SPILL IMPACT MITIGATION ASSESSMENT (SIMA) IN SUPPORT OF BP CANADA ENERGY GROUP ULC SCOTIAN BASIN EXPLORATION PROJECT

NOVA SCOTIA CANADA

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SPILL IMPACT MITIGATION ASSESSMENT
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PREPARED FOR BP CANADA ENERGY GROUP ULC BY:

SPONSON GROUP INC.
1301 EAST DEBBIE LANE
SUITE 102; BOX 102
MANSFIELD, TX 75054
WWW.SPONSON.NET

AUTHORS:

ANN G. SLAUGHTER, MS
GINA M. COELHO, PhD
JAMES STAVES, MS
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<th>Definition</th>
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<tr>
<td>ADDS</td>
<td>Airborne Dispersant Delivery System</td>
</tr>
<tr>
<td>API</td>
<td>American Petroleum Institute</td>
</tr>
<tr>
<td>ASD</td>
<td>Aerial Surface Dispersant</td>
</tr>
<tr>
<td>bbl</td>
<td>Barrels of oil</td>
</tr>
<tr>
<td>bpd</td>
<td>Barrels per day</td>
</tr>
<tr>
<td>BTEX</td>
<td>Benzene, Toluene, Ethylbenzene and Xylenes</td>
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<tr>
<td>CNSOPB</td>
<td>Canada-Nova Scotia Offshore Petroleum Board</td>
</tr>
<tr>
<td>COSEWIC</td>
<td>Committee on the Status of Endangered Wildlife in Canada</td>
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<tr>
<td>CRA</td>
<td>Comparative Risk Assessment</td>
</tr>
<tr>
<td>CS</td>
<td>Capping Stack</td>
</tr>
<tr>
<td>DOR</td>
<td>Dispersant to Oil Ratio</td>
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<tr>
<td>DWH</td>
<td>Deepwater Horizon</td>
</tr>
<tr>
<td>DFO</td>
<td>Fisheries and Oceans Canada (aka Department of Fisheries and Oceans)</td>
</tr>
<tr>
<td>EBSA</td>
<td>Ecologically and Biologically Significant Areas</td>
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<tr>
<td>ECRC</td>
<td>Eastern Canada Response Corporation</td>
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<tr>
<td>EEZ</td>
<td>Exclusive Economic Zone</td>
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<tr>
<td>EIS</td>
<td>Environmental Impact Statement</td>
</tr>
<tr>
<td>EL</td>
<td>Exploration Licenses</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>EU</td>
<td>Environmental Unit</td>
</tr>
<tr>
<td>FSC</td>
<td>Food, Social and Ceremonial</td>
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<tr>
<td>GDS</td>
<td>Global Dispersant Stockpile</td>
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<tr>
<td>ICS</td>
<td>Incident Command System</td>
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<tr>
<td>IOGP</td>
<td>International Oil and Gas Producers</td>
</tr>
<tr>
<td>IPIECA</td>
<td>International Petroleum Industry Environmental Conservation Association</td>
</tr>
<tr>
<td>ISB</td>
<td>In Situ Burn</td>
</tr>
<tr>
<td>km</td>
<td>Kilometre</td>
</tr>
<tr>
<td>km²</td>
<td>Cubic kilometre</td>
</tr>
<tr>
<td>LAA</td>
<td>Local Assessment Area</td>
</tr>
<tr>
<td>LC</td>
<td>Lethal Concentration</td>
</tr>
<tr>
<td>LFA</td>
<td>Lobster Fishing Area</td>
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<tr>
<td>m</td>
<td>Metre</td>
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<tr>
<td>MGS</td>
<td>Membertou Geomatics Solutions</td>
</tr>
<tr>
<td>MPA</td>
<td>Marine Protected Area</td>
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<tr>
<td>m³</td>
<td>Cubic metre</td>
</tr>
<tr>
<td>µm</td>
<td>Micrometre</td>
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<tr>
<td>NAFO</td>
<td>Northwest Atlantic Fisheries Organization</td>
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<tr>
<td>NCNS</td>
<td>Native Council of Nova Scotia</td>
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<tr>
<td>NEBA</td>
<td>Net Environmental Benefit Analysis</td>
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<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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<tr>
<td>NRC</td>
<td>National Research Council</td>
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<tr>
<td>PAH</td>
<td>Polycyclic Aromatic Hydrocarbon</td>
</tr>
<tr>
<td>OSAT</td>
<td>Operational Science Advisory Team</td>
</tr>
<tr>
<td>OSCAR</td>
<td>Oil Spill Contingency and Response</td>
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<tr>
<td>OSRL</td>
<td>Oil Spill Response Limited</td>
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<tr>
<td>ppb</td>
<td>Parts per billion</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Definition</td>
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<tr>
<td>PAH</td>
<td>Polycyclic Aromatic Hydrocarbon</td>
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<tr>
<td>ppm</td>
<td>parts per million</td>
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<tr>
<td>RAA</td>
<td>Regional Assessment Area</td>
</tr>
<tr>
<td>RRT</td>
<td>Regional Response Teams</td>
</tr>
<tr>
<td>ROV</td>
<td>Remotely Operated Vehicle</td>
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<tr>
<td>SARA</td>
<td>Species at Risk Act</td>
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<tr>
<td>SIMA</td>
<td>Spill Impact Mitigation Assessment</td>
</tr>
<tr>
<td>SMART</td>
<td>Special Monitoring of Applied Response Technologies</td>
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<tr>
<td>SSDI</td>
<td>Subsea Dispersant Injection</td>
</tr>
<tr>
<td>UINR</td>
<td>Unama’ki Institute of Natural Resources</td>
</tr>
<tr>
<td>USCG</td>
<td>United States Coast Guard</td>
</tr>
<tr>
<td>VOC</td>
<td>Volatile Organic Compound</td>
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<tr>
<td>VC</td>
<td>Valued Components</td>
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<tr>
<td>WAF</td>
<td>Water Accommodated Fraction</td>
</tr>
<tr>
<td>WCCD</td>
<td>Worst Cast Credible Discharge</td>
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PREFACE

Spill Impact Mitigation Assessment (SIMA) is a process that is intended to be used as a spill response decision support tool. This SIMA has been prepared for BP Canada Energy Group ULC as part of the contingency planning process for exploratory drilling in the Scotian Basin area. Specifically, it is being used to inform the development of the overall Oil Spill Response Plan and individual response option tactical plans. The guiding principle behind the selection of any response option, including the authority to permit the use of dispersants, 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 this SIMA is to guide planning and preparedness toward this objective, and to assist the relevant decision-makers to make the determination of net environmental benefit.

This document illustrates the use of the SIMA process to support contingency plan development for specified geographic areas, seasons, and spill scenarios. The SIMA is not a “stand alone” contingency plan, and is not intended to be applicable to all spill scenarios.

UNDERSTANDING THE PURPOSE OF THIS SIMA

This SIMA “is”:
- A tool to support the development of contingency plans for BP drilling in NS
- A framework for selecting response options
- Designed with a matrix that can be rapidly adapted for real 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 tactics
- An academic review of dispersed oil fate and effects
- An endorsement of any given response option

The use of the SIMA process is intended to support, not replace other aspects of the spill response decision-making process. The SIMA process is most effective when involving stakeholders as a mechanism to identify resources that are important to the stakeholders, while providing a clear direction for selecting response options. The risk matrix presented in Table 14 in Section 6.4 would be modified ‘real-time’ based on specifics of the incident, conditions at the time, and advice of the resource trustees to select 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. This SIMA should be viewed as a process, not a product that promotes any given response option over another.

This SIMA report was based on one hypothetical scenario. If a spill should occur in the Scotian Basin Region, it is highly unlikely that the spill scenario, seasons, and release location would duplicate this hypothetical. The process that is presented here, however, could be used as a guide for conducting a real time SIMA. In such an event, the analysis must be conducted rapidly, by individuals and organizations that possess the most current real time environmental, oceanographic, and climatological information. The process can be facilitated by reviewing this existing SIMA, updating the spill specifics and environmental concerns, conferring with local experts to determine what biological resources are in the region on that day, and performing a real time SIMA using the methods illustrated here. An actual SIMA for a spill would be generated ‘real time’ incorporating the review and advice from the Science Table members.
1 Spill Impact Mitigation Assessment

1.1 Background

This Spill Impact Mitigation Assessment (SIMA) has been prepared for BP Canada Energy Group ULC as part of the contingency planning process for exploratory drilling in the Scotian Basin area. The purpose of the SIMA is to evaluate logistically feasible response options that can aid in minimizing impacts from an oil spill in the Scotian Basin region and to promote rapid ecological, cultural and socio-economic recovery. The recent publication, *Guidelines on Implementing Spill Impact Mitigation Assessment (SIMA)* (Industry Environmental Conservation Association-American Petroleum Institute-International Oil and Gas Producers [IPIECA-API-IOGP], 2017), provides the strategy for analyzing oil spill impacts and facilitating response option selection. All response options determined to be both feasible and potentially effective in the Scotian Basin region are evaluated in this SIMA.

The Scotian Basin region provides some unique meteorological and oceanographic conditions that, at certain times of the year, may pose challenges to oil spill response, but also enables a high degree of natural dispersion. For this SIMA, summer and winter Tier 3 subsea discharges from a loss of source control at two potential drilling site locations in the Scotian Basin are evaluated. While there are other potential forms of oil spills that could possibly occur, the Tier 3 scenarios allow for the evaluation of all possible response options that are available for implementation by BP using their response groups, Eastern Canada Response Corporation (ECRC) and Oil Spill Response Limited (OSRL). The SIMA utilizes information provided in the following:

- Scotian Basin Exploration Drilling Project Environmental Impact Statement (EIS) (Stantec, 2016)
- SIMA modelling runs using SINTEF Oil Spill Contingency and Response Model (OSCAR)

A recent publication from IPIECA (2015b), *Response strategy development using net environmental benefit analysis: Good practice guidelines for incident management and emergency response personnel*, defines the SIMA process in four stages:

1. Compile and evaluate data to identify an exposure scenario and potential response options, and to understand the potential impacts of that spill scenario.
2. Predict the outcomes for the given scenario, to determine which techniques are effective and feasible.
3. Balance trade-offs by weighing a range of ecological benefits and drawbacks resulting from each feasible response option. This will also include an evaluation of socio-economic benefits and costs resulting from each feasible response option.
4. Select the best response options for the given scenario, based on which combination of tools and techniques will minimize impacts.

Figure 1 provides a high-level snapshot of the first two steps of the SIMA process. 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 is presented in Section 6 of this report. Finally, recommendations for the most appropriate response options for the Scotian Basin are summarized in Section 7 of this report.
Before presenting detailed information for the Scotian Basin, a brief overview of SIMA and the various applications for SIMA are provided in Sections 1.2 and 1.3.

1.2 Overview of SIMA

Net Environmental Benefit Analysis (NEBA) is a structured approach used by the response community and stakeholders during oil spill preparedness, planning and response, to compare the impact mitigation potential of candidate response options and develop a response strategy that will minimize the net impact of an oil spill on the environmental, socio-economic and cultural resources of concern.

The term Net Environmental Benefit Analysis and its acronym NEBA has been used to describe a process 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, the term “Spill Impact Mitigation Assessment” (SIMA) was introduced as a replacement for the former NEBA process that had been used by response planners, although the underlying principles of the risk analysis process have not changed. The SIMA process encompasses ecological, socio-economic and cultural considerations, and this new term eliminates the perceptions associated with the word ‘benefit’.

While the transition to SIMA will take some time, industry believes it is important to begin the process of more accurately describing this long-standing practice and its objectives.
Regardless of terminology, effective implementation of NEBA/SIMA processes are incumbent on the use of competent and knowledgeable experts to understand specific event conditions and local resources, and make reasonable response trade-off decisions. In all cases, this risk assessment process aims to support the selection of an agreed strategy for oil spill response, which has been informed by a systematic assessment and evaluation of multiple factors, with input from a range of stakeholders.

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 harbor may only require a few page 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.

In 2013, IOGP-IPIECA in conjunction with API, developed an outreach presentation on SIMA that emphasized the focus on local and regional priorities. 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, 2015b). More recently, IPIECA-API-IOGP (2017) developed guidelines for implementing spill impact mitigation assessment.

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.

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 planning phase, depending on the similarity of conditions in the hypothetical scenario analyzed for the SIMA to 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. Figure 2 provides an overview of how SIMA is applied in both instances.

History has shown that contingency planning SIMAs may be invaluable during actual spill responses. In the case where a 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.

In Canada, response actions are typically managed through use of the Incident Command System (ICS). The ICS provides a common, functional organizational structure, nomenclature and terminology, and is used by both regulatory agencies and industry. In this system, the use of SIMA would occur primarily within the Environmental Unit (EU), which contains industry and agency personnel, and advises the Incident Commander on environmental issues. The EU quickly assesses real-time spill conditions (e.g., oil type, quantity, trajectory, etc.), reconfirms information about actual resources at risk in the vicinity, and then adapts conclusions from planning SIMAs, as appropriate, to the actual spill conditions. The SIMA process is cyclical in that the plan is adapted to meet changing spill conditions.

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.
An overview of past SIMA efforts to evaluate dispersant usage - for contingency planning and spill response exercises in North America - has been provided in Appendix A. Additional information on SIMA can be found in a recent overview of the new SIMA process, provided by Taylor and Cramer (2017).

1.4 Overview of Dispersants and Dispersed Oil

The Scotian Basin Exploration Drilling Project Environmental Impact Statement provides a detailed discussion of the potential effects of an unmitigated oil spill in this Project Area (Sections 8.5.1 to 8.5.6 in [Stantec, 2016]). 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 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 parts per million (ppm) for the first hour after dispersants are applied in the top few metres 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 (Operational Science Advisory Team [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 available information on dispersed oil concentrations resulting from subsea dispersant injection (SSDI) operations is from the DWH incident. 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 Total Petroleum Hydrocarbon (TPH) concentration higher than 10 parts per billion (ppb) (Coelho et al., 2011; Lee, 2013).

Cross-section illustrations of the oil behaviour from a hypothetical subsea release are provided for an unmitigated release (Figure 3) and SSDI treated blowout (Figure 4). Estimated oil concentrations in the vicinity of the spill are provided using measured concentrations reported from the 2010 DWH incident (National Oceanic and Atmospheric Administration [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.

Refer to Appendix B for a more in-depth discussion on the role of dispersants in oil spill response, including the basic principles of chemical dispersion and factors that affect dispersant effectiveness.
Figure 3 Cross-section of an unmitigated subsea release.
Note: The vertical scale has been exaggerated for illustrative purposes (IPIECA, 2015a).

Figure 4 Cross-section of a subsea release treated with SSDI.
Note: The vertical scale has been exaggerated for demonstrative purposes and graphic does not illustrate concurrent ASD treatment (IPIECA, 2015a).
2 Scotian Basin SIMA Overview

This section provides a brief overview of the Geographical Area of Interest (Section 2.1), Physical Environment (Section 2.2) and Oil Spill Scenarios (Section 2.3) for the Scotian Basin SIMA. This section, combined with the following sections – Response Options (Section 3), Resources of Concern (Section 4) and Spill Modelling (Section 5) – are evaluated for this SIMA.

The geographical area of interest and a description of the physical environment are presented in the Scotian Basin EIS (Stantec, 2016) and summarized in the following Sections 2.1 and 2.2. In Section 2.3, the worst case subsea blowout scenarios, oil characteristics and associated modelling approach are summarized from information provided in Appendix H of the EIS (2016) and the SIMA modelling runs using SINTEF OSCAR. The spill modelling approach and results are provided in greater detail in Section 5.

A summary of the relevant factors is provided below, including references to specific sections of the EIS, where appropriate. The EIS should be consulted if additional technical detail is desired.

2.1 Geographical Area of Interest

As described in the EIS, the exploration Project Area is in the Scotian Slope and as such the Scotian Basin is the geographic area of interest analyzed for this SIMA. The basin extends approximately 1,200 kilometres (km) from the United States (US) and Canadian border in the southwest to the lower portion of the Grand Banks of Newfoundland in the northeast. As described in CNSOPB (2013), the Scotian Basin has a total area of approximately 300,000 square kilometres (km²) with depths ranging from less than 200 metres (m) in the continental shelf (Scotian Shelf) to greater than 4,000 m in the continental slope (Scotian Slope). This region has been defined as the Regional Assessment Area (RAA) in the EIS (2016) to assess potential environmental effects that may occur beyond the Project Area. The RAA includes the offshore marine waters of the Scotian Shelf and Slope within Canadian jurisdiction to the 200-nautical mile limit of the Exclusive Economic Zone (EEZ).

The Project Area consists of four Exploration Licenses (EL) 2431, 2432, 2433, and 2434 (Figure 5). At their shortest distance, the ELs are located approximately 230 km southeast of Halifax and 48 km southeast of Sable Island National Park Reserve. The ELs cover 13,982 km² and have water depths ranging from 100 m to more than 3,000 m. The Project Area in the Scotian Slope is characterized by a gentle gradient with low gentle hills and valleys, sloping towards the deep Scotian Rise and Abyssal Plain (WWF, 2009). The Sable Island Bank is a large defining bank of the Scotian Shelf.
2.2 Physical Environment

The description of the physical environment for the Scotian Basin Project Area (e.g., oceanography, climatology and meteorology) is described in detail in the EIS (Section 5.1 [Stantec, 2016]). With the exception of wind speed and wave height (Table 1) and ocean currents (Figure 6), other physical environment data from the EIS have not been reproduced in this SIMA report.

During the development of the EIS, 60 years of hourly wind and wave data from 1954 to 2013 were obtained from the MSC50 Grid Point 3551 (42.9°N, 60.6°W; water depth 2,326 m), which is located within the Project Area. This information is summarized in Table 1. Additional extreme wind and wave data at the Grid Point 3551 are provided in Section 5.1.2.3 and 5.1.3.3 of the EIS (2016).
Table 1 Historical wind and wave data for the Project Area (60-year average)\(^1\).

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean Wind Speed (m/s)</th>
<th>Most Frequent Direction(^2)</th>
<th>Mean Wave Height (m)</th>
<th>Most Frequent Direction(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>11.0</td>
<td>NW</td>
<td>3.44</td>
<td>E</td>
</tr>
<tr>
<td>February</td>
<td>10.8</td>
<td>NW</td>
<td>3.35</td>
<td>E</td>
</tr>
<tr>
<td>March</td>
<td>10.1</td>
<td>NW</td>
<td>3.10</td>
<td>E</td>
</tr>
<tr>
<td>April</td>
<td>8.5</td>
<td>NW to SW</td>
<td>2.52</td>
<td>NE, E, SW</td>
</tr>
<tr>
<td>May</td>
<td>6.8</td>
<td>SW</td>
<td>1.89</td>
<td>NE</td>
</tr>
<tr>
<td>June</td>
<td>6.1</td>
<td>SW</td>
<td>1.64</td>
<td>NE</td>
</tr>
<tr>
<td>July</td>
<td>5.6</td>
<td>SW</td>
<td>1.50</td>
<td>NE</td>
</tr>
<tr>
<td>August</td>
<td>6.1</td>
<td>SW</td>
<td>1.57</td>
<td>NE</td>
</tr>
<tr>
<td>September</td>
<td>7.3</td>
<td>NW to SW</td>
<td>2.01</td>
<td>All</td>
</tr>
<tr>
<td>October</td>
<td>8.9</td>
<td>NW and SW</td>
<td>2.47</td>
<td>E</td>
</tr>
<tr>
<td>November</td>
<td>9.9</td>
<td>NW</td>
<td>2.94</td>
<td>E</td>
</tr>
<tr>
<td>December</td>
<td>10.9</td>
<td>NW</td>
<td>3.39</td>
<td>E</td>
</tr>
</tbody>
</table>

\(^1\) Based on 60 years of MSC50 hourly wind data from 1954 to 2013.
\(^2\) Direction from which winds are blowing.
\(^3\) Direction from which waves are propagating.

(Stantec, 2016)

Major and minor ocean currents are depicted on the Scotian Shelf and Slope as shown in Figure 6, including the three major currents – the Nova Scotia current along the coast of Nova Scotia, the Shelf Break current and the Gulf Stream current offshore. More information is providing in Section 5.1.3.2 in the EIS (2016).

![Figure 6 Overview of ocean currents in the RAA.](Stantec, 2016)
2.3 Oil Spill Scenarios

The Oil Spill Trajectory Modeling report in Appendix H of the EIS (2016) and SIMA modelling runs using SINTEF OSCAR provide hypothetical oil spill scenarios developed for a subsea blowout in the Scotian Basin ELs for two sites (Site 1 “Case 1” and Site 2 “Case 2”) and two seasons (winter and summer). Case 1 demonstrates a smaller volume and shallower release location closer to Sable Island, while Case 2 depicts a larger volume and deeper release location. The exact location for the well has yet to be determined, however, these hypothetical scenarios encompass the range of the anticipated location and potential oil release volume of the actual well. General parameters for a source control blowout are summarized in Table 2 and discussed in greater detail in Section 5 - Oil Spill Modelling. Figure 7 shows the locations of the hypothetical wells in the EL 2434 and EL 2432.

The Sture Blend crude oil is the reference oil type for the spill modeling since this oil aligns with the expected reservoir characteristics. Section 4.1.1 of the EIS provides a summary of reservoir fluid properties and the rationale for choosing Sture Blend crude oil. These large scale, worst case scenarios allow for inclusion of the broadest range of oil spill response options and form the basis for the risk analysis conducted in Section 6.

Table 2 General parameters for a Tier 3 hypothetical source control blowout for two locations.

<table>
<thead>
<tr>
<th>Source of Spill</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blowout at sea floor</td>
<td>Blowout at sea floor</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Release Location</th>
<th>EL 2434</th>
<th>EL 2432</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long = 60.434610°,</td>
<td>Long = 61.229314°,</td>
<td></td>
</tr>
<tr>
<td>Lat = 43.046428°</td>
<td>Lat = 42.692076°</td>
<td></td>
</tr>
<tr>
<td>105,000 m from Sable Island</td>
<td>170,000 m from Sable Island</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Depth</th>
<th>2,104 m</th>
<th>2,652 m</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Oil Type (API gravity)</th>
<th>Sture Blend Crude (API gravity of 34.1)</th>
<th>Sture Blend Crude (API gravity of 34.1)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Duration of Spill</th>
<th>30-day continuous release</th>
<th>30-day continuous release</th>
</tr>
</thead>
</table>

| Release Rate | 24,890 bpd (total oil released 733,000 bbl) | 35,914 bpd (total oil released 1,056,000 bbl) |

Note: barrels per day (bpd) and barrels (bbl).
For purposes of this SIMA, the Worst Credible Case Discharge (WCCD) is considered to be the worst credible consequence that could occur over 120 day modelled time period, from an environmental impact and emergency response perspective. The relationship of WCCD to other frequently used planning terms, such as Worst Case Discharge (WCD), is described in the JIP-6 (IPIECA IOGP, 2013). WCCD oil spill modelling was used to generate both stochastic and deterministic simulations for summer and winter seasons. Stochastic modelling predicts the probability of sea surface, shoreline, or water column contact that could occur for a given spill event. The model, which is described in more detail in Section 5.1, runs numerous individual spill trajectory simulations using a range of meteorological and oceanographic (metocean) data, including wind and currents. When combined, these trajectories produce statistical outputs that predict the probability of where oil may travel or occur. Stochastic model outputs do not represent the extent of any one spill event, but instead provide a summary of the total individual simulations for a given spill scenario. In contrast, deterministic modelling predicts the fate and transport of oil resulting from a single hypothetical spill event using predefined metocean data. Therefore, using both stochastic and deterministic modelling provides an indication of both the likelihood and magnitude of the potential effects of the spill scenarios considered for this SIMA.

Analyzing Tier 3 scenarios trajectories 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. For the stochastic modelling in the EIS, “Summer” and “Winter” seasons represent mean weather conditions for two periods of time, with the summer season from May to October and the winter season from November to April. Deterministic modelling
was derived from stochastic simulations that produced the worst environmental impacts from an emergency response point of view and analyzed in the EIS as an unmitigated spill result. For the SIMA, these resulting deterministic simulations represent a “no intervention” unmitigated spill scenario for both summer and winter. Further deterministic modelling was performed on these same dates using surface dispersant alone and a combination of surface dispersant and SSDI.
3 Response Options

The six response options considered in this SIMA are:

• Natural attenuation (no intervention)
• Shoreline protection and recovery
• On-water mechanical recovery
• In-situ burning
• Aerial surface dispersant application (ASD)
• Surface dispersant application in combination with SSDI

The purpose of this section is to provide a short summary of each response option to ensure a common framework of understanding for the SIMA analysis. Since every response option has benefits and limitations, a full discussion of response options and tactics will be available in the BP Canada Energy Group ULC Scotian Basin Oil Spill Response Plan and associated Tactical Response Plans, which are currently in development and will be finalized later in 2017.

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 and limitations of each response method are described below.

3.1 Natural Attenuation

Natural attenuation, also referred to as “the no-response option” or “an unmitigated spill” 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. Once stranded, weathering will continue and the oil will gradually biodegrade or be incorporated into the sediments. It is also possible for oil stranded on shorelines to be re-mobilized from the shoreline and redistributed several times until it finally degrades, is consumed by organisms, or buried through natural tidal processes. Natural recovery may be an appropriate option for spills at sea which do not threaten worker health and safety, species of importance, shoreline or potentially sensitive environmental areas. 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 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.
Limitations: Natural attenuation is a passive response option which will not protect high value shoreline habitats in the event the 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 volatile organic compounds (VOCs) of the oil which can create a health and safety risk.

3.2 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 they are addressed together in this section. The trajectory modelling for the Project Area demonstrates that there is a high likelihood of spilled oil reaching the shoreline of Sable Island in Case 1, but a lesser probability for mainland shorelines. In conditions where oil will reach shore, shoreline protection and recovery are considered important tools when oil cannot be effectively treated or collected on-water prior to encounter with shoreline areas.

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 such as those that may be experienced in offshore Nova Scotia (e.g., Sable Island). 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 1-2 m. High winds can also blow the oil past the boom, and tides and currents can also pose a challenge. For the specific spill location considered, the options listed below are the most typical shoreline recovery options that may be utilized if oil does reach mainland shorelines, where operations would be prioritized based on tidal inlet protection site maps and plans, with the goal of protecting associated backshore lagoons and salt marshes:

- Manual Removal - removal of surface oil by manual means (hands, rakes, shovels, buckets, scrapers, 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.
- Limited use of mechanical recovery equipment in accessible areas if justified by the contamination level.

For the purposes of this SIMA, it is assumed that few to no shoreline protection options are feasible for Sable Island shorelines.
Benefits: Protective booming can protect relatively short stretches of the coast and as such should be used strategically in selected areas such as protecting lagoons, backwater entrances, marshes, 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 the following:

- Reduction in shoreline oiling.
- Physical removal of oil from the environment.
- Recycling or proper disposal of recovered oil.
- 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 scaring 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 the plant 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 to preventing the oil from reaching the shoreline in the first place. Ultimately, shoreline recovery may take weeks or up to months or years, depending on the type of oil spilled and different environmental variables (i.e., wave energy, amount of solar exposure, rainfall, shoreline type and erosion processes).

3.3 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 stored in tanks on vessels, or in floating temporary storage devices such as 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 a shore operations base for offloading and recycling or disposal. Although there have been some advances in using night vision devices 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 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 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 a limited recovery capability. Thus, there will be a lag time from the time of the spill to the time of conducting on-water mechanical recovery on a large scale, reducing the window of opportunity to conduct on-water mechanical recovery. Once additional equipment has been deployed from the Halifax supply base, the low encounter rate and need to dispose of captured oil limit the effectiveness of this technique. Beyond the encounter rate limitations, typical wave heights are a key consideration in the Scotian Basin. For example, open water booming with associated oil skimming operations begins to fail in sea states with waves over approximately 2 m. However, equipment capable of functioning in high sea states will be available on-site and deployed during an actual spill. In the Scotian Basin area, wave heights typically exceed this operational limit during winter season (see Table 1). Even when sea states are conducive for on-water mechanical recovery operations, these techniques typically recover no more than approximately 10 percent of the oil spilled in open ocean environments. During the DWH response in which wave height was seldom restrictive, less than 5% of the oil released was estimated to have been removed (Federal Interagency Solutions Group, 2010). 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 were favorable.

### 3.4 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 some instances, herding agents may be used to aid in containing or thickening 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. 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 - 5 mm continues to be maintained (IPIECA, 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 but 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 Scotian Basin region, the only likely human exposures would be to response workers, as these plumes would 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. For deep water spill responses, the great distance from shore typically means that the ISB smoke plume would not affect shore-based populations of people, so it is considered a primary response option for offshore response.

**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” (Fisheries and Oceans Canada, 2001). Reductions in air quality due to gases and particulate material may be a concern in some jurisdictions (if there are populated areas nearby) 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, 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 to become an issue for any response in Scotian Basin due to the great distance from the mainland.

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, 2016), conditions that rarely exist in this Project Area (see Table 1). On-water ISB has been used once as a response method, for the DWH incident, on sea states that were essentially flat, and yielded a recovery rate of approximately 5% (Federal Interagency Solutions Group, 2010).

### 3.5 Surface Dispersant Application

For this project, 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. Ideally, oil particles that are 10-200+ micrometres (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 Scotian Basin region, 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 monitoring. Due to the long transit distances from Halifax airport to the Scotian Basin, large aircraft such as a C-130 equipped with a 5,280 gallon (20 cubic metre [m³]) Airborne Dispersant Delivery System (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 m³ of oil in one sortie. Spotter aircraft are used to assist in targeting dispersible surface slicks for the dispersant spraying aircraft. In the Scotian Basin, dispersant aircraft would be on-scene within 24-hours of spill notification, and would be ready for operation by Day 2 of a spill.

Surface dispersant application requires good visibility and can only be done during daylight hours to visually target thick oil, ensure that humans, marine mammals and sea turtles are not in the spray area, ensure its safe application, and observe the effectiveness of the dispersant application (e.g. colour change). 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.

Dispersants can also be sprayed from vessels that are deployed from the port, or vessels in the vicinity of the platform, such as the Emergency Response and Rescue Vessel or Platform Supply Vessel. 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, and become less effective as oil weathers. For application scenarios that involve a one-time batch spill, there is a “window of opportunity” 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.
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 to the collection of samples near the surface. Aerial observation is generally sufficient for small batch spills, while surface and near surface monitoring and sampling are more likely to be used on large Tier 3 spills.

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: The limitations on effectiveness of surface dispersant application in the Project Area 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 brooms require a safe sea state. 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.

### 3.6 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 incident 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 remotely operated vehicle (ROVs) are used to oversee the operation, deploy injection equipment, and assist in 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 per day. In the Scotian Basin, it is assumed that SSDI operations would be deployed by Day 10 of a subsea spill.
In general, the same chemical dispersion principles apply that are discussed in the Aerial 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 ppm.

Monitoring to determine SSDI dispersant efficacy consist primarily of visual and sensor observations at the injection site by ROVs (e.g., underwater camera and particle size detector), and at the surface by aircraft observations or satellite imagery. Since effective SSDI operations reduce VOC levels at the water surface, air monitoring near the release point can also provide an indication of dispersant efficacy. 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 ability to operate somewhat continuously.

During the DWH response, SSDI was observed to reduce the size and thickness of surface slicks, and reduce VOC levels at the water surface. This lowers the risk to workers in the immediate release area by reducing the potential for fire and explosions, and reducing inhalation risks for 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.

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 by RPS ASA (under API funding) using the OILMAPDeep and SIMAP models to examine a 45,000 bpd blowout scenario (French McCay, et al. 2017). 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.”

* Final publication of the API Technical Report for this CRA is anticipated in Fall 2017.
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 < 2 m). Vessels are still needed to support dispersant resupply and pumping. In the Scotian Basin region, metocean conditions could hamper SSDI sea surface logistics in sea states above 5 m.

**Limitations:** Vessels, equipment and dispersant supplies to conduct SSDI operations take some time to be acquired and transported 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 (OSAT, 2010), which demonstrates the benefits of SSDI to effectively disperse oil.
4 Resources of Concern

The framework for identifying resources of concern (ROCs) for the Scotian Basin SIMA consists of understanding ecosystem health, human safety and socioeconomic concerns in the Project Area and RAA, as shown in Figure 5 in Section 2.1. Under this framework, key resources are identified using physical, biological and socio-economic data about the Project Area and RAA presented in the Scotian Basin Exploration Drilling Project Environmental Impact Statement (EIS) (Stantec, 2016) and Tangier 3D WATS seismic survey (LGL Limited, 2014).

In addition, key resources have been identified through BP’s engagement with various federal, provincial and municipal regulators, Aboriginal organizations, fish producers and fish associations, non-governmental stakeholders and the public in the development of the EIS (Stantec, 2016). These efforts help build positive relationships, trust, and provide transparent and timely communication about the Project. The 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. A summary of the stakeholder engagement is provided in Sections 3 and 4 of the EIS.

In addition to the information provided in the EIS, the fate and behaviour of oil in the Project Area and RAA are studied to identify resources that may be distinctively 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).

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

- Migratory Birds
- Fish
- Invertebrates
- Marine Mammals
- Sea Turtles
- Vegetation
- Corals and Sponges
- Commercial Fisheries
- Aboriginal Fisheries

A geographical area, habitat and brief description of each environmental compartment are provided in the resources of concern table (Table 3). The ROC Table is constructed to emphasize the difference between habitats offshore, on the slope, on the shelf and on the shoreline. The assessment is based on the generalized ecological communities and/or habitat types present in the affected area since this SIMA is intended to consider a holistic protection of the environment, not the protection of individuals or specific species.

Supporting information to identify species present in the Project Area include seasonal distribution and life stages of wildlife, which are summarized in the EIS (2016). The EIS also lists species occurring on the Scotian Shelf and Slope 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 scarce in the Project Area, but 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 EIS. These Special
Areas and Ecologically and Biologically Significant Areas (EBSAs) have been designated because of their biodiversity and ecological importance in Canada's oceans, and the need to proactively conserve and protect marine ecosystem functions for future generations. However, specific species at risk, Special Areas and EBSAs are not included in the Resources of Concern (Table 3) or in the Comparative Risk matrix (Table 14) because the components of these areas are already captured under the broader areas, habitats and environmental compartments listed in the Resources of Concern table. For example, the Haddock Box Special Area is captured within the Shelf/Water Column environmental compartment. This means when considering fish (in general) in the water column, implications to the Haddock Box are considered when analyzing modelling results for that location. Similar situation for a species at risk, these species (e.g. Roseate Tern) are already considered when evaluating its broader resource category (e.g. birds) for each habitat being evaluated. Section 6.3 provides more information on how species at risk, Special Areas and EBSAs are considered in the SIMA process.

In addition to ecological resources, Table 3 includes socio-economic resources since a high level of importance is attached to them, as outlined in the EIS. These resources are depicted crossing both the habitat and resource category columns in the table to symbolize their assignment across all resource categories and habitats. In particular, Commercial Fisheries is an important and long-standing component of the Nova Scotian 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 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 Project Area during the public, stakeholder, or Aboriginal engagement activities completed for the EIS. 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>
<thead>
<tr>
<th>AREA</th>
<th>HABITAT</th>
<th>DESCRIPTION OF ENVIRONMENTAL COMPARTMENT</th>
<th>RESOURCE CATEGORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoreline</td>
<td>Nova Scotia Intertidal</td>
<td>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.</td>
<td>Birds, Invertebrates, Mammals, Vegetation</td>
</tr>
<tr>
<td></td>
<td>Sable Island Intertidal</td>
<td>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.</td>
<td>Birds, Invertebrates, Mammals, Vegetation</td>
</tr>
<tr>
<td></td>
<td>Sea Surface</td>
<td>The sea surface microlayer (SML) is the top 1 millimetre of the ocean surface. This is the boundary layer where exchanges occur between the atmosphere and the ocean surface.</td>
<td>Birds, Marine Mammals, Fish eggs/larvae, Sea Turtles</td>
</tr>
<tr>
<td></td>
<td>Water Column (shallow: less than 20 m)</td>
<td>The oceanic mixed layer pelagic environment from the surface to the depth of ~20 m.</td>
<td>Birds (Diving), Fish eggs/larvae, Fish, Marine Mammals, Plankton, Sea Turtles, Vegetation, Birds (Diving)</td>
</tr>
<tr>
<td></td>
<td>Water Column (deeper: greater than 20 m)</td>
<td>The marine pelagic environment from the oceanic mixed layer (~20 m) to the boundary of the benthic zone.</td>
<td>Birds (Diving), Fish, Marine Mammals, Plankton, Sea Turtles, Corals &amp; Sponges, Fish eggs/larvae, Invertebrates, Fish</td>
</tr>
<tr>
<td></td>
<td>Benthos</td>
<td>The benthic zone is the lowest level in the marine environment which includes the sediment surface as well as sub-surface layers.</td>
<td>Corals &amp; Sponges, Invertebrates, Fish</td>
</tr>
<tr>
<td>Slope (extending offshore from the shelf break)</td>
<td>Sea Surface</td>
<td>The sea surface microlayer (SML) is the top 1 millimetre of the ocean surface. This is the boundary layer where exchanges occur between the atmosphere and the ocean surface.</td>
<td>Birds, Marine Mammals, Fish eggs/larvae, Sea Turtles</td>
</tr>
<tr>
<td></td>
<td>Water Column (shallow: less than 20 m)</td>
<td>The oceanic mixed layer pelagic environment from the surface to the depth of ~20 m.</td>
<td>Birds (Diving), Fish eggs/larvae, Fish, Marine Mammals, Plankton, Sea Turtles</td>
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<td>The marine pelagic environment from the oceanic mixed layer (~20 m) to the boundary of the benthic zone.</td>
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</tr>
<tr>
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<td>The benthic zone is the lowest level in the marine environment which includes the sediment surface as well as sub-surface layers.</td>
<td>Corals &amp; Sponges, Invertebrates, Fish</td>
</tr>
<tr>
<td>Socio-economic</td>
<td>Commercial Fisheries, Indigenous Fisheries</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Description of Resources of Concern

*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. The 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). This ROC also considers all migratory birds listed under Schedule 1 of SARA, COSEWIC, and/or the Nova Scotia *Endangered Species Act*. Migratory birds can be found in and around the RAA year-round carrying out various life cycle processes. Figure 8 illustrates bird critical habitats designated under SARA. Figure 9 shows two bird surveys for the Shearwater migratory bird, as an example of seasonal distribution.

![Critical Habitat Designated under SARA for Bird Species at Risk](image)

Figure 8 Critical Habitat Designated under SARA for Bird Species at Risk. (Stantec, 2016)
An estimated 30 million seabirds use the eastern Canadian waters each year including breeding marine birds and migrating birds from the southern hemisphere and northeastern Atlantic (Fifield et al., 2009). The combination of northern hemisphere and southern hemisphere birds results in peak diversity during spring and summer months (Fifield et al., 2009). Significant numbers of overwintering birds, including alcids, gulls, and Northern Fulmars can also be found in Atlantic Canadian waters during the fall and winter (Brown 1986), whereas species assemblages are dominated by shearwaters, storm-petrels, Northern Fulmars and gulls in summer (Fifield et al., 2009).

The waters of the RAA are known to support approximately 19 species of pelagic seabirds, 14 species of neritic seabirds, 18 species of waterfowl and loons, and 22 shorebird species. Seven migratory bird Species at Risk (SAR) and Species of Conservation Concern (SOCC) are known to occur in waters of the Scotian Shelf and Slope and could occur within the RAA: Ivory Gull, Piping Plover, Roseate Tern, Red Knot, Harlequin Duck, Red-necked Phalarope, and Barrow’s Goldeneye, Horned Grebe, Bank Swallow and Buff-breasted Sandpiper. Two terrestrial (land) birds, the Peregrine Falcon and the Savannah Sparrow, are known for their rare occurrences both nearshore or on Sable Island.

Fourteen coastal Important Bird Areas (IBAs), including Sable Island, are present within the RAA. IBAs are discrete areas that support nationally or globally important groups of birds where concentrations congregate or provide habitat for groups of birds restricted by range or specific habitat requirements. The IBAs are scattered throughout the RAA but many are
located in the southeastern portion of Nova Scotia, between Halifax and Cape Breton Island. These 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.

**Fish and Fish Habitat** are selected as a ROC in consideration of the ecological value provided to marine ecosystems, the socio-economic importance of fisheries resources, and the potential for interactions with the hypothetical scenario subsea blowout oil spill scenario (see Figure 10). Fish and fish habitat are also regulated under the federal *Fisheries Act*, which includes provisions to protect the productivity of commercial, recreational and Aboriginal fisheries.

![Figure 10 Fish and fish habitat.](Stantec, 2016)

The Project Area and RAA provide habitat for a variety of groundfish and pelagic fish species. There are 24 fish SAR/SOCC that may be present on the Scotian Shelf or Slope at various times of the year. Within the Project Area and RAA there are five fish species formally protected under the SARA: Atlantic salmon (Inner Bay of Fundy population), Atlantic wolffish, Northern wolffish, Spotted wolffish, and white shark. The complete list of SAR fish is provided in the EIS (2016). While the potential for occurrence of these species at risk in the Project Area is believed to be low based on known habitat preferences, distribution mapping and catch data (where available), in the event of a spill there would be potential for interaction with these species in the larger RAA.
A variety of fish species have been recorded in Nova Scotia’s nearshore, some species enter the inshore only to feed and others are seasonal migrants. Some species spend their whole life in inshore areas while others spend only certain stages of their life in the inshore. Coastal and estuarine areas offer suitable cover for use as spawning and nursery grounds. Examples of species that spawn in inshore areas include Atlantic herring, haddock, pollock, witch flounder and yellowtail flounder.

Bundy et al. (2014) identified at least 58 species of groundfish that are known to occur in the inshore areas of the Scotian Shelf, although few are restricted to the inshore only. Most frequently encountered groundfish are Atlantic cod, skates, winter flounder, pollock, haddock, and yellowtail flounder. The inshore pelagic habitat extends from surface waters to near bottom. Large pelagic species observed inshore include bluefin tuna, swordfish, and several shark species. These species are typical of offshore habitats but enter shallower waters of the Scotian Shelf in the warmer months to feed. Small pelagics in the inshore include Atlantic herring and Atlantic mackerel. At the interface between salt and freshwater environments, the inshore area is particularly important to diadromous species that require this habitat to complete their lifecycle, such as Atlantic sturgeon, Atlantic salmon, and American eel.

Some fish are found within both inshore and offshore habitats depending on the lifecycle and season, such as Albacore tuna, Bigeye tuna, Yellowfin tuna, and Atlantic herring.

**Invertebrates** are selected as a ROC due to their ecological, commercial and cultural value, such as American lobster, Green sea urchin, Atlantic sea scallop, clams, Northern shrimp and crabs.

**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*, and potential interactions with the hypothetical subsea blowout oil spill scenario. Figure 11 illustrates critical habitats in the RAA for marine mammals. This ROC considers secure marine mammals as well as species listed under *SARA* or considered at risk by COSEWIC.
There are six species of mysticetes (baleen whales), 11 species of odontocetes (toothed whales), and five species of phocids (seals) that could potentially be present in the Project Area and surrounding RAA. Seven of these species are designated at risk by either SARA or the COSEWIC - three species of mysticetes, and four species of odontocetes.

The majority of mysticetes are migratory, and are present on the Scotia Shelf and Slope from late spring through fall. The fin whale, however, is present year-round. On the Scotian Shelf and Slope there is designated critical habitat under SARA for endangered species including the North Atlantic right whale and the northern bottlenose whale. Critical habitat for the endangered North Atlantic right whale has been identified in Roseway Basin on the Scotian Shelf within the RAA (Brown et al., 2009). Critical habitat for the endangered northern bottlenose whale has been designated in the Gully MPA and in the Shortland and Haldimand Canyons on the east of the Scotian Shelf and Slope (DFO, 2010).

Seals are most commonly found over the Scotian Shelf, north of the Project Area, in the nearshore waters around Sable Island. Sable Island hosts the world’s largest breeding colony of grey seals (DFO, 2011a; Freedman, 2014). Other species known to breed and forage in the area include harp, hooded, and ringed seals. No seal populations on the Scotian Shelf are designated at risk under SARA or by COSEWIC.
Harbour porpoise and Atlantic white-sided dolphins have been sighted at locations in Halifax Harbour, with occasional sightings of larger whales at the approaches to the harbour (Brodie, 2000).

**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, and potential interactions with the oil from the hypothetical subsea blowout oil spill scenario. Figure 12 provides survey results for sea turtle sightings in the RAA. This ROC considers secure sea turtles as well as species listed under SARA or considered at risk by COSEWIC.

Within the Scotian Shelf and Slope waters, four species of sea turtles can be found migrating and foraging. Two sea turtle species most likely to occur in the region, the leatherback and loggerhead, are listed as endangered under Schedule 1 of SARA and COSEWIC. Critical habitat for leatherback turtles in Atlantic Canada has been proposed based on a DFO Science Advisory Process (DFO, 2011b), but not yet formally designation under SARA.

**Marine Plants** are selected as a ROC (listed as “vegetation” in this SIMA) due to their importance for providing food and shelter to juvenile fish and waterfowl and sediment stabilization. Marine plants can include macrophytic marine algae (also referred to as seaweeds), flowering plants (e.g., seagrasses), and phytoplankton. Seaweeds found along rocky shores of Nova Scotia include species of green algae, red algae and brown algae. Green algae require a large amount of light and are generally found closer to the surface in intertidal or shallow subtidal areas. Red algae (e.g., Irish moss) grow at greater depths and
are generally found in the intertidal zone, below the low water mark. Brown algae (e.g., kelp, rockweeds) are the dominant seaweeds and are found in subtidal and intertidal zones (DFO, 2013b). Irish moss (*Chondrus crispus*) and rockweed (*Ascophyllum nodosum*) are harvested commercially in Nova Scotia. Eelgrass (*Zostera marina*), the dominant seagrass found in coastal and estuarine areas around Nova Scotia, is very sensitive to environmental changes and has declined considerably along the Nova Scotia coastline in recent decades (DFO, 2009; DFO, 2013b; Hastings et al., 2014).

**Coral and Sponges** are selected as a ROC in recognition of the ecological value they provide to the marine ecosystems, specific regulatory requirements of Northeast Channel Coral Conservation Area and other protected areas, and potential interactions with oil from the hypothetical subsea blowout oil spill scenario. Figure 13 illustrates the location of sensitive coral and sea sponge areas. These fragile or unique species or habitats depicted are protected from bottom fishing activities.

![Figure 13 Known coral and sponges on the Scotian Shelf and Slope. (Stantec, 2016)](image)

There are two major groups of cold-water corals offshore Nova Scotia: hard/stony corals and octocorals or soft corals. These cold water corals can live at aphotic zone depths, and can occur in solitary or reef formations. Most corals require a hard substrate to attach to, although some species can anchor themselves into soft sediments (ASZISC, 2011). Most species are found at water depths greater than 200 m on continental slopes, canyons, or seamounts (DFO, 2011a).
Reef structures are more likely to be encountered on hard substrates which can be observed along the end of channels between fishing banks and in submarine canyons. The largest octocorals reported on the Scotian Shelf are gorgonian corals (e.g., bubblegum and seacorn corals) of which the highest concentration in the Maritimes occurs in the Northeast Channel and is now protected from bottom fishing disturbances in the Northeast Channel Coral Conservation Area. Other designated areas on the Scotian Shelf and Slope offering protection to corals includes the Gully MPA, which has the highest known diversity of corals in the Atlantic Canada (Moors-Murphy, 2014) and the Lophelia Coral Conservation Area on the southeastern slope of Banquereau Bank.

At least 34 species of sponge have been identified on the Atlantic coast, including the Russian hat glass sponge which is known only to occur in specific locations on the Scotian Shelf, the Gulf of Mexico, and the Azores. Globally unique sponge grounds for this species on Sambro Bank and Emerald Basin have recently received protection as DFO closed these areas to bottom-contact fishing in 2013 to help protect these sponges from further damage (DFO, 2013c).

**Commercial Fisheries** are chosen as a ROC in consideration of the economic importance of fishing areas and the potential interaction of oil from the subsea blowout oil spill scenario. The RAA is dominated by commercial fisheries activity with groundfish, pelagic, and invertebrate fisheries occurring on the Scotian Shelf and Slope. Figures 14 and 15 show locations for groundfish and pelagic landings. For the purpose of this SIMA, recreational fisheries are not categorized separately as the resources are already considered under Commercial Fisheries and Indigenous categories.

Figure 14 Commercial fisheries landings - groundfish.  
(Stantec, 2016)
Commercial fisheries can occur year-round for most species, although it is understood that the majority of fishing near the Project Area occurs between February and October with peak fishing efforts for pelagic and groundfish species occurring from July to September (Table 5.3.5 [Stantec, 2016]).

The RAA is located within Commercial Fisheries Management Areas for lobster, shrimp, scallop and crab, and within Northwest Atlantic Fisheries Organization (NAFO) Divisions 4VN, 4VS, 4W, 4X, and 5ZE. From 2010 to 2013 in NAFO Divisions within the RAA, invertebrates dominated the commercial landing values with between 71 and 84% of the total catch value in that period. In the Project Area, large pelagic fish are most commonly harvested (e.g., tuna, swordfish and shark). There are over 250 aquaculture leases in Nova Scotia, including both finfish (e.g., Atlantic salmon, cod, trout) and shellfish (e.g., oyster, mussel, scallop, quahaug, clam) operations (NSDFA, 2013).

Within Halifax Harbour nearshore commercial fisheries include groundfish (cod, haddock, pollock and halibut) and pelagic (herring and mackerel) species. Other areas throughout the Harbour support a bait fishery for both commercial and recreational bait (Rozee, 2000). Lobster is the primary commercial species harvested within Halifax Harbour (Stantec, 2014). The Harbour is included within the boundaries of Lobster Fishing Area (LFA) 33, which extends from southwestern Nova Scotia and into the Bay of Fundy. LFA 33 has the highest landings and most participants of any LFA in Canada (DFO, 2013a).
Traditional Use is included as a ROC (listed as Indigenous in this SIMA) in consideration of Aboriginal Treaty rights and its socio-economic, socio-cultural and/or traditional use areas and the potential interaction with the subsea blowout oil spill scenario. Figure 16 provides the location of Traditional Use Food, Social and Ceremonial (FSC) and Commercial fisheries in the RAA.

Figure 16 Traditional Use FSC and Commercial Fisheries locations. (Stantec, 2016)

All 13 Mi’kmaq First Nation communities in Nova Scotia currently have communal commercial fishing licences for various species that may be harvested in the RAA. There are 25 species being fished by the Nova Scotia Mi’kmaq First Nation communities under communal commercial licences within the RAA. Those nearer the Project Area include: Atlantic cod, bluefin tuna, halibut, mahi-mahi, silver hake and swordfish. The Native Council of Nova Scotia (NCNS) fish 19 species (including by-catch species) within the RAA under communal commercial licences, with seven being fished within the Project Area. Species fished commercially by the NCNS within the Project Area include: albacore tuna, bluefin tuna, bigeye tuna, halibut (by-catch), mahi-mahi (by-catch), swordfish, and yellowfin tuna (Membertou Geomatics Solutions [MGS] and Unama’ki Institute of Natural Resources [UINR], 2016). Additionally, New Brunswick Mi’kmaq and Wolastoqiyik (Maliseet) also hold communal fishing licences for various species that may be harvested from the RAA. Interviews with Fort Folly, Woodstock and St. Mary’s First Nation communities revealed that 16 species are fished within the RAA, with 10 being harvested in the vicinity of the Project Area. Silver hake and swordfish are the only species that may also be harvested within the Project Area (MGS and UINR, 2016).

No FSC fishing is reported to occur in the Project Area, although it is possible FSC fishing could occur presently or in the future (Stantec, 2016). FSC fisheries for Atlantic herring,
Atlantic mackerel, Greenland halibut, lobster, redfish, and silver hake are reported by the Nova Scotia Mi’kmaq First Nation communities and/or the NCNS as occurring in the vicinity of the Project Area and additional species are fished for FSC purposes in the larger RAA. Within the RAA, lobster, scallops, and clams, were identified as being fished for food, social, and ceremonial purposes.

The potential environmental effects, effect pathways, and measurable parameters identified in Table 7.7.1 in the EIS (Stantec, 2016) for Current Aboriginal Use of Lands and Resources for Traditional Purposes for routine activities remain valid for the assessment of potential environmental effects from an accidental event. Likewise, the criteria for characterizing residual environmental effects and determining significance (refer to Section 7.7.5 in the EIS [Stantec, 2016]) remain valid for the accidental events assessment.

Special Areas on the Scotian Shelf and Slope are included in developing the ROCs list and further SIMA evaluations due to their ecological and/or conservation sensitivities and potential interaction with the subsea blowout oil spill scenario. These areas include a National Parks Act park, an Oceans Act Marine Protected Area (MPA), Species at Risk Act Critical Habitat areas, Fisheries Act closure areas (significant spawning areas and coral conservation areas), and EBSAs (Figure 17).

![Figure 17 Ecologically and Biologically Significant Areas. (Stantec, 2016)](image URL)
EBSAs overlapping the Project Area include the Scotian Slope EBSA and the Emerald Western Sable Bank Complex. The Scotian Slope EBSA is of importance due to its high productivity; species diversity and richness; unique and sensitive benthic communities; migratory routes; overwintering habitat; foraging area for leatherback sea turtles; and habitat for Greenland sharks (Doherty and Horsman, 2007; DFO, 2014). The Emerald Western Sable Bank Complex contains the Haddock Box, which represents an important nursery area for the protection of juvenile haddock. This area is closed to the commercial groundfish fishery year-round by DFO.

Beyond the Scotian Slope EBSA and the Haddock Box, there are several Special Areas located within the RAA, which could potentially interact with a Project-related accidental spill. Of particular note is the distance of the Project Area to Special Areas providing critical habitat for species at risk and/or important habitat for migratory birds, including Sable Island National Park Reserve (48 km), the Gully MPA (71 km), Shortland Canyon and Haldimand Canyon (139 km and 171 km, respectively) and Roseway Basin (264 km) (see Figure 18 and 19). The Gully MPA preserves underwater canyons along Canada’s Atlantic coast, providing safe habitat for the SARA designated endangered northern bottlenose whale as well as rare deep water marine life, such as cold-water corals. Roseway Basin provides a critical habitat feeding ground to the SARA designated endangered right whale.

Figure 18 Special Areas.
(Stantec, 2016)
Additional designated protected areas (e.g., national park, wilderness areas, nature reserve), along the coast of Nova Scotia could also potentially interact with a Project-related spill, including Kejimkujik National Park seaside, Bonnet Lake Barrens, Canso Coastal Barrens and Terrance Bay Wildness Areas, Musquodoboit Harbor and Duncan’s Cove Nature Reserve (Figure 19).

Figure 19 Special Areas (focusing on coastal areas).
(Stantec, 2016)
5 Spill Modelling

5.1 Background and Approach

Initial spill modelling for the BP Scotian Basin Exploration Project was performed as part of the EIS to evaluate the effects of potential spill scenarios. The scope of the modelling described in the EIS for an unmitigated subsea blowout scenario included several factors:

- a prediction of the movement and weathering of the oil originating from two different release sites using spatial wind data, current data and specific hydrocarbon properties;
- seasonal variation in the modelled impacts during summer and winter conditions;
- modelling to predict the probability and areal extent of oiling above threshold levels at the sea surface, on shorelines and in the water column for each scenario;
- modelling to show the single spill trajectory with the highest amount of oil reaching the shore; and
- a calculation of the maximum amount of shoreline oiling.

Oil spill trajectory and fate modelling was conducted using the SINTEF OSCAR model. OSCAR is a 3-dimensional model that calculates and records the distribution (and mass and concentrations) of contaminants on the water surface, on shorelines, in the water column, and in sediments (which may include flocculants, oil mineral aggregates and marine snow).

As discussed in Section 2.3, the SINTEF OSCAR model was used to generate both stochastic and deterministic simulations for both summer and winter seasons, which provides an indication of both the likelihood and magnitude of the potential effects of the spill scenarios considered for this SIMA. In addition, the stochastic modelling approach was used to produce statistical outputs that include the probability of where oil might travel and the time taken for the oil to reach a given boundary or shoreline outside the RAA.

For the stochastic modelling in the EIS, “Summer” and “Winter” seasons represent mean weather conditions for two periods of time, with the summer season from May to October and the winter season from November to April. Deterministic modelling was derived from stochastic simulations that produced the worst environmental impacts from an emergency response point of view and analyzed in the EIS as an unmitigated spill result.

For the SIMA, the unmitigated deterministic simulations represent a “no intervention” unmitigated spill scenario for both summer and winter at two well locations:

- Case 1A Summer (June 19, 2006)
- Case 1A Winter (November 4, 2006)
- Case 2A Summer (June 24, 2008)
- Case 2A Winter (April 18, 2009)

Further deterministic modelling was performed on these same dates using aerial surface dispersant (ASD) only, and combined ASD plus SSDI response scenarios.
5.1.1 Unmitigated Modelling

As mentioned above, two locations (Site 1 “Case 1” and Site 2 “Case 2”) were selected for SIMA modelling to evaluate a WCCD scenario for the proposed well drilling locations shown in Figure 7 in Section 2.3. Scenarios at both locations depict subsea blow outs, and the release duration for both was 30 days. Table 4 provides the results from deterministic models.

Table 4 Deterministic modelling - maximum oil on shoreline trajectory scenarios.
(SIMA OSCAR Model Output)

<table>
<thead>
<tr>
<th>Deterministic simulations</th>
<th>Scenario - Case 1A (Maximum oil on shoreline - Winter Season)</th>
<th>Scenario - Case 1A (Maximum oil on shoreline - Summer Season)</th>
<th>Scenario - Case 2A (Maximum oil on shoreline - Winter Season)</th>
<th>Scenario - Case 2A (Maximum oil on shoreline - Summer Season)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
<td>Winter Season (November - April)</td>
<td>Summer Season (May - October)</td>
<td>Winter Season (November - April)</td>
<td>Summer Season (May - October)</td>
</tr>
<tr>
<td>Simulation number</td>
<td>31</td>
<td>13</td>
<td>161</td>
<td>104</td>
</tr>
<tr>
<td>Simulation duration</td>
<td>04 November 2006 21:00</td>
<td>19 June 2006 23:00</td>
<td>18 April 2009 03:00</td>
<td>24 June 2008 03:00</td>
</tr>
<tr>
<td>Release duration</td>
<td>30 days</td>
<td>120 days</td>
<td>120 days</td>
<td>120 days</td>
</tr>
<tr>
<td>Initial Release rate</td>
<td>24,890 bpd</td>
<td>24,890 bpd</td>
<td>35,914 bpd</td>
<td>35,914 bpd</td>
</tr>
<tr>
<td>Total oil release</td>
<td>99,553 tonnes</td>
<td>99,553 tonnes</td>
<td>143,433 tonnes</td>
<td>143,433 tonnes</td>
</tr>
<tr>
<td>First shore hit</td>
<td>5.8 days</td>
<td>7.0 days</td>
<td>31.0 days</td>
<td>12.0 days</td>
</tr>
<tr>
<td>Maximum mass on shoreline</td>
<td>239 tonnes</td>
<td>670 tonnes</td>
<td>105 tonnes</td>
<td>669 tonnes</td>
</tr>
<tr>
<td>Ashore time (maximum mass)</td>
<td>18.0 days</td>
<td>42.0 days</td>
<td>34.0 days</td>
<td>32.0 days</td>
</tr>
<tr>
<td>Length of coastline impacted</td>
<td>27.8 km</td>
<td>27.8 km</td>
<td>55.6 km</td>
<td>79.5 km</td>
</tr>
<tr>
<td>Maximum length of coastline</td>
<td>27.8 km</td>
<td>27.8 km</td>
<td>55.6 km</td>
<td>79.5 km</td>
</tr>
<tr>
<td>Ashore time (maximum length)</td>
<td>12.0 days</td>
<td>13.0 days</td>
<td>110.0 days</td>
<td>161.0 days</td>
</tr>
</tbody>
</table>

The OSCAR model tracks oil on the sea surface, on the shoreline, in the water column and in sediments to levels that have little relevance from a response or environmental impact perspective. Therefore, conservative threshold levels were applied in the modelling of each of these impact compartments as follows (see EIS Appendix H Section 4.5 [Stantec, 2016]):

- **Surface Oil:** thickness of emulsified oil on the water surface - 0.04 µm (French-McCay, 2009)
- **Shoreline:** volume of oil reaching the shoreline - 1.0 g/m² (French-McCay, 2011)
- **Water Column:** concentration of oil in the water column - 58 ppb (Neilson et al., 2005, as reported in OLF, 2008)

5.1.2 Mitigated Modelling

For this SIMA, to understand the effects of dispersant application via ASD and SSDI, further modelling was performed using mechanical and logistical considerations, oil characteristics, and oil/water interfacial tension data. The effectiveness was estimated at 85% for ASD and
95% for SSDI. The mitigated results are then compared to the no intervention results and are subsequently used during the risk assessment of response options presented in Section 6.

The modelling study addressed the following spill scenarios and treatment regimes.

1. Capping stack (CS) unmitigated scenario.
   - Unmitigated WCCD subsea release until the well is capped after 30 days
2. CS scenario with ASD application.
   - WCCD subsea release until the well is capped after 30 days
   - 0-2 days unmitigated
   - ASD application from Day 2 - 30
3. CS scenario with combined ASD and SSDI application.
   - WCCD subsea release until the well is capped after 30 days
   - 0-2 days unmitigated
   - ASD application from Day 2 - 30
   - SSDI from Day 10 - 30

While mechanical recovery and ISB are not modelled for this hypothetical oil spill scenario, in the event of an actual spill these responses would be employed, if conditions warrant. However, effectiveness and efficiency are anticipated to be limited.

5.2 Modelling Results

To facilitate a comparison of environmental impacts associated with the different locations, seasons, and spill scenarios, Case 1A Summer was selected as the primary scenario for analysis in this SIMA. This case yielded the most challenging spill response conditions from the deterministic modelling simulations (Table 4), based on initial time to landfall, and extent and duration of oil exposure to ROCs. The other three spill scenarios were then compared to Case 1A Summer in Section 6.4.2.

5.2.1 Case 1A Summer

5.2.1.1 Maximum Surface Thickness

Figure 20 illustrates the maximum thickness of surface oil that could be expected within the Project Area 30 days after the start of the release. The legend also displays the mass balance for oil within environmental compartments including the water surface, atmosphere, water column, sediments, ashore, and biodegraded. Without mitigation, oil is expected to make landfall on Sable Island in this scenario in 7 days. In the mass balance, oil is shifted from the surface to the water column by dispersant application. The percentage of oil on the surface is reduced from 13.2 % in the unmitigated spill, to 0.6 % by the combined application of ASD and SSDI, a decrease of 95%. Oil in the water column is increased from 37.1% in the unmitigated spill to 59% by the combined application of ASD and SSDI. Oiling of sediments is reduced from 4.5% to 1.2%. Significantly, exposure of Sable Island to surface oil is nearly eliminated by the combined use of ASD and SSDI at day 30.
Figure 20 Case 1A Summer scenario with and without dispersant application - snapshot maps showing the maximum surface oil thickness 30 days after the start of the subsea blowout. (SIMA OSCAR Model Output)
Likewise, cumulative exposures (compilation of all trajectories for 120 days) to thicker oil at the surface is shown to decrease significantly over a 120-day time period with the combined use of ASD and SSDI (Figure 21).

Figure 21 Case 1A Summer scenario with and without ASD and SSDI application - cumulative surface oil coverage over 120 days.
(SIMA OSCAR Model Output)
Note: (1) Black lines depict boundary lines between Canadian, US, French and international waters. (2) This cumulative figure is a compilation of trajectories for 120 days, it is not a snapshot of one specific time during the event, as is shown in Figure 20.
5.2.1.2 Footprint of Total Hydrocarbon Concentrations in the Water Column

As shown in Figure 22, the use of ASD alone during the first 10 days results in significant reductions of oil on the water surface, and increased oil dispersed into the shallow water column. Similarly, the combined use of ASD and SSDI (Figure 23) produces significant mass balance shifts from the water surface, to the water column after 30 days. Surface oil is significantly reduced by combined use of ASD and SSDI.

Figure 22 Case 1A Summer scenario with and without ASD application - snapshot map showing the maximum concentration of total hydrocarbons (dispersed and dissolved oil) in the top 100 m of the water column 10 days after the start of the subsea blowout.
(SIMA OSCAR Model Output)
Figure 23 Case 1A Summer scenario with and without dispersant application - snapshot map showing the maximum concentration of total hydrocarbons (dispersed and dissolved oil) in the top 100 m of the water column 30 days after the start of the subsea blowout. (SIMA OSCAR Model Output)
Within 30 days of an unmitigated spill, the shoreline at Sable Island is heavily oiled (> 10 mm). The use of ASD and SSDI results in decreased oiling in some areas, as shown in Figure 24.

Figure 24 Case 1A Summer scenario with and without dispersant application - snapshot maps showing the severity of shoreline oiling 30 days after the start of the subsea blowout. (SIMA OSCAR Model Output)
5.2.1.3 Footprint of Oil Incorporated into Sediments

The deposit of oil onto sediments is also reduced by use of ASD and SSDI, as shown in Figure 25, while oil on the water surface is decreased and dispersed oil in the water column is increased.

Figure 25 Case 1A Summer scenario with and without dispersant application - snapshot maps showing the concentration of oil incorporated into sediments on the seafloor 30 days after the start of the subsea blowout. (SIMA OSCAR Model Output)
5.2.1.4 Mass of Oil with and without Dispersant Use for Case 1A Summer

The mass of oil at the sea surface decreases rapidly after initiation of both ASD after Day 2 and addition of SSDI at Day 10 (Figure 26). The effect on surface oil levels continues after the well is capped at Day 30. The figures illustrate the percentages of oil in the various compartments that make up the total mass of oil remaining at each point in time. They do not represent “quantities” of oil remaining in the environment at the end of 120 days.

Figure 26 Case 1A Summer scenario - mass of oil on sea surface after 120 days. (SIMA OSCAR Model Output)

The effect of ASD alone, and combined ASD and SSDI on oil on the shoreline follows the same pattern, with significant reductions in heavily oiled shorelines (Figure 27).

Figure 27 Case 1A Summer scenario - mass of oil stranded on shoreline after 120 days. (SIMA OSCAR Model Output)
Figure 28 illustrates the mass balance of oil in varying environmental compartments that results from the spill scenario without mitigation, over time, and the change in mass balance that results from the use of ASD and SSDI. Oil at the water surface is reduced by ASD alone, and further reduced when ASD and SSDI are used together, and oil concentrations in the water column increase concomitantly. The combined use of ASD and SSDI decreases oiling of sediments and increases oil biodegradation.
Figure 28 Case 1A Summer scenario - mass balance distribution of oil after 120 days. (SIMA OSCAR Model Output)
5.2.1.5 Summary of Case 1A Summer

Table 5 summarizes model outputs for Case 1A Summer as illustrated in Figures 20-28 above.

Some of the key findings from the hypothetical scenario are:

- The first hit of oil onto a shoreline occurs at 7 days.
- The maximum mass of oil on the shoreline by Day 30 was reduced from 670 tonnes without mitigation to 409 tonnes with combined ASD and SSDI use.
- The maximum mass of oil on the water surface was reduced from 16,180 tonnes without mitigation to 6,327 tonnes with combined ASD and SSDI use.
- The average area covered by emulsified oil on the sea surface was reduced from 6,770 km² without mitigation to 1,963 km² with combined ASD and SSDI use.
- The average mass of oil on the sea surface was reduced from 3,107 tonnes without mitigation to 672 tonnes with combined ASD and SSDI use.

Table 5 Case 1A Summer scenario - summary of deterministic modelling for stranded oil and surface oil.
(SIMA OSCAR Model Output)

<table>
<thead>
<tr>
<th>Deterministic simulations</th>
<th>Well Name: NS1 - Case 1A - Maximum oil on shoreline capping stack scenario (Summer Season)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Dispersant</td>
</tr>
<tr>
<td>Stranded oil</td>
<td></td>
</tr>
<tr>
<td>First shore hit</td>
<td>7.0 days</td>
</tr>
<tr>
<td>Maximum mass of oil on the shoreline</td>
<td>670 tonnes</td>
</tr>
<tr>
<td>Maximum mass of emulsified oil on the shoreline</td>
<td>3,482 tonnes</td>
</tr>
<tr>
<td>Ashore time (maximum mass)</td>
<td>42.01 days</td>
</tr>
<tr>
<td>Length of coastline impacted (at maximum mass ashore)</td>
<td>27.8 km</td>
</tr>
<tr>
<td>Maximum length of coastline impacted</td>
<td>27.81 km</td>
</tr>
<tr>
<td>Ashore time (maximum length)</td>
<td>13.0 days</td>
</tr>
<tr>
<td>Surface Oil</td>
<td></td>
</tr>
<tr>
<td>Maximum mass of oil on the sea surface</td>
<td>16,180 tonnes</td>
</tr>
<tr>
<td>Time of occurrence (maximum surface mass)</td>
<td>32.0 days</td>
</tr>
<tr>
<td>Average mass of oil on sea surface</td>
<td>3,107 tonnes</td>
</tr>
<tr>
<td>Maximum area coverage of emulsified oil (&gt; 0.04 microns) on the sea surface</td>
<td>38,780 km²</td>
</tr>
<tr>
<td>Time of occurrence for maximum area coverage of emulsified oil (&gt;0.04 microns thickness) on the sea surface</td>
<td>60.0 days</td>
</tr>
<tr>
<td>Average area coverage of emulsified oil (&gt;0.04 microns) on the sea surface</td>
<td>6,770 km²</td>
</tr>
<tr>
<td>Maximum area coverage of thick emulsified oil (&gt; 100 microns) on the sea surface</td>
<td>90.3 km²</td>
</tr>
<tr>
<td>Time of occurrence for maximum area coverage of thick emulsified oil (&gt; 100 microns thickness) on the sea surface</td>
<td>32.0 days</td>
</tr>
<tr>
<td>Average area coverage of thick emulsified oil (&gt; 100 microns) on the sea surface</td>
<td>24.6 km²</td>
</tr>
<tr>
<td>Max water content of surface oil</td>
<td>78% %</td>
</tr>
<tr>
<td>Average Mean Viscosity of Surface Oil</td>
<td>55,047 cP</td>
</tr>
</tbody>
</table>

Note: Ashore time (maximum mass) - elapsed time from the beginning of the simulation when the maximum mass of stranded emulsified oil on the shoreline occurs. Ashore time (maximum length) - elapsed time from the beginning of the simulation when the maximum length of shoreline covered with stranded oil occurs.
5.2.2 Comparison of Case 1A Summer to Other Modelling Scenarios

The following tables contain model outputs for the additional scenarios, which include Case 1A Winter (Table 6), Case 2A Summer (Table 7), and Case 2A Winter (Table 8).

5.2.2.1 Case 1A Winter

Some of the key differences in model outputs for Case 1A Winter, as shown in Table 6, include:

- The first shoreline hit occurs earlier at 5 days.
- The maximum mass of emulsified oil on the shoreline is less (239 tonnes for the unmitigated scenario vs. 670 tonnes for the summer season).
- The maximum mass of oil on the sea surface is less (13,870 tonnes versus 16,180 tonnes for unmitigated spill).
- In general, model outputs for mass and coverage followed the same trend with respect to no mitigation, ASD, and SSDI use.
- The ashore time (maximum length) increases from 12 days without mitigation, to 18 days with combined ASD and SSDI use, versus 13 days for all summer season scenarios.
- Several model outputs based on time did not follow the same trend for no mitigation, ASD, and SSDI use.

Table 6 Case 1A Winter scenario - summary of deterministic modelling for stranded oil and surface oil.
(SIMA OSCAR Model Output)
5.2.2.2 Case 2A Summer

Some of the key differences in model outputs for the Case 2A Summer, as shown in Table 7, include:

- The first shore hit occurs later at 12 days.
- The spill is larger (142,902 tonnes versus 99,190 tonnes for Case 1A Summer).
- The ashore time is significantly longer for the unmitigated spill (101 days versus 13 days for Case 1A Summer).
- Combined ASD and SSDI use results in reductions in maximum mass of emulsified oil on the shoreline and all other quantitative surface oil outputs.

Table 7 Case 2A Summer scenario – summary of deterministic modelling for stranded oil and surface oil.
(SIMA OSCAR Model Output)

<table>
<thead>
<tr>
<th>Deterministic simulations</th>
<th>No Dispersant</th>
<th>Aerial Surface Dispersant (ASD) application - Initiated from Day 2</th>
<th>Subarea Dispersant Injection (SSDI) - Initiated Day 10 through Day 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stranded Oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First shore hit</td>
<td>12.0 days</td>
<td>12.0 days</td>
<td>12.0 days</td>
</tr>
<tr>
<td>Maximum mass of oil on the shoreline</td>
<td>669 tonnes</td>
<td>710 tonnes</td>
<td>98 tonnes</td>
</tr>
<tr>
<td>Maximum mass of emulsified oil on the shoreline</td>
<td>3,487 tonnes</td>
<td>3,701 tonnes</td>
<td>511 tonnes</td>
</tr>
<tr>
<td>Ashore time (maximum mass)</td>
<td>32.01 days</td>
<td>53.01 days</td>
<td>54.01 days</td>
</tr>
<tr>
<td>Length of coastline impacted (at maximum mass ashore)</td>
<td>27.8 km</td>
<td>75.5 km</td>
<td>31.8 km</td>
</tr>
<tr>
<td>Maximum length of coastline impacted</td>
<td>79.45 km</td>
<td>87.4 km</td>
<td>35.75 km</td>
</tr>
<tr>
<td>Ashore time (maximum length)</td>
<td>101.0 days</td>
<td>71.0 days</td>
<td>56.0 days</td>
</tr>
<tr>
<td>Surface Oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum mass of oil on the sea surface</td>
<td>33,570 tonnes</td>
<td>17,720 tonnes</td>
<td>11,030 tonnes</td>
</tr>
<tr>
<td>Time of occurrence (maximum surface mass)</td>
<td>25.0 days</td>
<td>25.0 days</td>
<td>32.0 days</td>
</tr>
<tr>
<td>Average mass of oil on sea surface</td>
<td>6,475.6 tonnes</td>
<td>3,449.5 tonnes</td>
<td>1,625.1 tonnes</td>
</tr>
<tr>
<td>Maximum area coverage of emulsified oil (&gt; 0.04 microns) on the sea surface</td>
<td>52,450 km²</td>
<td>27,500 km²</td>
<td>18,960 km²</td>
</tr>
<tr>
<td>Time of occurrence for maximum area coverage of emulsified oil (&gt; 0.04 microns thickness) on the sea surface</td>
<td>62.0 days</td>
<td>62.0 days</td>
<td>32.0 days</td>
</tr>
<tr>
<td>Average area coverage of emulsified oil (&gt; 0.04 microns) on the sea surface</td>
<td>10,030 km²</td>
<td>6,654 km²</td>
<td>4,497 km²</td>
</tr>
<tr>
<td>Maximum area coverage of thick emulsified oil (&gt; 100 microns) on the sea surface</td>
<td>198.4 km²</td>
<td>85.5 km²</td>
<td>38.9 km²</td>
</tr>
<tr>
<td>Time of occurrence for maximum area coverage of thick emulsified oil (&gt; 100 microns thickness) on the sea surface</td>
<td>32.0 days</td>
<td>32.0 days</td>
<td>6.0 days</td>
</tr>
<tr>
<td>Average area coverage of thick emulsified oil (&gt; 100 microns) on the sea surface</td>
<td>58.4 km²</td>
<td>36.1 km²</td>
<td>12.5 km²</td>
</tr>
<tr>
<td>Max water content of surface oil</td>
<td>78%</td>
<td>78%</td>
<td>78%</td>
</tr>
<tr>
<td>Average Mean Viscosity of Surface Oil</td>
<td>53,430 cP</td>
<td>48,791 cP</td>
<td>41,685 cP</td>
</tr>
</tbody>
</table>

5.2.2.3 Case 2A Winter

Some of the key differences in model outputs for Case 2A Winter, as shown in Table 8, include:

- The first shore hit occurs much later at 31 days for the unmitigated scenario, and 73 days when combined ASD and SSDI are used.
• The maximum length of coastline impacted for unmitigated, ASD and combined ASD and SSDI is shorter in Case 2A Winter than for Case 2A Summer.
• In general, combined ASD and SSDI use results in significant differences in oil mass, both on the shoreline and water surface.

Table 8 Case 2A Winter scenario - summary of deterministic modelling for stranded oil and surface oil. (SIMA OSCAR Model Output)

<table>
<thead>
<tr>
<th>Deterministic simulations</th>
<th>Well Name: NS1 - Case 2A - Maximum oil on shoreline capping stack scenario (WinterSeason)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Dispersant</td>
</tr>
<tr>
<td>First shore hit</td>
<td>31.0 days</td>
</tr>
<tr>
<td>Maximum mass of oil on the shoreline</td>
<td>105 tonnes</td>
</tr>
<tr>
<td>Maximum mass of emulsified oil on the shoreline</td>
<td>540 tonnes</td>
</tr>
<tr>
<td>Ashore time (maximum mass)</td>
<td>34.01 days</td>
</tr>
<tr>
<td>Length of coastline impacted (at maximum mass ashore)</td>
<td>15.9 km</td>
</tr>
<tr>
<td>Maximum length of coastline impacted</td>
<td>55.62 km</td>
</tr>
<tr>
<td>Ashore time (maximum length)</td>
<td>110.0 days</td>
</tr>
<tr>
<td>Maximum mass of oil on the sea surface</td>
<td>18,060 tonnes</td>
</tr>
<tr>
<td>Time of occurrence (maximum surface mass)</td>
<td>17.0 days</td>
</tr>
<tr>
<td>Average mass of oil on sea surface</td>
<td>2,760.9 tonnes</td>
</tr>
<tr>
<td>Maximum area coverage of emulsified oil (&gt; 0.04 microns) on the sea surface</td>
<td>42,380 km²</td>
</tr>
<tr>
<td>Time of occurrence for maximum area coverage of emulsified oil (&gt;0.04 microns thickness) on the sea surface</td>
<td>75.0 days</td>
</tr>
<tr>
<td>Average area coverage of emulsified oil (&gt; 0.04 microns) on the sea surface</td>
<td>12,160 km²</td>
</tr>
<tr>
<td>Maximum area coverage of thick emulsified oil (&gt; 100 microns) on the sea surface</td>
<td>63.3 km²</td>
</tr>
<tr>
<td>Time of occurrence for maximum area coverage of thick emulsified oil (&gt; 100 microns thickness) on the sea surface</td>
<td>29.0 days</td>
</tr>
<tr>
<td>Average area coverage of thick emulsified oil (&gt; 100 microns) on the sea surface</td>
<td>15.6 km²</td>
</tr>
<tr>
<td>Max water content of surface oil</td>
<td>78% %</td>
</tr>
<tr>
<td>Average Mean Viscosity of Surface Oil</td>
<td>50,591 cP</td>
</tr>
</tbody>
</table>

5.3 Summary of Modelling Results

The four scenarios examined have some potential to impact Sable Island, and lesser potentials to impact the shorelines of Nova Scotia. The scenario that posed the most immediate threat to Sable Island was Case 1A Winter, which could reach the shoreline within 5 days. However, the largest mass of oil (670 tonnes) that could be deposited occurred during the summer season (Table 5 - Case 1A) for the unmitigated spill, which also had the highest ashore time (maximum mass) of 42 days. The summer season also produced the highest mass on shoreline for Case 2A, at 669 tonnes.

Case 2A was a larger spill (142,902 tonnes versus 99,190 tonnes for Case 1A), and produced the highest ashore time (maximum length of 101 days for unmitigated).
In general, the use of ASD produced reductions in mass and aerial extent of oil on the shoreline, the water surface, and sediment for each of the scenarios modelled, and the combined use of SSDI/ASD produced further reductions. Reductions in oil on the shorelines and the water surface were accompanied by increases in oil concentrations in the water column.

For example, in the Case1A Summer scenario (Figure 20, bar chart):

- **Surface Slick**: ASD application reduced the percentage of the oil on the water surface from 13.2% (unmitigated spill) to 5.5%, and the addition of SSDI reduced the surface oil further to 0.6%. This represents overall surface slick reductions of 58% (ASD) and 95% (combined ASD and SSDI) over the unmitigated spill.
- **Sediments**: ASD application reduced the percentage of oil in the sediment from 4.5% (unmitigated spill) to 1.5%, and the addition of SSDI reduced oil in the sediment further to 1.2%. This represents overall oil reductions in sediment of 67% (ASD) and 73% (combined ASD and SSDI) over the unmitigated spill.
- **Atmosphere**: ASD application reduced the percentage of evaporating oil from 22.5% (unmitigated spill) to 14.9%, and the addition of SSDI reduced evaporation further to 13.6%. This represents overall oil reductions to the atmosphere of 34% (ASD) and 39% (combined ASD and SSDI) over the unmitigated spill.
- **Water Column**: ASD application increased dispersed oil in the water column by 30% and the addition of SSDI further increased oil concentrations in the water column to 37%, when compared to the unmitigated spill. The percentage of oil that was biodegraded (over the first 30 days) increased from 22% without mitigation, to 23.7% and 25.2% with ASD and combined ASD/SSDI use respectively. However, further biodegradation of dispersed oil in the water column would be expected to continue beyond the 30 day modelling run depicted in Figure 20.

The other scenarios produced somewhat varying results, but the overall pattern of impacts observed were the same. Additional modelling results that illustrate projected fate and transport of the unmitigated spill scenario are available in the EIS (2016).

The modelling results for this project demonstrated the potential locations for spill effects exceeding threshold levels beyond the RAA boundary, and in some cases, beyond Canadian jurisdiction. Figure 21 provides a broad view at transboundary effects from an unmitigated spill and mitigated spill (Case 1A Summer). The EIS (2016) assessed these transboundary potentials for the spilled oil. Assuming no mitigation, the model estimates a 16% probability of surface oil resulting as a sheen (0.04 μm surface layer thickness) within the international boundaries of Saint-Pierre et Miquelon (France), which could occur in a minimum of 12 days of a blowout event, but would generally average 34 days for the minimum arrival time. At Site 1 in the summer, the average probability of an unmitigated spill resulting in surface oiling exceeding the threshold level within the US waters is approximately 7% (with a minimal arrival time of approximately 22 days but on average a minimum of 55 days); this average probability increases to 14% for Site 2 in winter with similar minimum arrival times. The average probability of an unmitigated spill resulting in surface oiling exceeding the threshold level within the waters of Bermuda is approximately 2%, with a minimum arrival time of approximately 44 days but on average a minimum of 60 days. As shown in Figure 21, ASD plus SSDI reduced cumulative surface oil coverage and transboundary effects beyond the Canadian jurisdiction compared to no mitigation.
6 Risk-Based Assessment of Response Options

6.1 Potential Effects for No Intervention

The Scotian Basin 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 a resource are briefly summarized in the following paragraphs. More detailed information is provided in the EIS (Sections 8.5.1 to 8.5.6 [Stantec, 2016]).

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 could 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 the eggs, larvae and juveniles of demersal species and other fish species including those in spawning and nursing areas.

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. Zooplankton which cannot avoid exposure are likely to experience oil exposure. In the event that the spill encompasses areas where fish eggs or larvae are located, lethal and sub-lethal effects could occur.

Marine Mammals

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, clogging of baleen plates), inhalation of aerosols of particulate oil and hydrocarbons, and ingestion of contaminated prey (Lee et al., 2015).

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.

The extent of the potential effects depends on how the spill trajectory and marine mammals overlap spatially and temporally. In this SIMA, a 10 μm thick layer of oil on water is used as...
the threshold concentration for potentially lethal effects to marine mammals (French et al., 1996; French-McCay and Rowe, 2004; French McCay, 2009). Marine mammals can congregate in high numbers, thereby potentially increasing impacts.

Very little is known about the impacts of exposure to low concentrations of dispersed oil in the water column on marine mammals. While this is clearly a consideration, the authors have assumed that the exposure to dispersed oil in the water column would be less of a concern than physical oil coating at the waters' surface.

Sea Turtles

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).

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 (French et al., 1996; French-McCay and Rowe, 2004; French McCay, 2009).

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 et al., 1985; Leighton, 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).

**Commercial Fisheries**

Subsea oil spill scenarios considered in this assessment could result in effects on availability of fisheries resources, access to fisheries resources, and/or fouling of fishing or cultivation gear. Hydrocarbons could reach an active fishing area on the Scotian Shelf or shelf break where harvesting activity is more concentrated. Under some circumstances oil could reach coastal locations, potentially interacting with nearshore fisheries and aquaculture operations. As indicated in the EIS (2016), adult free-swimming fish rarely suffer long-term damage from oil spills, primarily due to rapid dispersion and dissolution of the oil. Sedentary species such as edible seaweeds and shellfish, are particularly sensitive to oiling (ITOPF, 2011).

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 levels, variation in fishing effort, climatic effects, or contamination from other sources) making it difficult to assess implications of an oil spill itself (ITOPF, 2011).

**Current Aboriginal Use of Lands and Resources for Traditional Purposes**

Subsea oil spill scenarios considered in this assessment could have an adverse environmental effect on Current Aboriginal Use of Lands and Resources for Traditional Purposes. In particular, an accidental event could impact the fisheries (direct or indirect effects on fished species affecting fisheries success) and/or fishing activity (displacement from fishing areas, gear loss or damage) resulting in a disruption to Traditional Use. In the event of a spill, there could be effects on active offshore FSC activities, nearshore fisheries, and/or on FSC species 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 purposes, a change in habitat traditionally fished by Aboriginal peoples, and/or area closures could disrupt traditional use of marine waters and resources.

**Special Areas**

Special Areas could be compromised due to harm to resources exposed to surface oiling (i.e., 0.04 μm surface oiling), stranded oil (1 g/m²), and heavy oiling (> 10 mm thickness). Surface oiling within the Special Areas, such as Gully MPA and Scotian Slope EBSA, would be mostly limited to the surface and mixed layer of the water column. Sub-lethal and lethal effects to
eggs and larvae that drift in the mixed surface layer of the water column may result following exposure to entrained oil, above the 58 ppb and 200 ppb in-water concentrations, respectively.

Environmental effects from stranded oil on migratory birds on Sable Island (including the Roseate Tern) are described in Sections 8.3 and 5.2.10 of the EIS). Sable Island hosts the largest breeding colony of grey seals in the world, a population of wild horses, contains one of the largest dune systems in eastern North America, hosts a number of species at risk and endemic species, and exhibits an extremely dynamic ecology (Freedman, 2014). Recovery rate of sand beaches (e.g., recovery of vegetation or structure) following oiling is variable, depending on conditions and initial disturbance during spill response, but is assumed to occur within approximately three years (French-McCay, 2009).

6.2 Risks Associated with Dispersants and Dispersed Oil Exposure

6.2.1 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 EC9500A 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 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 very low.

This SIMA assumes that a properly deployed dispersant operation uses visual monitoring (e.g., ROVs or spotter aircraft) to ensure that dispersants are properly 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 risk of not dispersing the oil. Dispersed oil exposures in the water are the predominate exposure pathway for environmental considerations. Controlled studies at wave basins, such as the test facility used by DFO, and monitoring after actual spills, such as the Sea Empress and DWH incidents, has shown that sediments rarely have accumulations of dispersed oil at levels that pose environmental concerns. This is because dispersed oil is much less “sticky” than untreated oil, and therefore does not easily adhere to sediments.

The toxicity of dispersed oil in the water column is related to three factors (Chapter 7 [BP Dispersant Manual, 2014]):

- Exposure concentrations that develop after the oil is spilled and treated
• Duration of exposure
• 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, but are also volatile and tend to evaporate rapidly. Other compounds that make up the oil are partially soluble, and are released slowly into the water column. These compounds are known collectively as the “water accommodated fraction,” or WAF. 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 (when SSDI operations were occurring) 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 deepsea 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). 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 will 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, but those concentrations rapidly dilute to below 10 ppm within the first hour and to less than 1 ppm within a few hours. 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 29 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.
During the DWH incident, SSDI was used almost continuously, and concentrations of dispersed oil were monitored throughout the duration of the response. Due to potential conflicts with response operations and safety concerns, most of the subsea monitoring was conducted outside of a surface vessel exclusion zone of 1 km from the well head. Beyond the 1 km surface vessel 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 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 results are still preliminary, a recent 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 30, 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 30 Species sensitivity distribution comparing a deep sea species (sablefish) to other organisms LC50s when exposed to ANS dispersed oil. (Naile, 2016)

A more robust discussion on the role of dispersants, the principles of chemical dispersion, and the factors that affect dispersant effectiveness is provided in Appendix B. In addition, a recent publication summarizes information on the sensitivity on Arctic species to physically and chemically dispersed oil (Bejarano et al., 2017).

6.2.2 Biodegradation

Specific effects to deep water micro-organisms from SSDI is 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 metres) are colonized by deep water microbial communities (Figure 31).
Within a few days following an oil spill, the populations 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, 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 incident 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 creates 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 recent 2014 laboratory flume study by Brakstad et al. (2014) in Norway assessed degradation rates of physically and chemically dispersed Macondo oil. This study demonstrated that 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 32 (Brakstad et al., 2014).

![Figure 32 Biodegradation rates of physically dispersed versus chemically dispersed Macondo Oil based on laboratory plume studies conducted by SINTEF.](Brakstad et al., 2014)

A recent 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 recent 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. Likewise, in a BP-funded 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 mesocosm study. A more recent 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 BP project area. Even more recently, modelling work by French-McCay et al. (2017) 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

Other studies have confirmed that these findings are not limited to the relatively warm, nutrient rich waters of the Gulf of Mexico. Hazen (2016) reported that oil degrading bacteria occur in virtually all of the world’s 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 the DWH incident. Campeao (2017) found that the autochthonous 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 the DWH incident 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, but appear to be 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 Analysis 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). The newly drafted risk method uses a single comparative matrix instead of the more typical square risk reporting matrix. This new method incorporates four elements: 1) Potential Relative Impact Assessment; 2) Impact Modification Factor; 3) Relative Impact Mitigation Score using mean compartment impact scores, if
necessary, 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 Scotian Basin 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 Matrix (Table 14) needs to be quickly revised for a future spill exercise or actual incident.

The resource categories for the risk assessment include:

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

The emphasis on this SIMA is to develop a ‘process’. The above categories include species at risk, Special Areas and EBSAs. During a spill, actual slick surveillance would identify which species at risk, Special Areas or EBSAs might be affected, and those 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.

The EBSAs and Special Areas should be used to prioritize the application of response tactics during an ongoing spill response. For example, in this SIMA, when evaluating the oil trajectories, the Haddock Box was considered when developing the score for fish impacts in the water column on the Shelf. However, during an actual spill event, the stakeholders might identify the Haddock Box as a priority protection area, and would prioritize the use of response assets (mechanical recovery, surface dispersants, or both) to prevent oil from floating over the Haddock Box. Alternatively, there could be a decision to set up an aerial dispersant exclusion zone around this box to prevent oil from being dispersed into the water column in this particular area. These decisions must come from the stakeholder and designated agencies, and are outside of the scope of this SIMA. As stated in the Preface, this SIMA focuses on a holistic approach to the protection of the environment as a whole, not on the protection of individuals or specific species.

Following are the steps for the single comparative matrix process, which analyzes the impacts of oil spill response options described in Section 3 against the Scotian Basin resource categories. For 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. 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 Project Area, such as sensitive ecosystems, critical habitats, protected species and particular VC designations, 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 no intervention to the oil spill occurs (also referred to as Natural Attenuation). Table 9 shows the potential relative impact assessment developed for the Scotian Basin SIMA. Section 2 (Stage 2 – Predict Outcomes) and Appendix 1 of the IPIECA Guidelines (2017) provides guidelines to assessing relative impact.
2. Impact Modification Factor

As each feasible response option is evaluated, it is assigned an impact modification factor, as shown in Table 10, to indicate the level of impact a given response could affect a resource category when compared to the no intervention option. For purposes

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**Table 9 Potential Relative Impact Assessment.**

<table>
<thead>
<tr>
<th>Resource Categories</th>
<th>Spatial Scale</th>
<th>No Intervention</th>
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<tbody>
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<td></td>
<td></td>
<td>Potential relative impact</td>
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<tr>
<td>Shoreline (Sable Island)</td>
<td></td>
<td>Birds R</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Invertebrates L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marine Mammals R</td>
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<tr>
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<td></td>
<td>Birds R</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Invertebrates L</td>
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<tr>
<td></td>
<td></td>
<td>Marine Mammals R</td>
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<tr>
<td></td>
<td></td>
<td>Vegetation L</td>
</tr>
<tr>
<td>Surface</td>
<td></td>
<td>Fish (eggs/larvae) L</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td>Sea Turtles R</td>
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<tr>
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<td>Seabirds R</td>
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<tr>
<td>Water Column</td>
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<td>Fish R</td>
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<td>Sea Turtles R</td>
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<tr>
<td></td>
<td></td>
<td>Seabirds (diving) R</td>
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<tr>
<td>Benthos</td>
<td></td>
<td>Fish R</td>
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<td></td>
<td></td>
<td>Invertebrates L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corals and Sponges L</td>
</tr>
<tr>
<td>Socio-economic</td>
<td></td>
<td>Commercial Fisheries R</td>
</tr>
<tr>
<td>Cultural and Subsistence</td>
<td></td>
<td>Aboriginal Fisheries R</td>
</tr>
</tbody>
</table>

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*Local (L); Regional (R)*

*Based on the top 100 m of the water column, as described in the modeling results.*
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 - shoreline protection and recovery, on-water mechanical recovery, ISB, ASD and ASD/SSDI - based on a qualitative review of published information and professional judgement for each of the ecological, socio-economic and indigenous resources when compared to the no intervention option. 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 Appendix 2 of the IPIECA Guidelines (2017) provides guidelines to assigning impact modification factors.

Table 10 Impact Modification Factor.

<table>
<thead>
<tr>
<th>Impact Modification Factor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+4</td>
<td>Major mitigation of impact</td>
</tr>
<tr>
<td>+3</td>
<td>Moderate mitigation of impact</td>
</tr>
<tr>
<td>+2</td>
<td>Minor mitigation of impact</td>
</tr>
<tr>
<td>+1</td>
<td>Negligible mitigation of impact</td>
</tr>
<tr>
<td>0</td>
<td>No alteration of impact</td>
</tr>
<tr>
<td>-1</td>
<td>Negligible additional impact</td>
</tr>
<tr>
<td>-2</td>
<td>Minor additional impact</td>
</tr>
<tr>
<td>-3</td>
<td>Moderate additional impact</td>
</tr>
<tr>
<td>-4</td>
<td>Major additional impact</td>
</tr>
</tbody>
</table>

3. Relative Impact Mitigation Scores

For each resource category, the Numerical Relative Impact value (Table 9) is multiplied by the associated Impact Modification Factor (Table 10) to create a relative impact mitigation score for a response option, as shown in Table 11. 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.

The Scotian Basin 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 11 Relative Impact Mitigation scores.

<table>
<thead>
<tr>
<th>Resource Categories</th>
<th>Spatial Scale</th>
<th>No Intervention</th>
<th>Response Option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Potential relative impact</td>
<td>Numerical relative impact</td>
</tr>
<tr>
<td>Shoreline (Sable Island)</td>
<td></td>
<td>Birds R</td>
<td>High 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Invertebrates L</td>
<td>Med 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marine Mammals R</td>
<td>High 4</td>
</tr>
<tr>
<td></td>
<td>Shoreline (SI) Compartment Average</td>
<td>Birds R</td>
<td>Med 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Invertebrates L</td>
<td>Low 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marine Mammals R</td>
<td>Low 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vegetation L</td>
<td>Low 2</td>
</tr>
<tr>
<td></td>
<td>Shoreline (NS) Compartment Average</td>
<td>Birds R</td>
<td>Med 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Invertebrates L</td>
<td>Low 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marine Mammals R</td>
<td>Low 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vegetation L</td>
<td>Low 2</td>
</tr>
<tr>
<td>Surface</td>
<td></td>
<td>Fish (eggs/larvae) L</td>
<td>High 4</td>
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<tr>
<td></td>
<td></td>
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<td>High 4</td>
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<td></td>
<td>Sea Turtles R</td>
<td>High 4</td>
</tr>
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<td></td>
<td></td>
<td>Seabirds R</td>
<td>High 4</td>
</tr>
<tr>
<td></td>
<td>Surface Compartment Average</td>
<td>Fish R</td>
<td>Low 2</td>
</tr>
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<td></td>
<td>Marine Mammals R</td>
<td>Low 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sea Turtles R</td>
<td>Low 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seabirds (diving) R</td>
<td>Low 2</td>
</tr>
<tr>
<td></td>
<td>Water Column Compartment Average</td>
<td>Fish R</td>
<td>Low 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marine Mammals R</td>
<td>Low 2</td>
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<tr>
<td></td>
<td></td>
<td>Sea Turtles R</td>
<td>Low 2</td>
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<tr>
<td></td>
<td></td>
<td>Seabirds (diving) R</td>
<td>Low 2</td>
</tr>
<tr>
<td>Benthos</td>
<td></td>
<td>Fish R</td>
<td>None 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Invertebrates L</td>
<td>Low 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corals and Sponges L</td>
<td>Low 2</td>
</tr>
<tr>
<td></td>
<td>Benthos Compartment Average</td>
<td>Fish R</td>
<td>None 1</td>
</tr>
<tr>
<td>Socio-economic</td>
<td></td>
<td>Commercial Fisheries R</td>
<td>High 4</td>
</tr>
<tr>
<td>Indigenous</td>
<td></td>
<td>Aboriginal Fisheries R</td>
<td>High 4</td>
</tr>
</tbody>
</table>

a Local (L); Regional (R)

b Based on the top 100 m of the water column, as described in the modeling results.

Within each resource category, a mean score is then calculated across environmental compartments. This step allows resource categories such as “Surface”, which contains four environmental compartments (e.g., fish, marine mammals, sea turtles, seabirds)
to be compared without bias to categories such as “Socio-economic”, which contain 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. For the Scotian Basin SIMA, Table 12 displays the colour code as a scale from red to green indicating major increase in impact to major impact mitigation.

Table 12 Range of scores colour coding.

<table>
<thead>
<tr>
<th>Range of Scores</th>
<th>Colour Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+16 to +20</td>
<td>Green</td>
<td>Major mitigation of impact</td>
</tr>
<tr>
<td>+11 to +15</td>
<td>Green</td>
<td>Moderate mitigation of impact</td>
</tr>
<tr>
<td>+6 to +10</td>
<td>Green</td>
<td>Minor mitigation of impact</td>
</tr>
<tr>
<td>+1 to +5</td>
<td>Green</td>
<td>Negligible mitigation of impact</td>
</tr>
<tr>
<td>0</td>
<td>Yellow</td>
<td>No alteration of impact</td>
</tr>
<tr>
<td>-5 to -1</td>
<td>Yellow</td>
<td>Negligible increase in impact</td>
</tr>
<tr>
<td>-10 to -6</td>
<td>Yellow</td>
<td>Minor increase in impact</td>
</tr>
<tr>
<td>-15 to -11</td>
<td>Brown</td>
<td>Moderate increase in impact</td>
</tr>
<tr>
<td>-20 to -16</td>
<td>Red</td>
<td>Major increase in impact</td>
</tr>
</tbody>
</table>

4. Total Impact Mitigation Scores

The Total Impact Mitigation scores are the totals of the mean environmental compartment scores for each response option, located on the bottom row of the table, as shown in Table 13. This overall score is a qualitative prediction of how each response option might mitigate the overall impacts when compared to no intervention for a specific scenario. Section 2 (Stage 4 - Select Best Response Options) and Appendix 3 of the IPIECA Guidelines (2017) provides guidelines on using the finalized comparative risk matrix.

For the Scotian Basin SIMA, the total mitigation scores are generated for each of the feasible response options, which include shoreline protection, on-water mechanical recovery, in-situ burn, surface dispersant, and combined surface/subsea dispersant.
Table 13 Total Impact Mitigation scores.

<table>
<thead>
<tr>
<th>Resource Categories</th>
<th>Spatial Scale&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Potential relative impact</th>
<th>Numerical relative impact</th>
<th>Impact modification factors</th>
<th>Relative impact mitigation score</th>
<th>Impact modification factors</th>
<th>Relative impact mitigation score</th>
<th>Impact modification factors</th>
<th>Relative impact mitigation score</th>
<th>Impact modification factors</th>
<th>Relative impact mitigation score</th>
<th>Impact modification factors</th>
<th>Relative impact mitigation score</th>
</tr>
</thead>
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<td>High</td>
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<tr>
<td></td>
<td>Invertebrates</td>
<td>L</td>
<td>Med</td>
<td>3</td>
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<td>4</td>
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<td>Shoreline (Nova Scotia)</td>
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<td></td>
<td>Vegetation</td>
<td>L</td>
<td>Med</td>
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<td>Shoreline (NS) Compartment Average</td>
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<tr>
<td>Surface</td>
<td>Fish (eggs/larvae)</td>
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<td>4</td>
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<td>Marine Mammals</td>
<td>R</td>
<td>Low</td>
<td>2</td>
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<tr>
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<td>Seabirds (diving)</td>
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<td>2</td>
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<td>Water Column Compartment Average</td>
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</tr>
<tr>
<td>Socio-economic</td>
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<td>R</td>
<td>High</td>
<td>4</td>
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</tr>
</tbody>
</table>

<sup>a</sup> Local (L); Regional (R)

<sup>b</sup> Based on the top 100 m of the water column, as described in the modeling results.

<sup>c</sup> Surface dispersant only for days 2 - 9; surface and subsea dispersants for days 10-30.
6.4 Risk Assessment Results

A single comparative risk matrix for the response options was generated for the Case 1A Summer scenario (see Section 6.4.1), taking into consideration the resources of concern identified in Table 3 for the Scotian Basin area. The oil spill scenario for the Case 1A Summer 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 that season. The results for the Case 1A Summer scenario were then reviewed and compared to the differing weather, hydrological, and resources at risk described for the other three spill scenarios. While there were some differences in those factors, they were not significant enough to change the results of the risk assessment. For that reason, rather than prepare separate comparative matrices for each scenario, the comparative matrix for the Case 1A Summer scenario was used as a baseline, and any variation from scores in that matrix are discussed in Section 6.4.2.

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 (no intervention). Thus, the first step in the process was to assign relative risks, and associated numerical scores (numerical relative impact) for the no intervention option, 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.

Sable island is unique in that the modelled spill scenario demonstrated far more rapid, and heavier shoreline oiling than any other shoreline area in the study area. For that reason, it was evaluated separately from the Nova Scotia shoreline. For this analysis, the shoreline includes the intertidal area. The Water Column category for this analysis was assumed to be the upper 100 m, since modelling results indicated significant oiling in that area, and environmental impacts could be relatively higher. The Benthos category is the sea floor and includes the sediments. The modelling results assume mixing of oil into the substrate to a depth of 5 cm.

The Socio-economic category pertained only to commercial fishing. Likewise, the Indigenous resource category impacts were assumed to be limited to Aboriginal fishing.

As discussed in 6.3, for this SIMA, species at risk, Special Areas and EBSAs were considered during the evaluation, but not scored separately.

Relative Risks of No Intervention

The no intervention option was found to pose the highest risk (4) for all resource categories except the water column and benthos. On the shoreline and water surface, oil poses a high level of risk through exposure pathways including ingestion, dermal contact, and inhalation. A significant adverse residual environmental effect is predicted for Marine Mammals for this scenario due to the probability of interaction with breeding seals on Sable Island and marine mammal species at risk inhabiting the affected area.
At the water surface, plankton, floating eggs, and larvae were deemed particularly sensitive. Diving birds and aquatic mammals also have the potential to be exposed. In addition, oil can coat the fur and feathers of marine mammals and birds, and result in hypothermia. In this Case 1A Summer scenario, heavy oiling occurred on Sable Island, and much smaller quantities of oil reached the Nova Scotia shoreline. Oil that did reach Nova Scotia would be highly weathered, given the great distance traveled from the spill release site. Roseway Basin (North Atlantic right whale critical habitat) had low probability of surface oiling, while the Gully MPA had a higher likelihood.

Left unmitigated, the amounts of oil entering the water column and benthos were relatively small, so the risk scores were lower (2) for all resource categories. In the Benthos category, little exposure to oil is expected, 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. In the Case 1A Summer scenario, some oil is expected to reach the benthos through sedimentation in areas to the northeast of the spill site, approaching Sable Island, but the overall quantities of oil are expected to be low (from mass balance modelling, Figure 25).

In the Socio-economic and Indigenous 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, 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.

6.4.1 Comparative Risk Matrix

Using the risk methodology explained in Section 6.3 and the impact modification factors and Colour Coding described in Tables 10 and 12, the comparative matrix for Case 1A Summer was developed, as shown in Table 14.
### Table 14 Comparative Risk Matrix

#### Case 1 A Summer Season Scenario

**Spill Modeling Start Date: June 19, 2006**

#### BP Scotian Basin SIMA

| Resource Categories | Spatial Scale | Potential relative impact | Numerical relative impact | Impact modification factors | Relative impact mitigation score | Impact modification factors | Relative impact mitigation score | Impact modification factors | Relative impact mitigation score | Impact modification factors | Relative impact mitigation score | Impact modification factors | Relative impact mitigation score | Impact modification factors | Relative impact mitigation score |
|---------------------|--------------|---------------------------|---------------------------|----------------------------|--------------------------------|-------------------------------|--------------------------------|-------------------------------|--------------------------------|-------------------------------|--------------------------------|-------------------------------|--------------------------------|-------------------------------|-------------------------------|--------------------------------|
| **Shoreline (Sable Island)** |             |                           |                           |                            |                                |                               |                                |                               |                                |                               |                               |                               |                               |                               |                               |
| Birds R High        | 4            | 0                         | 0                         | +1                         | 4                              | +1                            | 4                              | +3                            | 12                             | +4                            | 16                             | +4                            | 16                             | +4                            | 16                             |
| Invertebrates L Med | 3            | 0                         | 0                         | +1                         | 3                              | +1                            | 3                              | +3                            | 9                              | +4                            | 12                             | +4                            | 12                             | +4                            | 12                             |
| Marine Mammals R High | 4          | 0                         | 0                         | +1                         | 4                              | +1                            | 4                              | +3                            | 12                             | +4                            | 16                             | +4                            | 16                             | +4                            | 16                             |
| Shoreline (SI) Compartment Average | | 0                          | 4                         | 6                           | +1                            | 3                              | +1                            | 3                              | +3                            | 6                              | +4                            | 16                             | +4                            | 16                             | +4                            | 16                             |
| **Shoreline (Nova Scotia)** |             |                           |                           |                            |                                |                               |                                |                               |                                |                               |                               |                               |                               |                               |                               |
| Birds R Med         | 3            | +2                        | 6                         | +1                         | 3                              | +1                            | 3                              | +2                            | 6                              | +3                            | 9                              | +3                            | 9                              | +3                            | 9                              |
| Invertebrates L Low | 2            | +2                        | 4                         | +1                         | 2                              | +1                            | 2                              | +2                            | 4                              | +3                            | 6                              | +3                            | 6                              | +3                            | 6                              |
| Marine Mammals R Low | 2           | +2                        | 4                         | +1                         | 2                              | +1                            | 2                              | +2                            | 4                              | +3                            | 6                              | +3                            | 6                              | +3                            | 6                              |
| Vegetation L Low    | 2            | +2                        | 4                         | +1                         | 2                              | +1                            | 2                              | +2                            | 4                              | +3                            | 6                              | +3                            | 6                              | +3                            | 6                              |
| Shoreline (NS) Compartment Average | | 5                          | 2                         | 6                           | +1                            | 3                              | +1                            | 3                              | +2                            | 6                              | +3                            | 9                              | +3                            | 9                              | +3                            | 9                              |
| **Surface**         |             |                           |                           |                            |                                |                               |                                |                               |                                |                               |                               |                               |                               |                               |                               |
| Fish (eggs/larvae) L High | 4           | 0                         | 0                         | +1                         | 4                              | +1                            | 4                              | +3                            | 12                             | +4                            | 16                             | +4                            | 16                             | +4                            | 16                             |
| Marine Mammals R High | 4           | 0                         | 0                         | +2                         | 8                              | +2                            | 8                              | +3                            | 12                             | +4                            | 16                             | +4                            | 16                             | +4                            | 16                             |
| Sea Turtles R High  | 4            | 0                         | 0                         | +2                         | 8                              | +2                            | 8                              | +3                            | 12                             | +4                            | 16                             | +4                            | 16                             | +4                            | 16                             |
| Seabirds R High     | 4            | 0                         | 0                         | +1                         | 4                              | +1                            | 4                              | +3                            | 12                             | +4                            | 16                             | +4                            | 16                             | +4                            | 16                             |
| Surface Compartment Average | | 0                          | 6                         | 6                           | +1                            | 2                              | +1                            | 2                              | +2                            | 4                              | +3                            | 6                              | +3                            | 6                              | +3                            | 6                              |
| **Water Column**    |             |                           |                           |                            |                                |                               |                                |                               |                                |                               |                               |                               |                               |                               |                               |
| Fish R Low          | 2            | 0                         | 0                         | +1                         | 2                              | +1                            | 2                              | -3                            | -6                             | -8                            | -8                             | -8                            | -8                             | -8                            | -8                             |
| Marine Mammals R Low | 2           | 0                         | 0                         | +1                         | 2                              | +1                            | 2                              | -2                            | -4                             | -6                            | -6                             | -6                            | -6                             | -6                            | -6                             |
| Sea Turtles R Low   | 2            | 0                         | 0                         | +1                         | 2                              | +1                            | 2                              | -2                            | -4                             | -6                            | -6                             | -6                            | -6                             | -6                            | -6                             |
| Seabirds (diving) R Low | 2           | 0                         | 0                         | +1                         | 2                              | +1                            | 2                              | -2                            | -4                             | -6                            | -6                             | -6                            | -6                             | -6                            | -6                             |
| Water Column Compartment Average | | 0                          | 2                         | 2                           | +1                            | 1                              | +1                            | 1                              | +1                            | 2                              | +2                            | 4                              | +2                            | 4                              | +2                            | 4                              |
| **Benthos**         |             |                           |                           |                            |                                |                               |                                |                               |                                |                               |                               |                               |                               |                               |                               |
| Fish R None         | 1            | 0                         | 0                         | 0                            | 0                              | 0                              | 0                              | 0                             | 0                              | 0                             | 0                              | 0                             | 0                              | 0                             | 0                              |
| Invertebrates L Low | 2            | 0                         | 0                         | +1                         | 2                              | +1                            | 2                              | -1                            | 2                              | +1                            | 2                              | +1                            | 2                              | +1                            | 2                              |
| Corals and Sponges L Low | 2           | 0                         | 0                         | +1                         | 2                              | +1                            | 2                              | -1                            | 2                              | +1                            | 2                              | +1                            | 2                              | +1                            | 2                              |
| Benthos Compartment Average | | 0                          | 1                         | 1                           | 1                              | 1                              | 1                              | 1                             | 1                              | 1                             | 1                              | 1                             | 1                              | 1                             | 1                              |
| **Socio-economic**  |             |                           |                           |                            |                                |                               |                                |                               |                                |                               |                               |                               |                               |                               |                               |
| Commercial Fisheries R High | 4           | +1                        | 4                         | +1                         | 4                              | +1                            | 4                              | +3                            | 12                             | +3                            | 12                             | +3                            | 12                             | +3                            | 12                             |
| Indigenous          |             |                           |                           |                            |                                |                               |                                |                               |                                |                               |                               |                               |                               |                               |                               |
| Aboriginal Fisheries R High | 4           | +1                        | 4                         | +1                         | 4                              | +1                            | 4                              | +3                            | 12                             | +3                            | 12                             | +3                            | 12                             | +3                            | 12                             |

| Total               | 13           | 23                        | 23                        | 48                           | 58                             |                                |                               |                               |                                |                               |                               |                               |                               |                               |                               |

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**Notes:**

- **a** Local (L); Regional (R)
- **b** Based on the top 100 m of the water column, as described in the modeling results.
- **c** Surface dispersant only for days 2-9; surface and subsea dispersants for days 10-30.
The following paragraphs describe how each response option was assigned an impact modification factor from Table 10 to indicate the level of impact a given response could have on a resource category compared to the no intervention option.

6.4.1.1 Shoreline Protection and Recovery

For purposes of this SIMA, shoreline protection and recovery is defined as the placement of booms and any other mechanical diversion devices in strategic locations that will prevent oil from reaching particularly sensitive areas. Such devices may herd oil into areas where it can be recovered with skimmers or other mechanical devices. The Shoreline Protection and Recovery response method is described in Section 3.2.

For the Case 1A Summer scenario, oil is expected to reach the Sable Island shoreline in 7 days. Due to the short lead time available, and the low gradient, shifting, sandy shorelines of Sable Island, it is extremely unlikely that shoreline protection and recovery could be used effectively. The BP “Shoreline Response Program Tactical Response Plan (OSRP Annex D, pp 32-34) lists the possible construction of a sand barrier, but it is unlikely this could be completed before initial oiling has already occurred on the island. Protective booming is not practical in this area. The Nova Scotia shoreline is more conducive to boom placement, but the overall probability of oil reaching that shoreline is very low. For these reasons, mitigation scores of 0 and +2 were assigned to Sable Island and the Nova Scotia Shoreline, respectively. In the event shoreline protection and recovery could be implemented, it could prevent oil from reaching sensitive shoreline areas, as well as prevent re-floating or entrainment of oil from shoreline areas due to tidal action. It is also possible that some coastal areas that may be important for clam and crab fishing could be protected, so a score of +1 was assigned to Commercial and Aboriginal fisheries.

6.4.1.2 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 encountered from the ecosystem, and is therefore a preferred option when it can be effectively deployed. For the scenario evaluated here, however, relatively high wave heights, long distances from shore, and low oil encounter rates severely reduce the efficiency of this method. During the DWH incident, 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, 3% was conservatively used as the assumed oil recovery rate due to weather conditions that are less favorable than those during the DWH incident.

The greatest mitigation impact for on-water mechanical recovery would occur at the water surface. A negligible impact modification factor of +1 was assigned for fish eggs/larvae near the surface with no mobility and seabirds in the vicinity. A minor mitigation factor of +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. 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 an impact mitigation value of +1 was assigned to all water column organisms. Finally, there would be negligible alteration of impact to the Benthos category.
6.4.1.3 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, and mean wave heights in the study area typically 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 very low probability that it could be utilized. For reference, during the DWH incident, 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 study area 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 mechanical recovery. There were minor benefits (+2) to the marine mammals and sea turtles at the surface due to the removal of some quantity of oil and negligible benefits (+1) to the Shoreline, Water Column, Benthos, Air, Socio-economic, and Indigenous categories.

6.4.1.4 Surface Dispersants

The Surface Dispersants response method is described in Section 3.5. For the surface dispersant response method, described as ASD in this document, both aircraft and vessel application systems were assumed to be viable. Vessel based spraying would probably be conducted close to the oil release point, where workers may be involved in well containment activities. As with the previously discussed response methods, this method can only be conducted during daylight hours. Due to the high oil encounter rate, large amounts of oil could be treated and dispersed into the water column, so the mitigation factor assigned to the Surface category was moderate (+3), as shown in Figure 20’s snapshot maps and mass balance charts. For example, ASD use decreases surface oil, which mitigates marine birds and diving seabird 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, Special Areas and EBSAs.

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, vertical migrating fish, and epipelagic fish at that depth. However, the majority of fish species on the Scotian Shelf and Slope spawn in a variety of large areas, over long time scales, and a spill is not predicted to encompass all of these areas or time scales within the RAA 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. 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. 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 exposure alone.

Modelling suggested that a slight reduction in exposures to the benthos category should occur due to the reduction in oil reaching the sediment. As a result, impact scores of +1 were assigned to the corals, sponges, and invertebrates. Dispersant spraying can have a decreased impact due to airborne VOC concentrations on air breathing organisms since large amounts of oil can be removed from the water surface. Commercial 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 would likely 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 commercial fishing bans. A moderate mitigation score of +3 was assigned. Since Aboriginal fishing can occur in the similar areas as commercial fishing, the same score of +3 was assigned.

Field monitoring, using a protocol like SMART (see textbox in Section 3.5), is suggested to confirm if the aerial dispersant operation is working as expected. Additionally, real-time monitoring of surface water hydrocarbon concentrations (in the top 10 m) can help validate predicted (modelled) concentrations and is essential for informing ongoing SIMA discussions during the response. Operational field data should be collected and interpreted quickly so that results can inform ongoing response planning cycles. This data is invaluable when assessing decisions about the continued use of aerial dispersants (e.g., is the dispersant application effective? and is it achieving the expected results?).

6.4.1.5 Combined Surface (ASD) and Subsea Dispersant (SSDI) Application

For this response option, all ASD dispersant application methods are assumed to continue after Subsea Dispersant Application (SSDI) is initiated. SSDI differs from all other response methods 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, implemented on Day 10.

The relative impact mitigation scores changed in the same pattern that was observed for the surface dispersant spraying category. In general, positive mitigation scores increased slightly for all Shoreline and Surface resources and stayed the same as ASD for Air, Socio-economic and Commercial categories. Negative impacts to organisms in the water column all increased due to oil that was dispersed into deeper portions of the water column by SSDI, which also includes species at risk, Special Areas and EBSAs.

The combined ASD and SSDI applications could cause oil to disperse in the water column to a depth of around 10 m from ASD and deeper in water column regions from SSDI. Higher oil exposures could occur to 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 fish due primarily to impacts on their eggs, larvae, and sensitive life stages. However, it should be noted that the majority of fish species on the Scotian Shelf and Slope spawn in a variety of large areas, over long time scales, and a spill is not predicted to encompass all of these areas or time scales.
within the RAA to such a degree that natural recruitment of juvenile organisms may not re-
establish the population(s) to their original level within one generation.

Diving seabirds, mammals, and sea turtles were assigned a moderate impact score of -3, since exposures would likely be more, compared the no intervention levels for these mobile marine organisms. 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.

The modelling study showed that the combined use of ASD and SSDI resulted in a reduction of 95% of the oil on the surface when compared to the unmitigated scenario, as shown in Figure 20. ASD and SSDI can prevent large quantities of oil from surfacing and in this study, resulted in a 40% decrease in the quantity of oil evaporating into the atmosphere. As with ASD alone, a moderate mitigation (+3) is expected for the Socio-economic category (Commercial Fisheries) and Indigenous (Aboriginal fisheries) because oil is prevented from surfacing, and biodegradation rates are accelerated, which could shorten commercial fishing bans. 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 commercial fisheries, which is a socio-economic impact on the fishermen. 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 of fishing bans.

The reduction in oil present at the water surface also results in a reduction in the quantity of oil potentially reaching the shoreline. In the Case 1A Summer scenario, the high levels of oil that were removed from the water surface resulted in correspondingly high reductions in the quantities of oil reaching the shorelines of Sable Island and Nova Scotia. This resulted in high positive impact scores (+4) for birds, marine mammals, and invertebrates for Sable Island, and moderate positive impact scores (+3) for the same organisms, plus aquatic vegetation along the less likely to be oiled Nova Scotia shoreline. This resulted in moderate positive impact scores for birds, marine mammals, and invertebrates, plus aquatic vegetation for less likely oiled areas along the Nova Scotia shoreline.

In addition to SMART monitoring for ASD (described in the previous section), 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 deduct a slight depletion in oxygen concentrations in the dispersed oil plumes, but not to levels that would result in hypoxia (JAG NOAA, 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.

6.4.2 Impact of Alternative Scenarios on Risk Rankings

In this section, the relative impacts of changing scenario conditions on the Comparative Risk Matrix scoring for the response methods considered are examined. Model outputs for three
other scenarios — Case 1A Winter, Case 2A Summer, and Case 2A Winter — are summarized in Section 5.2.2.

6.4.2.1 Case 1A Winter

The winter season used for this study encompasses November through April. The same release scenario and location were used as for Case 1A Summer. Because of more adverse weather conditions, all response methods that relate to surface oil have lower encounter rates, on a daily basis, and were found to be less efficient than during the summer season. The primary differences in spill behaviour and environmental conditions that would influence risk scoring are as follows:

- Mean wave heights are higher (3.12 m versus 1.84 m during the summer season).
- Winds are more frequently from the East, versus Northeast for the summer season.
- The relative abundance of sensitive environmental receptors is lower.
- The first shore hit occurs earlier at 5 days rather than 7, leaving less time to implement an initial response.
- The maximum mass of emulsified oil that reaches the shoreline is less, at 239 tonnes rather than 670 tonnes.
- The maximum mass on the sea surface is less, at 13,870 tonnes, versus 16,180 tonnes.

The variation in weather conditions had the net effect of increasing natural oil dispersion and evaporation, which resulted in a reduction of oil quantities on the surface, and shoreline, and an increase in oil quantities in the sediments, water column, and atmosphere. Those impacts are illustrated in the mass balance illustrations for the summer and winter seasons, 30 days after the start of the spill (Figure 33).

Figure 33 Comparison of oil mass balance for Case 1A Winter (left) and Summer (right), 30 days after the spill, with no intervention.
(SIMA OSCAR Model Output)
For the no intervention response option, the impacts to Sable Island are nearly the same, although less oil reaches the shoreline. Oil quantities are lower on the surface, and higher in the water column, but the locations and spill behaviour are not markedly different. Since the changes in oil transport and fate are not significantly different for the summer and winter conditions, the ratings for spatial scales (local versus regional), and numerical relative impacts should not change for the winter condition.

The higher winds, mean wave height, and more easterly wind direction, as well as shorter daylight hours, would have the effect of increasing the difficulty of implementing shoreline protection measures. Since that method was already rated as negligible to low on the comparative risk matrix, the scoring would likely not change.

The higher mean wave heights and shorter daylight hours would also reduce the efficiency of both on-water mechanical recovery and in situ burning. Both were already rated as negligible to low for all resource categories due to low encounter rates and prohibitively high wave heights. In the winter season, with lower quantities of oil on the surface and higher mean wave heights, it is highly unlikely that either method could be successfully employed, and even if so, the impacts would be negligible.

Since there is less oil on the surface during the winter season, the impact of ASD could also be somewhat reduced. Applications from vessels or platforms in the immediate spill area could still be beneficial for protecting worker safety and health. Farther away from the spill location, thinner oil slicks resulting from natural dispersion would be more difficult to target and the overall efficiency of ASD would be reduced. The modelling study found that during the summer season, ASD reduced surface oil from 13.2% to 5.5%, while during the winter season ASD reduced surface oil from 2.4% to 1.3%, as shown in Figure 34.

SSDI is unique in that it is the only response measure that can operate continuously, night and day, and is relatively insensitive to weather conditions. In this scenario, SSDI would have the effect of increasing oil concentrations in deeper portions of the water column, and reducing the size and thickness of surface slicks. Even though the amount of oil on the water surface was relatively low due to natural dispersion and the use of ASD, the addition of SSDI reduced the percentage of oil on the water surface from 2.4% to 0.1%, for a reduction of 96%, as shown in Figure 34.
In the winter season, the efficiency of all response methods is reduced by challenging weather conditions, shorter days, and high rates of evaporation and natural dispersion. Even though the overall quantity of oil on the surface is small, ASD supplemented by SSDI continues to have the highest impact mitigation scores. In the event that weather conditions prevent the use of ASD, SSDI (alone) could continue to produce reductions in risk to workers in the well area, and shift the mass balance of oil to deeper portions of the water column.

6.4.2.2 Case 2A Summer

Case 2A is based on a different release scenario that is located farther to the southeast from Sable Island (170 km versus 105 km for Case 1A), in deeper water (2,652 m versus 2,104 m), and with a higher release rate (35,914 bpd versus 24,890 bpd). Other aspects of the scenario are the same.

Due to the higher release rate, the total oil release during the 30 day study period is higher, at 142,902 tonnes versus 99,190 for Case 1A. Since the well is farther from Sable Island, landfall is later (12 days versus 7 days). Many of the impacts, however are very similar to those for Case 1A. The maximum mass on the shoreline and length of shoreline oiled are the same. The environmental resources impacted are also largely the same. The overall quantities of oil in the water column and on the water surface are larger, but proportionate to the larger spill size. The partitioning of oil in the mass balance is also similar, as indicated in Figure 35.
In general, the risks parameters for Case 1A and Case 2A are largely the same. The water surface and water column receive heavier oiling due the larger spill size. Since the water surface was already rated high (4), the relative impact rating in that category would remain the same. In the water column, impacts could be rated slightly higher, since that category was rated only moderate (2) in Case 1A. Both commercial and Aboriginal fisheries could be affected over larger areas, but since those categories were already rated high (4), relative risk factors would remain unchanged.

A slightly longer period of time is available to initiate response actions, but the limitations for shoreline protection, mechanical recovery, and in situ burning remain the same. Longer transit times to shore to offload collected oil would reduce mechanical recovery efficiency slightly. Similarly, transit times for dispersant spraying aircraft and vessels would be slightly longer, but the results should be negligible.

The impact mitigation predicted by the modelling study for ASD and SSDI for Case 2A Summer followed the same pattern as Case 1A Summer. Notably, the use of ASD and SSDI reduced the magnitude of shoreline oiling on Sable Island from heavy to light or moderate 30 days after the spill. Similar to Case 1A Summer, the oil quantities were reduced on the surface, shoreline, atmosphere and in the sediments, but increased in the water column. Oil that was biodegraded increased slightly, from 21.9% to 25.2%, as indicated in Figure 36.
Figure 36 Deterministic modelling results for oil spill scenario Case 2A Summer mass balance results. (SIMA OSCAR Model Output)

6.4.2.3 Case 2A Winter

The Case 2A Winter scenario provided the longest lead time before landfall (31 days) and also produced the smallest maximum mass of oil reaching the shoreline. The length of shoreline impacted was similar to both Case 1A scenarios. Similar to the Case 1A Winter, the variation in weather conditions had the net effect of increasing natural oil dispersion and evaporation, which resulted in a reduction of oil quantities on the surface, and shoreline, and an increase in oil quantities in the sediments, water column, and atmosphere. Those impacts are illustrated in the mass balance illustrations comparing Case 2A Winter with Case 1A Summer, 30 days after the start of the spill (Figure 37).
The impact mitigation predicted by the modelling study for ASD and SSDI for Case 2A Winter followed the same pattern as Case 1A Winter. Similar to Case 1A Winter, the oil quantities were reduced on the surface, shoreline, atmosphere and in the sediments, but increased in the water column.

Although more lead time is available for the Case 2A Winter scenario, the same weather condition limitations on mechanical recovery and in situ burn apply as in the Case 1A winter scenario. Likewise, since there is less oil on the surface, ASD probably will not be as effective as in the summer months. As in the Case 1A Winter, ASD could still produce significant benefits to worker safety and health in the immediate well head area.

Since SSDI is relatively insensitive to weather, it can operate continuously and disperse oil into deeper portions of the water column. Even though the oil mass on the surface was relatively low for the Case 2A Winter scenario, the use of ASD and SSDI still resulted in a reduction of surface oil from 5.2% to 0.3%, as indicated in Figure 38. While water column concentrations in the upper 100 m were increased by the use of ASD and SSDI, the increase was small relative to water column effects resulting from natural dispersion, and would not warrant changing the existing moderate to high levels (-3 to -4) assigned for Case 1A.
Figure 38 Deterministic modelling results for oil spill scenario Case-2A Winter mass balance results. (SIMA OSCAR Model Output)

6.4.2.4 Summary

Overall, the variations in mass balances for the Case 1A Summer, 1A Winter, 2A Summer, and 2A Winter are illustrated in Figure 39.

Figure 39 Comparison of oil mass balance for the Case 1A Summer, 1A Winter, 2A Summer, and 2A Winter scenarios, 30 days after spill with no mitigation. (SIMA OSCAR Model Output)

The mass balance graphs for the two seasons are actually more similar than for the two spill locations. The two summer scenarios have significantly higher amounts of oil in the surface.
category, and less in water column. The reverse is true for the winter scenarios. This suggests that the seasonal influences are more controlling for the mass balances of oil than the spill location. This also suggests that the impact mitigation potential of the response methods evaluated may be controlled more by weather than by spill location within the study area.

Of the response methods evaluated in this SIMA, only ASD and SSDI exhibited a potential to produce significant environmental impact mitigation for a blowout in the study area. During the summer season, the combination of ASD and SSDI resulted in significant shifts in the mass balance of the oil spills evaluated from the water surface and shoreline, to the water column, and also significantly reduced the amount of oil reaching Sable Island. While the concentration of oil in the upper 100 m of the water column increased, experience has shown that oil concentrations in the upper water column decrease relatively rapidly over time, particularly for surface spills that have been treated with ASD, as was observed during DWH, (Boehm et al., 2016). SSDI reduces the amount of oil reaching the surface, and results in less oil reaching the water surface.

At distances of 1km or more from the well site, the concentration of oil in submerged plumes has been shown to be relatively low, and to dissipate relatively rapidly as a result of dissolution and biodegradation.
7 Summary

The assessment of impact mitigation potential for the response options presented in this SIMA is based on assumptions regarding typical weather and environmental conditions in the Scotian Basin area. It is not intended to recommend, or eliminate, a response option from consideration for any 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, which is the No Intervention response option. 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 produces a dimensionless number to indicate the potential for reducing (mitigating) or increasing impact risk, relative to the baseline condition of natural attenuation.

For this SIMA, resources of concern were identified for the Scotian Basin in Section 4, Table 3. Resources were identified using physical, biological and socio-economic data about the Project Area and RAA presented in the Scotian Basin Exploration Drilling Project Environmental Impact Statement (EIS) (Stantec, 2016) and Tangier 3D WATS seismic survey (LGL Limited, 2014). Those identified resources take into consideration species at risk, Special Areas and EBSAs.

In Section 5, the Oil Spill Trajectory Modeling report in Appendix H of the EIS (2016) provided background information and SIMA SINTEF OSCAR modelling provided hypothetical oil spill scenarios for a subsea blowout in the Scotian Basin ELs for two sites (Site 1 “Case 1” and Site 2 “Case 2”) and two seasons (summer and winter). These scenarios were analyzed using the SIMA comparative risk matrix approach. Case 1 involves a smaller volume and shallower release location closer to Sable Island, while Case 2 depicts a larger volume and deeper release location.

The modelling results for the four scenarios demonstrated a high likelihood for shoreline oiling of Sable Island, and lesser potentials for oiling of Nova Scotia shorelines. The scenario that posed the most immediate threat to Sable Island was Case 1A Winter, where oil could reach the shoreline within 5 days. However, the largest mass of oil (670 tonnes) that could be deposited occurred during the summer season, which also had the highest ashore time (maximum mass) of 42 days. The summer season also produced the highest mass on shoreline for Case 2A, at 669 tonnes.

In general, winter conditions were considered more operationally challenging than summer, but less oil was present 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 (ASD) and subsea dispersant (SSDI) response methods were less dependent on weather, and both methods are capable of removing large quantities of oil from the surface. 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. 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 resulted in some potential short term exposures of fish, sea turtles, and aquatic mammals in the upper 10 m of the water column. In contrast, SSDI increased 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 than would have occurred if the oil was not treated.

In Section 6.4, the potential relative impact of the spill on each resource category was assessed for the No Intervention options and a preliminary prediction was made of how each feasible response option modified the impact when compared to No Intervention. The resulting comparative risk matrix, Table 14, was developed. For the summer scenario, using this rating method, the combined ASD and SSDI received the highest score (58) for impact mitigation, followed by ASD alone (48), on-water mechanical recovery (23), in-situ burn (23) and shoreline protection (13). It is important to note that the scoring was based on hypothetical scenarios and weather conditions, a specific study area, the RAA, and the assumption that all methods evaluated could be deployed to the study area. This ranking should not be assumed to be applicable to all spill scenarios and all times of the year for the two well sites considered. Species distribution can change rapidly during migration season, and local resource experts should always be consulted to identify what 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. Nonetheless, in all four scenarios the use of ASD and SSDI resulted in a shift of significant percentages of the overall mass balance of the spills evaluated, by removing oil from the water surface. In both seasons, the use of ASD and SSDI could result in localized reductions in VOC exposures to spill response workers.

Without mitigation, there are potential environmental effects for Tier 3 scenarios for species at the water surface, and, in general, all methods produced their highest impact mitigation scores in that resource category.

In addition, modelling results for this project demonstrated the potential locations for spill effects exceeding threshold levels beyond the RAA boundary, and in some cases, beyond Canadian jurisdiction. Assuming no mitigation, the model estimates a 16% probability of surface oil within the international boundaries of Saint-Pierre et Miquelon (France), which could occur in a minimum of 12 days of a blowout event, and lower probabilities and more time for oil reaching the United States and Bermuda.
All of the response methods that were 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, as there is typically a public expectation that an attempt will be made to remove the spilled product 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 matrix presented in Chapter 6 was populated based on assumed local protection priorities for the Scotian Basin and a hypothetical scenario. The ultimate utility of this SIMA framework is that this risk matrix 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 SIMA process is most effective when involving stakeholders as a mechanism to identify resources that are important to the stakeholders, while providing a clear direction for selecting response options. The risk matrix presented in Table 14 in Section 6.4 would be modified ‘real-time’ based on specifics of the incident, conditions at the time, and advise of the resource trustees to decide 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. Trade-offs must be made once oil is released in the environment, and this SIMA process can help the Incident Management Team 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.
8 References


LGL Limited, Mahone Bay, NS and St. John’s, NL for BP Exploration Canada Limited, Calgary, AB.


Appendix A: Historical Use of SIMA in the United States and Canada

The integration of NEBA into oil spill response planning in the US ramped up in the mid-1990s, when the USCG developed a multi-agency approach to evaluate the ecological effects from various response options. The effort was spurred from a publication in Spill Science and Technology (Aurand, 1995) which outlined the essential elements of what was, at that time, referred to as “Consensus Ecological Risk Assessment (CERA).” The USCG fostered the development of a “Guidelines” document, which provided a practical approach to conducting the environmental analysis. The document entitled “Developing Consensus Ecological Risk Assessments: Environmental Protection in Oil Spill Response Planning: A Guidebook” was published in 2000, after a four-year interagency development period (Aurand et al., 2000).

USCG, with support from a variety of other U.S. Federal and state agencies, including EPA, NOAA, U. S. Fish and Wildlife Service, Texas General Land Office, and California Office of Spill Prevention and Response, has sponsored more than twenty Ecological Risk Assessment workshops in the US that have considered the impacts and ecosystem recovery rates from various oil spill response options at hypothetical open water and inland spills. In each of these workshops, participants evaluated surface dispersant use along with other oil spill response strategies, with the goal of preparing a response option trade-off analysis.

Facilitated workshop locations included:

- Galveston Bay (1999)
- San Francisco Bay (1999)
- Mississippi Sound (2000)
- Long Island Sound (2001)
- Santa Barbara Channel (2002)
- Chesapeake Bay (2002)
- Upper Florida Keys (2002)
- Casco Bay, Maine (2003)
- Upper Mississippi River (2004)
- Cape Flattery, WA (2004-2005)
- Delaware Bay (2005)
- Guayanilla Bay Area, Puerto Rico (2007)
- Mexico- United States Gulf of Mexico Coastal Border Region (2008)
- Northwest Arctic Alaska (2012)
- Delaware Bay - Bakken and Dilbit transportation (2016)

In addition, Regional Response Teams (RRT) (members from state and federal agencies) conducted several dozen additional ERA workshops “in house” (e.g., without the use of a contracted facilitator). Each CERA involved a several-month process to:

- develop scenarios and identify Resources at Risk,
• conduct multi-day workshops involving more than a dozen different federal and state agencies, academic institutions, oil and gas companies, oil spill response organizations, and non-governmental organizations, and

• publish a final report.

While early workshops focused purely on environmental considerations, the process was eventually adapted to include some socio-economic considerations such as commercial fishing and marine transportation, subsistence uses of marine and coastal areas, and recreational use of coastal areas and beaches.

All of the workshops resulted in final publications (available from USCG) that were delivered to the Area Committees and RRTs to assist with response planning. An example of using this CERA/NEBA process to inform dispersant use decision-making is summarized in several papers authored by regulators in the state of California (Addassi & Faurot-Daniels, 2005; Addassi et al., 2005). The applicability of the CERA/NEBA process as a tool for facilitating dispersant decision-making during spill response and planning was also evaluated by NOAA. Ultimately, the USCG and U.S. EPA used their CERAs to help establish dispersant pre-authorization zones across many offshore regions in the US.

In addition to being an ideal team-building mechanism to bring many federal, state, and local organizations together, the CERA process has helped build relationships between response technology experts and decision-makers. One of the outcomes of these workshops was the development of a series of habitat fact sheets that were developed by the workshop participants, which considered the impacts of oil on various important natural resources or ecosystems, and assisted the CERA participants with making response option trade-off analyses. The fact sheets were modified and evolved with each workshop, and were eventually published as a series of NOAA publications.

Since the DWH incident in 2010, interest in routinely conducting NEBAs/SIMAs for offshore drilling locations has increased in the US, and beginning in 2012, have been routinely integrated into contingency plans and exercises in US and Canadian waters, as summarized below:

• In 2012-2013, a series of NEBA workshops were conducted for an ongoing response in the Gulf of Mexico. The project involved multiple inter-agency and industry workshops to examine the potential ecological impacts of response alternatives being considered for sheen abatement for the remnants of the Taylor Energy Company, LLC MC-20A Platform in the Gulf of Mexico, which was destroyed during a subsea mudslide.

• In 2013, a NEBA was conducted to evaluate dispersant use for spills in the Newfoundland Grand Banks region in Eastern Canada.

• In early 2014, an expedited NEBA was prepared for a Freeport McMoRan exercise in the Gulf of Mexico. The resultant findings led to the first ever “mock approval” of SSDI during a U.S. offshore blowout/Source Control exercise.

• Later in 2014, a more comprehensive NEBA was prepared for a BP exercise in the Gulf of Mexico. This is the first time that modeling results were incorporated into a US NEBA for the purposes of a blowout/Source Control exercise. This NEBA set the standard for how NEBA has since been applied to response exercises in the US.

• In 2014-2015, a Shelburne Basin NEBA was prepared for Shell Canada. This project involved close coordination with and involvement of regional and national Canadian
regulators and stakeholders, including the Canada-Nova Scotia Offshore Petroleum Board, Canadian Coast Guard, Environment Canada, and Fisheries and Oceans Canada.

- In 2015, an Expedited NEBA was prepared for BP Alaska. This NEBA resulted in the first ever “mock exercise” surface dispersant application approval in US Arctic Alaska.

- In 2016, another expedited NEBA was prepared for LLOG drilling operations in support of a drill in the Gulf of Mexico drill. After this drill concluded, the RRT in that region has taken steps to formalize the process for using SIMAs as a required component for requesting surface dispersant and/or SSDI approval during spill responses in the Gulf of Mexico. The guidance document was released in 2017 (API, 2017).

- In 2016, a Comparative Risk Assessment study was conducted to evaluate response options for a deep water blowout, both with and without the use of SSDI. The study culminated in a workshop with US agency representatives in November 2016. While the final report is still under preparation, a summary of the study was recently presented at IOSC (French-McCay et al., 2017). The report concluded that “SSDI substantially decreased the amount of oil on the water surface and on the shoreline and … decreased VOC emissions to the atmosphere”.

- In March 2017, an expedited SIMA was prepared for Anadarko for drilling operations in the Gulf of Mexico. This effort was coordinated within a larger US-Mexico source control drill. One of the outcomes for the overall activity was the need for greater emphasis on data management during a spill of national significance.

- In 2017, a SIMA was conducted for Statoil exploration efforts in Flemish Pass, in coordination with the Canada-Newfoundland Labrador Offshore Petroleum Board.

Suggested Additional Reading:


Appendix B: An Overview of Dispersants

The Role of Dispersants in Oil Spill Response

Industry is committed to responding to any open water oil spill with a full complement of response strategies, including mechanical on-water recovery, dispersants, in situ burning, shoreline recovery, and preventative containment booming. In numerous regions, mechanical recovery is the preferred method of many regulating agencies to remove oil from the surface of the water when environmental conditions permit. However, past government and industry experience with responding to open water oil spills has demonstrated that mechanical recovery alone has traditionally yielded poor rates of recovery because of low encounter rates and reduced efficiency due to higher wave conditions offshore. As industry operates in deeper waters farther offshore, there are additional limitations for greater transit distances by boats supporting the response, and adverse weather conditions that can hamper safe operations and returns to port.

For these reasons, the appropriate use of dispersants, applied either at the ocean’s surface or subsea, may provide the only means of removing significant quantities of oil from the surface quickly, therefore rapidly and efficiently reducing overall environmental impacts from the spill to nearshore, shallow water environments. Industry and government agencies are working together to use SIMA principles to consider the consequences of using dispersants to move the oil into the water column where it can be rapidly biodegraded, against the impacts of oil remaining on the water surface or oil stranding on the shoreline if mechanical containment and recovery efforts are ineffective or inefficient.

In cases where dispersants are a viable strategy as part of an overall oil spill response, they should be considered as a primary response tool. As is the case with every response option, the decision to use dispersants must be carefully considered to determine if the oil is dispersible, if environmental conditions are appropriate for safe application and surveillance, and if the dispersant application will result in improved recovery of the ecosystem once the spill response has concluded.

When dispersants are considered a viable option, it is important to use high-quality dispersant products. The following guidelines should be considered when selecting a dispersant.

- The dispersant degrades into environmentally safe bi-products and does not contain endocrine disruptors.
- The dispersant is effective over a wide range of spill conditions (including broad range of oil types, weathering states, and environmental conditions).
- Low aquatic toxicity at dispersant concentrations that are relevant to field application is documented.
- The availability of the dispersant is in sufficient quantity to quickly respond to a worst-case discharge event.

Dispersants, when applied properly in the right situations, can produce higher levels of environmental protection than other response strategies. Dispersants increase the amount of oil that dissipates into the water column, and reduce the amount of oil remaining on the surface. Dispersant use, therefore, reduces the potential for floating oil to reach ecologically and economically sensitive open water or shoreline environments. The oil that disperses into the water column may pose temporary elevated exposures to organisms in the immediate
area, but research and experience has shown that those exposures are rapidly mitigated by the effects of dilution and microbial degradation of the dispersed oil.

**Principles of Chemical Dispersion**

Natural dispersion of floating oil is a process facilitated by wave action that breaks the oil into small droplets and disperses them into the water column. It is affected by the properties of the oil and the amount of wave energy at the sea surface. In general, oils with lower viscosity are more amenable to natural dispersion than those with higher viscosity, and higher wave energy produces more natural dispersion. Very small oil droplets (less than 70 µm in diameter) generally tend to stay suspended in the water column, while larger ones are more likely to float to the surface and can re-coalesce into a slick.

Natural dispersion also occurs during subsea discharges but is largely dependent on droplet size which, in turn, is dependent on discharge velocity, rate, and oil to gas ratios. Like surface spills, droplet sizes less than 70 µm in diameter typically remain dispersed in the water column whereas larger droplets are more buoyant and will generally float to the surface and form floating oil slicks.

Chemical dispersants are surfactants that enhance natural dispersion by reducing the surface tension at the oil/water interface, making it easier for waves or turbulence to create small oil droplets. Modern chemical dispersants are a blend of surfactants (surface active agents or soap) in a solvent. The solvent has two functions: 1) to reduce the viscosity of the surfactant, which enables it to be sprayed, and 2) to promote the penetration of the surfactant into the oil slick. The surfactant molecules are the key component of the dispersant. They are made up of two parts: an oleophilic part (oil-loving) and a hydrophilic part (water-loving). When dispersants are sprayed onto an oil slick, the solvent transports and distributes the surfactants into the oil slick and the surfactants reduce the surface tension at the oil/water interface. As a result, small oil droplets are formed, which break away from the oil slick with the help of wave energy. Re-coalescence is minimized by the presence of the surfactant molecules on the droplet surface.

Dispersants have traditionally been applied to the surface by properly equipped vessels, helicopters, and fixed-wing aircraft. There are many examples of surface dispersant use in North America since 1990 that involved smaller volumes of dispersant application, including these events:

- T/V Mega Borg - 1990 (dispersant test only)
- West Cameron Block 168 Oil Spill - 1995
- High Island Pipeline System Spill - 1998
- T/V Red Seagull - 1998
- BP-Chevron Pipeline - 1999
- Blue Master - 1999
- Poseidon Pipeline - 2000
- Main Pass 69 Oil Spill - 2004
- Shell Pipeline Ship Shoal Block 142 - 2009
- Galveston Endeavor vs. M/T Krymsk - 2009

Another notable example of dispersant use is the *Sea Empress* oil spill (1996) where significant volumes of dispersants were used near-shore to help protect sensitive resources.
from the impacts of floating oil. The use of around 445 tonnes of chemical dispersants sprayed by aircraft onto the oil slicks at sea prevented at least 36,000 tonnes of oil, from the Sea Empress coming ashore in this sensitive region of Wales.

The DWH incident was the first continuous, uncontrolled release of oil into the ocean where large quantities of dispersants (approximately 53,000 tonnes) were applied using a combination of aerial, vessel, and subsea dispersant application methods. As a result of the innovative use of SSDI during the DWH incident, new technologies for subsea dispersant use are evolving rapidly.

Factors that Affect Dispersant Effectiveness

Dispersant effectiveness for surface applications is influenced by the efficiency of the application process (encounter rate), the dispersibility of the oil, and the sea state (wave energy). Factors that affect oil dispersibility include the viscosity, pour point, chemical composition, and the degree of weathering. Many crude and some refined oils tend to form stable emulsions over time when mixed with water by wave action and these emulsions can be difficult to break and disperse. For surface oil, the time window within which dispersants are effective is generally less than a few days, after which the oil becomes too viscous or emulsified. Another important limitation for surface dispersant application is visibility. Aerial dispersant application can only be performed under conditions where visibility is sufficient to allow accurate slick targeting. Therefore, aerial dispersant application can be restricted by poor weather (i.e., low cloud ceiling) and can only be conducted during daylight hours.

The encounter rate for surface dispersant application is affected by the speed of the delivery system (i.e., workboat vs. multi engine aircraft), the amount of dispersant that can be carried, the width of the spray pattern, and the ability to deliver dispersants in small droplets capable of entering the oil without “punching through” to the water below. The optimum droplet size is generally considered to be about 600 to 800 µm. The targeted DOR for surface application of modern dispersants is generally around 1:20.

Sea state is important for surface dispersant application because it affects both the distribution of the oil and the mixing energy available for breaking slicks into small droplets. If the wave energy is too low, the oil may not be effectively dispersed into the water column and droplets may resurface. If wave energy is too high, the oil can be submerged by breaking waves, preventing direct contact between the dispersant and oil. Poor weather conditions can also affect the safety of surface spraying operations. Optimum wind speeds for surface dispersant application is about 5 to 25 knots.

The viscosity and pour point of a given oil provide a good indication of its dispersibility. As a general rule, fresh light to medium crude oils are considered to be readily dispersible whereas highly viscous oils are not. The upper limit of dispersibility is likely to be reached with heavier oils (group 4 oils\(^1\)). As a general rule, dispersant effectiveness will decrease as oil viscosities increase. They are likely to be ineffective for oils with an initial viscosity above 10,000 cSt at the time they are spilled. Pour point is also an important parameter. Any oil with a pour point

\(^1\) For more information, please see the 2011 International Tanker Owners Pollution Federation, Ltd., Technical Information Paper (TIP) titled Fate of Marine Oil Spills, available online at http://www.itopf.com/information-services/publications/documents/tip2fateofmarineoilspills.pdf.
higher than the ambient temperature will start to become very viscous as it cools after spillage.

Subsea dispersant application was first used in the DWH response in 2010. To date, industry, academia and other research organizations are making concerted efforts to learn more about the effectiveness of this response option and the potential fate and effects to the deep water environment. Research has been recently published on how various factors, such as temperature, pressure, gas-to-oil ratio, etc., affect subsea dispersant application methodology and effectiveness. Additionally, testing of low-solvent dispersants is underway to assess their utility for subsea injection, and a new protein-based dispersant hit the US market in 2016 and is undergoing further evaluation.

Several of the limitations that apply to surface application may not affect SSDI. For example, subsea injection is relatively unaffected by weather and sea state. As the encounter rate is much higher due to more accurate targeting of the released oil by the dispersant application system, the DOR required to promote effective dispersion is much lower. The rate can be adjusted during a response event to optimize the effectiveness, based on real-time subsea dispersant monitoring data.

**Suggested Additional Reading**