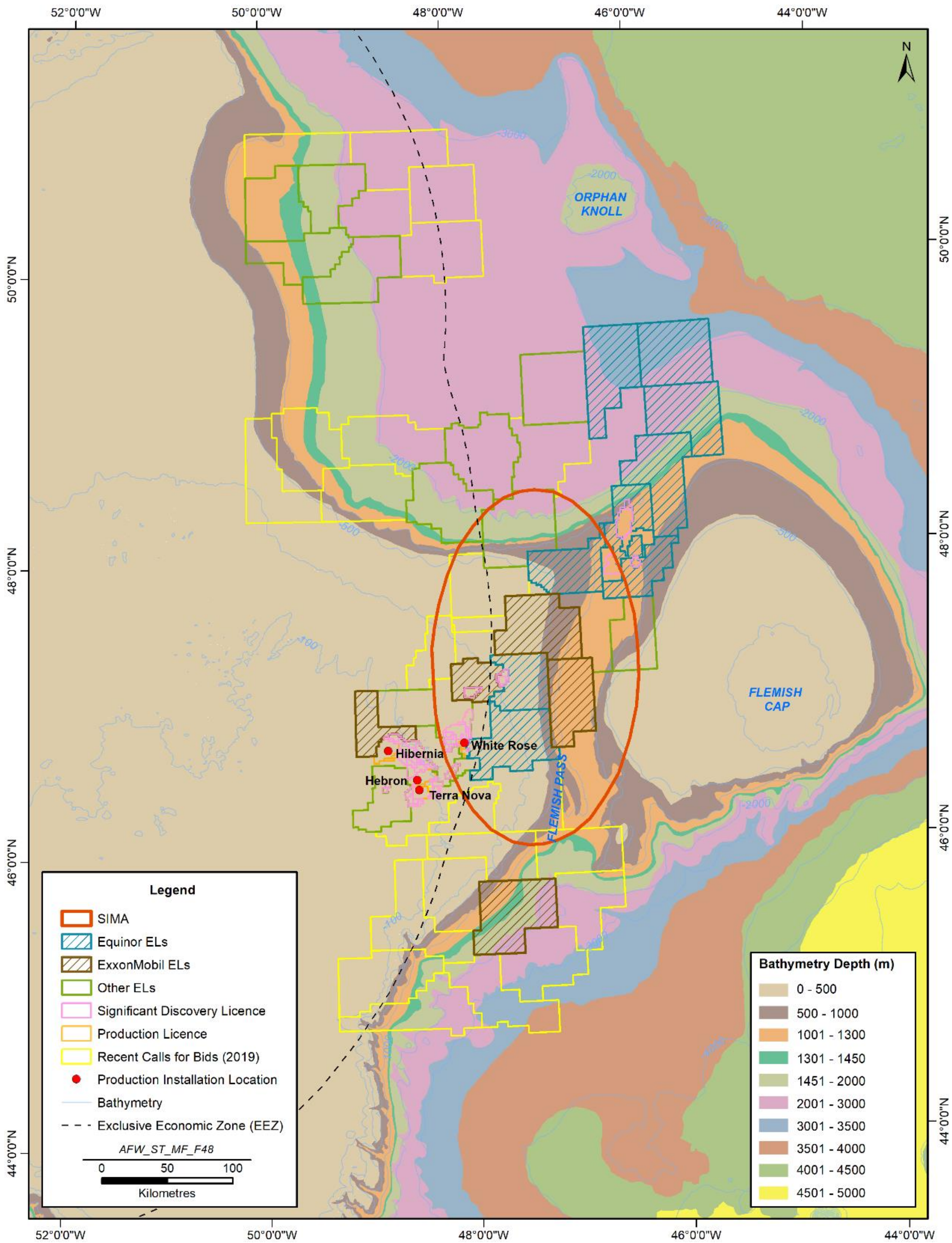


Figure 7 Bathymetry of the RSA.
(Equinor Canada)

Ice Conditions

The RSA is subject to seasonal intrusions of sea ice and icebergs. Sea ice data originates from the Sea Ice Climatic Atlas, as summarized in the 2014 Eastern Newfoundland Strategic Environmental Assessment (Canadian Ice Service as cited in AMEC, 2014, Table 4.42), which shows only one week in March with a 1-15% frequency of the presence of sea ice in Flemish Cap. Low concentrations (e.g., 1 to 3/10 concentration intervals [ratio of sea ice to water]) of thin ice (e.g., 70 cm thickness or less) is the predominant ice present at Flemish Cap for one week in mid-February and one week in mid-March (AMEC, 2014, Tables 4.43 and 4.44).

Iceberg data originates from the National Research Council (NRC) Iceberg Sightings Database, as summarized in the 2014 SEA (NRC as cited in AMEC, 2014) and in Table 5. Icebergs have been most frequently observed in the Flemish Cap area from January to August. The mean monthly iceberg sightings for *winter* (December through February) range from 0 – 51 sightings in the Flemish Cap region, with considerably more sightings during the summer months.

Table 5 Iceberg sightings.

Flemish Cap	Iceberg Sightings
Dec	-
Jan	8
Feb	51
Mar	82
Apr	93
May	179
Jun	84
Jul	86
Aug	42
Sep	-
Oct	-
Nov	-

Source: Table 4.48 (AMEC, 2014)

Shoreline

Shoreline classification is provided in Figure 8 to illustrate the varied shoreline habitats located along coastal Newfoundland. These shoreline habitats are >250 km from the proposed drilling locations.

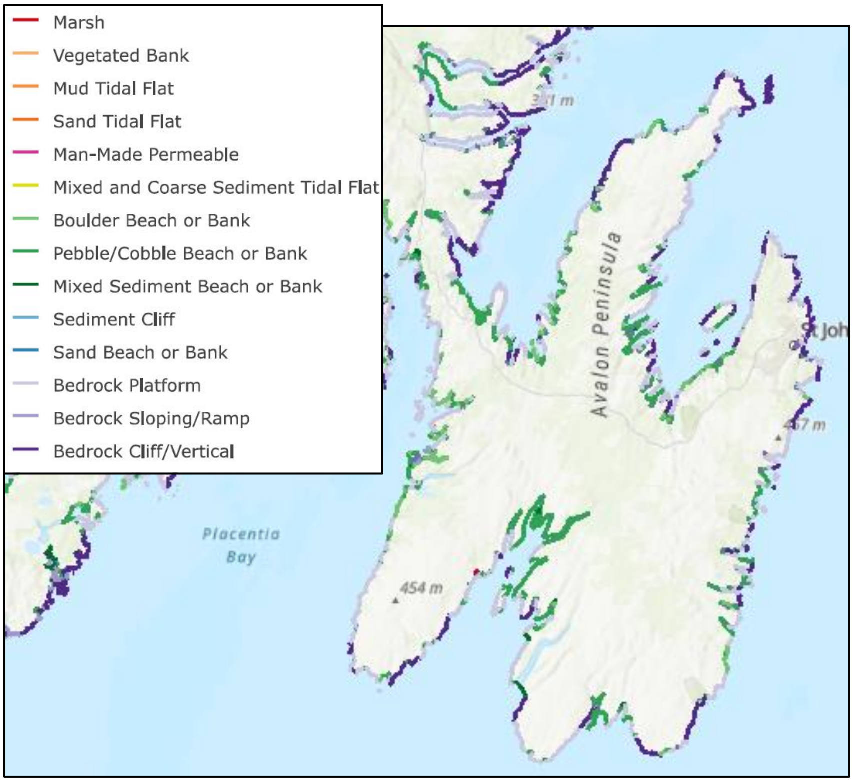


Figure 8 Shoreline classification map* for coastal Newfoundland.
(Therrien, 2019)
*Shoreline classification website maintained by Environment and Climate Change Canada.

2.3 Oil Characteristics and Spill Scenario Overview

The oil used in the Tier 3 spill scenario for this revised SIMA is Bay du Nord (BdN), a light crude oil (API gravity of 34-36°). SL Ross (2017) performed a full chemical characterization of BdN and reported good dispersibility of it using the standard Baffled Flask Test, which most closely approximates the high mixing energy that exists in the RSA. Fresh BdN dispersant effectiveness using Corexit 9500 was 91% at 9 °C (representative summer temperature) and 92% at 2 °C (representative winter temperature). Similarly, Corexit effectiveness on weathered BdN (at 23% evaporated weathering state) was 88% at 9 °C and 74% at 2 °C, with dispersant effectiveness continuing to decrease as the BdN oil became more highly weathered.

The scenario used for this Equinor Canada SIMA is the same unmitigated subsea blowout scenario that was presented in the Flemish Pass EIS (2017), *Appendix E: Trajectory Modelling in Support of the Statoil Exploration Drilling Project* (Statoil, 2017, Appendix E [RPS, 2017]). The modelling effort associated with the Flemish Pass EIS (2017) involved a hypothetical BdN oil release site in the Flemish Pass area (Figure 5). The broader geographic extent of the oil spill area footprint (RSA) is illustrated in Figure 6.

The unmitigated spill involves a hypothetical worst-case discharge scenario of 15,000 m^3/day of BdN. This scenario assumes that a Capping Stack is not deployed, and therefore represents a continuous release for 113 days (the estimated time to drill a relief well). Both summer and winter trajectories are assessed. Refer to Section 5 for more information on the unmitigated scenario. Table 6 summarizes the spill scenario.

Table 6 General parameters for the Tier 3 hypothetical source control blowout scenario.

<table>
<tr><th></th><th>Unmitigated Blowout Scenario</th><th>Response Option Mitigation</th></tr>
<tr><td>Source of Spill</td><td>Subsea blowout</td><td rowspan="6">Three sources of information were consulted to assess the various response options available within the RSA. These included empirical data from 2010 DWH spill, an evaluation of SSDI at varying depths using the OSCAR model (Daae, et al, 2017); and mitigated modelling from the Comparative Risk Assessment (CRA) study (French-McCay et al., 2018; Bock et al., 2018).</td></tr>
<tr><td>Release Location</td><td>48.3ºN, 45.8ºW</td></tr>
<tr><td>Water Depth</td><td>1,100 m</td></tr>
<tr><td>Oil Type</td><td>BdN (API gravity of 34.1 used in the model)</td></tr>
<tr><td>Duration of Spill</td><td>113-day continuous release (assumes no Capping Stack intervention)</td></tr>
<tr><td>Release Rate</td><td>15,000 m^3/day
(total oil released 1,695,000 m^3)</td></tr>
</table>

This large scale, worst-case scenario allows for inclusion of the broadest range of oil spill response options and forms the basis for the risk analysis conducted in Section 6. Assessing a Tier 3 scenario trajectory in both summer and winter has two objectives: 1) evaluate the differences in reasonable response operational effectiveness across the two seasons, and 2) evaluate the impact of the response operations to the regional resources of concern across two seasons.

3 Response Options

The six response options considered in this SIMA are:

- Natural attenuation (i.e., no intervention)
- On-water mechanical recovery
- In-situ burning
- Surface dispersant application
- Subsea dispersant injection (SSDI)
- Shoreline protection and recovery

The purpose of this section is to provide a short summary of each response option to ensure a common framework of understanding as they relate to the RSA. Since every response option has benefits and limitations, a full discussion of response options and tactics will be available in the Equinor Canada Oil Spill Response Plan.

Factors considered in assessing the efficacy of potential response methods include metocean considerations, oil characteristics, the nature and location of the release, and regulatory and logistical considerations. In actual practice, it is rare that one response method would be solely used to the exclusion of all others. For most spill events, optimal response actions vary depending on many factors, and at any given moment several response methods are likely to be used concurrently. The potential 'operational' benefits, limitations, and site-specific considerations of each response method are described in the following sections.

3.1 Natural Attenuation

Natural attenuation, also referred to as "the no-response option", "an unmitigated spill", or "no intervention", is the baseline to which all other potential response options are compared in this SIMA risk analysis. Without intervention, spilled oil will drift with the winds and currents and then gradually weather until it evaporates, dissolves, and disperses into the water column, or strands on the shoreline. Although oil stranding is not anticipated in this SIMA given the distances from shore, it is understood that if stranded, weathering would continue, and the oil will gradually biodegrade or eventually be buried in sediments through natural tidal processes. Remote sensing, real-time modelling and monitoring at sea and on potentially affected shorelines would be implemented to track the fate of naturally weathering oil slicks or stranded oil. This is sometimes considered the "monitor and wait" approach.

Benefits: Natural attenuation may be an appropriate option for spills at sea which do not threaten worker health and safety (e.g., Volatile Organic Compound [VOC] inhalation), shoreline or protected habitats, or during periods of high sea state (winter months, storm events) which facilitate natural oil dispersion and may prevent other response options from being safely deployed. It may also be appropriate for certain sensitive shoreline habitats where intrusion by people and equipment may cause more environmental damage than allowing the oil to degrade naturally. The lack of direct human involvement, other than for spill monitoring, would result in the lowest level of health and safety risk to response workers of any of the response methods.

Limitations: Natural attenuation is a passive response option which will not protect high value shoreline habitats in the event oil reaches shore. Natural attenuation may also result in persistence of oil slicks on the sea surface, which may range from hours for light oil in high seas to months for heavier or emulsified oils in relatively quiescent conditions. Reliance on natural attenuation can affect emergency response capabilities at the well site, as it will not reduce the potential for exposure of surface vessels and personnel to VOCs of the oil which can create a health and safety risk.

Site Specific Considerations: For this region, monitoring actions may be hampered by weather conditions, since the RSA is considered to have periods of low visibility due to fog (Statoil, 2017, Table 5.11). Oil slick monitoring would probably utilize some combination of remote sensing (e.g., oil spill tracking buoys), and aerial observations (via aircraft or satellite imagery). Aircraft used would need to travel roughly 200 nm to get "on station", so the long transit time would limit available fuel to remain on station for extended periods. This consideration, coupled with the potential for periods of poor visibility for airborne trained observers or infrared telemetry, would limit overall observation from aircraft-based platforms.

3.2 On-Water Mechanical Recovery

On-water mechanical recovery typically involves the use of skimming vessels, support vessels, storage barges, spotter aircraft, booms, and skimmers to redirect, contain and remove oil from the water surface. The success rate of oil removal by means of on-water mechanical recovery is dependent upon factors such as wind, waves, and daylight. Once oil has been collected and removed, it must be transferred and stored in oil containment barges or towable bladders. Vessels pulling skimmers usually travel at speeds on the order of 1 knot, so the rate of oil encountered is relatively low. Once the oil storage devices are full, they must be returned to port-based response operations for offloading and recycling or disposal, following approval from Service NL. Although there have been some advances in using night vision devices and infrared telemetry to support nighttime operations, on-water mechanical recovery is typically conducted only during the day, and in conditions with relatively good visibility. Monitoring to determine the effectiveness of on-water mechanical recovery is limited to visual observations from surveillance aircraft or satellite imagery.

Benefits: The primary benefit of on-water mechanical recovery is that the recovered oil is physically and permanently removed from the marine environment. As a result, public acceptance for use of on-water mechanical recovery is relatively high. Oil can still be recovered even after some weathering occurs, so skimmers can usually continue to operate for longer periods of time than other on-water response methods. Generally, if it is possible to safely recover oil by means of on-water mechanical recovery, then this response option would be implemented, when sea states permit it.

Limitations: On-water mechanical recovery is hampered by weather and sea-state restrictions, limitation to daylight operations, time required for deployment, and relatively low operational efficiency. Although there will be recovery vessels in the area available to assist with the immediate response, these vessels will have limited recovery capability. Thus, there will be a time lag from the spill onset to the time when large-scale mechanical recovery operations begin at the site, reducing the window of opportunity to conduct on-water mechanical recovery. Once additional equipment has been deployed from shore, the low encounter rate and need to dispose of captured oil limit the effectiveness of this technique.

Site Specific Considerations: In the RSA, wave heights often exceed the operational limits for on-water mechanical recovery (see Table 4), resulting in likely only being able to deploy in certain seasons. For example, open water booming with associated oil skimming operations begin to become ineffective in sea states with waves greater than approximately 2.5 to 3 m (for Norlense 1200-R self-inflating boom). Even when sea states are favorable for on-water mechanical recovery operations, these techniques typically recover no more than approximately 10% of the oil spilled in open ocean environments (Federal Interagency Solutions Group, 2010; Pew Charitable Trust, 2013; ITOPF, 1995, 2020). Despite the logistical and operational limitations to the effectiveness of mechanical recovery in these scenarios, it remains a desirable response option since it is the only method that physically and immediately removes oil from the environment. For that reason, mechanical recovery equipment will be maintained on site and would be used if weather conditions and sea-states are favorable.

3.3 On-Water In-Situ Burning

On-water in-situ burning (ISB) is similar to on-water mechanical recovery in that it involves collection and concentration of oil on the surface using vessels and booms. However, there are a few key differences: 1) the booms used to collect oil must be fire resistant; 2) in ice-covered waters, helicopter-applied herding agents may be used to shrink and thicken the oil, but currently no herding agents are approved for use in Canada; and 3) heavy oils and highly weathered oils are less amenable to burning. Refer to a recent publication for an in-depth review of the current state-of-science on in-situ burning with chemical herders for Arctic spill response (Bullock et al., 2019). Typically, a test burn is conducted on spilled oil to determine if ISB will work. Once oil is collected (and concentrated until it reaches a thickness that will support combustion), it is ignited using flares, torches, or improvised ignition devices. The collected oil will burn as long as an oil thickness of 2 to 5 mm continues to be maintained (IPIECA IOGP, 2016). Dense black smoke plumes are produced that consist primarily of small carbon particles which disperse into the atmosphere. Typically, a small amount of oil residue remains on the surface, however the quantities are too small to collect. Air monitoring may be appropriate, depending on the potential for human exposures to the smoke plumes. In the RSA, the only likely human exposures would be to response workers, as these plumes are estimated to dissipate before reaching any populated land mass.

Benefits: ISB significantly reduces the amount of oil that remains in the aquatic environment, although it increases the amount of oil particulate matter in the atmosphere. Since no oil is collected for disposal, at sea storage for collected oil is not needed and there is no need to transfer oil back to a shore base for recycling or disposal. Under optimal conditions, ISB can reduce significantly more oil from the water surface than on-water mechanical collection and disposal.

Limitations: The decision to use ISB is dependent on the feasibility under existent environmental conditions at the time of an incident and regional government policies- some guidance is available in the “British Columbia/Canada In-situ Oil Burning Policy and Decision Guidelines” (DFO, 2001). If herding agents were being considered, they must be listed under the Canada Oil and Gas Operations Act, which has established a list of approved spill-treating agents. Currently none are approved. Reductions in air quality due to gases and particulate material may be a concern in some jurisdictions (but not considered a factor for the RSA) and ISB creates limited by-product burn residues that can sink into the ocean and cannot be recovered. ISB has many of the same limitations that on-water mechanical recovery has with respect to speed, weather, sea-state and daylight. Oil must first be collected using vessels and booms so the encounter rate is relatively low. In addition, specialized “fire booms” must be used, which are fire resistant booms designed for ISB operations. Public perception can be low due to the physical appearance of the smoke plumes, but that is unlikely an issue for any response in the RSA due to the distance to the nearest community (e.g., greater than 250 km).

Site Specific Considerations: Given the significant distance from shore, the ISB smoke plume would not affect shore-based populations of people, so it is considered a viable response option in the RSA. In this region, the most significant limitation is wave height. ISB is more sensitive to wave height than on-water mechanical recovery since the booms must concentrate oil to a much greater thickness to burn and this wave action is disruptive to combustion. Effective ISB requires wave heights typically below 1 m and wind speeds below 10 knots (IPIECA IOGP, 2016), conditions that rarely exist in the RSA (see Tables 3 and 4). While the use of herding agents is currently not permitted in Canadian waters by regulation, their use could extend viable ISB operations in much higher wave heights and in ice-covered waters. On-water ISB has been used once on a subsea blowout event, during DWH, on sea states that were essentially flat, and yielded a recovery rate of approximately 5% (Federal Interagency Solutions Group, 2010).

3.4 Surface Dispersant Application

Surface dispersant application involves using aircraft or spray-boom fitted vessels to spray dispersants on the water surface. The commercial dispersant products function as a surfactant, and break oil into small droplets that will disperse into the water column. Typically, oil particles that are 10-200+ µm in diameter will remain dispersed in the top few metres of the water column. By breaking floating oil into small, dispersed droplets, the surface area-to-volume ratio is increased, which increases the rate of dissolution of oil constituents, dilution, weathering and microbial degradation. Biodegradation is discussed in more detail in Section 6.2.2.

Since the dispersants can be applied from aircraft or relatively fast vessels, the encounter rate for treating surface oil is much faster than with other surface response methods. With sufficient wave action, which nearly always occurs in the RSA, floating oil should disperse into the upper 10 m rapidly.

Dispersants are typically applied at an initial dispersant-to-oil ratio (DOR) of around 1:20 for surface applications. This DOR can vary depending on oil type and degree of weathering and will likely be adjusted (up or down) to optimize efficiency of the surface application based on real-time operational monitoring. Due to the long transit distances from St. John's airport to the RSA, large aircraft such as a C-130 equipped with a 5,280 gallon (20 cubic metre [m^3]) Airborne Dispersant Delivery System (known as ADDS Pack), or the new OSRL 727 are the only options, since smaller aircraft cannot be operated at this distance from shore. These large aircraft can treat up to 400 m^3 of oil in one sortie. Spotter aircraft are used to assist in targeting dispersible surface slicks for the dispersant spraying aircraft. In the RSA, the first dispersant aircraft would be on-scene within 24-hours of spill notification and would be ready for operation by Day 2 of a spill.

> ***From a SIMA perspective****, the specific mechanism for applying surface dispersant is not relevant. Whether the dispersant is applied from an aircraft, or a spray-vessel, the result is that the floating oil is dispersed into small droplets that rapidly mix into the top few metres of the water column.*
>
> *However, operational and safety limitations can impact the timing of the surface dispersant application. If the oil slick is located within the aerial exclusion zone (or no fly zone) around source control, aircraft-based dispersant operations will not be permitted. The recommended exclusion zone will be determined by the safety team. Any surface oil close to the well would need to be strategically treated with spray vessels. The transit times from port are considerable in the RSA, so the window of opportunity for using dispersants on floating oil would have to be carefully considered.*

Surface dispersant application requires good visibility and can only be conducted during daylight hours to visually target thick oil and observe the effectiveness of the dispersant application (e.g., colour change and reduction in surface slick footprint). Dispersants require some minimal wave action (approximately 0.5 m) to be effective, and in general, dispersants can be applied in high wind and wave conditions, so long as the aircraft can be operated safely. Maximum treatable wave heights are generally on the order of 4 m. At sea states higher than this, natural dispersion would likely occur without the aid of dispersant application.

Dispersants can also be sprayed from vessels that are deployed from the port, or support vessels in the vicinity of the platform. Although the encounter rate is lower using this approach, the targeting of oil can be more accurate. During the DWH response, vessels were used to treat surface oil in the vicinity of well containment and response operations to reduce VOCs exposure risks to workers.

Dispersants work most efficiently on fresh oil, becoming less effective as oil weathers. For application scenarios that involve a one-time batch spill, there is a "window of opportunity" (typically up to 4 days, but varies based on specific spill conditions) within which surface dispersant application will be effective, contingent upon many factors including oil type, emulsification rates, etc. For continuous releases, such as a subsea well blow out, surface dispersant application could continue until the source is contained.

SMART Protocols - "Special Monitoring of Applied Response Technologies (SMART) is a cooperatively designed monitoring program for in-situ *burning and dispersants. The SMART program is a joint project of the U.S. Coast Guard, National Oceanic and Atmospheric Administration, U.S. Environmental Protection Agency, Centers for Disease Control and Prevention, and the Bureau of Safety and Environmental Enforcement (USCG, 2006). SMART is tiered, with Tier 1 consisting of visual observation, while Tier 3 involves monitoring and sampling at various depths.*

In the U.S., SMART teams are specially trained to the protocols and are prepared to rapidly respond. Because of this, aerial application of dispersants can be deployed rapidly, without delay of waiting for a monitoring plan to be prepared. Many other regions of the world have adopted the SMART protocols or equivalent monitoring methods (OSRL, 2013).

Monitoring to determine the effectiveness of the dispersant application is usually conducted using the internationally recognized "Special Monitoring of Applied Response Technologies (SMART)" protocols or an equivalent monitoring method (United States Coast Guard [USCG] et al., 2006; OSRL, 2013). The SMART protocol is tiered and establishes monitoring methods ranging from aerial visual observation from spotter aircraft to the collection of samples near the surface. Aerial observation is generally sufficient for small batch spills. During a Tier 3 spill, monitoring of hydrocarbon concentrations (in the top 10 m) can help validate predicted (modelled) concentrations and is essential for informing expedited SIMA discussions during the response. Operational field data should be collected and interpreted quickly so results can inform daily response planning cycles. This type of real-time data is invaluable when assessing continued use of aerial dispersants (e.g., is the dispersant application effective and is it achieving the expected results?).

Benefits: The primary benefits of surface dispersant application, relative to other response methods, are the speed with which it can be deployed and the high encounter rate. The application of surface dispersants reduces the oil at the water surface, thereby reducing levels of VOCs at the water surface.

Limitations: Dispersant application cannot proceed without regulatory approval. The regulatory authorities may require certain criteria to be met before aerial dispersant application can proceed. These may include water depth limitations, distances from shore, exclusion zones around environmentally sensitive areas, etc. There are also operational limits for safe operation of both the vessels and aircraft. As mentioned previously, the window-of-opportunity for given spill conditions (oil type, sea conditions, etc.) must be considered.

Site Specific Considerations: The limitations on the effectiveness of surface dispersant application in the RSA are primarily related to weather and the conditions in which aircraft or spray-vessels can be used safely. Aerial application requires daylight and good visibility, while vessel-mounted spray booms require a safe sea state (which varies based on vessel and spray system configuration). High wind and wave conditions not only affect the safety of surface dispersant operations, they also affect the efficacy of dispersants. At wave heights above 4 m, breaking waves entrain oil in the water column, and prevent appropriate interaction between the oil and the dispersant. In these conditions, natural dispersion will likely occur without any intervention.

3.5 Subsea Dispersant Injection (SSDI)

SSDI is used to inject dispersant directly into the flow of subsea oil released from a fixed point(s). SSDI was first conducted in a response during the DWH oil spill in 2010, where dispersants were applied nearly continuously at the well head opening at the sea floor. SSDI operations are conducted from a vessel that contains storage for dispersants, pumps and coiled tubing to deliver dispersants to the release point. Prior to capping stack deployment, dedicated ROVs are used to oversee the operation, clear debris, deploy injection equipment, and assist in video and particle size monitoring to ensure dispersant efficacy. Configuring and loading a vessel to support SSDI takes several days but once deployed, SSDI operations are less sensitive to weather than other response methods and can continue 24 hrs/day.

In general, the same chemical dispersion principles apply that are discussed in the Surface Dispersant Application section, with a few key distinctions. With SSDI, the encounter rate is extremely high because the dispersant is being applied directly to the oil source as it is released from the sea floor. Because of the high encounter rate, an initial DOR of 1:100 should be targeted, then adjusted (up or down) based on real-time monitoring to optimize efficiency of the response option (API, 2017; Brandvik et al., 2014; IPIECA, 2015a). The lower subsea DOR of 1:100, compared to surface DOR of 1:20, means that less dispersant is required for SSDI versus surface dispersant application. Because the injection is occurring at the sea floor, the dispersed oil will dilute vertically and horizontally over a much greater volume of water. Rapid dilution equates to lower concentrations of dispersed oil than those typically measured after a surface application (where the dispersed oil is typically limited to 10 m of vertical dilution). During the DWH incident, measured dispersed oil concentrations at about 1 km distance from the well head and 1,200 m depth were consistently below 1 part per million (ppm).

A subsea dispersant monitoring plan should be activated, as soon as practical, to monitor deep water hydrocarbon and dissolved oxygen concentrations. It is noteworthy that during the DWH response, there were initial concerns that deep water oxygen concentrations could be depleted due to microbial degradation processes. Extensive monitoring throughout the SSDI operation did detect a slight depletion in oxygen concentrations in the dispersed oil plumes, but not to levels that would result in hypoxia (National Oceanic and Atmospheric Administration [NOAA] Joint Advisory Group [JAG], 2012). Nevertheless, real-time operational monitoring of hydrocarbon concentrations and dissolved oxygen should be conducted to confirm that the SSDI operation is working as expected, to determine if the SSDI operation is resulting in detrimental dissolved oxygen levels, and to make ongoing SIMA decisions about the continued use of SSDI throughout the response.

Monitoring to determine SSDI dispersant efficacy consists primarily of visual and sensor observations at the injection site by ROVs (e.g., underwater camera and particle size detector), above the surface by aircraft observations or satellite imagery, as well as on or near the water surface (e.g., surface VOC monitoring in the Source Control area). A reduction in VOC levels at the water surface near source control is expected if SSDI is working (French-McCay et al., 2018; Crowley et al., 2018). Ideally, adjustments (up or down) to the initial 1:100 DOR, in conjunction with monitoring, should allow optimization of the dispersant injection rate for a particular oil type and flow rate (API, 2017; IPIECA, 2015a).

Benefits: SSDI use offers several unique benefits when compared to other response methods. Chief among those are improved worker safety, higher oil encounter rates, lower dispersant DORs, lower sensitivity to weather conditions, no daylight restrictions, and the potential to operate nearly continuously.

During the DWH response, SSDI was observed to reduce both the size and thickness of surface slicks and VOC levels at the water surface. This VOC reduction lowers the risk to workers in the immediate release area by reducing the potential for fire and explosions, and reducing inhalation risks from volatile hydrocarbons. Ultimately, SSDI allows workers to more effectively engage in well capping and source control operations. Since most of the SSDI operations are carried out by ROVs at the sea floor, the potential for workers to be exposed to oil, dispersants, and dispersed oil is also lower than for most other response methods.

Once SSDI vessels and equipment are in place, dispersant injection operations can run continuously in much higher sea states than ISB (limited to <1 m) or mechanical recovery (limited to <3 m for Norlense 1200-R self-inflating boom). Vessels are still needed to support dispersant resupply and pumping. In the RSA, metocean conditions could hamper SSDI sea surface logistics in sea states above 5 m.

Understanding Volatile Organic Compound (VOC) *concentrations at larger oil spills has been an increasing area of focus for scientists, modellers and spill responders. VOC monitoring is typically conducted at the surface of larger oil spills to comply with worker health and safety compliance measures. However, these data can often be compromised by vessel exhaust emissions and by the fact that the vessel-mounted monitoring units are frequently moving in and out of the slick, so correlation of VOC results is difficult.*

In 2016, an extensive modelling and Comparative Risk Assessment (CRA) study was conducted using the OILMAPDeep and SIMAP models to examine a 45,000 barrels per day (bpd) blowout scenario (French McCay, et al., *2018). The model output concluded:*

"…SSDI substantially decreased the amount of oil on the water surface and on the shoreline, increased dissolution and degradation rates of hydrocarbons at depth, increased weathering rate of rising oil such that floating oil contained much less soluble and semi-soluble hydrocarbons (BTEX, PAHs, soluble alkanes), and decreased VOC emissions to the atmosphere and therefore reduced human and wildlife exposures to VOCs."

Limitations: Similar to Surface Dispersant, SSDI cannot proceed without regulatory approval, and there may be specific criteria set by the regulators before SSDI is approved. Vessels, equipment and dispersant supplies to conduct SSDI operations take several days to be mobilized to the response site. After the dispersant and ROV operation vessels are deployed to the well location and a dispersant manifold is positioned on the dispersant supply vessel, the coiled tubing is deployed to the seafloor via ROVs. A minimum of two ROVs are needed for this operation. One is used for dispersant injection into the oil release point, and the other is used for observation and to support dispersant efficacy determination. Monitoring for SSDI efficacy requires the use of ROVs and may also require the use of a dedicated monitoring vessel if there are concerns about the transport and fate of dispersed oil plumes in the region.

Public perception of SSDI is often negative due to misunderstandings about dispersed oil fate and transport. Since dispersed oil occurs in the water column and cannot be readily seen, the public may incorrectly assume that the oil is sinking rather than dispersing and will surface in the future. However, during the DWH response, continuous sampling and monitoring at thousands of locations failed to detect the presence of undispersed subsea oil slicks (Operational Science Advisory Team [OSAT], 2010), which demonstrates the benefits of SSDI to effectively disperse oil.

Site Specific Considerations: The SSDI response option can be deployed in the broadest range of weather and sea conditions of any of the active response options. SSDI may become less effective in shallow water locations, so the decision to proceed with SSDI will require consideration of water depth. Two recent reports (NASEM, 2019; Daae et al., 2017; 2018) highlighted some of the challenges of using SSDI in depths shallower than roughly 300-500 m, where hydrate formation and reduced oil rise times can reduce SSDI effectiveness. NASEM (2019, p. 205) concluded that, "SSDI will generally have fewer fates benefits at a 500 m site compared to a 1400 m site, and at some threshold [i.e., shallower] water depth, SSDI benefits will become negligible." However, the Daae et al. reports (2017, 2018) point out that even if SSDI-treated oil reaches the surface, it will be less likely to form persistent emulsions.

3.6 Shoreline Protection and Recovery

Shoreline protection (e.g., diversion and deflection booming of oil) and recovery (manual retrieval of oil) are two response techniques that are usually used in combination so are addressed together in this section. The trajectory modelling used for this SIMA suggest an extremely low likelihood of spilled oil reaching any Canadian shoreline. Regardless, shoreline protection and recovery are considered important tools when oil cannot be effectively treated or collected on-water prior to encounter with shoreline areas, and for this reason, this response option is reviewed here.

Both shoreline protection and recovery tend to be labour intensive and involve large numbers of responders who must be trained, transported, housed, and managed. The logistics associated with such operations can be complex, particularly if they are to occur in remote areas, or adverse weather conditions. In addition, worker personal protective equipment, hand tools, washing equipment, protective and containment boom, and any appropriate mechanical equipment must be provided, stored, transported and maintained. Difficulties in gaining access to impacted shorelines due to logistic or topographical obstacles can make shoreline protection and recovery operationally difficult and it may not be possible to implement such options in all potentially affected areas due to these constraints.

Protective booming strategies may vary depending on tides, currents and weather conditions. However, these static boom systems require relatively quiescent waters as protective booms will likely fail in sea states above approximately 1-2 m. High winds can also blow the oil past the boom, and tides and currents can also pose a challenge. The following options listed are the most typical shoreline recovery options that may be utilized if oil does reach these shorelines, where operations would be prioritized based on tidal inlet protection site maps and plans, with the goal of protecting inlets and associated backshore lagoons and salt marshes:

- Manual removal – removal of surface oil by manual means (hands, rakes, shovels, buckets, scrappers, sorbents, etc.);
- Debris removal – manual or mechanical removal of debris (oiled and unoiled) from the shore or water surface to prevent additional sources of contamination;
- Low-pressure cold water flushing; and
- Limited use of mechanical recovery equipment in accessible areas if justified by the contamination level.

Benefits: Protective booming can protect relatively short stretches of the coast and as such should be used strategically in selected areas such as estuaries, marshes, beaches, or other ecologically or socially important areas. Protective booming should be used strategically to the extent practical based on current forecasted spill trajectory, the environmental context and conditions at the time of the incident. Once oil reaches the shoreline, the potential benefits of shoreline recovery options relative to natural attenuation include:

- Reduction in shoreline oiling;
- Physical removal of oil from the environment;
- Recycling or proper disposal of recovered oil; and
- Mitigation of impacts to culturally, environmentally or economically important areas.

Limitations: While protective booming can be valuable, it can also create a risk of collateral damage due to physical disturbance by work crews installing, maintaining and dismantling the boom. This may include disturbance and scarring from anchoring the materials to soils, sediments or plants, along with increased erosion of shoreline and sediments while the boom jostles in place. This potential damage is considered minor relative to the damage likely to result from the oil itself left unmitigated. The use of protective boom is also highly dependent on weather, type of shoreline, topography and hydrographic conditions.

For shoreline recovery, heavy machinery on beaches and intrusion by humans on foot can have negative impacts to some shorelines. In marsh and wetland habitats, the activity associated with the cleanup can often be more damaging than the oil itself; the cleanup operations can drive the contaminants below the surface and make them available to the root systems of plants and the organisms that burrow into the sediments. It is common in these environments for oil to be allowed to remain on the surface of the sediments with sorbents being placed at the edge of the water line to passively collect any oil that re-floats. Shoreline recovery tends to be more intrusive than any of the on-water response options. Shoreline recovery operations can only be undertaken during daylight hours, when weather conditions are conducive to worker safety. Given the logistical challenges and limitations, on-water cleanup will almost always be environmentally preferable to on-shore recovery, with a goal of preventing the oil from reaching the shoreline in the first place. Ultimately, shoreline recovery may take weeks, or more likely months or even years, depending on the volume of oil reaching shore, type of oil spilled and different environmental variables (i.e., wave energy, amount of solar exposure, rainfall, shoreline type and erosional processes).

Site Specific Considerations: Given the great distance from shore, and <1% probability of oil reaching or stranding on shorelines within the RSA, based on the unmitigated scenario, no shoreline impacts are anticipated for this particular hypothetical scenario (see Section 5). As a result, the 'shoreline protection and recovery' response option has been omitted from the risk analysis in Section 6.4. The response option was discussed since this SIMA serves as a template for this region, and Shoreline Recovery may be relevant for other spill scenarios considered by Equinor Canada in the future.

4 Resources of Concern

The framework for identifying resources of concern (ROCs) for the Equinor Canada SIMA involves understanding ecosystem health, human safety and socioeconomic activities in the RSA, as described in Section 2.1 and as shown in Figure 4. Under this framework, key resources are identified using physical, biological and socio-economic data about the RSA presented in the *Flemish Pass Exploration Drilling Program –Environmental Impact Statement* (Statoil, 2017), the *Newfoundland and Labrador Offshore Area 2019 Environmental Assessment Update* (Equinor Canada, 2019) and the *Flemish Pass Exploration Drilling Project and Eastern Newfoundland Offshore Exploration Drilling Project Environmental Assessment Report* (CEAA, 2019).

In addition, key cultural and subsistence resources have been identified through Equinor Canada's ongoing engagement with various regulators, Indigenous groups, fishers and fish processing associations, non-governmental stakeholders and the public in the development of the Flemish Pass EIS (Statoil, 2017). These efforts help build positive relationships and provide transparent and timely communication about the project in the area. Equinor Canada's ongoing engagement process also provides a forum for understanding stakeholders' concerns and priorities, which are taken into consideration and incorporated in the SIMA's resources of concern and risk analysis. A summary of the stakeholder engagement is provided in the Regulatory, Indigenous and Stakeholder Engagement section of the Flemish Pass EIS (Statoil, 2017, Chapter 3) and EIS update (Equinor Canada, 2019).

In addition to the information provided in the Flemish Pass EIS, the fate and behaviour of oil in the RSA are assessed to identify resources that may be affected due to age, species type, sensitivity to oil, etc. These resources are taken into consideration during the risk assessment phase of the SIMA (Section 6). When analyzing the modelling for the hypothetical spill, resources may be omitted in the risk analysis stage if overlap does not occur and effects are not expected.

Under the framework described above, the following resources are identified as the ROCs for the Equinor Canada SIMA and are described in more detail in the following paragraphs:

- Marine Fish and Fish Habitat
- Marine and Migratory Birds
- Marine Mammals and Sea Turtles
- Corals and Sponges
- Fisheries (Commercial, Indigenous, and Commercial Communal)
- Responder Safety

A geographical area, habitat and brief description of each environmental compartment are provided in the ROC table (Table 7). This table differentiates between habitats offshore, on the slope, on the shelf and on the shoreline. This SIMA considers environmental effects and species holistically rather than on individual or specific species. Consequently, the assessment is based on the generalized ecological communities and/or habitats present in the affected area. A complete list of species known to likely occur in the RSA is provided in the Flemish Pass EIS (Statoil, 2017, Appendix F).

Supporting information to identify species present in the RSA includes seasonal distribution and life stages of wildlife, which are summarized in the Flemish Pass EIS (Statoil, 2017). The

Flemish Pass EIS also lists species occurring in the Newfoundland area designated as "threatened" or "endangered" under the *Species at Risk Act (SARA*) or the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Some of these protected species are rare in the RSA, however they are still considered in the analysis due to their designated status in Canada and elsewhere.

Additional areas of potential environmental sensitivity are identified in the Flemish Pass EIS (Statoil, 2017, Section 11) and discussed in Section 4.1.1. These special areas have been designated because of their biodiversity and ecological importance and the need to proactively conserve and protect marine ecosystem functions for future generations. As part of the assessment, specific species at risk and special areas are not included in the ROC (Table 7) or later in the comparative risk matrices (Tables 16 and 17), as these species or areas are already captured under the broader environmental compartments. For example, when considering fish (in general), implications to its habitat, which could overlap a special area, is also considered. Similarly, for a particular species at risk (e.g., Ivory gull), the species is already taken into account when evaluating the broader resource category (e.g., birds) for each environmental compartment. Sections 4.1.1 and 6.3 provide more information on how species at risk and special areas are regarded in the SIMA process.

The ROC table (Table 7) also includes socio-economic resources since a high level of importance is attached to them, as outlined in the Flemish Pass EIS (2017). These resources are depicted crossing both the habitat and resource category columns in the table to highlight their assignment across all resource categories and habitats. In particular, Commercial Fisheries is an important and long-standing component of the Newfoundland and Labrador economy and is therefore included as a resource of concern. In addition, the Indigenous category (to denote Aboriginal Use), for both historic fisheries and commercial communal fisheries, is included as a resource of concern. No cultural heritage areas, sites, structures, or other such resources have been identified in or around the RSA during the public, stakeholder, or Indigenous engagement activities completed for the Flemish Pass EIS (2017). For this SIMA, resources for recreational fisheries are already accounted for in the fisheries categories and not included as a separate category. Likewise, other socio-economic resources, such as marine traffic, tourism, etc., would be expected to be affected by surface oiling and response options in a similar way to fisheries, therefore were not analyzed under separate categories for this SIMA.

Table 7 Resources of concern for the Newfoundland and Labrador region.

COMPARTMENT	HABITAT	DESCRIPTION OF ENVIRONMENTAL HABITAT	RESOURCE CATEGORY
Shoreline	**Intertidal**	Marine intertidal zone is defined as the area of the foreshore and seabed that is exposed to the air at low tide and submerged at high tide.	Birds Fish eggs/larvae Invertebrates Mammals
Shelf (subtidal zone to the shelf break)	**Sea Surface**	The sea surface microlayer is the top 1 mm of the ocean surface. This is the boundary layer where exchanges occur between the atmosphere and the ocean surface.	Birds Marine Mammals Fish eggs/larvae Sea Turtles
	Water Column ***(shallow: less than 20 m)***	The oceanic mixed layer pelagic environment from the surface to the depth of ~20 m.	Birds (diving) Invertebrates Fish Marine Mammals Sea Turtles
	Water Column ***(deeper: greater than 20 m)***	The marine pelagic environment from the oceanic mixed layer (~20 m) to the boundary of the benthic zone.	Birds (diving) Fish Invertebrates Marine Mammals Sea Turtles
	Benthos	The benthic zone is the lowest level in the marine environment which includes the sediment surface as well as sub-surface layers.	Corals & Sponges Fish eggs/larvae Invertebrates Fish
Slope (extending offshore from the shelf break)	**Sea Surface**	The sea surface microlayer is the top 1 mm of the ocean surface. This is the boundary layer where exchanges occur between the atmosphere and the ocean surface.	Birds Marine Mammals Fish eggs/larvae Sea Turtles
	Water Column ***(shallow: less than 20 m)***	The oceanic mixed layer pelagic environment from the surface to the depth of ~20 m.	Birds (diving) Fish eggs/larvae Fish Marine Mammals Sea Turtles
	Water Column ***(deeper: greater than 20 m)***	The marine pelagic environment from the oceanic mixed layer (~20 m) to the boundary of the benthic zone.	Birds (diving) Fish Marine Mammals Fish eggs/larvae Invertebrates Sea Turtles
	Benthos	The benthic zone is the lowest level in the marine environment which includes the sediment surface as well as sub-surface layers.	Corals & Sponges Invertebrates Fish Fish eggs/larvae
Safety			Responder Safety
Socio-economic			Commercial Fisheries Commercial Communal Fisheries
Cultural and Subsistence			Indigenous Fisheries

NOTE: Compartments or ROCs may be omitted for the risk analysis stage based on the hypothetical spill's fate and behaviour or overlapping resources among compartments or habitats.

4.1 Special Areas and Protected Species

4.1.1 Special Areas

Special areas in offshore NL are identified based on their defining environmental features, including the presence of sensitive habitats and species (fish, seabirds, marine mammals and sea turtles) and their human use and societal value. Various types of special areas in the marine and coastal environment have been identified and / or protected based on socioeconomic interests such as economic or recreational / cultural activities. These designated areas include protective measures to reduce the effects of bottom-trawl fishing, which are designed to support long-term protection of corals and sponges, and to contribute to long-term conservation of biodiversity. These measures also support long-term sustainability of commercial fisheries. Special areas in offshore NL are designated under Canadian, Provincial, and international regulatory frameworks and processes, including Canada's *Oceans Act*, Canada's Wildlife Act United Nations Convention on Biological Diversity, and North Atlantic Fisheries Organization. Figure 9 shows locations of special areas and ELs in offshore NL.

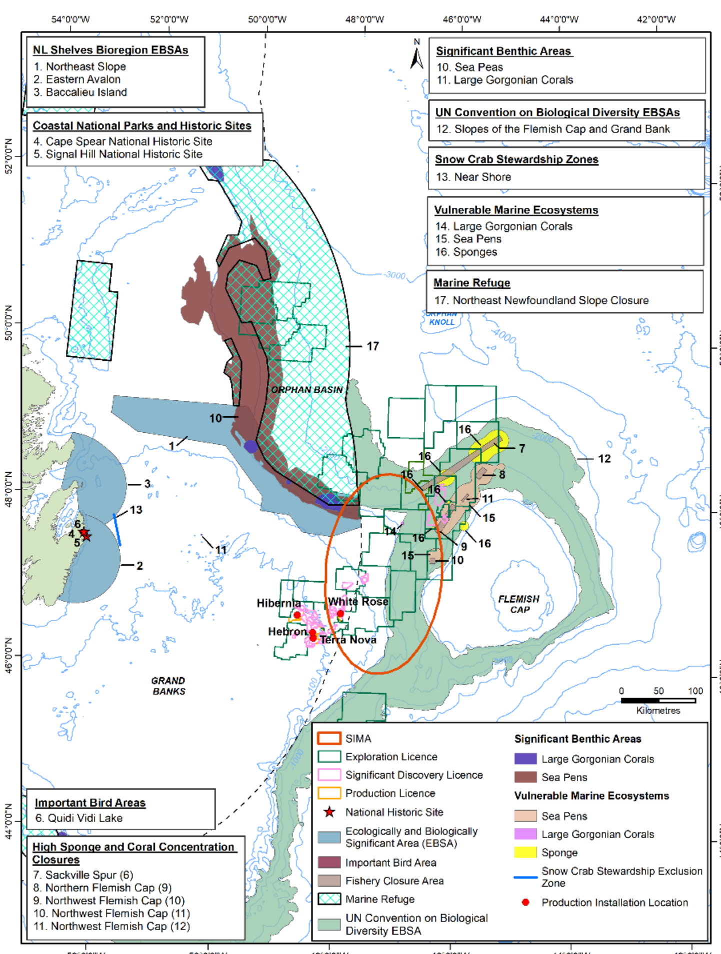


Figure 9 Locations of special areas in the RSA. (Equinor Canada)

4.1.2 Listed Species in the Newfoundland and Labrador Region.

Table 8 lists species designated as resources at risk by *SARA* and COSEWIC for the Grand Banks and Flemish Pass areas. More information on listed species is provided in the following sections.

There are no critical habitats for marine mammals or sea turtles in the RSA (Equinor Canada, 2019). Outside the RSA, the nearest marine mammal critical habitats are those for the North Atlantic Right Whale, near the Bay of Fundy, and the Northern Bottlenose Whale (Scotian Shelf Population), in the Scotian Shelf area (Equinor Canada, 2019). Similarly, there are no critical habitats in the RSA for birds; however, outside the RSA, there are a few critical habitat locations for piping plover shorebirds in coastal Newfoundland. For fish, the Northern and Spotted Wolffish are designated "threatened" under *SARA* and COSEWIC. The areas depicted in Figure 10 show the critical habitats for these species, which overlap the RSA (Section 2.1, Figure 4). The Wolffish spawn from June to October, depending on the species; the larvae are pelagic, while juveniles and adults occupy deep water habitats.

Table 8 Listing of *SARA* and COSEWIC protective species in the RSA. (Equinor Canada, 2019, Appendix C)

Common Name Species	**SARA Status (Schedule 1)**	**COSEWIC Designation**	**IUCN Designation**
MARINE FISH			
Atlantic Wolffish	SC	SC	
Northern Wolffish	T	T	
Spotted Wolffish	T	T	
American eel		T	
Basking shark		SC	
Lumpfish		T	
Atlantic cod (NF and Labrador)		E	
Cusk		E	
Porbeagle		E	V
Shortfin mako		E	V
White shark	E	E	V
Roundnose grenadier		E	CE
White hake		T	
American plaice		T	
Smooth skate		E	E
Thorny skate		SC	V
Winter skate (Eastern Scotian and NF)		E	E
Atlantic salmon (South NF)		T	
Atlantic salmon (Outer Bay of Fundy)		E	
Atlantic bluefin tuna		E	
Acadian redfish (Atlantic)		T	
Deepwater redfish (Northern)		T	LC
Greenland Shark			NT
Haddock			V
Little skate			NT
Spinytail skate			NT
Spiny dogfish		SC	V
MARINE BIRDS			
Ivory Gull	E	E	NT
Harlequin duck (Eastern pop.)	SC (V-NL ESA)	SC	
Barrow’s goldeneye (Eastern pop.)	SC	SC	
Piping plover	E (V-NL ESA)	E	NT
Red Knot	E	E	NT
Buff-breasted sandpiper	SC	SC	NT
Red-necked phalarope	SC	SC	
Ivory gull	E	E	
Ross’s gull	T	T	
Long-tailed duck			V
Black-legged kittiwake			V
Leach’s storm-petrel			E
Bermuda petrel			V
Desertas petrel			V
Zino’s petrel			E

Common Name Species	SARA Status (Schedule 1)	COSEWIC Designation	IUCN Designation
Peregrine falcon	SC (V- NL ESA)	SC	
MARINE MAMMALS and SEA TURTLES			
Blue Whale (Atlantic)	E	E	
Fin Whale (Atlantic)	SC	SC	
North Atlantic Right Whale	E	E	
Northern Bottlenose Whale (Scotian Shelf)	E	E	
Sowerby's Beaked Whale	SC	SC	
Killer Whale (Northwest Atlantic/Eastern Arctic)		SC	
Harbour Porpoise (NW Atlantic)		SC	
Leatherback Sea Turtle (Atlantic)	E	E	
Loggerhead Sea Turtle	E	E	

Note: Endangered (E), Threatened (T), Special Concern (SC), Vulnerable (V), Critically Endangered (CE), Near Threatened (NT)

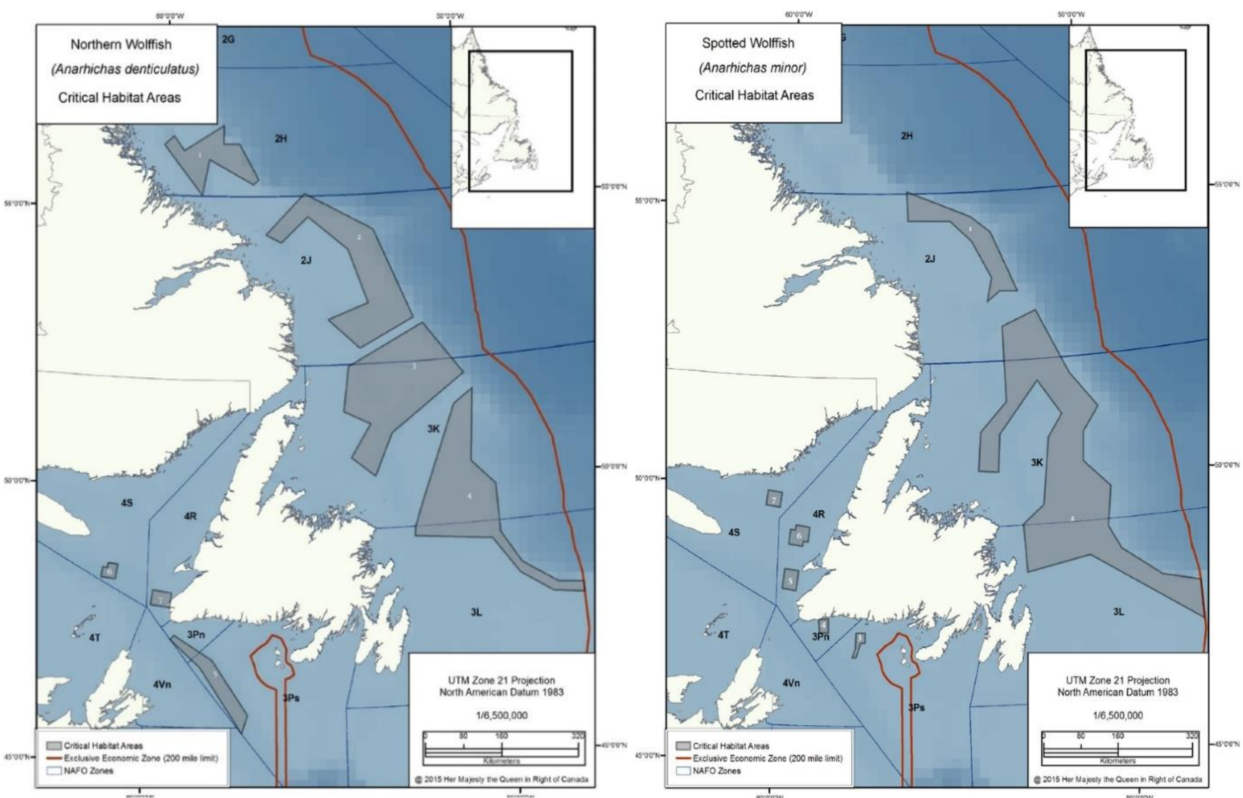


Figure 10 Location of Northern and Spotted Wolffish critical habitats. (DFO, 2018)

4.2 Marine Fish and Fish Habitat

Marine Fish and Fish Habitats are selected as a ROC due to the ecological value provided to marine ecosystems, the socio-economic importance of fisheries resources, and the potential for interactions with the hypothetical subsea blowout oil spill scenario. The recently updated federal *Fisheries Act* (2019) provides clear regulatory authority over all fish and fish habitats, including the productivity of commercial, recreational and Aboriginal fisheries and their ecosystems. Fisheries are described in more detail in Section 4.6.

The RSA provides habitat for a variety of groundfish and pelagic fish species, which Northwest Atlantic Fishery Organization (NAFO) (2013) recognizes as three general functional groups: the Grand Banks/Newfoundland Shelf; the Flemish Cap; and the oceanic waters beyond the shelf break. Canadian research vessel (RV) surveys for the drilling project area, which is smaller part of the RSA, identified 99 fish species. Of these 99 fish species, 13 species constitute 95% of all captured fish (capelin, deepwater redfish, lanternfish, American plaice, Greenland halibut, blue hake, longnose eel, sand lance, roughhead grenadier, common grenadier, eelpout, Vahl's eelpout, and sculpin).

A variety of fish species have been recorded in Newfoundland's nearshore, some species enter the inshore only to feed and others are seasonal migrants. Coastal and estuarine areas offer suitable cover for use as spawning and nursery grounds. Examples of species that spawn in inshore areas include Atlantic cod, American plaice, and capelin. However, other species remain offshore (e.g., continental slopes and deep channels), such as redfish, Greenland halibut and snow crab.

As described in the Flemish Pass EIS (Statoil, 2017, Table 6.14), the dominant key fish species identified during the Canadian RV surveys of fisheries management areas in the RSA are capelin (46.3%) and deepwater redfish (29.2%) in the northern box depicted in Figure 11, and sand lance (44.7%) and capelin (28.6%) in the southern box. The abundance of fish decreases from shelf/slope zones to deep slope zones and fish species assemblages change quickly between depth zones. Key species surveyed (from shallowest to deepest) for the northern box include capelin, deepwater redfish, lanternfish, roundnose grenadier and blue hake. For the southern box in Figure 11, the key species consist mainly of sand lance, deepwater redfish, blue hake and roundnose grenadier. Figure 11 illustrates the capelin and deepwater redfish abundance and distribution in the RSA.

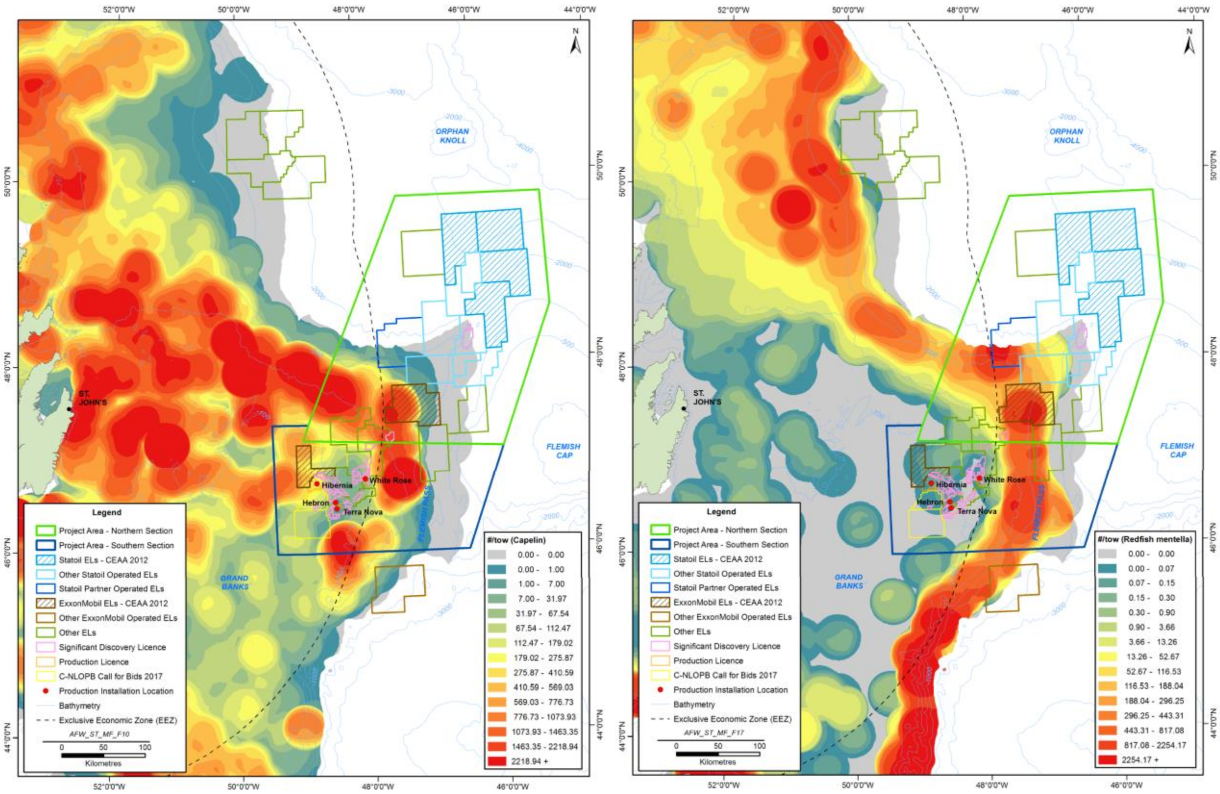


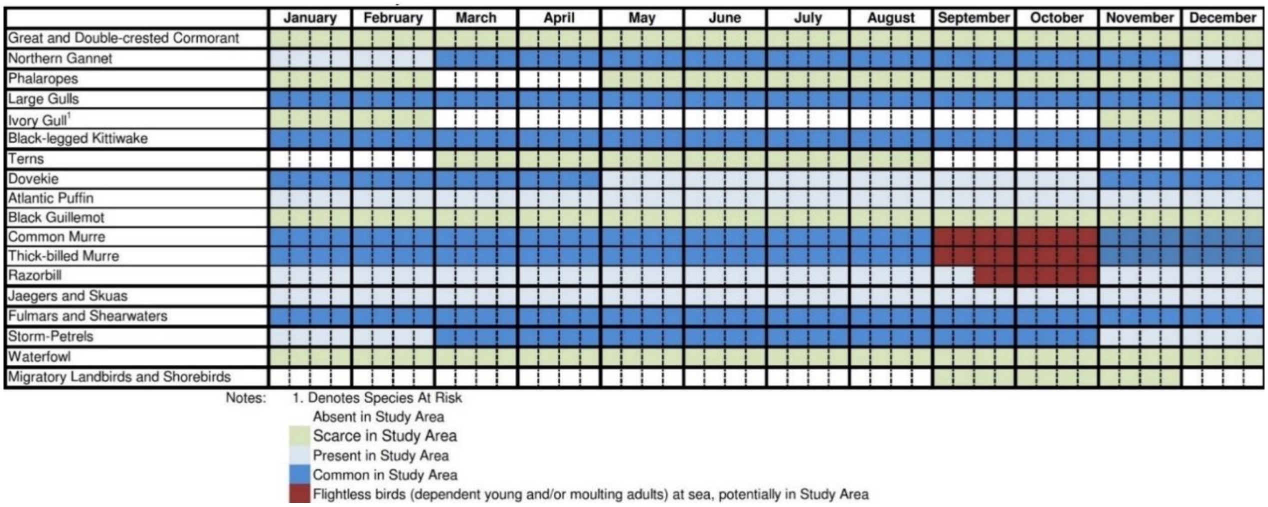
Figure 11 Capelin (left) and deepwater Redfish (right) distribution and abundance.
(Statoil, 2017, Figures 6-16 and 6-19)

There are 23 *SARA*/COSEWIC-protected fish that may be present in the region at various times of the year. Within the RSA, there are four fish species formally protected under *SARA* that include the Atlantic Wolffish, Northern Wolffish, Spotted Wolffish, and white shark. The protected fish are described in detail in the Flemish Pass EIS (2017). While the potential for occurrence of these species in the drilling project areas is low based on known habitat preferences and distribution mapping (e.g., white shark [Statoil, 2017, Figure 6-37]), in the event of oil in the broader RSA, there would be potential for interaction with these species.

4.3 Marine and Migratory Birds

Marine and Migratory Birds are selected as a ROC due to their ecological value to marine and coastal ecosystems, regulatory considerations and potential interaction with the hypothetical subsea blowout oil spill scenario. Migratory birds ROC includes pelagic (i.e., offshore) and neritic (i.e., inshore) seabirds, waterfowl, and shorebirds that are protected under the *Migratory Birds Convention Act* and additional marine-related birds not protected under the Act (e.g., cormorants). Marine and migratory birds can be found in and around the RSA year-round throughout various life cycle processes (Table 9).

Table 9 General summary of seasonal presence of marine-associated birds off Eastern Newfoundland (Statoil, 2017, Table 6-64).



The Eastern Newfoundland shoreline and waters are important habitat regions, while the offshore areas are important feeding grounds for many marine bird species. The largest and most diverse concentration of seabirds in the offshore waters of Newfoundland and Labrador shelves is found during spring and summer (Fifield et al., 2009; Bolduc et al., 2018). Species assemblages within the Grand Banks are dominated by Black-legged Kittiwakes (Fredericksen et al., 2012), dovekies (Fort et al., 2013), gulls, murres (Hedd et al., 2011, McFarlane, Tranquilla et al., 2013, Fredericksen et al., 2016) and Northern Fulmars in winter; Northern fulmars, dovekies, gulls, Black-legged Kittiwakes in spring; storm-petrels, shearwaters (Hedd et al., 2012) and shearwaters in summer; and, murres, dovekies and Northern fulmars in fall (Fifield et al., 2009). The Flemish Cap and Pass have high densities of Black-legged Kittiwake, Dovekie, gulls (in spring), murres, Northern fulmars and shearwaters (in summer) (Fifield et al., 2009). Figure 12 illustrates the distribution of waterbirds (most abundant) during the surveys (Fifield et al., 2009). Canadian Wildlife Service has made more recent and comprehensive seasonal mapping available through government of Canada open data portal (Bolduc et al. 2018).

This ROC also considers all migratory birds listed under Schedule 1 of *SARA*, COSEWIC, and/or the Newfoundland *Endangered Species Act;* however, few protected marine or migratory birds are likely to occur in the RSA. In small numbers, and outside their breeding seasons and areas, the endangered Ivory Gull occurs in offshore waters and the Barrow's Goldeneye and Harlequin Duck occur in nearby coastal areas. The endangered Piping Plover shorebird has a breeding population in Newfoundland that nests in sandy beaches in the southwestern and western part of the island. Other *SARA*-protected species are the Peregrine Falcon, found migrating the Newfoundland coast and nesting on high cliffs of coastal Labrador, and the Red Knot, found on sandy inlets and coastal mudflats that nest outside the RSA.

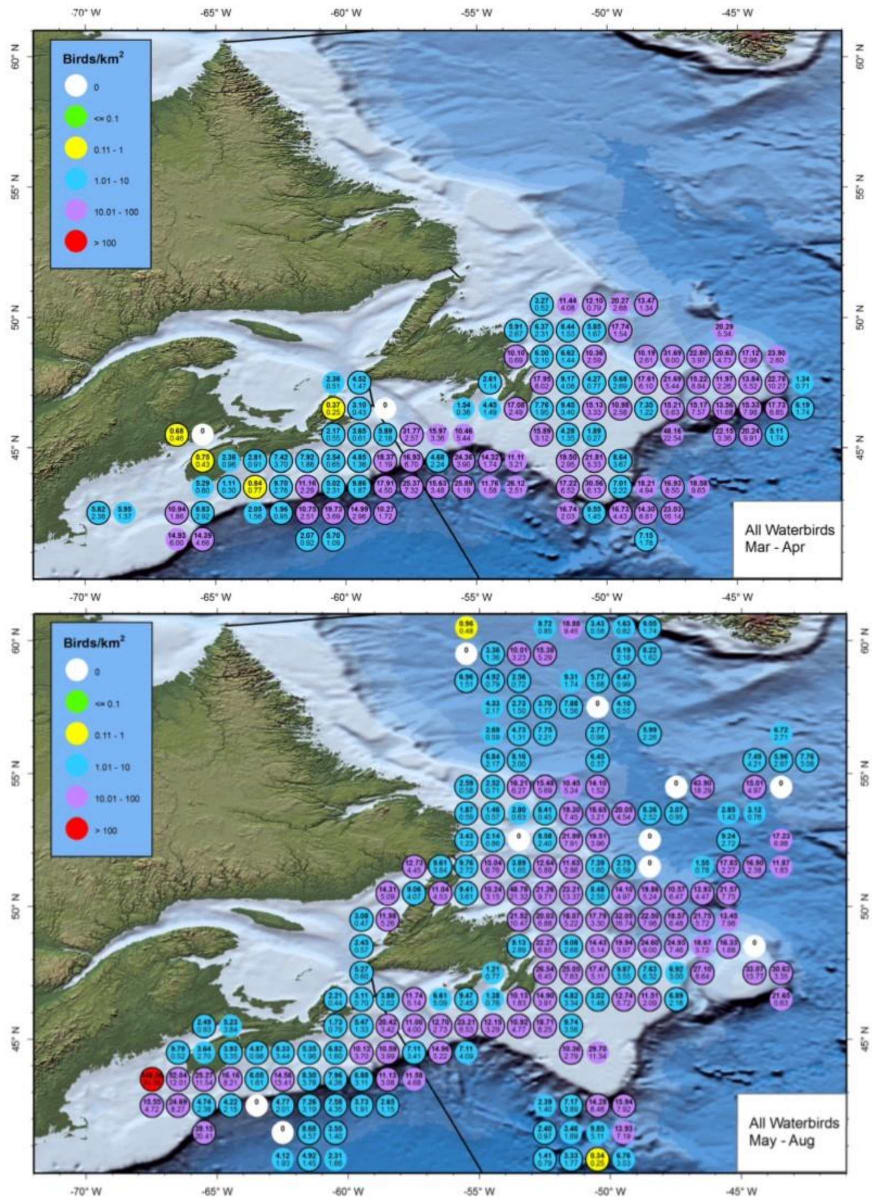


Figure 12 Distribution of all waterbirds March-April (top) and May-August (bottom). (Fifield et al., 2009)

While not a protected species, Leach’s storm petrels have been identified as a species of concern offshore NL by regulatory agencies. Leach’s storm-petrel is the most numerous breeding seabird in NL. The largest colony in the world, Baccalieu Island, supports approximately one third of the species’ global population (CWS, 2017). Foraging Leach’s storm petrols from Baccalieu Island forage in deep oceanic waters or beyond the continental slope concentrated over the northern Grand Banks and Flemish Cap island (Hedd et al., 2018). However, in recent years the population is experiencing a decline. Preliminary results from a 2013 survey of nesting Leach’s storm-petrels on Baccalieu Island provide an estimate of just under 2 million pairs, a decline of 40% from the previous survey in 1984 (Hedd et al., 2018). The cause of the Leach’s storm-petrel population decline has not yet been determined. This species is designated globally Vulnerable by the International Union for Conservation of Natura (IUCN) (Birdlife International, 2018).

As shown in Figure 13, several coastal Important Bird Areas (IBAs) and bird colonies are present within the RSA, including Baccalieu Island, Witless Bay Islands, Mistaken Point and Western Head in Newfoundland's eastern coastal areas. IBAs are discrete areas that support nationally- or globally-important groups of birds. These unique areas have been designated as IBAs for a variety of reasons, including the presence of breeding habitat for SAR, important shorebird migration habitat, important coastal waterfowl habitat, and/or the occurrence of regionally significant colonial water bird colonies. Witness Bay Island IBA supports globally-important seabird colonies that include Leach's Storm-petrels, 300,000 breeding pairs of Atlantic Puffin, 83,000 nesting pairs of Common Murre, and 24,000 nesting pairs of Black-legged Kittiwake. Mistaken Point is designated an IBA for the significant numbers of Purple Sandpiper and Common Eider. Western Head hosts 1,000 nesting pairs of Black-legged Kittiwake, Common Murre and Razorbill.

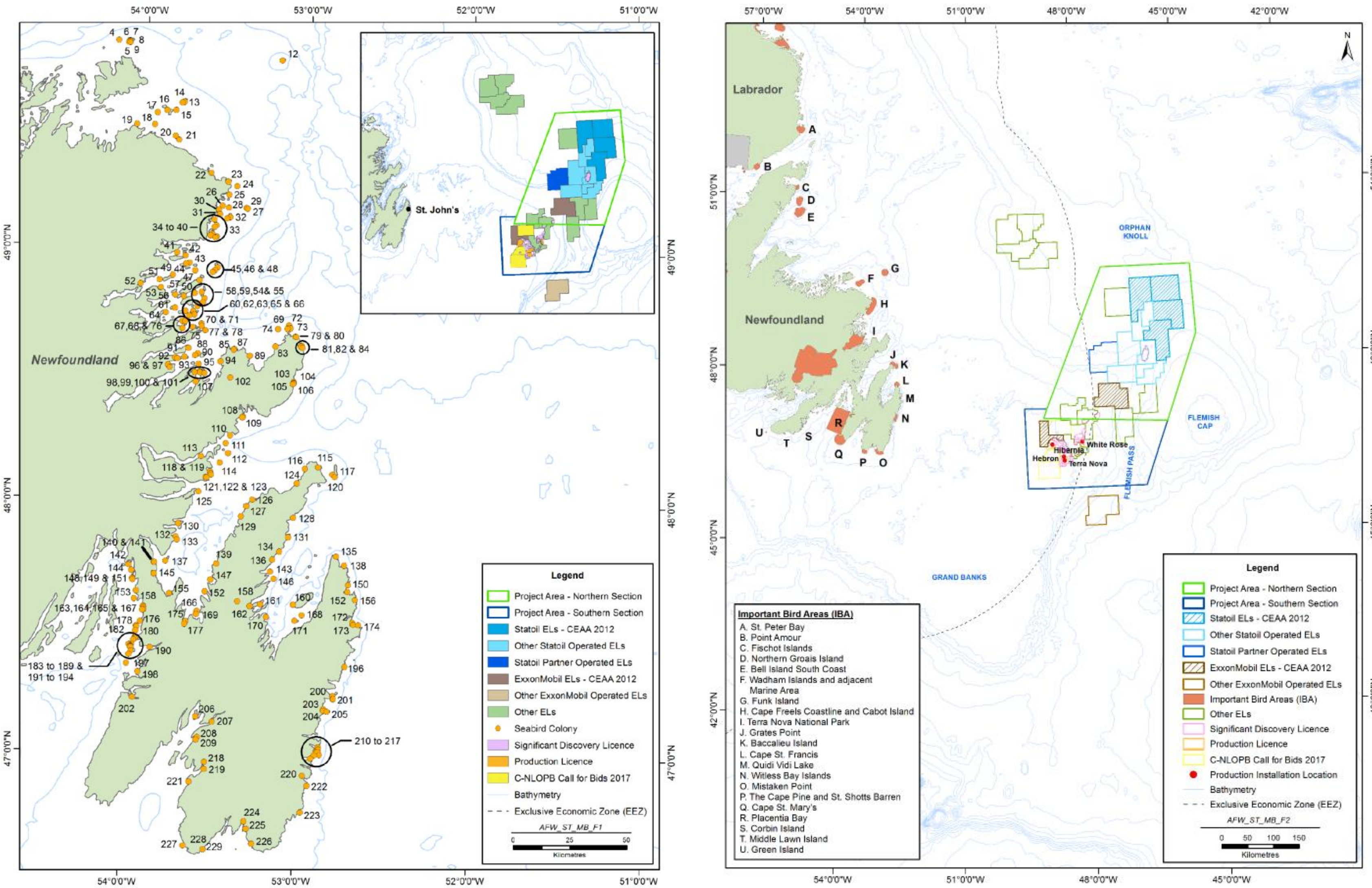


Figure 13 Map of Bird Colonies (left) and Important Bird Areas (right). (Statoil, 2017)

4.4 Marine Mammals and Sea Turtles

4.4.1 Marine Mammals

Marine Mammals are selected as a ROC in recognition of the ecological value they provide to marine ecosystems, specific regulatory requirements of the *Fisheries Act* and *SARA*/COSEWIC, and potential interactions with the hypothetical subsea blowout oil spill scenario.

There are six species of mysticetes (baleen whales), nine species of odontocetes (toothed whales), and four species of phocids (seals) that could potentially be present in the RSA. Seven of these species are designated by either *SARA* or the COSEWIC — four species of mysticetes (blue whale [Atlantic], fin whale [Atlantic], North Atlantic right whale, and Northern Bottlenose whale [Scotian Shelf]) and three species of odontocetes (Sowerby's beaked whale, killer whale [Northwest Atlantic/Eastern Arctic], and harbour porpoise [NW Atlantic]) (Equinor Canada, 2019). There is no designated critical habitat under *SARA* for endangered marine mammal species in the RSA.

In the Flemish Pass EIS, tables are provided that list the marine mammals with their designation, potential for occurrence and timing of presence (Statoil, 2017, Table 6.37 and 6.38). To briefly summarize those tables, the majority of mysticetes are migratory and are present in highest concentrations in the RSA from late spring through fall. However, there are year-round occurrences for several species, such as the fin whale and humpback whale. The more commonly occurring odontocetes are the Atlantic white-sided dolphin and the long-finned pilot whale, both are present year-round. Seals also occur year-round in the RSA, with the highest concentrations in winter. The harp and hooded seals are the more common seals expected in this area.

4.4.2 Sea Turtles

Sea Turtles are selected as a ROC in recognition of the ecological value they provide to marine ecosystems, specific regulatory requirements of the *Fisheries Act* and *SARA*/COSEWIC, and potential interactions with the oil from the hypothetical subsea blowout oil spill scenario. However, the leatherback and loggerhead sea turtles (listed as endangered by SARA and assessed as endangered by COSEWIC) rarely occur in the RSA. Sea turtle occurrences in the RSA are typically from summer through fall in the coastal feeding areas.

4.5 Invertebrates

Invertebrates are selected as a ROC in recognition of the ecological value they provide to the marine ecosystems, specific regulatory requirements of protected areas, and potential interactions with oil from the hypothetical subsea blowout oil spill scenario. A summary of surveyed macroinvertebrates is provided in the Flemish Pass EIS (Statoil, 2017, Table 6.2) and include squid, shrimp and jellyfish species.

Figure 14 illustrates the surveyed Northern Shrimp abundance and distribution. In addition, this figure shows the domestic snow crab harvest locations, which are concentrated around the shelf edge of the Grand Banks. Snow crab is the most commercially important benthic invertebrate within the RAA (NLDFA, 2018) and ranges from the southern Labrador Shelf to the eastern slope of the continental shelf and Tail of the Grand Bank (Dawe et al., 2002). The seasonality of the snow crab harvesting is April through August (Statoil, 2027, Figure 7-18).

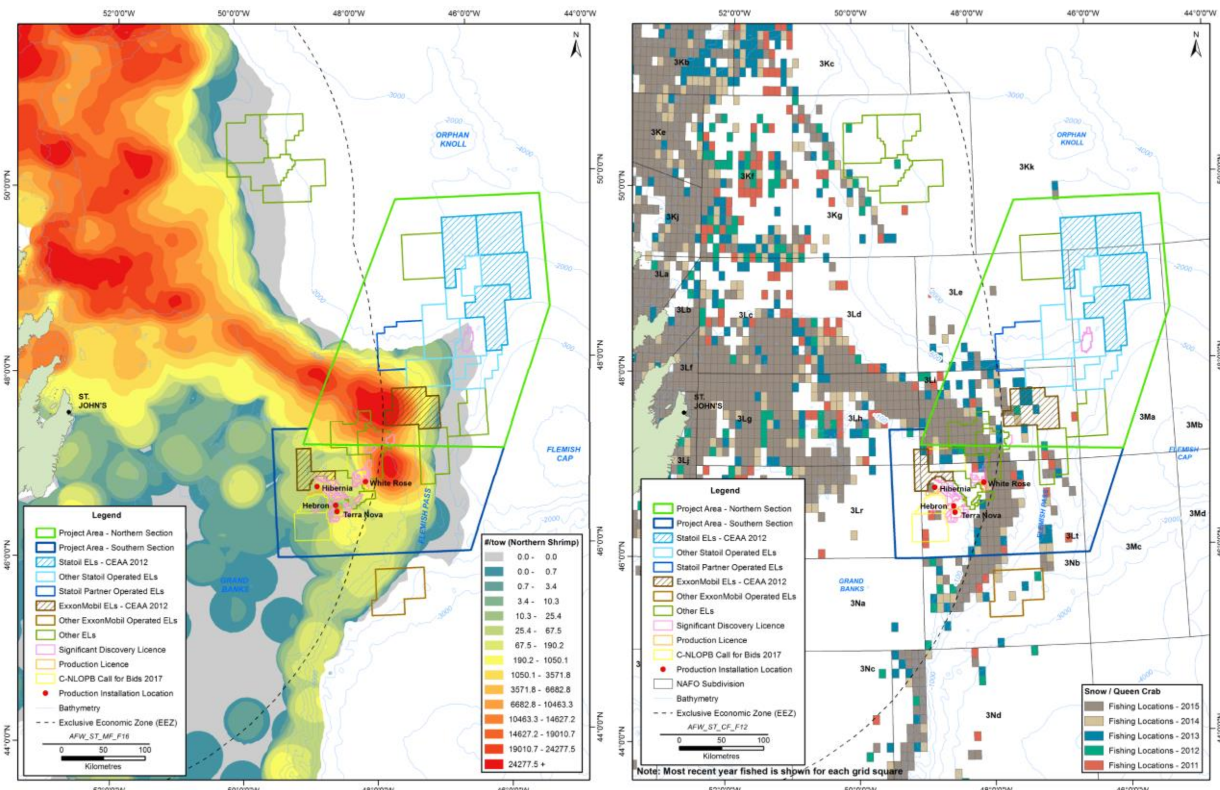


Figure 14 Northern shrimp distribution and abundance data (2008-2013) (left) and snow crab harvesting locations (2011-2015) (right). (Statoil, 2017, Figures 6-6 and 7-17)

Other dominant benthic invertebrates found in the RSA include scallops, sea dollars, sea urchins, crabs, and polychaetes in the Grand Banks shelf; sponges in the Grand Banks slope; sponges, corals, seastars, crustaceans, and sea urchins in the Flemish Cap; and sponges, echinoderms, jellyfish, arthropods, and polychaetes in the Flemish Pass (Statoil, 2017, Tables 6.3, 6.4, 6.5 and 6.6).

Finally, blue mussels are an important aquaculture species, with facilities located in the coastal areas of Newfoundland. In the wild, these blue mussel benthic communities provide a rich habitat for other marine organisms (e.g., worms and crustaceans). Detailed information on aquaculture locations is contained in the Flemish Pass EIS (Statoil, 2017, Section 7.1.9). Other important species, corals and sponges, are discussed in more detail in Section 4.5.1.

4.5.1 Coral and Sponges

Coral and Sponges are selected as a ROC in recognition of the ecological value they provide to the marine ecosystems, specific regulatory requirements of protected areas, and potential interactions with oil from the hypothetical subsea blowout oil spill scenario. They are recognized as an important and vulnerable component of the deep sea and slope. The deep-sea soft coral is the major cold-water coral of the Grand Banks shelf and slope edge (120 to 250 m). In the Flemish Cap area at 500 to 1,000 m depths, corals and sponges are the most dominant surveyed species. Supporting information listing the coral species and depth ranges surveyed in the RSA is provided in the Flemish Pass EIS (Statoil, 2017; Table 6.8).

Figure 15 illustrates the regional distribution of coral and sea sponges in the RSA, with the slope areas containing highest densities. Many of the special areas in the RSA (as discussed in Section 4.1.1) have high concentrations of corals and sponges. Some of these areas are closed to bottom trawl fisheries (Fisheries Closure Areas [FCA]). Closed NAFO FCAs protect these fragile or unique species or habitats from bottom fishing activities.

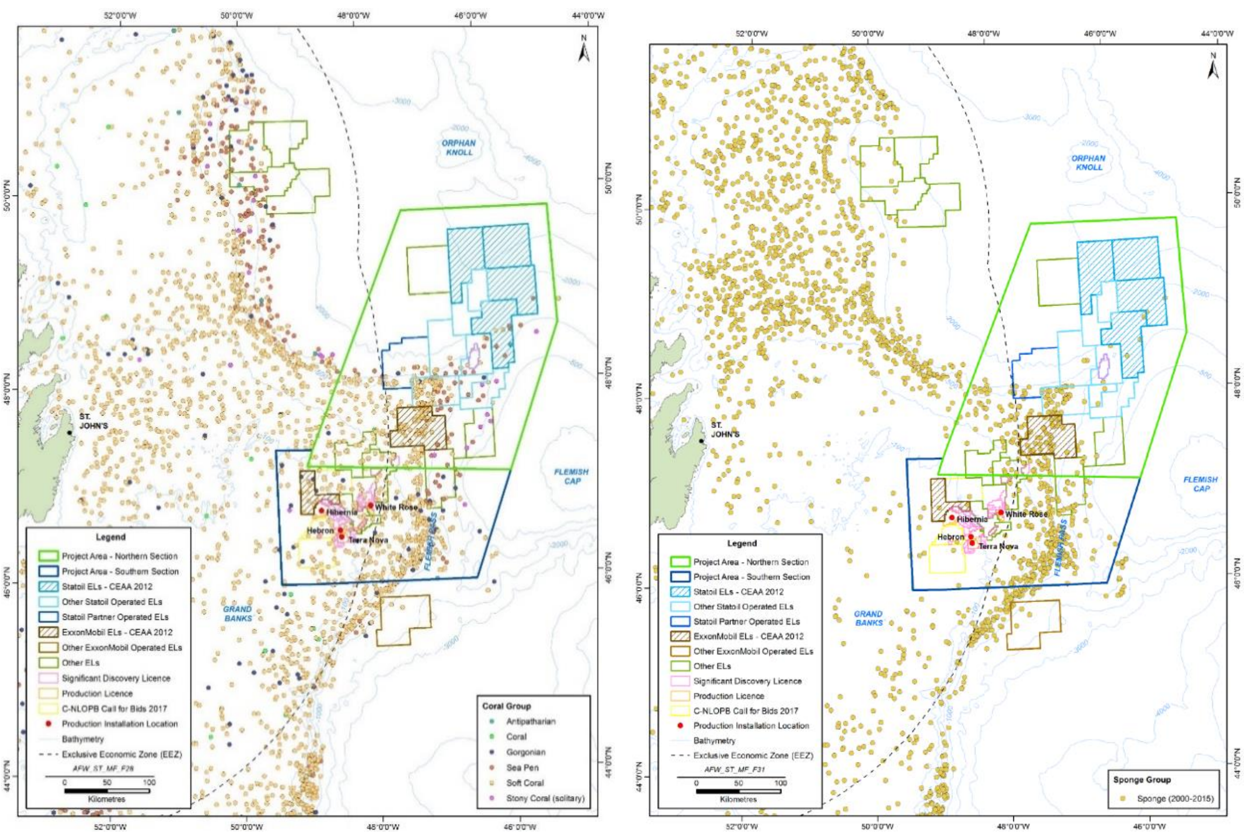


Figure 15 Summary of regional coral (left) and sponge (right) distributions compiled from Canadian RV data and literature sources. (Statoil, 2017)

4.6 Fisheries

4.6.1 Indigenous Fisheries

As a Cultural and Subsistence use, the ***Indigenous Fisheries*** category is included as a ROC in consideration of Aboriginal treaty rights and socio-economic, cultural and traditional fishery areas, and the potential interactions with oil from the hypothetical subsea oil blowout. During the development of the Flemish Pass EIS (2017), Equinor Canada engaged with Indigenous groups that reside in Newfoundland and Labrador regarding proposed drilling activities. These Indigenous groups included the Nunatsiavut Government, Labrador Innu, NunatuKavut Community Council, Qalipu and Miawpukek First Nations. In addition, Equinor Canada engaged with Mi'kmaq communities in Nova Scotia, New Brunswick, PEI and the Gaspe region of Quebec, the Wolastoqey Nation in New Brunswick, and two Innu First Nations located on the north shore of Quebec with maritime interests offshore Newfoundland and Labrador.

In Indigenous communities, traditional fishing for food, social and ceremonial (FSC) purposes includes harvesting marine species in both salt and freshwater areas. Although no FSC fishing is reported to occur in the offshore project area, considering the larger RSA, inshore FSC fishing could occur.

4.6.2 Commercial Communal Fisheries

Commercial Communal Fisheries licenses are provided to Indigenous community enterprises to operate in a variety of NAFO sites in the RSA for groundfish, swordfish, tuna, shrimp and/or seal harvesting. The category was chosen as a ROC due to the Indigenous groups' maritime fishery activities, including commercial communal fishing, as listed in 4.6.1. For example, the Nunatsiavut Government has licenses for snow crab, turbot and shrimp. In addition, they have a seal license for access in Seal Fishing Areas (Atlantic-wide).

4.6.3 Commercial Fisheries

Commercial Fisheries are chosen as a ROC in consideration of the socio-economic importance of fishing areas to Newfoundland and Labrador and the potential interaction oil from the subsea blowout oil spill scenario. Based on Canadian catch data, commercial fishing in the RSA is dominated by invertebrate, pelagic and groundfish fisheries. For the purpose of this SIMA, recreational fisheries are not categorized separately as the resources are already considered under Commercial Fisheries and Indigenous categories.

The RSA is located within the main NAFO Divisions of 3KLMNO, a further breakdown of subdivisions is described in the Flemish Pass EIS (Statoil, 2017, Table 7.1 and Figure 7.1). Snow crab and northern shrimp are the primary species harvested by fishers, in addition to groundfish (e.g., cod and halibut) and pelagic fish (e.g., capelin and herring) (Newfoundland and Labrador Department of Fisheries and Aquaculture [NLDFA], 2018). Snow crab and shrimp are also the highest valued seafood products; all the shellfish combined capture 82% of the total harvested seafood catches (NLDFA, 2018). International fishers traditionally harvest snow crabs, northern shrimp, redfish, Greenland halibut, Atlantic cod and yellowtail flounder in greatest numbers in NAFOs areas outside the EEZ.

Commercial fisheries' activities occur year-round for a variety of species in the RSA, although the majority of fisheries are active in the spring and summer months, particularly along the edges of the Grand Banks for snow crabs. In particular, the snow crab fishery consistently takes place from early April to the end of July, with the predominance of activities occurring in late June. Similarly, peak fishing efforts for pelagic and groundfish species occur from June to August (Statoil, 2017, Tables 7-3 and 7-10; NLDFA, 2018). Figure 16 depicts domestic harvesting locations for all species and all months (2011-2015).

Aquaculture is a growing industry in Newfoundland and Labrador with 47 shellfish and 88 salmon licensed commercial sites that augment the province's fishing sector and economy. The majority of the farmed species are finfish (e.g., Atlantic salmon and steelhead trout) and shellfish (e.g., blue mussels), with the majority of operations found along the coastal areas, outside the RSA (NLDFA, 2018).

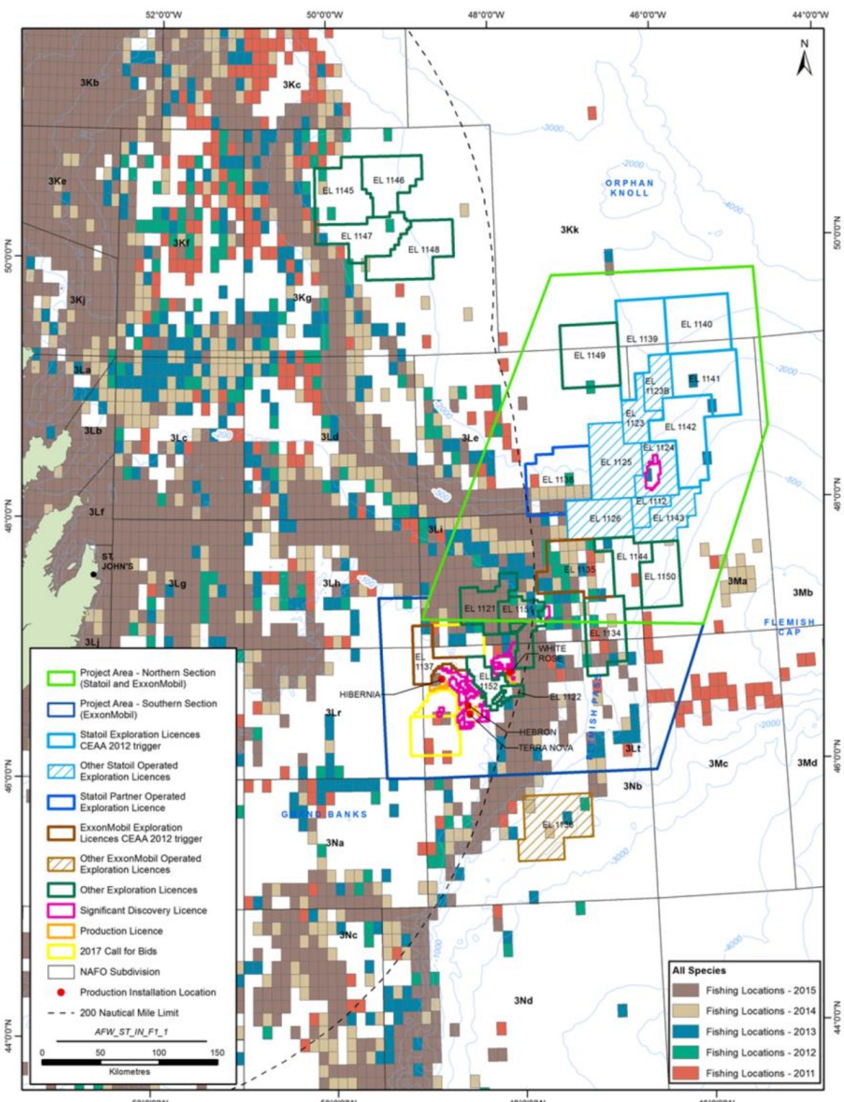


Figure 16 Domestic harvesting locations for all species and all months (2011-2015). (Statoil, 2017)

4.7 Responder Safety

Maintaining the health and safety of responders is the primary goal for spill response decision-makers and stakeholders when choosing response options to attain the lowest overall negative effect on the environment. The health and safety objectives include considering air quality as it relates to response worker safety and VOC exposure from oil. For example, dispersant spraying and SSDI should have a major mitigation impact on airborne VOC concentrations, which would improve worker safety by removing (or omitting, as it relates to SSDI) large amounts of oil from the water surface. In particular, SSDI is an important operation to commence prior to capping stack installation to reduce health and safety risks at the well site. Therefore, this surface dispersant use and SSDI mitigation lower the risk to workers in the immediate release area by reducing potential risk from fire or explosions and inhalation risks from volatile hydrocarbons.

As stated in a recent NAS report (NASEM, 2019, p. 14), which was based on results from field and modelling studies, “surface and subsurface dispersant application represents a useful tool for oil spill response. When used appropriately, dispersants decrease the amount of oil at the surface, thereby reducing the potential exposure of response personnel to VOCs and decreasing the extent of oiled areas encountered by marine species at the surface.”

5 Spill Modelling

5.1 Background and Approach

Trajectory modelling for Flemish Pass Exploration Drilling Project was conducted in support of the Flemish Pass EIS (Statoil, 2017). Appendix E of the EIS contains the full trajectory modelling report prepared by RPS (Statoil, 2017, Appendix E [RPS, 2017]) for an unmitigated subsea blowout scenario, which is summarized in the following paragraphs.

Oil spill trajectory and fate modelling was conducted using two RPS 3-dimensional (3D) models: the OILMAPDeep blowout model (for near-field, close to source control release point – i.e., the well opening) and the far-field Spill Impact Model Application Package (SIMAP) model. The study used both stochastic and deterministic approaches to determine potential behaviour of a subsea blowout resulting from a loss of source control. The stochastic modelling provides probabilities of the likelihood of a given region being exposed to oil over a range of environmental conditions, using 119 model runs (55 winter and 64 summer). The deterministic analysis provides a time series picture of a how an individual spill event might progress. Consequently, output from the two models, used in tandem, provides an indication of both the likelihood and magnitude of the potential effects of the blowout scenario considered for this Equinor Canada SIMA.

An overview of the spill scenario was provided in Section 2.3, Table 6. The winter model assumes a spill date in mid-December and the summer model in late-July, for a 15,000 m^3 release over 113-days. The duration of each modelled simulation was 160 days. Refer to the RPS report (2017, Section 3 – Model Input Data) for the detailed parameters used to produce the model results.

An extensive review of oil subsurface transport models, both near-field and far-field, is conducted in the recent NASEM (2019, Chapter 2 - Fate and Transport) report, which provides additional information on current state-of-the-science knowledge on modelling capabilities. It also provides information on model uncertainty that arises from limited scientific understanding on subsea oil behaviour (e.g., tip streaming, pressure gradients, and outgassing).

5.2 Modelling for an Unmitigated Subsea Blowout

The figures in this section are directly reproduced from the stochastic modelling results of the RPS report (Statoil, 2017, Appendix E [Section 4.1.1]) for the unmitigated subsea blow out release site, and from deterministic results for water column exposure case (Section 4.2.2) of that same report. The probability of average oil thickness in excess of 0.04 µm threshold and minimum time (in days) to exceed this threshold are depicted for summer (Figure 17) and winter (Figure 18).

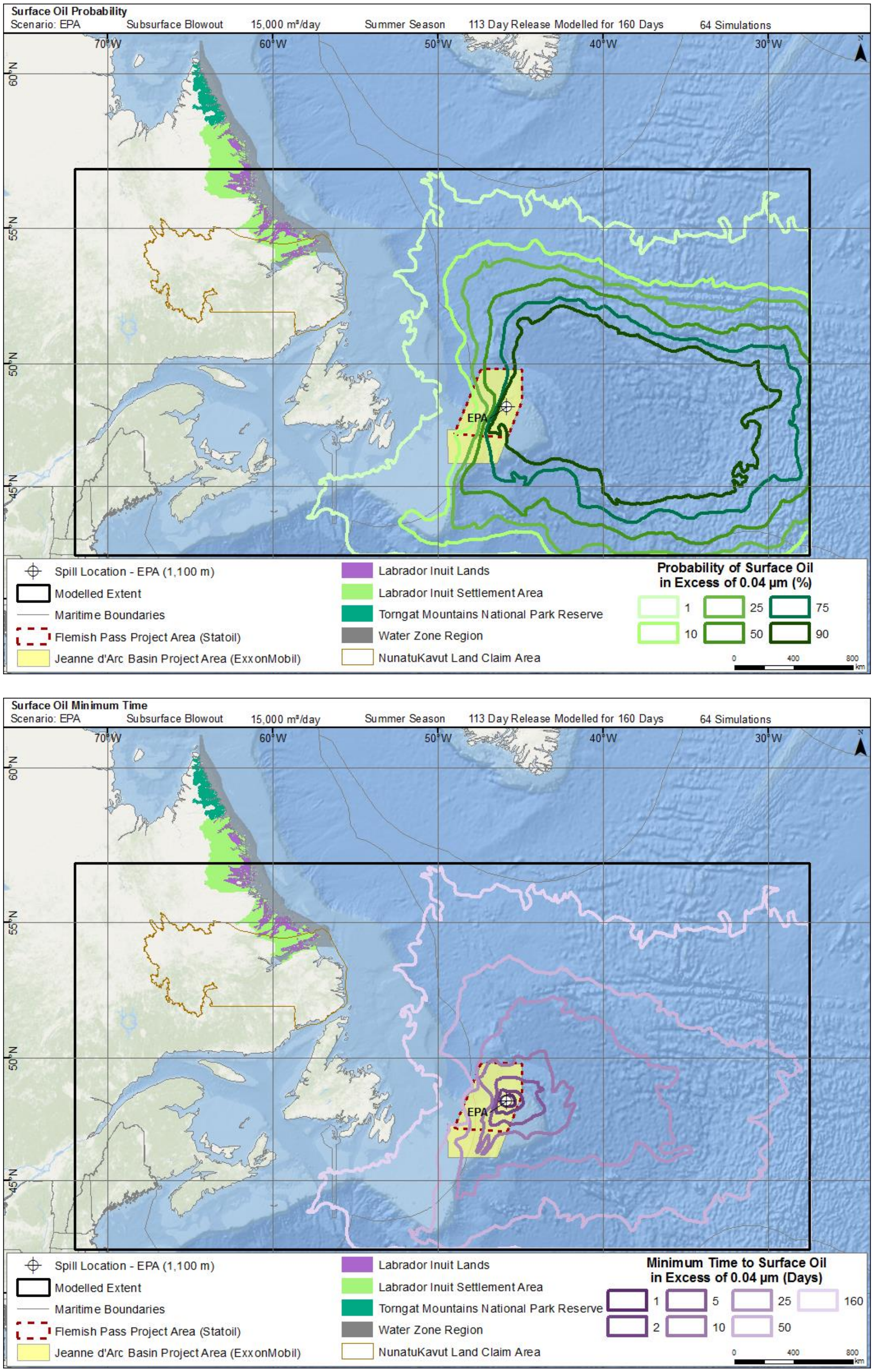
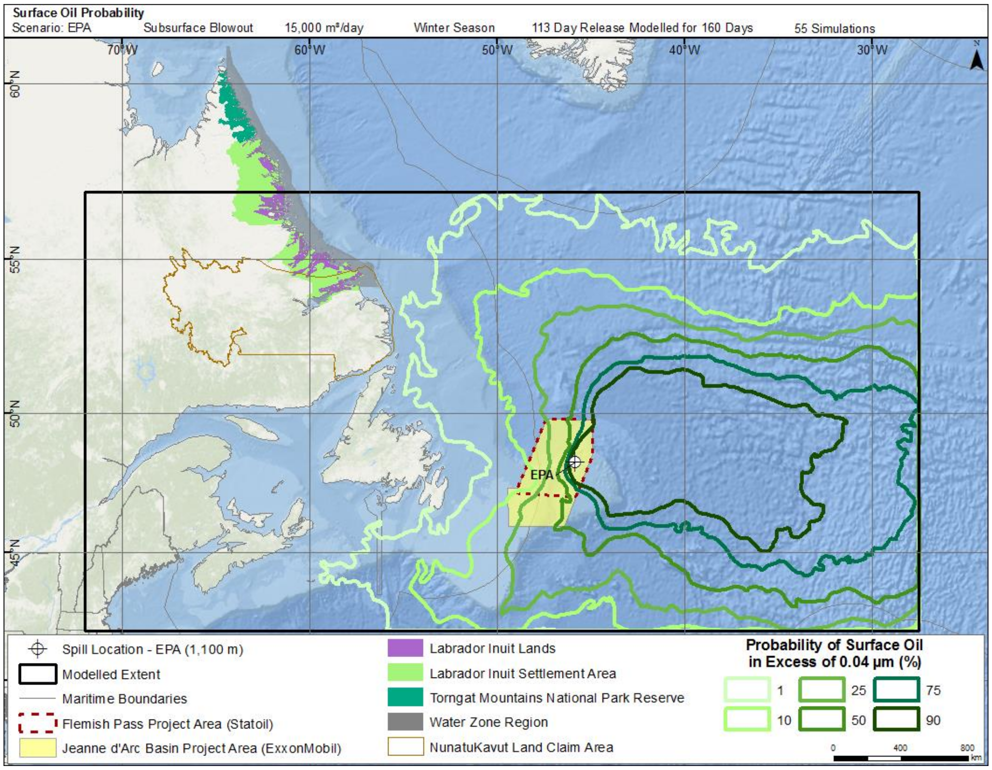


Figure 17 Summer probability of average surface oil thickness > 0.04 µm (top) and minimum time to threshold exceedance (bottom) resulting from a subsurface blowout.



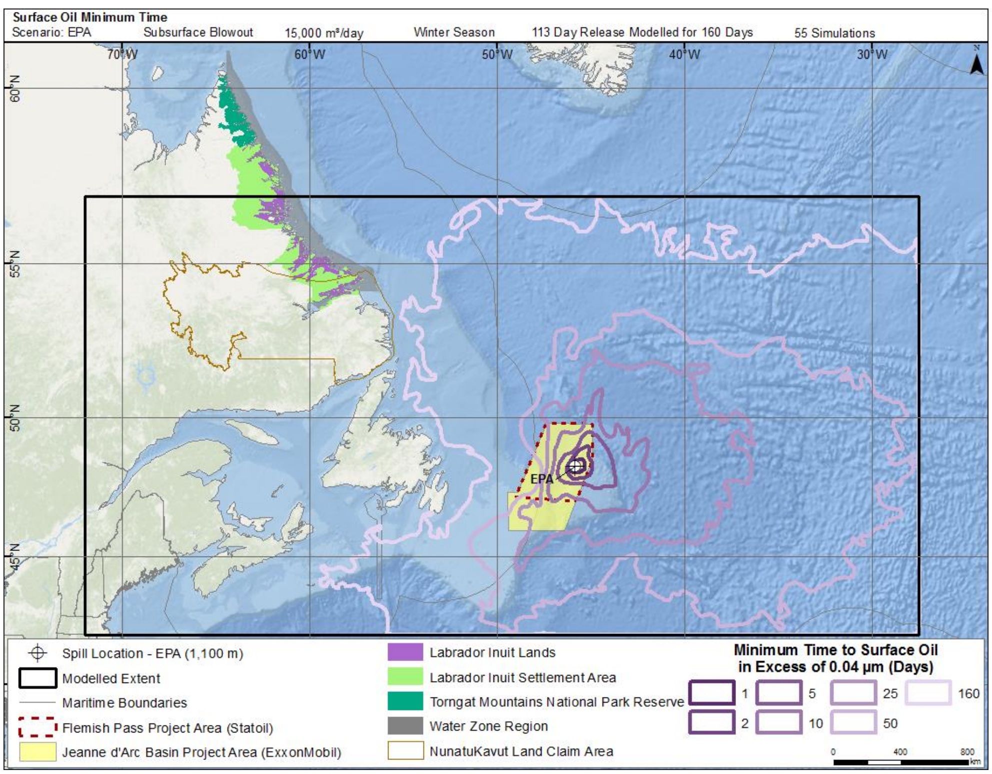


Figure 18 Winter probability of average surface oil thickness > 0.04 µm (top) and minimum time to threshold exceedance (bottom) resulting from a subsurface blowout.

Given the distance from shore, there is a minimal probability of shoreline oiling exceeding 1 g/m^2 for this continuous 113-day subsea blowout (Table 10). For the purpose of the response analysis in Section 6.4, which assumes that a capping stack is successfully implemented, thereby shutting-in the well at Day 36, no shoreline oiling is assumed.

Table 10 Probability of shoreline contamination and minimum time for predicted oil exposure exceeding 1 g/m^2.

Release	Scenario Timeframe	Probability of Shoreline Oil Contact (%)	Minimum Time to Shore (days)	Maximum Time to Shore (days)
Unmitigated subsurface blowout	Annual	< 1	78.7	157.4
	Winter	1.9	78.7	157.4
	Summer	1.6	78.7	83.7

The cumulative footprint for the surface slick is provided in Figure 19 for the Summer scenario. Note that this does not reflect the overall size of the surface oil for this spill, rather, surface oil may exist *somewhere* in this overall footprint during a *random time* within the 113-day release.

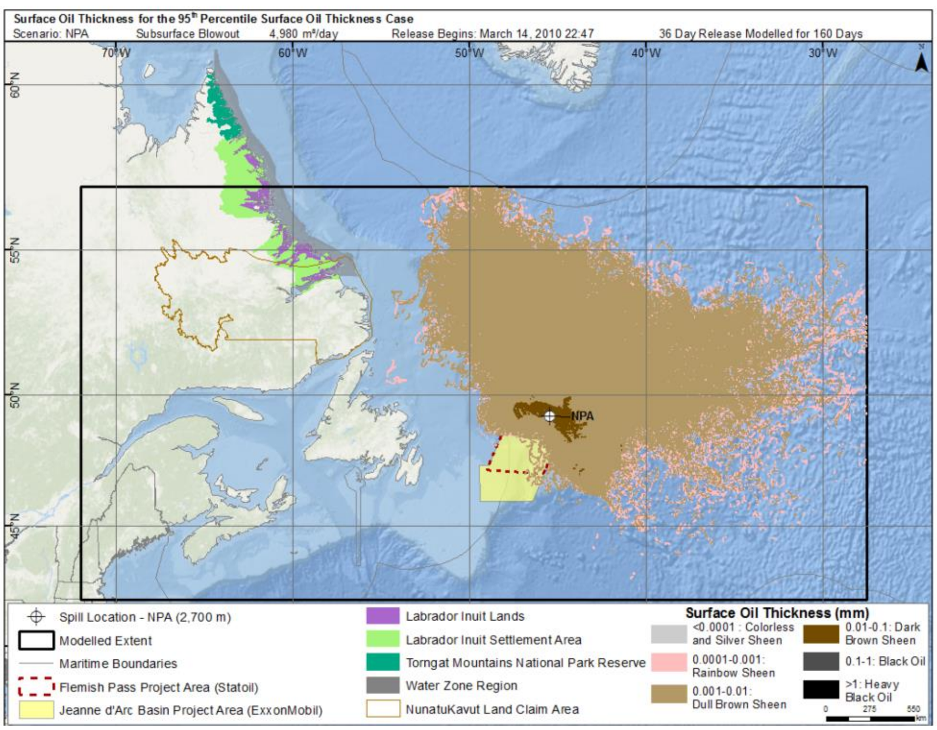


Figure 19 Surface oil thickness for the 95th percentile oil exposure case resulting from a subsurface blowout.

A time-series from a deterministic modelling run is provided in Figure 20, indicating that oil is being predominantly transported away from shore (north and eastward). This time-series provides snapshots at Day 2, Day 10, Day 50, Day 100 and Day 160 for the unmitigated subsea blowout (winter scenario). Note that the surface slick distribution becomes increasingly patchy over time and distance from the release point.

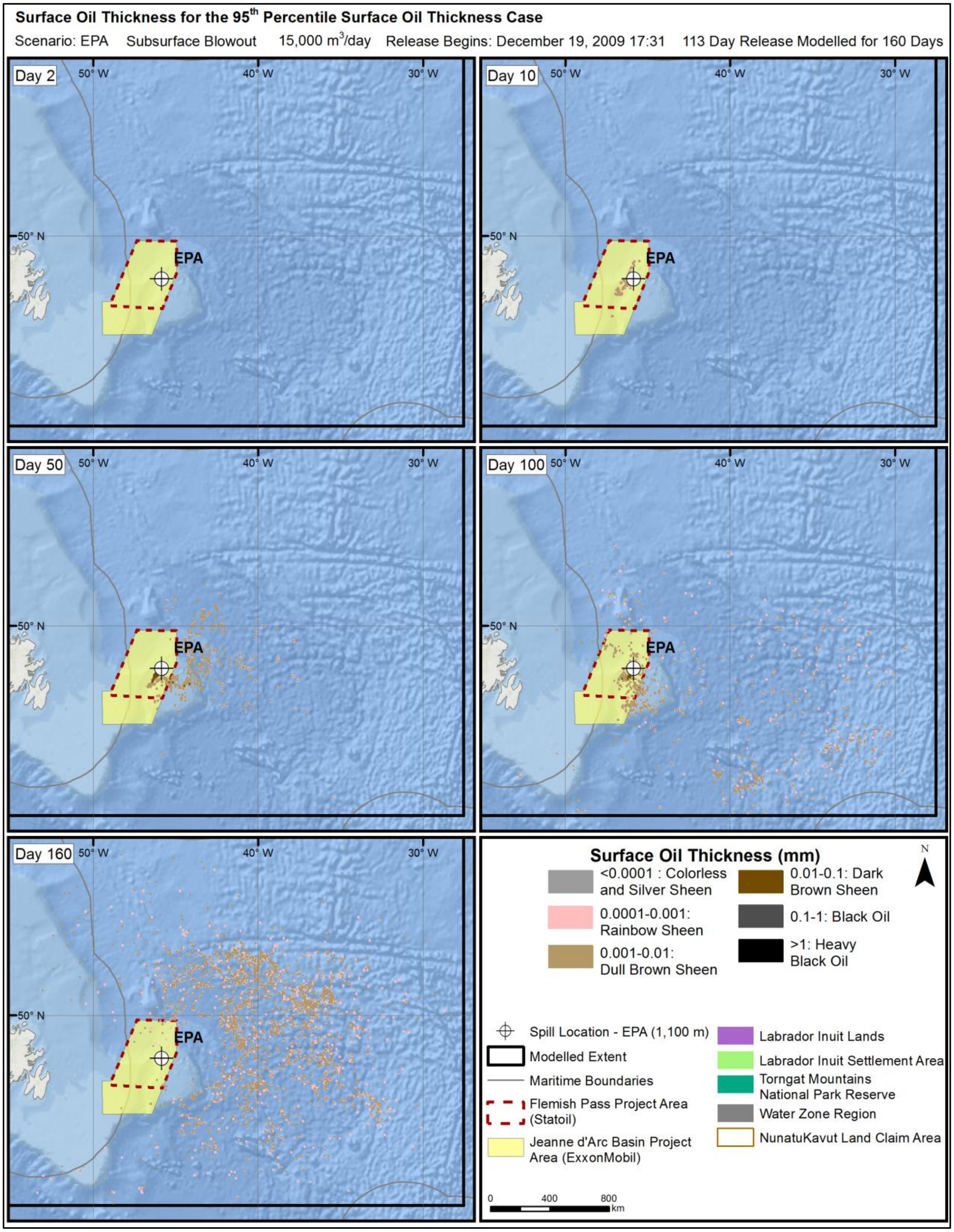


Figure 20 Predicted surface oil thickness for the 95th percentile surface oil exposure case at days 2, 10, 50, 100, and 160.

At the end of the 160-day model run, very little oil was predicted to remain on the surface. The mass balance plot shown in Figure 21 provides a breakdown of the various fates of the oil over the model duration. BdN crude oil is very light and has a large aromatic fraction, so by the end of the 160-day, approximately 85% of the oil is expected to evaporate to the atmosphere or undergo degradation. Approximately 10% of the oil will remain entrained in the water column, and no oil is expected to reach the bottom sediments or shorelines.

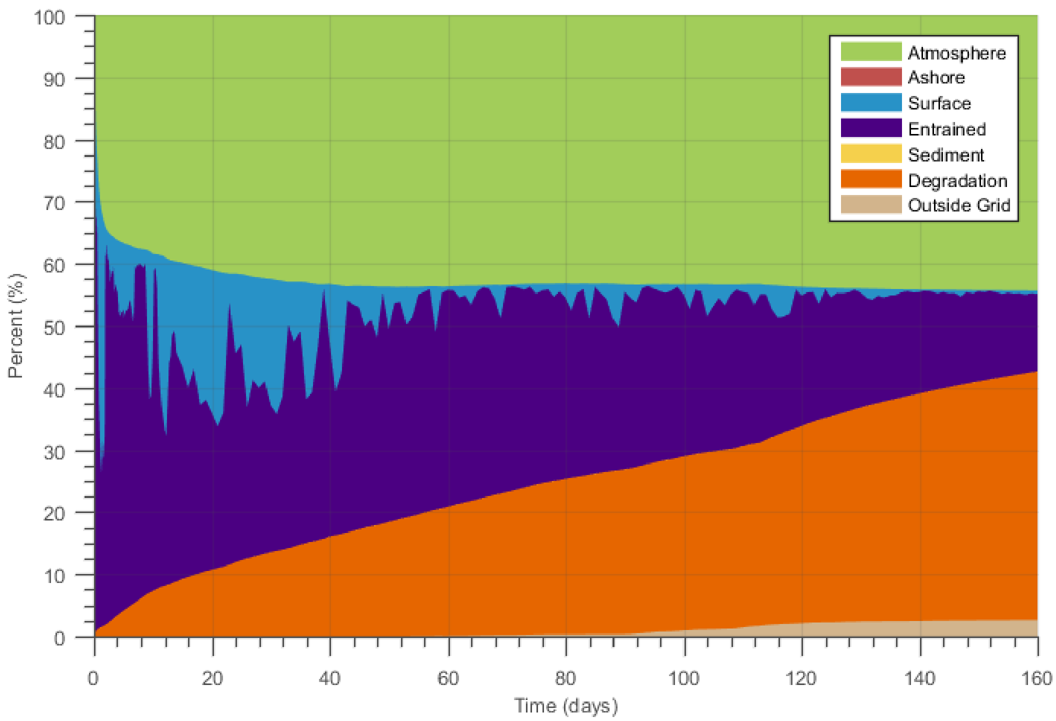


Figure 21. Mass balance plots for the 95th percentile surface oil thickness case.

The entrainment of oil into the water column as it rises from the seafloor, as well as oil that becomes entrained at the surface due to wind and wave action, are predicted to result in low concentrations of dissolved hydrocarbons (depicted in Figure 22) and total hydrocarbons (THC) in the water column (Figure 23).

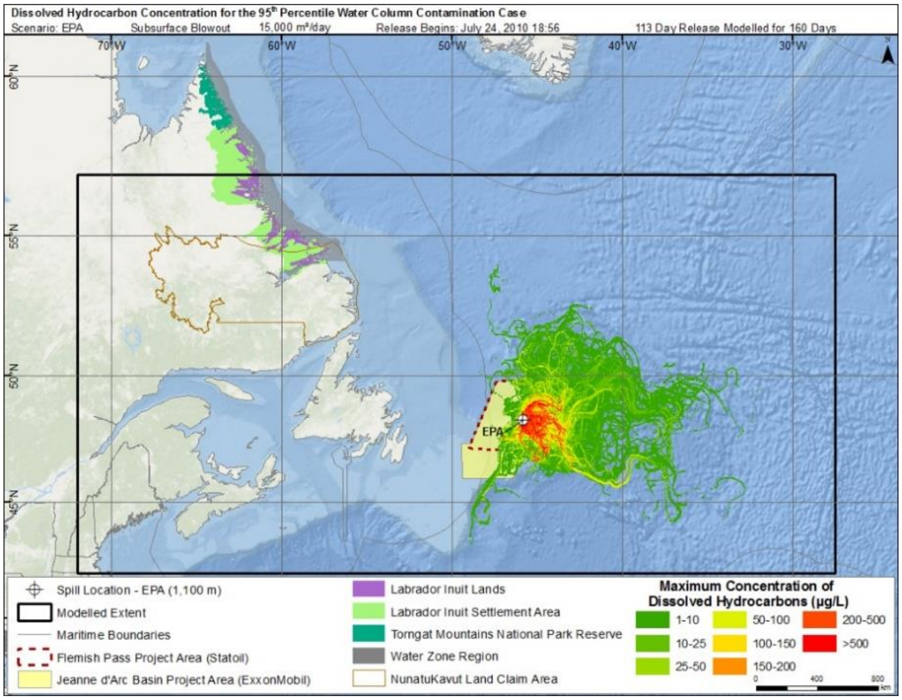


Figure 22. Maximum dissolved hydrocarbon concentration at any depth in the water column for the 95th percentile surface oil thickness case.

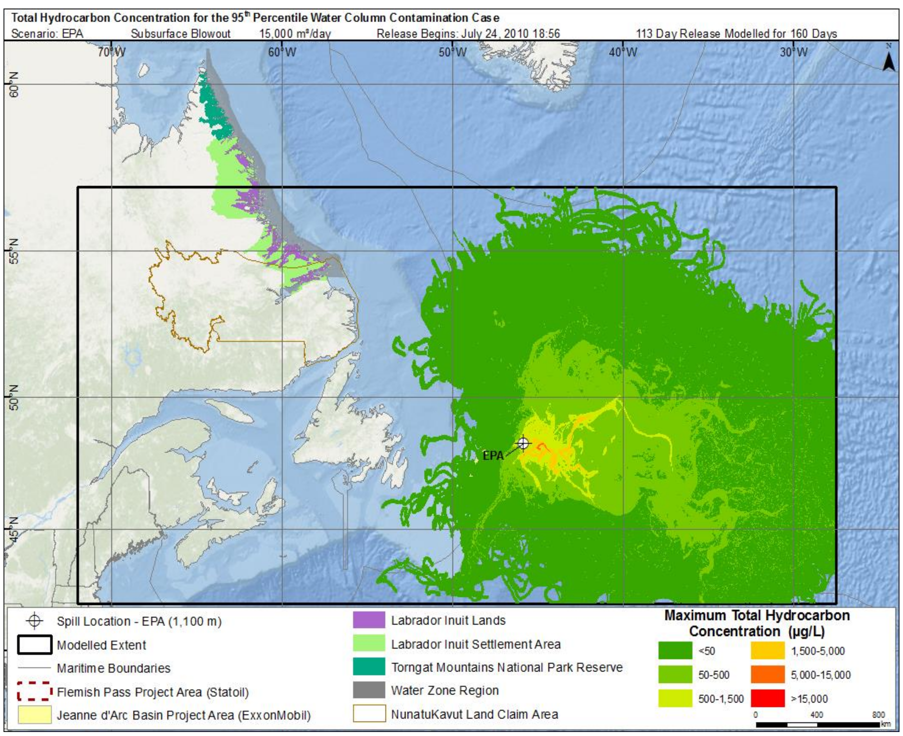


Figure 23. Maximum total hydrocarbon concentration (THC) at any depth in the water column for the 95th percentile water column contamination case from a subsurface blowout.

5.3 Response Option Mitigation of a Subsea Blowout

The use of aerially-applied or subsea-injected dispersants will change the fate of the oil (see Section 6.2.1 for detailed information). Mitigated modelling was not performed for the identical location in the RSA where the unmitigated modelling was conducted (described in Section 5.2). However, three sources of information were consulted to assess the various response options for a subsea blowout in this Equinor Canada SIMA:

- Empirical data from the 2010 DWH blowout (water depth of 1600 m);
- An evaluation of SSDI modelling at varying depths (using the OSCAR model); and
- Mitigated modelling from a Comparative Risk Assessment (CRA) study (water depth of 1400 m), which used an integrated model to predict both environmental and worker health impacts from VOC exposure that might arise in various response scenarios (using the OILMAP/SIMAP model).

Each of these information sources is summarized below:

<u>DWH Blowout SSDI Use (Empirical Data)</u>

The only empirical information on dispersed oil concentrations resulting from SSDI operations is from the DWH spill. Due to potential conflicts with response operations and safety concerns, most of the subsea monitoring during DWH response was conducted outside of an exclusion zone of 1 km from the wellhead. Beyond the 1 km exclusion zone, a subsea dispersed oil plume usually existed but was typically narrow, trended away from the site in the direction of very slight subsea currents, and was bounded by depths of about 900-1200 m. Of the 2779 individual samples collected in that area only 33 samples had TPH concentration higher than 10 parts per billion (ppb) (Coelho et al., 2011; Lee et al., 2013).

Cross-section illustrations of the oil behaviour from a hypothetical subsea release are provided for an unmitigated release (Figure 24) and SSDI treated blowout (Figure 25). Estimated oil concentrations (reported as THC) in the vicinity of the spill are provided using measured concentrations reported from the 2010 DWH spill (NOAA, 2012; Coelho et al., 2011).

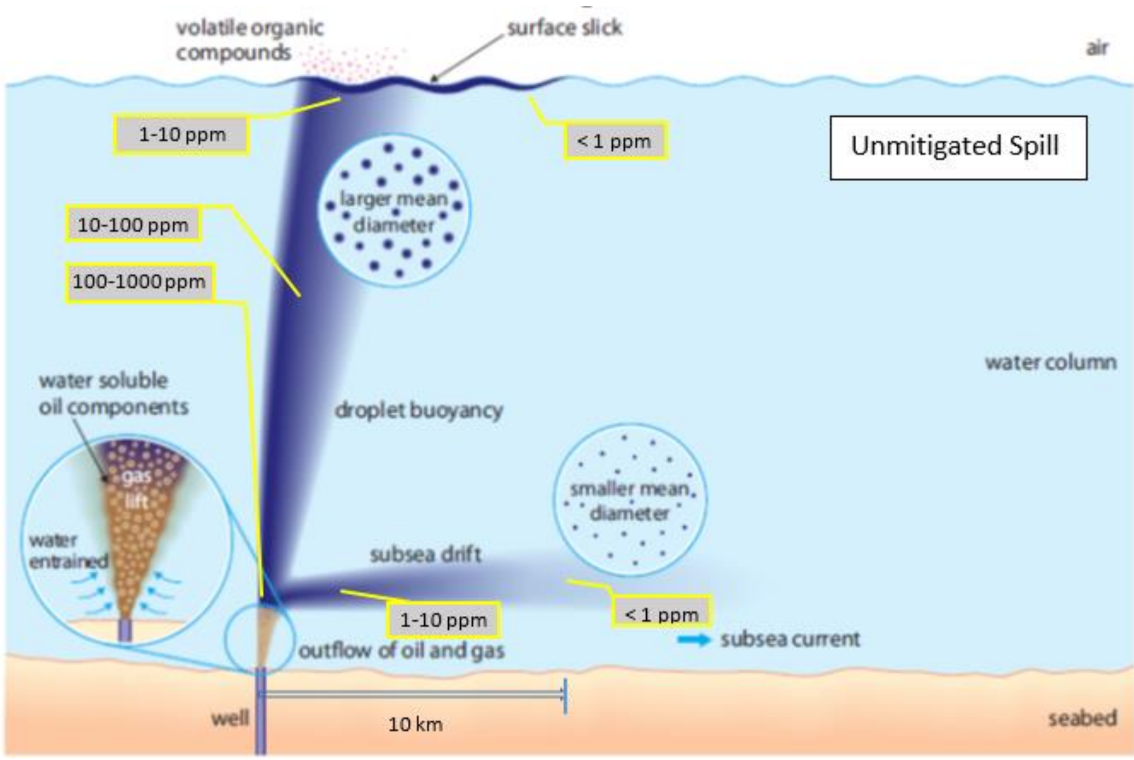


Figure 24 Cross-Section of an Unmitigated Blowout, with Estimated Oil Concentrations.
Note: the vertical scale has been exaggerated for illustrative purposes (Adapted from IPIECA, 2015a).

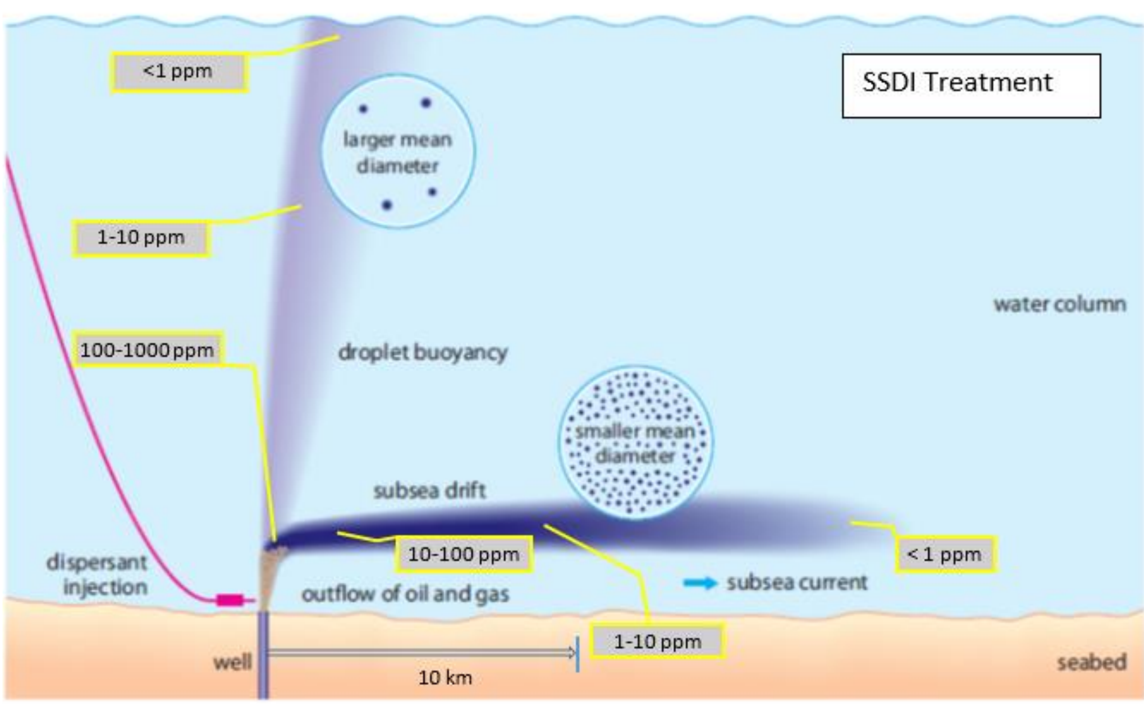


Figure 25 Cross-section of a SSDI-Treated Blowout, indicating estimated oil concentrations.
Note: the vertical scale has been exaggerated for illustrative purposes (Adapted from IPIECA, 2015a)

Evaluation of SSDI Modelling at Varying Depths (using OSCAR model)

In 2017, a study was undertaken to examine SSDI at varying sea depths and under several sets of wind conditions. The purpose of the study was to evaluate the resulting effects of wave action on surfaced oil that had previously undergone SSDI treatment at the sea floor (Daae et al., 2017, 2018). The OSCAR model was used to simulate a subsea release of 2-days, then continued to track the oil for a total of 10-days to examine oil fate. None of the modelling simulations with SSDI completely prevented the formation of surface slicks. However, the following conclusions were reached:

- SSDI did result in thinner slicks (compared to no treatment);
- Thinner slicks are more susceptible to natural dispersion from surface waves and therefore persist for considerably less time on the water surface;
- Thinner clicks did not emulsify in wind speeds of 10 m/s and therefore will not likely form tar balls;
- SSDI caused the surfacing oil slick to shift in location (roughly 1 km further away), which may offer a significant advantage for Source Control worker health and safety.

CRA-Study SSDI Results (using OILMAP/SIMAP model)

Another modelling study was recently undertaken to identify an oil response strategy that would minimize ecological risks, reduce exposures to VOCs (worker and surface-dwelling wildlife) and minimize socioeconomic disturbances for various combinations of mitigation measures (i.e., response options) that could be employed as part of a subsea blowout spill response (French McCay et al., 2018; Bock et al., 2018). The study, known as a Comparative Risk Assessment (CRA), sought to compare the consequences of various response options to a deepwater blowout spill. This study involved both fate and effects models, making it different from normal trajectory modelling that only consider the movement of the oil. In the CRA study, the following conclusions were reached:

- SSDI appeared to be ‘at least as effective’ at reducing impacts on species of concern, when compared to all other response options combined (surface dispersants, ISB and mechanical recovery);
- Surface species benefited most from the use of SSDI, while species at depth only saw a slight increase in exposure;
- SSDI was less effective at a 500 m depth compared to a 1,400 m depth, and modelling suggests that at some depth shallower than 500 m, SSDI benefits will become negligible; and
- SSDI reduces peak VOCs by a factor of 100- to 200-fold depending on winds (Crowley et al, 2018).

6 Risk-Based Assessment of Response Options

6.1 Potential Effects for Natural Attenuation

The Flemish Pass EIS describes the risks of mortality, injury or habitat quality for resources resulting from an unmitigated subsea blowout oil spill. The potential exposure pathways, toxicity and effects of an unmitigated spill to each resource is briefly summarized in the following paragraphs. More detailed information is provided in the Flemish Pass EIS "Accidental Events" section (Statoil, 2017, Section 15) and associated RPS report "Trajectory Modelling in Support of the Statoil Exploration Drilling Project" (Statoil, 2017, Appendix E).

Marine Fish and Fish Habitat

Risks for fish and fish habitats (i.e., seagrasses, wetlands, and other spawning or nursing grounds) exposed to an oil spill may include: reduction of water and/or sediment quality; reduction of primary productivity (phytoplankton and zooplankton) due to lower air-water gas exchanges and light penetration; disruption in food web dynamics; and lethal and sub-lethal effects from acute or chronic exposure to water-soluble fractions of hydrocarbons.

Greater concentrations of total hydrocarbons in spilled oil in the surface mixed layer following a subsea blowout could result in higher mortalities and sub-lethal effects on fish eggs, larvae and juveniles. If dissolved hydrocarbons are transported towards inshore waters, residual effects on fish may extend to lethal and sub-lethal effects on eggs, larvae and juveniles of demersal species and other fish species including those in spawning and nursing areas. However, as indicated in the Flemish Pass EIS (Statoil, 2017), adult free-swimming fish metabolize hydrocarbons rapidly through a process known as depuration, thereby reducing long-term injury from oil spills.

In the event of a blowout scenario, there would likely be a temporary decline in the abundance of phytoplankton in the immediate area of the spill. Zooplankton communities may be able to avoid exposure, depending on the species and life-history stage. In the event the spill encompasses areas where fish eggs or larvae are located, lethal and sub-lethal effects could occur. Sedentary species, such as edible seaweeds and shellfish, are particularly sensitive to oiling (ITOPF, 2011).

Marine Mammals and Sea Turtles

Risks to marine mammals exposed to surface oil could occur through three main exposure pathways: external coatings of oil (e.g., interaction with surface slicks when animals surface for air and clogging of baleen plates), inhalation of aerosols of particulate oil and hydrocarbons, and ingestion of contaminated prey (Lee et al., 2015). The extent of the potential effects depends on how the spill trajectory and marine mammals overlap spatially and temporally.

Direct contact with surface oil could cause fouling in fur-bearing marine mammals, such as seals, reducing thermoregulation abilities (Kooyman et al., 1977). However, hypothermia may be offset somewhat by thick layers of blubber (Lee et al., 2015). Most marine mammals could withstand some physical oiling without toxic or hypothermic effects. Whales and seals use blubber to maintain core body temperature, which is not affected by a covering of oil. Hypothermia is possible, such as if a young seal pup is covered in oil, because it takes several months to build up a blubber layer sufficient to maintain body heat.

Most scientists agree that cetaceans could be susceptible to respiratory distress or disease associated with inhalation of VOCs or aerosolized oil droplets when breathing in or adjacent to a fresh floating oil slick (NASEM, 2019). Exposure of this type could result in inflammation of airways, tissue damage within the respiratory system, long-term lung disease or pneumonia (Schwacke et al., 2013; Takeshita et al., 2017).

Very little is known about the impacts of exposure to low concentrations of dispersed oil in the water column on marine mammals. The majority of literature on the topic focuses on direct pathways, such as inhalation, ingestion and dermal exposure to study acute and potential long-term health effects on marine mammals (Helm et al., 2015), with less or no emphasis on potential water column effects.

Exposure pathways for effects on sea turtles are similar to those of marine mammals: external coatings of oil (e.g., interaction with surface slicks when animals surface for air), inhalation of aerosols of particulate oil and hydrocarbons, and ingestion of contaminated prey.

It is unknown if sea turtles can detect oil spills, but evidence suggests that they do not avoid oil at sea (Milton et al., 2010). Gramentz (1988) reported that sea turtles did not avoid oil at sea, and sea turtles experimentally exposed to oil showed a limited ability to avoid oil (Vargo et al., 1986) or petroleum fumes (Milton et al., 2010).

Similar to marine mammals, the extent of the potential effects of a subsea well blowout depends on how the spill trajectory and sea turtles overlap spatially and temporally. There are few studies about the effects of oil exposure on sea turtles, and mortality thresholds are often based on studies about other species (such as marine mammals or sea birds) that may have different life stage exposure and sensitivities. For this SIMA, a 10 µm thick layer of oil on water is used as the threshold concentration for potentially lethal effects to sea turtles, similar to the threshold used for marine mammals (refer to RPS Report: Statoil, 2017, Appendix E, Table 2.2).

Marine and Migratory Birds

Aquatic migratory birds are among the most vulnerable and visible species to be affected by oil spills. Risk of adverse effects to birds exposed to oil can occur through three main pathways: external exposure to oil (resulting in coating of oil on feathers); inhalation of particulate oil and volatile hydrocarbons; and ingestion of oil through preening or oiled prey.

Exposure to hydrocarbons frequently leads to hypothermia and deaths of affected marine birds. Although some may survive these immediate effects, long-term physiological changes may eventually result in lower reproductive rates or premature death. Oil is degraded by natural weathering processes (Payne et al., 1991), but it is not clear how this influences the oil's toxicity to seabirds (see Leighton 1985, 1986, 1993; Stubblefield et al., 1995a, b).

In 1995, the effect of naturally weathered *Exxon Valdez* crude oil was assessed on mallard ducks (Anas platyrhynchos), with deleterious effects noted only at the highest concentrations. This indicated that weathered oil was substantially less toxic to mallard ducks and their developing embryos than unweathered oil (Stubblefield et al., 1995). Sub-lethal effects of hydrocarbons ingested by marine birds may affect their reproductive rates or survival rates (Fingas, 2015). Sub-lethal effects may persist for years, depending upon generation times of affected species and the persistence of any spilled hydrocarbons.

Adult marine birds foraging offshore to provision their young may become oiled and bring hydrocarbons on their plumage back to the nest to contaminate their eggs or nestlings, causing embryo or nestling mortality. The survival rate for oiled birds often depends on the extent of oiling. The survival rate for heavily oiled birds is low (French-McCay, 2009).

The probability of lethal effects to birds is therefore primarily dependent on the probability of exposure, which is influenced by behaviour, including the percentage of time an animal spends on the water or shoreline as well as any oil avoidance behaviour (French-McCay, 2009).

Corals and Sponges

Corals are sensitive to oil and are typically assessed by visual indicators of stress (White et al., 2012). In addition, other invisible, long-term, sublethal impacts to corals could be associated with exposure to hydrocarbons, for example, reproductive, swimming and settlement behaviours (Fisher et al., 2014). In general, corals are slow growing and have long life spans, which make them susceptible to oil spill events because of their long recovery. In addition, coral and sponges' sessile adult and planktonic larval stages have no avoidance mechanisms to spill events. During DWH, many coral species 13 km from the wellhead were covered in brown flocculent, however, after 16 months, the corals showed signs of recovery (Fisher et al., 2014).

There is one noteworthy research effort that has assessed the impacts of shallow-water dispersant use on corals. The research study, known as TROPICS, was initiated in Panama in 1983 to compare the effects from untreated oil versus surface dispersant treated oil (Baca et al., 2014). The relative health of several subtidal plots has been evaluated over 30+ years, with the most recent evaluation occurring in 2015 (Renegar et al., 2017). Results over three decades indicate that the dispersant-treated plot has recovered to pre-spill conditions, and that exposure to dispersed oil (in this particular marine and intertidal community) was less disruptive compared to untreated oil.

Indigenous, Commercial and Commercial Communal Fisheries

Effects on fisheries resources can vary depending on the spill location, seasonal timing, and how much oil reaches the fisheries resource. Additionally, changes can arise from other factors (e.g., natural fluctuations in species densities, variation in fishing effort, climatic effects, or contamination from other sources) making it difficult to assess implications of an oil spill itself (ITOPF, 2011).

In the event of an oil spill in the RSA, surface slicks or subsea oil plumes could affect the availability of fishery resources and access to fisheries locations. The oil could also cause fouling of fishing or cultivation gear. Hydrocarbons from the oil could reach active offshore fishing areas where socio-economic, commercial and communal commercial fishing occur. In addition, oil could reach coastal locations, potentially interacting with nearshore fisheries and aquaculture operations.

Blowout oil spill scenarios could have an adverse environmental effect on cultural and subsistence fisheries and species that have a cultural significance to Indigenous groups. In particular, an accidental event could impact the fisheries and/or fishing activity (displacement from fishing areas, gear loss or damage). In the event of a spill, there could be effects on active nearshore or offshore activities, and/or species of cultural importance that could be migrating through or otherwise using the affected area. An effect on species fished for traditional (e.g., harvesting of fish for food, social or ceremonial purposes) or commercial (e.g. moderate livelihood fisheries) purposes, a change in habitat traditionally fished by Indigenous peoples, and/or area closures could disrupt traditional and commercial use of marine waters and resources.

Responder Safety

The NASEM (2019) review of dispersant use in the marine environment stated:

> *"If a response tool, such as dispersants, shortens the intensity and duration of response activities, and proper health and safety measures are in place, exposure risk would be lower, particularly for responders. This factor merits inclusion as part of the trade-off considerations with regard to decisions on dispersant use" (p. 10).*

This NASEM (2019) report also emphasized that any trade-off decision between response options should consider the addition or reduction of manpower requirements and associated safety concerns. Both shoreline and on-water mechanical recover are extremely labor-intensive response options. Reviews of past oil spills reveal that adverse health effects are almost always reported from response workers. For example, a study from the 2002 *Prestige* oil spill (in which dispersants were not used) reported increased headaches, sore throats and other airway injuries from response workers (Zock et al., 2012, 2014).

6.2 Risks Associated with Dispersants and Dispersed Oil Exposure

6.2.1 Overview of Dispersants and Dispersed Oil

This section provides introductory information on dispersants and dispersed oil to aid the reader with information provided in the following sections of the report. The reader is referred to the NASEM (2019) book for a comprehensive review on all topics related to dispersants and dispersed oil use in the marine environment. This publication contains individual chapters on fate and transport, aquatic toxicology and biological effects, human health considerations, tools for decision-making, comparing response options, research and decision-making protocols. NASEM (2019) is the third in a series of consensus studies on dispersants (prior NRC books on dispersants published in 1989 and 2005).

The use of dispersants (whether applied at the surface or subsea) will change the fate of the oil. For surface dispersant operations, past studies and spills have indicated that dispersed oil concentrations will range from 10-50 ppm for the first hour after dispersants are applied in the top few metres (m) of the water column. In the next few hours, rapid horizontal and vertical mixing will quickly reduce those concentrations to below 10 ppm, as evidenced from the Deepwater Horizon (DWH) spill (OSAT, 2010) and from past open ocean field trials conducted in the North Sea in 1994 (AEA Technology, 1994), in 1995 (AEA Technology, 1995; Jones & Petch, 1995), and in 1996 (Strøm-Kristiansen et al., 1997; Coelho et al., 1998).

The only empirical data on dispersed oil concentrations resulting from subsea dispersant injection (SSDI) operations is from the DWH oil spill. Due to potential conflicts with response operations and safety concerns, most of the subsea monitoring during DWH response was conducted outside of an exclusion zone of 1 km from the wellhead. Beyond the 1 km exclusion zone, a subsea dispersed oil plume usually existed but was typically narrow, trended away from the site in the direction of very slight subsea currents, and was bounded by depths of about 1100-1300 m. Within that plume dispersed oil concentrations were typically very low - in the 100 ppb to several ppm range (NOAA, 2012; IPIECA IOGP, 2015a).

In Section 5.3, cross-section illustrations of the oil behaviour from a hypothetical subsea release are provided for an unmitigated release (Figure 24) and SSDI treated blowout (Figure 25). Estimated oil concentrations in the vicinity of the spill are provided using measured concentrations reported from the 2010 DWH oil spill (NOAA, 2012; Coelho et al., 2011). Once the oil reaches the surface, the surface trajectory modelling report depicts visual images of the surface slick expression.

6.2.2 Toxicity

The toxicity of dispersants maintained within the Global Dispersant Stockpile (GDS) is considerably less than the toxicity of the crude oil itself. The GDS currently stocks three dispersants – Dasic Slickgone NS, Finasol OSR 52, and Corexit EC9500A (OSRL, 2017). In Canada, only C9500A/B is currently approved, and there is an extensive dataset on the toxicity of this commercial product to a variety of species. It is important to note that dispersant-only studies are frequently conducted in laboratory settings for the purposes of screening one dispersant against another, or to meet regulatory product listing requirements, but are not particularly relevant to real world spill exposure conditions. Regardless, laboratory tests have consistently shown that EC9500A is considerably less toxic than oil (Fingas et al., 1995; Environmental Protection Area [EPA] Office of Research and Development, 2010). Since the exposure concentrations associated with dispersant use are low due to the low application rates needed to disperse the oil, the additional toxicity risk from dispersants alone is also low.

This SIMA assumes that dispersants are properly targeted and applied to concentrated areas of oil, resulting in a chemically dispersed plume of oil. As such, we have limited our discussion of toxicity to *dispersed oil*, since there is no reason to expect that a dispersant-only condition would exist during an actual response. For this reason, the decision to use dispersants would be based on the assessment of the risks posed by *dispersed oil*, compared to the risk of not dispersing the oil. Dispersed oil exposures in the water are the predominant exposure pathways for environmental considerations. Dispersed oil is much less “sticky” than untreated oil, and therefore does not easily adhere to sediments. There is conflicting scientific data on the effect dispersants may have on transport processes known as marine oil snow sedimentation and flocculent accumulation. Some research studies indicate that dispersants inhibit the formation of marine snow due to increased buoyance of dispersed oil droplets (Passow, 2016), whereas other studies suggest it might accelerate the deposition process. This is an area of active debate among scientists, and the reader is directed to an extensive discussion of this topic in the latest NASEM report (2019; Ch. 2). The following section focuses on effects in the water column.

The toxicity of dispersed oil in the water column is related to four factors (NASEM, 2019, Ch. 3 Aquatic Toxicity):

- Exposure **concentrations** exceeding toxicity thresholds;
- **Duration** of exposure above a toxic threshold;
- **Distribution** of potentially affected resources (spatially and temporally); and
- Toxicological **sensitivity** of the exposed species.

The toxicity of oil is determined by its chemical makeup. Certain compounds, such as benzene, toluene, ethylbenzene and xylenes (known as BTEX), are acutely toxic, however they are also highly volatile and tend to evaporate rapidly. Other individual oil compounds are partially soluble and released more slowly into the water column. These compounds are known collectively as the “water accommodated fraction”. Dispersants can increase the dissolution of BTEX into the water column, thereby preventing evaporation of VOCs that pose a risk to response workers. Conversely, these soluble components will instead dissolve into the deep water column, in the case of SSDI, where fresh oil is being treated with dispersants at the sea floor. A review of hydrocarbon measurements taken in the vicinity of DWH Source Control (during SSDI operations) indicates measured BTEX concentrations up to 200 ppb were recorded in deep sea dispersed oil plumes at approximately 1200 m depth at 1 km, but rapidly diluted to non-detectable levels at distances beyond 10 km from Source Control (Coelho et al., 2011, Appendix G: Hydrocarbon Analytical Results). The potential aquatic impacts of these soluble concentrations to exposed deep sea organisms is poorly understood, but the field data confirms that concentrations rapidly dilute within a few kilometers of the SSDI operation.

Fate and transport models predict similar results for simulated blowouts (Gros et al., 2017; French-McCay et al., 2017, 2018).While the overall toxicity of dispersed oil is determined primarily by the toxicity of the oil (not the dispersant), dispersants serve to make the oil more bioavailable to organisms in the water column due to the increased dissolution of the soluble components, as well as the formation of small stable oil droplets that include polycyclic aromatic hydrocarbons (PAHs) and alkylated homologues. There is a wide range of sensitivity among species and at different life stages of the same species, so it is important to identify the species living in the area to be treated with dispersants, and their life stages (e.g., eggs, larvae, juveniles, and adults), to ensure decisions are based on local environmental conditions. For most aquatic organisms, the 96-hour LC50 (concentration that causes mortality in 50% of test organisms within 96 hours) for dispersed oil is on the order of 20-50 ppm TPH. Larval and embryonic life stages for some organisms can be much more sensitive, and may exhibit sub-lethal effects, such as delayed or abnormal development, at concentrations as low as a 1-5 ppm TPH (NRC 1989, 2003, 2005).

The concentrations of dispersed oil in the water column, following surface application under typical conditions, may approach 30-50 ppm TPH in the upper 10 m of the water column, however those concentrations rapidly dilute to below 10 ppm within the first hour and to less than 1 ppm within a few hours (Lee et al., 2013). Thus, for surface dispersant application, exposures to organisms are relatively short-lived and only occur in the upper few metres of the water column. Figure 26 summarizes sensitivity thresholds for chemically dispersed oil from standard laboratory toxicity tests and demonstrates how some wildlife species are more sensitive, and others less sensitive, resulting in an enormous range of mortality thresholds that vary by species.

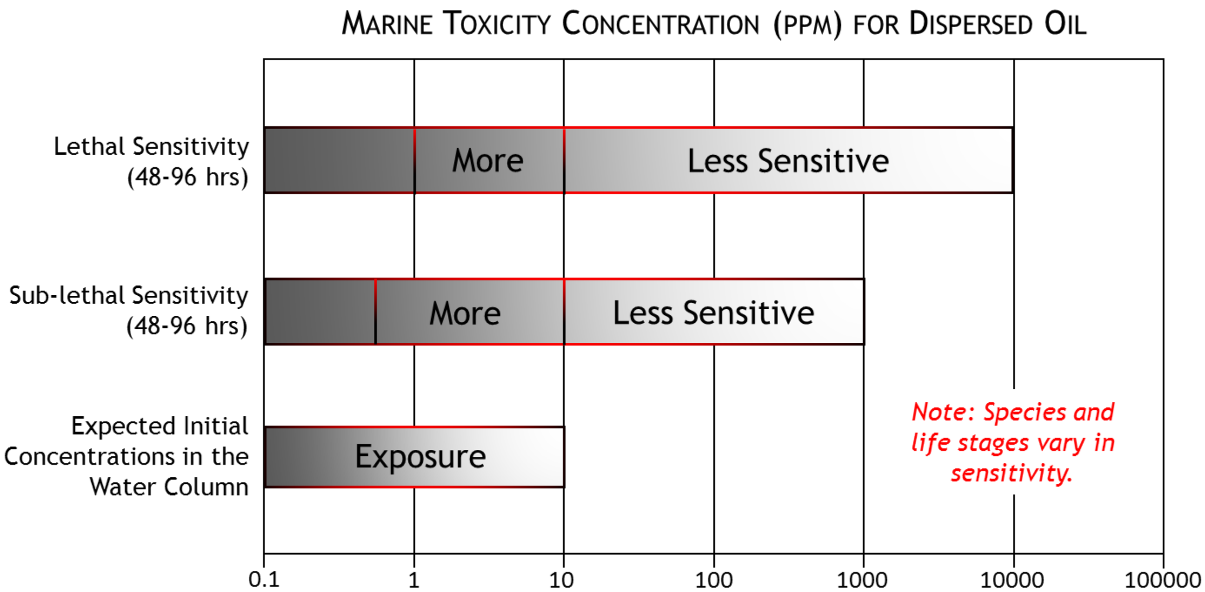


Figure 26 Sensitivity thresholds to dispersed oil concentrations.
(Developed from data reviewed in NRC, 1989; NRC, 2003; and NRC, 2005)

In 2014, research was initiated under an API Joint Industry Task Force to examine the toxic effects of dispersed oil to deep sea organisms, since past research has focused primarily on shallow water organisms. While testing is still underway, a presentation by Naile (2016) suggests that the sablefish – a deep sea species – may have similar exposure thresholds to more commonly tested shallow water species. The Species Sensitivity Distribution presented in Figure 27, indicates the LC50 for the sablefish compared to other species exposed to Alaska North Slope crude oil that was dispersed with EC9500A. These new findings provide some insight into how the scientific community can apply existing data on shallow water species to deep water environments.

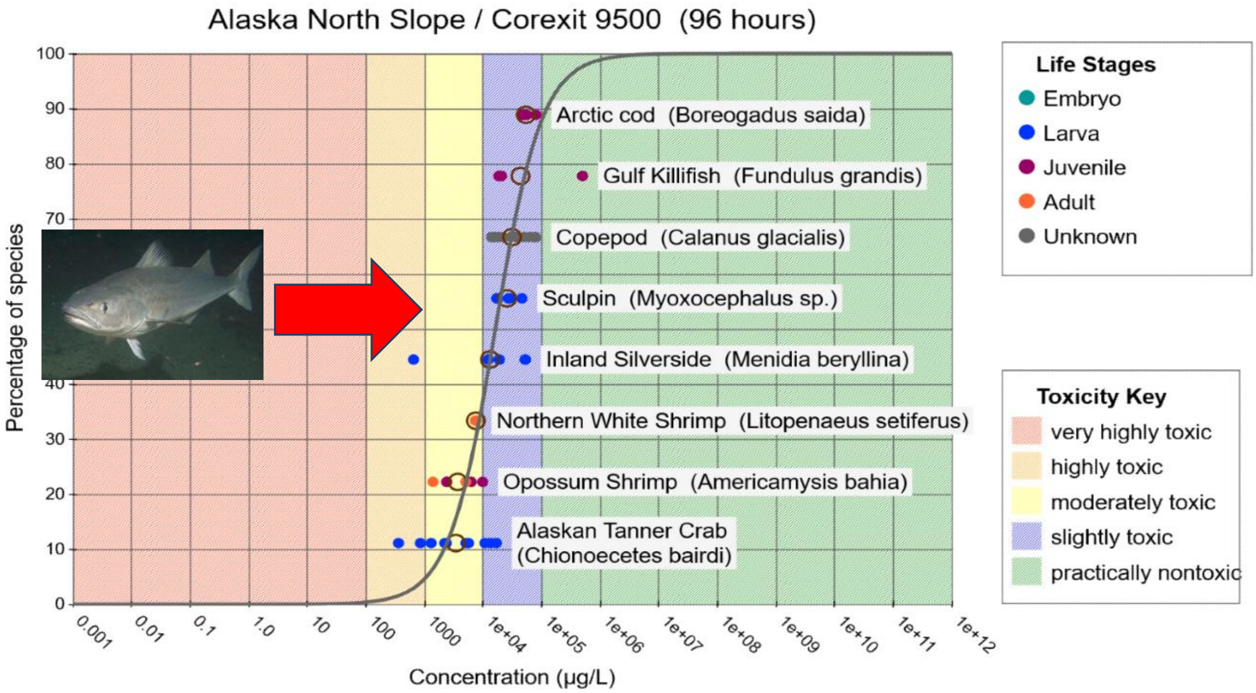


Figure 27 Species sensitivity distribution comparing a deep sea species (sablefish) to other organisms LC50s when exposed to ANS dispersed oil.
(Naile, 2016)

The 2019 NASEM (2019) report provides a comprehensive state-of-the science on the aquatic toxicology and biological effects of dispersed oil, resulting in a more robust discussion on the role of dispersants, the principles of chemical dispersion, and the factors that affect dispersant effectiveness. In addition, a recent publication summarizes information on the sensitivity on Arctic species to physically and chemically dispersed oil (Bejarano et al., 2017).

6.2.3 Other Biological Considerations

Another source of potential contamination of shoreline, bottom sediments, and benthic-dwelling organisms is through the physical transport oil and chemically dispersed oil, however, potential impacts of the benthic communities depend on wave action, currents, sediment type and benthic communities (Passow et al. 2012). In addition, Conover (1971), and more recently Lee et al. (2012), describe how the benthos could accumulate oil via organic (e.g., plankton, fecal pellets, detritus) and inorganic (e.g., minerals) particles, transporting oil from surface waters onto the bottom sediments. The effects of this vertical transport process of oil through the water column (often described as “marine snow”, among others) is expected to be relatively low; therefore, transfer of chemically dispersed oil to the benthos by fecal pellets would be the most likely mechanism, if it occurs at all. Some research studies indicate that dispersants inhibit the formation of marine snow due to increased buoyance of dispersed oil droplets (Passow, 2016).

NASEM (2019) recognized that, "in general, there is less known about the biota at depth, making it more challenging to assess potential impacts of response options such as dispersant use." NASEM (2019, pg. 46) continued the discussion of marine snow in the following paragraph:

> Brakstad et al. (2018) recently completed a comprehensive review of literature related to marine snow studies following the DWH oil spill, with a focus on the use of oil spill dispersants and the formation, fate and transport (i.e. sedimentation) oil-related marine snow (ORMS). They concluded that contribution of dispersant or any treatment to the formation of ORMs during the DWH spill could not be determined from the results of existing laboratory studies as experiments were only performed at high oil concentrations that did not take into account rapid dilution within the open sea. In summary, studies are still required to determine ORMS processes at oil concentrations under environmentally realistic conditions where dispersed oil plumes are expected to rapidly dilute to low concentrations below 1 ppm (Lee et al., 2013; Prince et al., 2016).

Separate from toxicity and marine snow, and specific to birds, laboratory studies have found that dispersants and chemically dispersed oil altered the feather structure of common murre causing waterproofing disruptions similar to that of undispersed oil, and a subsequent loss of buoyancy at high concentrations (Duerr et al., 2011; Whitmer et al., 2018).

6.2.4 Biodegradation

Specific effects to deep water micro-organisms from SSDI are still a debated topic in ongoing research. As is often the case during an oil spill response, scientists do not have the benefit of adequate control populations to quantify biological effects from oil spills, dispersant use and the resulting dispersed oil concentrations. The one apparent exception to this has been the real-time study of bacterial populations during the DWH incident, as well as ongoing laboratory-based studies that have examined the effects of dispersed oil and high-pressure on deep water species. Since one of the key justifications for dispersant use is to promote biodegradation of oil “at sea” before the floating oil reaches sensitive shoreline habitats, it is critical that decision-makers understand biodegradation.

Biodegradation of Oil

Biodegradation is the process wherein living microorganisms (bacteria, yeasts, molds, and filamentous fungi) alter and/or metabolize complex hydrocarbon compounds into simpler products, and in so doing obtain energy and nutrients. It is a natural process that actively removes organic matter such as oil from the environment. Biodegradation is the ultimate fate for oil released from natural oil seeps and for non-recovered oil following unintentional releases. Many different communities of microorganisms work together to degrade the wide range of hydrocarbon compounds found in oil.

Oil biodegradation is dependent on both biotic (microbial growth and enzymatic activity) and abiotic factors (i.e., water temperature, water salinity, wind and wave energy, oxygen and nutrient levels) as well as the quantity and quality of the hydrocarbon mixture and the properties of the affected ecosystem. Hydrocarbon degradation potential can be ranked from easily-biodegraded to more slowly processed chemical classes as follows:

linear alkanes > branched alkanes > small aromatics > cyclic alkanes

Some compounds, such as the very high molecular weight PAHs, may degrade very slowly, if at all, depending on the local populations of microbes.

Most oil biodegradation occurs via aerobic respiration. Oil-degrading microorganisms take up oxygen and metabolize hydrocarbons for energy. Under anaerobic (absence of oxygen) conditions, some microbes can degrade oil, but at a much slower rate. Some essential nutrients such as nitrogen and phosphorus are also needed to support microbial growth during the biodegradation processes. The end-products of a complete aerobic biodegradation of many oil components are carbon dioxide and water.

The rate of biodegradation is also dependent upon the composition and the quantity of oil available to the microbes. Biodegradation rates are related to the molecular weight and the structure of the oil, with the lower molecular weight fractions being utilized first by microbes due to their bioavailability. Light crude oils (oils with a low density, low viscosity, low specific gravity and high API gravity derived from a larger proportion of low molecular weight hydrocarbon fractions) are readily biodegraded. Heavy crude (oils with a high density, high viscosity, high specific gravity and a low API gravity) biodegrade more slowly, as it takes longer for microbes to process the higher proportion of high molecular weight hydrocarbons that make up these types of crude oils. Similarly, refined oil products show a range in biodegradation rates, with lighter fuels such as diesel biodegrading at faster rates than lubricating oils that contain large, long-chained paraffinic molecules.

The biodegradation process begins on the oil components that are left in the environment after evaporative losses. In the case of a subsea oil blowout, biodegradation begins almost immediately as rising and entrained oil droplets in the intrusion zone (typically at 1000-1300 m) are colonized by deep water microbial communities (Figure 28).

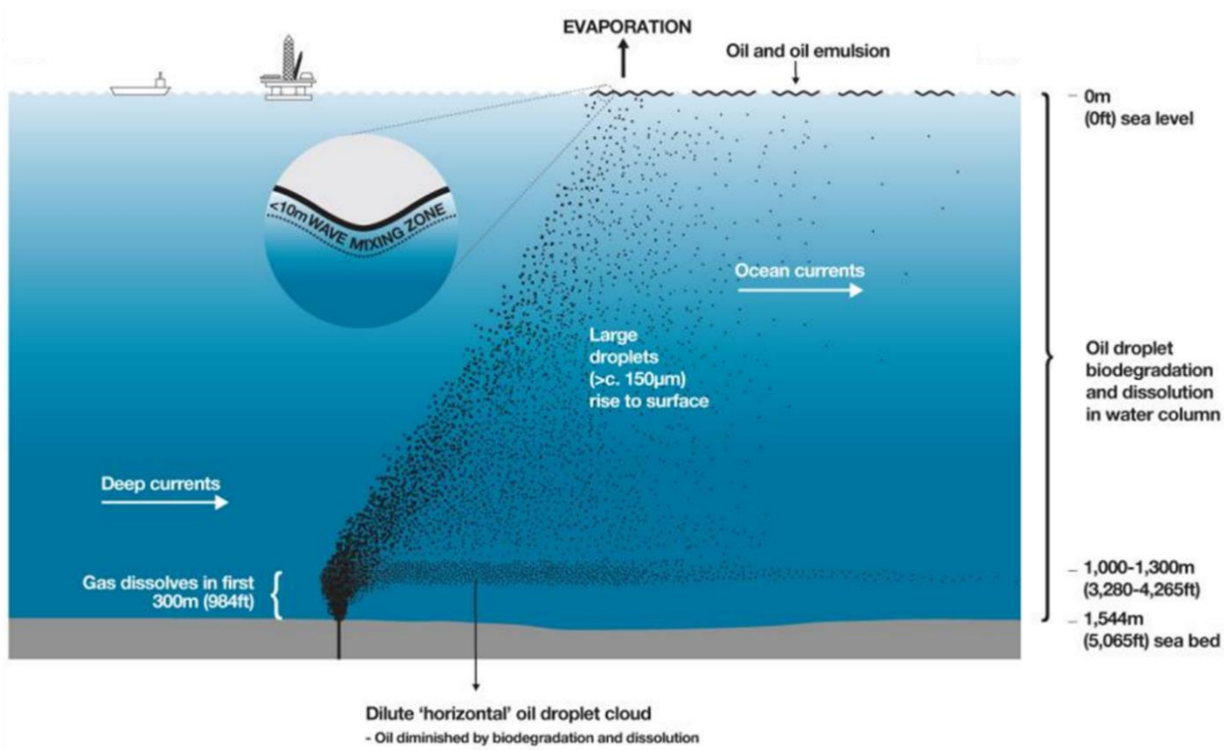


Figure 28 Schematic of oil transport in deep water sea floor blowout.
(Adapted from IPIECA, 2015a)

Within a few days following an oil spill, the population of oil-degrading microorganisms will increase in number, with the population's higher metabolic demands supported by the presence of readily degradable hydrocarbons. This is a natural process by which hydrocarbons are transformed into less harmful compounds through the metabolic or enzymatic activity of microorganisms that gain energy as well as carbon from this process. Petroleum hydrocarbons may be degraded to carbon dioxide, water and cellular biomass or degraded to smaller products that can undergo successive degradations until the compound is fully mineralized (Kissin, 1987; Mango, 1997).

Unless conducted as part of a routine water sampling analysis, it is difficult to determine the exact microbial community make-up prior to an oil spill. There are several types of marine bacteria that carry out similar functions, and the numbers of these groups may change, but the overall function of the microbial community remains relatively constant. Different genera of oil degrading bacteria may be present in different depths in the water column, and at different temperatures (Garneau, 2016; McFarlin et al., 2014; McFarlin et al., 2018), but all have the capability to degrade at least some constituents of crude oil rapidly (within a half-life of days) when the oil is dispersed as small droplets (Roy, 2012). Studies conducted by both Hazen et al. (2010) and Valentine et al. (2011) following the DWH oil spill documented the dynamic changes in the microbial communities in the water column following the subsea blowout. Although the characteristics of the community changed as oil residues peaked and decreased during the incident, monitoring after the well was capped showed population trends moving back to the expected pre-spill quantities and composition.

Effect of Dispersants on Biodegradation

Effectively applied dispersants have the potential to increase the rate and extent of biodegradation by moving a relatively thick and extensive oil slick into the water column as micro-sized (<300 µm) oil droplets. This change and movement essentially create more oil surface area on which microbial communities may colonize. This also reduces the tendency of oil to form tar balls or mousse and enables the retention of dispersed oil droplets in the water column instead of risking the potential for untreated oil slicks to strand on shorelines or become entrained in the sediment where degradation rates are commonly much slower.

A laboratory flume study by Brakstad et al. (2014) in Norway assessed degradation rates of physically and chemically dispersed Macondo oil. This study demonstrated the use of Corexit 9500A resulted in smaller median droplet sizes, compared to untreated oil. These smaller droplets were more amenable to biodegradation and as a result, the droplets were more rapidly depleted from the environment. Within the first hour, accelerated n-alkane degradation was apparent in the chemically dispersed oil in the lighter alkanes (below approximately nC-24) and within one day, the degradation of the n-alkanes (up to and beyond nC-30) was nearly complete in chemically versus physically dispersed oil as depicted in Figure 29 (Brakstad et al., 2014).

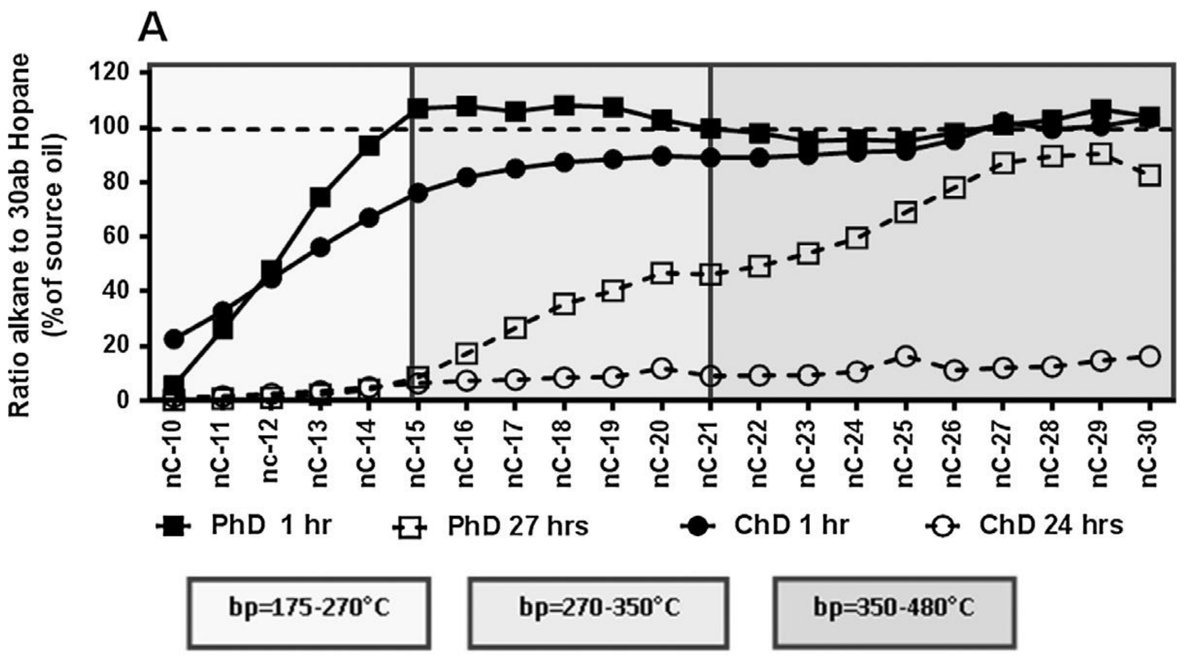


Figure 29 Biodegradation rates of physically dispersed versus chemically dispersed Macondo Oil based on laboratory plume studies conducted by SINTEF.
(Brakstad et al., 2014)

One biodegradation study focused specifically on crude oil, with and without dispersants, at environmentally relevant concentrations in indigenous arctic waters. Researchers concluded that biodegradation was stimulated by dispersants, especially in the first few weeks (McFarlin et al., 2014). In a different study of the effects of temperature and Corexit 9500A on biodegradation rates, Techtmann (2017) found that the presence of dispersant resulted in slight increases in biodegradation rates at temperatures of 5°C and 25°C. Some changes were observed in microbial community structures at 25°C, but none were noted at 5°C.

In a mesocosm study conducted in a wave tank in Canada, researchers found that indigenous bacteria from Halifax harbor showed a large increase in oil degrading phyla 24 hours after treatment with dispersant, but observed little change for untreated oil (Yergeau, et al., 2014). Researchers concluded that dispersant improved the availability of oil to hydrocarbon degrading microbes in this study. A follow-on field study conducted by some of the same research team members concluded that the addition of dispersant to crude oil enhanced oil degradation rates in open ocean surface waters (Tremblay et al., 2017). This field study examined surface waters from Nova Scotia, so the findings are especially relevant to microbial degradation that one might expect to observe in the waters of Eastern Canada. More recent modelling work by French-McCay et al. (2017, 2018) concluded that SSDI substantially increased dissolution and degradation rates of soluble hydrocarbons (such as BTEX) thereby reducing VOC emissions at the waters' surface; reducing the amount of oil and emulsified oil on the waters' surface; and reducing the overall footprint of floating oil.

Global Implications of Biodegradation

While it was once believed that biodegradation was only a relevant process for the relatively warm, nutrient rich waters of subtropical and tropical areas, Hazen (2016) reported that oil degrading bacteria occur in virtually all of the world oceans. Liu (2017) found rapid changes in indigenous bacterial communities in the Mediterranean deep sea when exposed to simulated oil spills. Both the community structures, and the biodegradation rates observed were similar to those observed during DWH. Campeao (2017) found that some deep sea microbial communities from the Amazonian margin deep sea water are capable of degrading oil within 48 hrs. Other studies conducted in the North Atlantic Sea, and the Arctic Sea have produced similar findings.

In summary, several studies have validated the findings of research that was conducted during DWH on the impacts of dispersed crude oil on populations and community structures of oil degrading microbes and have confirmed that some constituents of crude oil can be degraded rapidly regardless of depth and temperature. The presence of dispersant may affect the community structure of oil degrading microbes at some depths and temperatures, but degradation remains rapid for at least some crude oil components. Oil degrading bacteria community structures vary by depth and temperature and are present in all waters surveyed.

It is also noteworthy that microbial population blooms of oil degraders do not pose a risk to humans, wildlife, or fish. Experimental studies in bioremediation strategies that have been carried out in laboratory, mesocosm, and various field tests have not identified pathogen blooms as an environmental risk.

6.3 Risk Assessment Process

IPIECA-API-IOGP developed a new methodology for studying risk in oil spill response that helps improve challenges experienced in scoring and in acquiring stakeholder concurrence in past risk assessments (IPIECA-API-IOGP, 2017). This newer risk method uses a single comparative matrix instead of the more typical square risk reporting matrix used previously, which required dual-scoring and was therefore more difficult to adapt ‘real-time’ during a response. The SIMA method incorporates four elements: 1) Potential Relative Impact Assessment; 2) Impact Modification Factor; 3) Relative Impact Mitigation Score using mean compartment impact scores, and 4) Total Impact Mitigation Score. These elements provide a method to score the response options for each resource category. The overall score is a qualitative prediction of how each response option might mitigate the overall impacts to the resources of concern when compared to natural attenuation (aka no intervention).

For this SIMA, the resources of concern described in Section 4 are consolidated into shoreline, shelf and slope habitats since these areas support many of the same or similar species throughout different life cycles or seasons. This consolidation allows for a more manageable risk assessment, which is particularly important if the final Comparative Risk Matrices (Table 16 or Table 17) need to be quickly revised for a future spill exercise or actual response.

The resource categories include:

- Shoreline - fish (egg/larvae), invertebrates, mammals, birds
- Surface - fish (egg/larvae), marine mammals, sea turtles, seabirds
- Water Column – fish (egg/larvae), invertebrates, marine mammal, sea turtles, diving seabirds
- Benthos – fish, invertebrates, corals and sponges
- Socio-economic – commercial and communal commercial fisheries
- Cultural and Subsistence – Indigenous (traditional use/Aboriginal) fisheries

The emphasis on this SIMA is to develop a 'process'. The above categories include species at risk and special areas. During an oil spill, actual slick surveillance would identify which species at risk and/or special areas might be affected, and local resource experts would be consulted as the risk matrix is being adapted to real-time conditions (e.g., on that day, in that location). Justifications for the scoring, in consultation with appropriate stakeholders, would explain which areas might serve as "drivers" in the decision-making process, based on the specific resources threatened by advancing oil or dispersed oil. Furthermore, the SIMA process may need to be revised multiple times during a spill, as different seasonal resources, such as migratory birds, enter the response area.

Following are the steps for the single comparative matrix process to assess the impacts of oil spill response options described in Section 3 against the RSA resource categories. More detailed information on the SIMA guidelines is provided in IPIECA-API-IOGP (2017).

1. Potential Relative Impact Assessment

Each resource category is assessed a potential relative impact as either none, low, medium or high, and each assessment corresponds to a numerical weight, numerical relative impact (e.g., none = 1; low = 2; medium = 3; and high = 4). The weight attributed to each resource value is unique and tailored to the specific SIMA.

The basic principle of assigning a potential relative impact, or weight, requires estimating the proportion of the resource affected, and how long it will take to recover. It also considers the spatial scale for each individual resource category being considered. Resources are defined as either “local” or “regional” depending on their distribution, population characteristics and recovery pattern. For this SIMA, a Local (L) spatial scale is applied to invertebrates, corals and sponges, fish eggs/larvae and vegetation; whereas the remaining categories are assessed on a Regional (R) level.

To do this, key factors about the drilling project area, such as sensitive ecosystems, critical habitats, protected species and other valued components (e.g., indigenous fisheries) identified in the Flemish Pass EIS (2017), as they relate to potential impacts from an oil spill, are taken into consideration. This assessment is based on potential impacts to the resource if natural attenuation of the oil spill occurs. Table 11 shows the potential relative impact assessment developed for this Equinor Canada SIMA. Section 2 (Stage 2 – Predict Outcomes) and the IPIECA Guidelines (2017, Appendix 1) provide guidelines to assessing relative impact.

Table 11 Potential Relative Impact Assessment.

Resource Categories		Spatial Scale[a]	Natural Attenuation: Potential relative impact	Natural Attenuation: Numerical relative impact
Shoreline	*Fish (eggs/larvae)*			
	Invertebrates			
	Mammals			
	Birds			
	Shoreline Compartment Average			
Surface	*Fish (eggs/larvae)*			
	Marine Mammals/Sea Turtles			
	Seabirds			
	Surface Compartment Average			
Water Column	*Fish (eggs/larvae)*			
	Invertebrates			
	Marine Mammals/Sea Turtles			
	Seabirds (diving)			
	Water Column Compartment Average			
Benthos	*Fish (eggs/larvae)*			
	Invertebrates			
	Corals and Sponges			
	Benthos Compartment Average			
Socio-economic	*Commercial Fisheries*			
	Commercial Communal Fisheries			
	Socio-economic Compartment Average			
Cultural and Subsistence	*Indigenous Fisheries*			
Safety	*Responder*			

[a] Local (L); Regional (R)

2. Impact Modification Factor

As each feasible response option is evaluated, it is assigned an impact modification factor, as shown in Table 12, to indicate the level of impact a given response could affect a resource category when compared to natural attenuation. For purposes of this assessment, all options are assumed to be feasible (although that may not be the case at the actual time of a response).

For this SIMA, the impact modification factors are assigned for each response option – on-water mechanical recovery, ISB, surface and SSDI and shoreline protection – based on a qualitative review of published information and professional judgement for each of the ecological, socio-economic, safety and cultural and subsistence resources when compared to natural attenuation The basic principle of assigning an impact modification factor requires estimating the proportion of the resource affected, and how long it would take to recover. Section 2 (Stage 3 – Balance Trade-offs) and the IPIECA Guidelines (2017, Appendix 2) provide guidelines to assigning impact modification factors.

Table 12 Impact Modification Factor.

Impact Modification Factor	Description
+4	Major mitigation of impact
+3	Moderate mitigation of impact
+2	Minor mitigation of impact
+1	Negligible mitigation of impact
0	No alteration of impact
-1	Negligible additional impact
-2	Minor additional impact
-3	Moderate additional impact
-4	Major additional impact

3. Relative Impact Mitigation Scores

For each resource category, the Numerical Relative Impact value (Table 11) is multiplied by the associated Impact Modification Factor (Table 12) to create a relative impact mitigation score for a response option (Table 13). The score for each resource and response option combination represents the relative change that the response option would have on the impact. By using a qualitative ranking of impacts, a numerical value can be generated.

In summary, the SIMA relative impact mitigation score is generated by assessing response options and resource categories using four possible numerical impact values (1, 2, 3 and 4) and nine impact modification factors (+4 to -4), resulting in 36 possible scoring possibilities per resource.

Table 13 Relative Impact Mitigation scores.

			Natural Attenuation		Response Option	
			Potential relative impact	Numerical relative impact	Impact modification factors	**Relative impact mitigation score**
Resource Categories		**Spatial Scale**[a]		*A*	B_1	AxB_1
Shoreline	*Fish (eggs/larvae)*					
	Invertebrates					
	Mammals					
	Birds					
	Shoreline Compartment Average					
Surface	*Fish (eggs/larvae)*					
	Marine Mammals/Sea Turtles					
	Seabirds					
	Surface Compartment Average					
Water Column	*Fish (eggs/larvae)*					
	Invertebrates					
	Marine Mammals/Sea Turtles					
	Seabirds (diving)					
	Water Column Compartment Average					
Benthos	*Fish (eggs/larvae)*					
	Invertebrates					
	Corals and Sponges					
	Benthos Compartment Average					
Socio-economic	*Commercial Fisheries*					
	Commercial Communal Fisheries					
	Socio-economic Compartment Average					
Cultural and Subsistence	*Indigenous Fisheries*					
Safety	*Responder*					

[a] Local (L); Regional (R)

Within environmental compartments with multiple resources, a mean score is calculated. This step allows resource categories such as “Surface”, which contains three resources (e.g., fish, marine mammals/sea turtles and seabirds) to be compared without bias to categories such as “Safety”, which contains only one environmental compartment.

To provide a visual reference for the relative impact mitigation score, each cell is coded with a colour based on a range of equal interval scores. Table 14 displays the colour code as a scale from red to green indicating major increase in impact to major impact mitigation.

Table 14 Range of scores colour coding.

Impact Modification Factor	Description	Relative Impact Score Range	Color Code
+4	Major mitigation of impact	+13 to +16	
+3	Moderate mitigation of impact	+9 to +12	
+2	Minor mitigation of impact	+5 to +8	
+1	Negligible mitigation of impact	+1 to +4	
0	No alteration of impact	0	
-1	Negligible additional impact	-4 to -1	
-2	Minor additional impact	-8 to -5	
-3	Moderate additional impact	-12 to -9	
-4	Major additional impact	-16 to -13	

4. Total Impact Mitigation Scores

The Total Impact Mitigation scores, located at the bottom of the table, are the totals of the mean environmental compartment scores for each response option (Table 15). This overall score is a qualitative prediction of how each response option might mitigate the overall impacts of an oil spill, when compared to natural attenuation for a specific scenario. Section 2 (Stage 4 – Select Best Response Options) and the IPIECA Guidelines (2017, Appendix 3) provide guidelines on using the finalized comparative risk matrix.

The total mitigation scores are generated for each of the feasible response options.

Table 15 Total Impact Mitigation scores.

Resource Categories		Spatial Scale[a]	Response Options: Natural Attenuation		Shoreline Protection		On-water Mechanical		In Situ Burning		Surface Dispersants		Subsea Dispersants	
			Potential relative impact	Numerical relative impact	Impact modification factor	**Relative impact mitigation score**	Impact modification factors	**Relative impact mitigation score**	Impact modification factor	**Relative impact mitigation score**	Impact modification factor	**Relative impact mitigation score**	Impact modification factor	**Relative impact mitigation score**
				A	B_5	AxB_5	B_1	AxB_1	B_2	AxB_2	B_3	AxB_3	B_4	AxB_4
Shoreline	*Fish (eggs/larvae)*													
	Invertebrates													
	Mammals													
	Birds													
	Shoreline Compartment Average													
Surface	*Fish (eggs/larvae)*													
	Marine Mammals/Sea Turtles													
	Seabirds													
	Surface Compartment Average													
Water Column	*Fish (eggs/larvae)*													
	Invertebrates													
	Marine Mammals/Sea Turtles													
	Seabirds (diving)													
	Water Column Compartment Average													
Benthos	*Fish (eggs/larvae)*													
	Invertebrates													
	Corals and Sponges													
	Benthos Compartment Average													
Socio-economic	*Commercial Fisheries*													
	Commercial Communal Fisheries													
	Socio-economic Compartment Average													
Cultural and Subsistence	*Indigenous Fisheries*													
Safety (Air)	*Responder*													
[a] Local (L); Regional (R)		**Total Impact Mit. Score**												
		Ranking												

6.4 Risk Assessment Results

A single comparative risk matrix for the response options was generated for both a summer (June through August), and a winter (December through February) subsea blowout scenario, taking into consideration the ROC identified in Table 7 for the RSA. The subsea blowout scenario was used because it posed some of the greatest challenges from an emergency response perspective, and sensitive, threatened or endangered species were predicted to be relatively more abundant in the study area during the summer season.

The SIMA methodology used here was based on making comparisons of the impact mitigation potentials for varying response methods, to the relative risks that result from taking no response actions (natural attenuation). Thus, the first step in the process was to assign relative risks and corresponding numerical scores (numerical relative impact) for natural attenuation of oil for each resource category. Values of 1, 2, 3, or 4 were assigned to risk levels of none, low, medium, and high respectively. In addition, each resource category was assigned a spatial scale designator of Local (L) or Regional (R). For purposes of this SIMA, a “Local” impact was assumed to be one that was limited to the spill area, while a “Regional” impact could extend beyond the boundaries of the spill area.

Note that this SIMA did not score the “Shoreline” resource category, since the available spill trajectories for this Equinor Canada drilling location suggests <1% probability of oil reaching or stranding on shorelines for an unmitigated spill within the RSA. However, if oil is reaching the shoreline during an actual incident, it is assumed that all available shoreline protection strategies will be implemented.

6.4.1 Relative Risks of Natural Attenuation

Natural attenuation of oil poses a high risk (4) for the water surface, socio-economic, cultural and subsistence, and safety resource categories; a low risk (2) for the water column category and for coral and sponges within the benthos category; no risk (1) for the fish and invertebrates within the benthos category.

At the water surface, plankton, floating eggs, and larvae were deemed particularly sensitive. Seabirds, marine mammals, and sea turtles are highly susceptible to untreated floating oil, since oil can coat the fur of marine mammals and feathers of birds, resulting in hypothermia. In this summer scenario, without response intervention, a large footprint of surface oil will result from a subsea blowout (see Section 5.2). In the Socio-economic and Cultural and Subsistence categories, high (4) risk scores were assigned because of the likelihood of high levels of concern about impacts (real or perceived) to fishing. While significant exposures are not expected to occur to fish or invertebrates, it is likely that regulatory agencies would close fishing grounds, at least temporarily, until commercially harvested species could be tested and verified safe for consumption.

Left unmitigated, the amount of dissolved oil entering the water column and benthos were relatively small, so the risk scores were lower (2) or non-existent (1) for remaining resource categories. In the Benthos category, no exposure to oil is expected in the offshore environment, with the exception of a low risk of localized exposures to coral and sponge eggs and larvae that could drift into the vicinity of the wellhead during spawning periods.

6.4.2 Comparative Risk Matrix for Summer

Using the risk methodology explained in Section 6.3 and the impact modification factors and Colour Coding described in Tables 12 and 14, the comparative matrix for the summer scenario was developed, as shown in Table 16.

Table 16 Comparative Risk Matrix for Summer Season Blowout Scenario.

Equinor SIMA Summer Season			Natural Attenuation: Potential relative impact	Natural Attenuation: Numerical relative impact	Shoreline Protection: Impact modification factor	Shoreline Protection: Relative impact mitigation score	On-water Mechanical: Impact modification factors	On-water Mechanical: Relative impact mitigation score	In Situ Burning: Impact modification factor	In Situ Burning: Relative impact mitigation score	Surface Dispersants: Impact modification factor	Surface Dispersants: Relative impact mitigation score	Subsea Dispersants: Impact modification factor	Subsea Dispersants: Relative impact mitigation score
Resource Categories		Spatial Scale[a]		A	B_5	AxB_5	B_1	AxB_1	B_2	AxB_2	B_3	AxB_3	B_4	AxB_4
Shoreline	Fish (eggs/larvae)													
	Invertebrates													
	Mammals													
	Birds													
	Shoreline Compartment Average													
Surface	Fish (eggs/larvae)	L	High	4			+1	4	+1	4	+3	12	+4	16
	Marine Mammals/Sea Turtles	R	High	4			+2	8	+2	8	+3	12	+4	16
	Seabirds	R	High	4			+1	4	+1	4	+3	12	+4	16
	Surface Compartment Average							5		5		12		16
Water Column	Fish (eggs/larvae)	R	Low	2			+1	2	+1	2	-3	-6	-4	-8
	Invertebrates	R	Low	2			+1	2	+1	2	-3	-6	-4	-8
	Marine Mammals/Sea Turtles	R	Low	2			+1	2	+1	2	-2	-4	-3	-6
	Seabirds (diving)	R	Low	2			+1	2	+1	2	-2	-4	0	0
	Water Column Compartment Average							2		2		-5		-6
Benthos	Fish (eggs/larvae)	R	None	1			0	0	0	0	0	0	0	0
	Invertebrates	L	None	1			0	0	0	0	0	0	0	0
	Corals and Sponges	L	Low	2			0	0	0	0	0	0	-3	-6
	Benthos Compartment Average							0		0		0		-2
Socio-economic	Commercial Fisheries	R	High	4			+1	4	+1	4	+3	12	+3	12
	Commercial Communal Fisheries	R	High	4			+1	4	+1	4	+3	12	+3	12
	Socio-economic Compartment Average							4		4		12		12
Cultural and Subsistence	Indigenous Fisheries	R	High	4			+1	4	+1	4	+3	12	+3	12
Safety (Air)	Responder	L	High	4			+1	4	+1	4	+3	12	+4	16
[a] Local (L); Regional (R)		Total Impact Mit. Score						19		19		43		49
		Ranking						3rd Tie		3rd Tie		2nd		1st

The following sections describe how each response option was assigned an impact modification factor for the summer scenario comparative risk matrix (Table 16) to indicate the level of impact a given response could affect a resource category compared to natural attenuation.

6.4.2.1 Relative Risk of On-Water Mechanical Recovery

The On-Water Mechanical response method is described in Section 3.3. On-water mechanical recovery is the only response method that physically and permanently removes oil from the environment, making it a preferred option when it can be effectively deployed. For the scenario evaluated here, however, relatively high wave heights, long distances from shore (>200 nm), and low oil encounter rates reduce the efficiency of this method. During the DWH oil spill, in which response conditions were optimal, on-water mechanical recovery was estimated to remove only 3% of the oil from the water surface (Federal Interagency Solutions Group, 2010). For purposes of this evaluation, <10% was used as the assumed oil recovery rate due to weather conditions (e.g., fog and wave heights approaching 2 m in summer).

The greatest mitigation impact for on-water mechanical recovery would occur at the water surface. A minor modification factor (+2) was assigned to marine mammals and sea turtles, which are more regionally distributed and could also potentially benefit from even small, skimmed non-oiled surface areas through which they could surface to breathe. A negligible impact modification factor (+1) was assigned for fish eggs/larvae near the surface with no mobility and seabirds in the vicinity. Since small quantities of oil would be removed from the water surface, a negligible reduction of naturally dispersed oil in the water column would be expected, so a negligible impact modification factor (+1) was assigned to all water column organisms. A negligible modification factor (+1) was also assigned for the Socio-economic and Cultural and Subsistence categories since a reduction in the size of surface oil slicks, albeit negligible should result in a slightly shorter closure of fishing areas. Similarly, a negligible modification factor (+1) was also assigned to the Safety category because slight surface slick reduction will result in slight reduction in VOCs. Finally, there would be no alteration of impact to the Benthos category.

6.4.2.2 Relative Risk of In-Situ Burning

Weather conditions that are conducive to ISB are very unlikely to occur in the study area during the summer or winter seasons. Wave heights must be less than 1 m for the deployment of fire boom, and mean wave heights in the RSA exceed that height even during the summer period. The methodology and limitations for ISB are discussed in Section 3.4. In the event ISB can be conducted, large amounts of oil can be removed from the surface relatively quickly. For that reason, this response method was evaluated.

Before oil can be burned, it must first be concentrated by using fire boom pulled by vessels, as in mechanical on-water recovery. The primary difference in the methods is that instead of using skimmers to remove collected oil, the oil is ignited and burned. Since there is no need to separate collected oil from water fractions and store it for later disposal, ISB can proceed at a faster rate than on-water mechanical recovery.

In this assessment, the superior efficiency of ISB was deemed to be offset by the extremely low probability that it could be utilized. For reference, during DWH, sea states were typically below 1 m and ISB was estimated to remove 5% of the oil from the water surface (Federal Interagency Solutions Group, 2010). Higher sea states in the RSA would suggest a lower recovery rate for ISB. For purposes of this evaluation, 3% was used as the assumed oil recovery rate. As a result, the risk mitigation scoring was found to be the same as on-water mechanical recovery (see Section 6.4.2.1).

6.4.2.3 Relative Risk of Surface Dispersants

The Surface Dispersants response method is described in Section 3.5. For the surface dispersant response method, all application methods (aircraft, vessels, and platforms) were assumed to be viable. Vessel and platform-based spraying would probably be conducted close to the oil release point, where workers may be involved in well containment activities. It was assumed that up to four C-130 or 727 aircraft could make four sorties per day during the summer period. For this release scenario, operations should ideally occur within the 0.5 - 4 day window of opportunity for treatment of fresh surface slicks. As with the previously discussed response methods, this method can only be conducted during daylight hours. Past modelling studies suggest that surface dispersant application in offshore environments (for a subsea blowout) can reduce 15% of the overall surface slick (see Section 5; French-McCay et al., 2018; Bock et al., 2018; NASEM, 2019).

Due to the high oil encounter rate, large amounts of oil could be treated and dispersed into the water column, so the modification factor assigned to the Surface category was moderate (+3). For example, surface dispersant use decreases surface oil, which mitigates marine birds oil exposures on the surface. The rapid reduction of the thickness and extent of surface slicks should result in less impacted seabirds; therefore, a moderate mitigation impact score was assigned. This decrease in surface oil also applied to species at risk and special areas.

In the water column, oil would be expected to disperse to a depth of around 10 m, so higher oil exposures could occur to fish eggs and larvae, invertebrates (e.g. jelly fish and squid) vertical migrating fish, and epipelagic fish at that depth. However, the majority of fish and invertebrate species in the RSA spawn in a variety of large areas, over long time scales, and no single spill event would encompass all of these areas or time scales to such a degree that natural recruitment of juvenile organisms may not re-establish the population(s) to their original level. As a result, a moderate impact score of (-3) was assigned to fish and invertebrates in the Water Column category. The negative impact score for fish and water column invertebrates is more significant than for the diving seabirds, marine mammals and sea turtles because fish are more likely to be exposed through respiration and invertebrates by ingestion of small droplets, as opposed to dermal exposures alone. Diving seabirds, mammals, and sea turtles were assigned a minor impact score of (-2), since exposures would likely be below conservative lethal and sublethal levels for these mobile marine organisms.

Socio-economic and Cultural and Subsistence categories (i.e., fisheries) should benefit from surface dispersant application since oil will be removed from the surface, and dispersed oil should be limited to the upper 10 m. Although some initial toxicity could occur in the upper 10 m, dispersed oil is expected to dilute rapidly so any negative impact should be short lived. Fish below a depth of 10 m should be relatively unaffected. The rapid reduction of the thickness and extent of surface slicks should result in more rapid lifting of fishery closure areas. A moderate modification score of (+3) was assigned.

Dispersant spraying should have a moderate modification impact (+3) on the Safety category due to reduced airborne VOC concentrations for oil spill responders due to the removal of some surface oil. No exposure to the Benthos category should occur since oil that is dispersed by surface dispersant spraying should be limited to the upper 10 m of the water column.

6.4.2.4 Relative Risk of SSDI

SSDI differs from all other response methods considered in that it prevents oil from reaching the surface, rather than treating or removing it after it has surfaced. The description of the method and its limitations are described in Section 3.6. In general, this method has the highest encounter rate and potential for preventing the formation of surface slicks of any of the methods considered. For purposes of this assessment, the scoring process focused on the impact mitigation potential of a fully operational SSDI system. Past modelling studies suggest that SSDI in offshore environments (for a subsea blowout) can reduce 50% of the surface slick (see Section 5; French-McCay et al., 2018; Bock et al., 2018; NASEM, 2019).

Since SSDI should remove more oil from the surface than any other method, the impact modification factors were major (+4) for all the representative species in the Surface resource category. Since this response method is applied at the sea floor, considerably less oil reaches the surface, thereby reducing risks for marine mammals, sea turtles and seabirds.

The shift in the mass balance of oil from the surface to the deep water column, however, resulted in a concomitant increase in negative impacts to the Water Column category. Higher oil exposures could occur to invertebrates (e.g. jelly fish and squid) fish eggs and larvae, vertical migrating fish and epipelagic fish at that depth. As a result, a major impact score of (-4) was assigned to these species due primarily to potential impacts on their eggs, larvae, and sensitive life stages. However, as noted above, no single spill event would encompass such as significant area that natural recruitment of juvenile organisms may not re-establish the population(s) to their original level within one generation. In the water column category, mammals and sea turtles were assigned a moderate impact score of (-3), since exposures would likely be more, compared to natural attenuation for these mobile marine organisms. Since diving seabird dive depths are likely too shallow to encounter SSDI dispersed oil in the deep water column, they were assigned a score of 0. Note that the negative impact score for fish is more significant than for the diving seabirds, marine mammals and sea turtles because fish are more likely to be exposed through respiration, as opposed to dermal exposures alone.

As with surface dispersant application, a moderate mitigation (+3) is expected for the Socio-economic and Cultural and Subsistence categories (i.e., fisheries) because oil is prevented from surfacing, and biodegradation rates are accelerated, which could shorten the closure of fisheries areas. It is important to note the distinction between the increased water column impact on *fish* resulting from SSDI, versus the mitigation effects of SSDI on the *fisheries*, which is a socio-economic impact on the *fishers*. Therefore, while SSDI may increase short-term exposure (days to weeks) of dispersed oil to fish, the resulting decrease in surface oil could likely translate to reduced duration and/or extent of fishery closure areas.

When SSDI is used in depths greater than several hundred metres (1100 m in this scenario), a considerable reduction of the surface slick from SSDI, when compared to the unmitigated scenario, will result in a decrease of VOC emissions into the atmosphere. This will provide major mitigation of impact (+4) for Safety.

The Benthos category should be relatively unaffected since dispersed oil should remain in the water column, where it should biodegrade rapidly. A possible exception is corals and sponges which could be impacted by dispersed oil plumes in the immediately vicinity of the wellhead. The 2008 C-NLOPB EA Screening decision includes a requirement for pre-spud surveys to ensure a 100 m set back away from any coral colonies exceeding 30 cm in width or height. However, dispersed oil plumes could still potentially affect this benthic community at distances greater than 100 m from the wellhead. As such, a moderate impact score of (-3) was assigned.

6.4.2.5 Relative Risk of Shoreline Protection and Recovery

This response option was not considered for this scenario; however, it is listed here since this Equinor Canada SIMA serves as a template for this region, and Shoreline Protection and Recovery may be relevant for other spill scenarios considered by Equinor Canada in the future.

6.4.3 Comparative Risk Matrix for Winter

The comparative matrix for winter is shown in Table 17. The following paragraphs describe how each response option was scored using an impact modification factor from Table 12 to indicate the level of impact a given response could affect a resource category compared to natural attenuation.

In the winter scenario, daylight hours are shorter, winds are stronger, waves heights are greater, and surface oil slicks tend to be thinner and distributed over a slightly larger area, which result in somewhat increased natural dispersion of oil. Because of more adverse weather conditions, all response methods that relate to surface oil have lower encounter rates, on a daily basis, and are assumed less efficient than during the summer scenario. In addition, the potential for floating ice presents additional constraints to mechanical recovery and ISB during certain months. For resource categories that included endangered species during the summer scenario, it was assumed that those species could still be present in the winter scenario. Species composition for categories such as seabirds is known to change, but overall abundance was not assumed to change enough to modify potential relative impacts for the natural attenuation baseline condition.

The “on-water mechanical” response method is expected to have only minor impact mitigation potential due to poor encounter rates compared to more favorable conditions assumed for the summer scenario. Since overall efficiency would be even lower during the winter months, and threats to worker health and safety could be higher, this method was assumed to be impractical (in winter) and was not evaluated for the purposes of this assessment. However, on-water mechanical recovery would always be employed *if* conditions permit, regardless of season, as it is the preferred option to remove oil when the response option is feasible.

In-situ burning, which was likewise found to be relatively inefficient during the summer scenario since it depends on successful mechanical concentration and low wave heights. It is unlikely that winter sea states could support ISB operations. For the purposes of this assessment, ISB was assumed to be impractical (in winter) and was not evaluated.

The only response methods that were rated for the winter scenario were surface dispersant application and SSDI (Table 17).

Table 17 Comparative Risk Matrix for Winter Season Blowout Scenario.

Equinor SIMA Summer Season			Response Options											
			Natural Attenuation		Shoreline Protection		On-water Mechanical		In Situ Burning		Surface Dispersants		Subsea Dispersants	
			Potential relative impact	Numerical relative impact	Impact modification factor	Relative impact mitigation score	Impact modification factors	**Relative impact mitigation score**	Impact modification factor	**Relative impact mitigation score**	Impact modification factor	**Relative impact mitigation score**	Impact modification factor	**Relative impact mitigation score**
Resource Categories		**Spatial Scale**[a]		*A*	*B₅*	*AxB₅*	*B₁*	*AxB₁*	*B₂*	*AxB₂*	*B₃*	*AxB₃*	*B₄*	*AxB₄*
Shoreline	*Fish (eggs/larvae)*													
	Invertebrates													
	Mammals													
	Birds													
	Shoreline Compartment Average													
Surface	*Fish (eggs/larvae)*	*L*	*High*	*4*							+2	*8*	+3	*12*
	Marine Mammals/Sea Turtles	*R*	*High*	*4*							+2	*8*	+3	*12*
	Seabirds	*R*	*High*	*4*							+2	*8*	+3	*12*
	Surface Compartment Average											**8**		**12**
Water Column	*Fish (eggs/larvae)*	*R*	*Low*	*2*							-2	*-4*	-3	*-6*
	Invertebrates	*R*	*Low*	*2*							-1	*-2*	-2	*-4*
	Marine Mammals/Sea Turtles	*R*	*Low*	*2*							-1	*-2*	-2	*-4*
	Seabirds (diving)	*R*	*Low*	*2*							-2	*-4*	0	*0*
	Water Column Compartment Average											**-3**		**-4**
Benthos	*Fish (eggs/larvae)*	*R*	*None*	*1*							0	*0*	0	*0*
	Invertebrates	*L*	*None*	*1*							0	*0*	0	*0*
	Corals and Sponges	*L*	*Low*	*2*							0	*0*	-3	*-6*
	Benthos Compartment Average											**0**		**-2**
Socio-economic	*Commercial Fisheries*	*R*	*High*	*4*							+2	*8*	+2	*8*
	Commercial Communal Fisheries	*R*	*High*	*4*							+2	*8*	+2	*8*
	Socio-economic Compartment Average											**8**		**8**
Cultural and Subsistence	*Indigenous Fisheries*	*R*	*High*	*4*							+2	**8**	+2	**8**
Safety (Air)	*Responder*	*L*	*High*	*4*							+3	**12**	+4	**16**
[a] Local (L); Regional (R)		**Total Impact Mit. Score**										**33**		**39**
		Ranking										**2nd**		**1st**

6.4.3.1 Surface Dispersant Application

The primary limiting factors for use of surface dispersant application are hours of daylight and weather conditions favourable for flying. For the winter scenario, shorter days reduce useful daylight hours for dispersant aircraft operations. The thinning and spreading of oil slicks due to greater wind speeds and higher wave heights can reduce the efficiency of surface dispersant application; however, these winter conditions are not expected to cause enough of a difference to fate and behaviour of oil that would require a change in any of the overall ranking of the total Potential Relative Impact scores compared to summer.

In the summer scenario, it was assumed that four aircraft would be used, and that they would fly four sorties per day. During the winter scenario, four aircraft would probably still be used, but the shorter days would likely limit spraying opportunities to two sorties per day for the period of shortest daylight hours (i.e., December, January and February), and likely three sorties per day when daylight increases (i.e., Spring and Fall season).

The relative impact mitigation ratings remained essentially the same for the Resource Categories, but scores were generally one point less significant for all categories. Positive impact mitigation was assigned for Surface, Socio-economic, Cultural and Subsistence, and Safety categories, while negative impacts were assigned to the Water Column category. The two categories that were unchanged were Benthos (which were unaffected in both summer and winter scenarios) and Safety. For safety, it was assumed that the potential reduction in threats to worker safety still warranted a major mitigation score of (+3). It should be noted that VOC concentrations in the source control areas would probably also be somewhat reduced by the higher winds and lower temperatures expected during the winter scenario.

6.4.3.2 Subsea Dispersant Injection

SSDI operations that occur at the sea floor should be relatively unaffected by the daylight and weather changes. Surface support operations that are dependent on vessel operations, however, are affected by weather and wave conditions that may threaten the safety of surface operations. While surface vessels can maintain stationary position in high sea states by means of dynamic positioning systems, resupply of dispersants from shore-based stockpiles to the stationary SSDI surface support vessel could be hampered. For that reason, it was assumed that SSDI could have occasional delays during the highest sea states in winter and could therefore be somewhat less efficient compared to summer conditions.

Changes to impact mitigation scores changed in the same pattern that was observed for the surface dispersant spraying category. In general, all positive mitigation scores decreased slightly, with the exception of the Safety category, which remained at (+4) for protection of worker safety. Negative impact scores assigned to the Water Column category were reduced slightly due to assumed weather related reductions in the quantities of oil that would be dispersed into the deep water column.

As explained in Section 6.4.2.4 (summer scenario SSDI), the Benthos category should be relatively unaffected since dispersed oil should remain in the water column, where it should biodegrade rapidly. A possible exception is corals and sponges since, dispersed oil plumes could still potentially affect this benthic community at distances greater than 100 m from the wellhead. As such, a moderate impact score of (-3) was assigned.

7 Spill Impact Mitigation Assessment Summary

The assessment of impact mitigation potential for the response options presented in this Equinor Canada SIMA is based on assumptions regarding typical weather and environmental conditions in the RSA. It is not intended to recommend, or eliminate, a response option from consideration for any actual spill event. Instead, it is intended to provide a relative ranking of the potential for available response methods to mitigate impacts resulting from specified spill scenarios to selected environmental resource categories. As described in IPIECA-API-IOGP (2017), the SIMA provides a qualitative approach in the sense that the impact mitigation scores assigned for each response method represent an increase or decrease in risk relative to natural attenuation. During the final step of the risk assessment, impact mitigation scores are multiplied by the potential numerical impact for each resource category, and the scores are totalled for each response method. This result produces a dimensionless number that indicates the potential for reducing (mitigating) or increasing impact risk, relative to the baseline condition of natural attenuation (no intervention).

For this SIMA, Resources of Concern were identified for the RSA in Section 4, Table 7. Resources were identified using physical, biological and socio-economic data from the Flemish Pass EIS (Statoil, 2017). The identified resources were identified by taking into consideration ecological and socioeconomic concerns, including species at risk and special areas.

Section 5 briefly summarized the Oil Spill Trajectory Modeling report in the Equinor Canada EIS (Statoil, 2017, Appendix E) for a hypothetical oil spill scenario involving a subsea blowout in the NL offshore area in both summer and winter seasons. These scenarios were analyzed using the SIMA comparative risk matrix approach in Section 6. In both seasons, no shoreline oiling is expected to occur. Normally, the prevention of shoreline oiling to protect highly sensitive nearshore habitats is the highest priority for spill response decision-making. However, since no shoreline oiling occurred, the primary driver for this SIMA was protection of those resources that relied upon the open ocean water surface.

In general, winter conditions were considered substantially more operationally challenging than summer, but less oil is expected on the water surface due to higher rates of natural dispersion – primarily due to higher winter sea states. Prevailing weather conditions posed challenges for all response methods identified, particularly for those that relied on “at sea” vessel response operations. Winter conditions were more challenging than summer for all response methods.

The on-water recovery and ISB response methods were both dependent upon successful spill booming and oil collection, and neither was considered highly effective for the Tier 3 scenarios due to long transit times, low encounter rates, and wave height restrictions. However, on-water mechanical recovery would always be deployed when weather conditions permit, since removing oil from the environment is considered the preferred response option, when it can be performed effectively. When weather allows, ISB has the potential of removing more oil from the surface than on-water mechanical methods alone, but wave heights are often prohibitive during both summer and winter periods.

The surface dispersant application and SSDI response methods were less dependent on weather, particularly SSDI, and both methods can remove larger quantities of oil from the surface (compared to on-water mechanical recovery and ISB). A key distinction is that surface dispersant application is used *after* oil has reached the water surface, thereby increasing the potential for oil contact with species on the surface. SSDI, however, reduces the amount of oil from reaching the surface thereby reducing exposure risks to water surface resources, making it an important operation to commence prior to capping stack. Once started, SSDI should be able to operate almost continuously in both summer and winter conditions, although high storm sea states could potentially disrupt resupply of dispersants from shore to the SSDI staging area at source control. Surface dispersant use will likely result in some potential short-term exposures of fish, invertebrates, sea turtles, and aquatic mammals in the upper 10 m of the water column. In contrast, SSDI will increase dispersed oil concentrations in deeper regions of the water column. In both cases, dispersion of oil into very small droplets will result in accelerated microbial degradation of spilled oil compared to untreated the oil.

In Section 6.4, the potential relative impact of the spill on each resource category was assessed for effects from natural attenuation of the oil and a preliminary prediction was made about how each feasible response option modified the impact when compared to natural attenuation. The resulting summer comparative risk matrix (Table 16), was developed using this rating method, and the resulting relative impact mitigation scores show SSDI receiving the highest score (49), followed by surface dispersant use (43), on-water mechanical recovery (19), and in-situ burn (19). It is important to note that the scoring was based on hypothetical scenarios and past weather conditions, a specific area - the RSA, and, the assumption that all methods evaluated could be deployed as part of a unified spill response. This ranking should not be assumed to be applicable to all spill scenarios at all times of the year for this location. Species distribution can change rapidly during migration season, and local resource experts should always be consulted to identify which species are in the spill location during an actual event.

Unmitigated spills that occur during the winter season are less likely to result in high quantities of oil on the water surface and more likely to produce higher quantities of oil in the water column due to higher rates of natural dispersion. When considering response mitigation for both seasons, the use of dispersants (surface and SSDI) is expected to remove a substantial percentage of oil from the water surface, which can result in localized reductions of VOC exposures to spill response workers. Without mitigation (i.e., natural attenuation), there are potential environmental effects for Tier 3 scenarios for species at the water surface, and, in general, all response methods produced their highest impact mitigation scores in that resource category.

All the response methods evaluated in this SIMA were shown to have the ability to mitigate risks to some environmental resource categories. Not providing any intervention can result in negative public perception, since there is a public expectation that an attempt should be made to remove the spilled oil from the environment. For the scenarios evaluated in the SIMA, the most beneficial impacts occurred at the water surface. Both surface and subsea dispersant use were found to offer higher levels of impact mitigation than the other response methods considered. In an actual spill, it is likely that several (possibly all) response methods would be used in combination, at varying times and locations, depending on actual daily response conditions. Since implementation of SSDI requires additional deployment time, mechanical recovery and surface dispersant application should be implemented and continued until SSDI capability is available. No response method can remove all oil from the surface, so even with effective SSDI implementation, surface dispersant application in the source control area would likely continue to reduce VOC concentrations and mitigate threats to worker safety. In addition, continued on-water mechanical recovery and/or vessel and platform-based surface application are useful for targeting surface oil in areas where aircraft dispersant operations are restricted (e.g., aerial no-fly zones).

In conclusion, this SIMA is intended to lay the framework for a response option decision-making tool. The comparative risk matrices presented in Chapter 6 were developed based on assumed local protection priorities for the RSA and a hypothetical scenario. The ultimate utility of this SIMA framework is that either of these risk matrices (summer or winter) could be easily modified for an actual spill event to aid decision-makers in making real-time decisions on the selection of response methods that offer the best protection for local resource priorities. For this reason, the integration of resource and response subject matter experts into the SIMA process is critical for the SIMA to effectively inform contingency planning or actual spill response activities. The use of the SIMA *process* is intended to support, not replace, other aspects of the spill response decision-making process. The process is most effective when involving stakeholders as a mechanism to identify resources that are important, which then informs and provides clear direction to the response options decision-makers.

Trade-offs must be made once oil is released into the environment, and this SIMA process can assist Equinor Canada's Spill Management Team members make and document those decisions. This SIMA should be viewed as a *process*, not a product that promotes any given response option over another. An actual SIMA for a spill would be generated 'real-time' incorporating the review and advice from the Science Table members. The real-time SIMA is readily accomplished by modifying the summer or winter risk matrix presented in Tables 16 and 17 in Section 6.4 based on 'real-time' information (e.g., specifics of the incident, conditions at the time, and advice of the resource trustees). The SIMA process can help the team decide (and document) the best combination of response options that should be utilized to minimize ecological damages and promote the most rapid recovery of the ecosystem in that region.

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