Net Environmental Benefit Analysis in Support of the Shelburne Basin Venture Exploration Drilling Project

Nova Scotia, Canada

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List of Abbreviations, Symbols and Acronyms

bbl	barrel
bpd	barrels per day
CERA	Consensus Ecological Risk Assessment
CROSERF	Chemical Response to Oil Spills: Ecological Effects Research Forum
DMP2	Dispersant Mission Planner 2
DO	Dissolved oxygen
DOR	Dispersant to oil ratio
DOSS	Dioctyl Sodium Sulfosuccinate
DWH	Deepwater Horizon spill (aka Macondo spill)
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERA	Ecological Risk Assessment
ERD	Emergency Response Division
g	Gram
gal	Gallon
gpd	Gallon(s) per day
HAZMAT	Hazardous Materials
IBA	Important Bird Area
ISB	*In-situ* Burning
km	Kilometre
L	Local
m	Metre
NEBA	Net Environmental Benefit Analysis
NEDRA	Net Environmental Damage & Response Assessment
NOAA	National Oceanic & Atmospheric Administration
NRC	National Resource Council
ppb	Part per billion, as referring to concentration
ppm	Part per million, as referring to concentration
R	Regional
RAA	Regional Assessment Area
RAR	Resources at Risk
SIMAP^{TM}	Spill Impact Model Application Package, a 3D trajectory and fate model
SMART	Special Monitoring of Applied Response Technologies
TPH	Total Petroleum Hydrocarbons
µm	Micrometer or microns
USCG	United States Coast Guard
VC	Valued Components

Executive Summary

This Net Environmental Benefit Analysis (NEBA) was conducted in support of Shell Canada Limited's (Shell) oil spill response planning for the Shelburne Basin Venture Exploration Drilling Project (the Project). The analysis is based largely on information provided in several reports prepared in support of the Project. These supplementary sources include:

- Shelburne Basin Venture Exploration Drilling Project: Environmental Impact Statement (EIS; Stantec 2014a) and associated Appendices (Stantec 2014b)
- The preliminary findings of the Shelburne Basin Venture Seabed Survey (Stantec 2014c)
- Trajectory Modelling in Support of the Shelburne Basin Exploration Drilling Program: Model Description, Approach and Summary of Results (Horn and French McCay 2014a)
- Trajectory Modelling in Support of the Shelburne Basin Exploration Drilling Program: Analysis of Subsurface and Surface Dispersant Application Modelling (Horn and French McCay 2014b)
- Shelburne Basin Venture Exploration Drilling Project: Oil Spill Response Plan (OSRP) (Shell Canada Limited 2015a)
- Shelburne Basin Venture Exploration Drilling Project: Venture Dispersant Preparedness and Operations Plan (Shell Canada Limited 2015b)

These reports serve as the basis for this NEBA and are referenced where relevant, but the information has not been reiterated here to avoid duplication. As such, the reader is urged to refer to these reports for further background and operational information. This report is intended to support response efforts in association with a subsea blowout scenario in advance of successfully capping the well. This report does not examine alternative potential release scenarios (i.e., from other sources, such as surface releases from the rig platform or from support vessels or other drilling products. Additionally, this NEBA focuses on the *ecological* aspect of the associated response options. While it is understood that a large oil spill, such as that assessed as part of the NEBA, will have socio- economic, and cultural impacts, such impacts have been considered within the ecological context (i.e., impacts to the resource of concern that are of socio-economic and cultural importance). Detailed socio-economic and cultural impact assessments are beyond the scope of this NEBA.

In oil spill response, once human health and safety are addressed, the over-riding concern is containment and mitigation in order to minimize environmental impacts. In the majority of spill scenarios, no single response option is likely to be completely effective. Therefore, the best approach to minimize environmental impacts is to have multiple response options available. The objective of a NEBA is to consider all available response options and identify those techniques that will provide for the best opportunities to minimize environmental consequences.

When a NEBA approach is used, the analysis is based on the use of a relative, or comparative, risk framework. The basic premise of the analysis is that appropriate decisions are contingent upon determining how all available response options might be used to minimize damage and encourage recovery of the environmental and social-economic systems. This analysis is based on consideration of the benefits and limitations of each of the available response options. In addition, it provides an assessment of the relative risk to each resource of concern from each response option, using "natural attenuation" (i.e., no human intervention) as the baseline for comparison. This allows a comparison of how each response option affects resources of concern relative to the other available options. All available response options have both limitations and potential benefits. A recent publication by the International Petroleum Industry Environmental Conservation Association (IPIECA) describes the four elements associated with the NEBA process (IPIECA 2013, 2015c):

1. **Collect information on the physical and biological environmental conditions as well as the human use of the area of interest.**
    - *This step was completed via preparation of the Project EIS and preliminary baseline studies (Stantec 2014a,b,c) which are precursors to this NEBA document.*
2. **Review previous spill case histories and experimental results which are relevant to the area and to the available response methods.**
    - *Past scientific studies and learnings from previous offshore spill incidents were reviewed and, as applicable information has been incorporated into this report.*
3. **On the basis of previous experience and professional judgement, predict the likely environmental outcomes if the proposed response is used, and compare to if the area is left for natural attenuation.**
    - *Based largely on professional judgment as well as experience and learnings from other offshore spill incidents.*
4. **Compare and weigh the advantages and disadvantages of the available response options against the outcome of using natural attenuation.**
    - *This is a semi-qualitative process and relies heavily on the professional judgement and experience of the authors, as well as input from regulators and federal/provincial resource managers in the Nova Scotia region gathered through engagement and review.*

This NEBA was conducted using a risk matrix which supports the evaluation of the interaction of potential response options and ecological resources. This conceptual model is a depiction of how the various ecological resources (summarized by habitat) might respond when exposed to a response option. Once the risk matrix was completed and the resource and trajectory data evaluated, the study team used a “risk ranking matrix” in order to assign a level of concern to each box in the risk matrix. All subsequent rankings are relative to the baseline (natural attenuation of the oil spill), i.e., are conditions better or worse for each resource when using the response option. The results of this analysis were then used to develop recommendations regarding the available response options.

The NEBA analysis concluded that successful implementation of any of the available response options will result in a reduction in consequences to the considered resources of concern, when compared to the baseline condition of no active intervention. As a result, all available response options should be considered when developing the oil spill response plan for the Project.

However, the response options do vary in their potential effectiveness, based on operational or logistical considerations. Based on the NEBA analysis, subsea dispersant injection is considered the most operationally feasible spill response option available in association with the Project, and also offers the most environmental benefit. As a result, subsea dispersant injection is recommended as a primary response option for the reasons provided below. The anticipated operational effectiveness of each option is summarized in the order of least to most environmentally beneficial based on the results of the NEBA analysis:

- **On-water In-situ Burning (ISB**) – the majority of environmental conditions in the North Atlantic do not allow for successful implementation of this response option. Successful implementation requires effectively containing the oil (in fire boom) long enough to safely implement a burn, which is severely restricted by seasonal day length, year-round weather conditions, difficulty of corralling a thin sheen of oil in a turbulent offshore environment and logistical constraints. Although it may result in minor improvements over natural attenuation, it will not offer any substantial ecological benefits, but may provide localized benefits in areas where it is successfully deployed.
- **On-water mechanical recovery** – while this response option is constrained by factors that are similar to those for ISB, on-water mechanical recovery resources are generally easier to obtain and deploy in larger numbers than those for ISB. Although this option can be effective for smaller, confined spills, the estimated recovery for large volume discharge scenarios (with prevailing sea states in the North Atlantic) is considered too low to provide any material regional ecological benefit.
- **Shoreline protection and recovery** – The trajectory spill modelling completed for the Project indicates there is a low probability of shoreline contact resulting from an offshore spill incident. However, in the rare cases where shoreline contact occurs, this response option is essential. Shoreline protection and recovery can result in improvements over the natural attenuation and an effective response plan for protection of the ecological resources on Sable Island National Park Reserve (and other sensitive shorelines in the Project area) is a very important consideration.
- **Aerial dispersant application** – This response option was shown to be effective in reducing surface oil in treated areas. Trajectory modelling indicates that with the application of aerial dispersants the modelled oil (i.e., light oil) can be easily dispersed near the source. It will likely spread into thin layers as it remains on the surface of the water. Consequently, dispersant effectiveness will vary depending on the environmental conditions that affect both the physical properties of the oil and the operations needed to apply the dispersant. Hydrocarbon concentrations in the upper 10 to 20 m of the water column would increase in treated areas, but concentrations would decline within hours, and would not pose a long-term risk to the ecosystem given rapid dispersion, biodegradation and low toxicity of the dispersants. This response option is subject to weather and logistic limitation. While not as significant as on-water recovery and ISB, these limitations can affect deployment capabilities and potentially effectiveness. This option could be very valuable early in the release scenario while other response options, such as subsea dispersant injection equipment, is enroute.
- **Subsea dispersant injection (SSDI)** – This response option leads to the greatest net environmental benefit, and is recommended as a primary response option. This option provides the most marked improvement in risk scores for resources on the water surface and on the shoreline, with only a minor increase in the level of concern for invertebrates and plankton in the deep water column (based on an increase in the area of concern due to an expanded dispersed oil plume but still rapid recovery). It has the potential to substantially reduce floating oil (potentially near zero, once implemented), as well as reduce dispersed oil concentrations in the sensitive upper water column (surface to 100 m). Once in place, this response option is less sensitive to weather limitations than other available response options, and is the only option with the potential to operate 24 hours, seven days a week. It reduces the need for surface

> recovery, in-situ burning, and surface dispersant operations, thereby reducing the potential for oil exposure, and accidents or incidents during these operations. In addition to these ecological considerations, the importance of maintaining a safe Source Control environment for response workers operating above the oil release site is paramount to an effective emergency response. Use of SSDI can substantially reduce surface volatile organic compounds (VOCs) and reduce the likelihood of exceeding Lower Explosive Limits, improving well intervention activities and capping stack deployment capabilities. Consequently, it is an important tool that helps to safely sustain well-capping and source containment operations during a blowout situation.

It is important to recognize that during a spill, the best response almost always results when a combination of response techniques are used together to minimize ecological damage and promote the fastest overall recovery of the ecosystem. So while the response options are considered individually in this document, it is understood that multiple response options will likely be used during an actual spill.

1 Net Environmental Benefit Analysis

1.1 Background

WHAT IS NEBA?

The objective of a NEBA is to consider all available response options for an oil spill and select those techniques that will provide the best opportunities to minimize consequences for the environment (Aurand *et al*., 2000; IPIECA 2000, 2015c; ASTM 2014).

This section of the report provides an overview of the analytical approach used to prepare this Net Environmental Benefit Analysis (NEBA) in support of oil spill response planning for Shell Canada Limited's (Shell) Shelburne Basin Venture Exploration Drilling Project (the Project). The analysis is based largely on information provided in several existing reports prepared in support of the Project. They are:

- Shelburne Basin Venture Exploration Drilling Project: Environmental Impact Statement (EIS) (Stantec 2014a) and associated Appendices (Stantec 2014b)
- The preliminary findings of the Shelburne Basin Venture Seabed Survey (Stantec 2014c)
- Trajectory Modelling in Support of the Shelburne Basin Exploration Drilling Program: Model Description, Approach and Summary of Results (Horn and French McCay 2014a)
- Trajectory Modelling in Support of the Shelburne Basin Exploration Drilling Program: Analysis of Subsurface and Surface Dispersant Application (Horn and French McCay 2014b), and
- Shelburne Basin Venture Exploration Drilling Project: Oil Spill Response Plan (OSRP) (Shell Canada Limited 2015a).
- Shelburne Basin Venture Exploration Drilling Project: Venture Dispersant Preparedness and Operations Plan (Shell Canada Limited 2015b).

These existing reports serve as the basis for this NEBA and are referenced where relevant, but the information has not been reiterated here to avoid duplication. As such, the reader is urged to refer to these reports for further background and operational information. NEBA is a process generally coordinated between government and industry to identify the best available response options in the event of a spill in order to minimize the potential impacts on people and the environment (IPIECA Scan and Glance, 2013).

In oil spill response, once human health and safety are provided for, the over-riding concern is containment and mitigation in order to minimize environmental impacts. In the majority of spill scenarios, no single response option is likely to be completely effective. Therefore, the best approach to minimize environmental impacts is to have multiple response options available. 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. A NEBA provides response planners with a well-documented, transparent and easily understandable product to aid in response tactic decision making through provision of the rationale and justification for the selection of different response options during an incident. In general, NEBA becomes a more valuable planning tool as the potential incident threat, the value of the considered ecological component, and the diversity/complexity of available response options increase.

The NEBA concept has been employed by a number of countries for several decades (Baker 1995 and IPIECA 2000). While this document uses the term "NEBA" there is other terminology which has a similar, but not identical meaning. In some situations the terms Environmental Consequence Analysis or Relative Risk Assessment may be preferred as alternative terms for NEBA. In other cases the focus may be slightly different; for example, in the United States the US Environmental Protection Agency (EPA) and the US Coast Guard (USCG) may use the term Ecological Risk Assessment (ERA) or Consensus ERA (CERA) (Aurand *et al*., 2000). A recent NEBA publication by IPIECA (2015c) provides a more detailed discussion on the application of NEBA for response strategy development.

In the United States, the NEBA process is used in oil spill preparedness planning and response. Before a spill, the formal NEBA process is conducted during the planning phase at the Area and Regional Response Team levels with input from state and Federal participants to determine the benefits and limitations from using each response technology within their individual areas of responsibility. In most offshore regions of the US, this was accomplished in the form of the Consensus-Based Ecological Risk Assessments (CERA) process used by the USCG (Aurand *et al*., 2000), and supported by NOAA, EPA, other Federal and state agencies, and academia. More than twenty workshops were held in various locations around the continental US, Caribbean, and Alaska from 1995 to 2011 to compare the benefits and risks of various response options when considering resource trade-off decisions. All of the workshops resulted in final publications (available from USCG) that were delivered to the Area Committees and Regional Response Teams to assist with response planning. One example of how this CERA/NEBA process was used to inform dispersant use decision-making is summarized in several papers authored by regulators in the state of California (Addassi and 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 (Mearns and Evans, 2008). Ultimately, the USCG and EPA used their ERAs to help establish dispersant pre-approval zones across the U.S.

Another approach, the Net Environmental Damage and Response Assessment (NEDRA) has been developed in Norway (SINTEF 2012). NEDRA involves valuing ecological services or other properties, assessing adverse impacts, and evaluating restoration options. No matter what terminology is assigned to the process, the aim is the same: to reduce the overall impact (ecological, economics, etc.) resulting from an oil spill.

All of these approaches typically focus on only a portion of the issues which must be resolved in order to make a decision associated with a proposed response option. Figure 1 is a representation of all of the potential factors which may ultimately influence a decision by regulators on a proposed response plan. Some of these factors, such as technological feasibility, regulatory and legal requirements, and political issues (e.g., multi-national boundaries), may influence what response options are available for consideration in a NEBA, but may not be considered as part of the risk analysis. Exactly where the line is drawn for inclusion of social, economic, and ecological issues in a NEBA will differ between study locations, other concurrent planning activities and consultations. While it is understood that a large oil spill in the Shelburne Basin may have social, economic, and cultural impacts, such impacts have been considered primarily within the ecological context (i.e., impacts to the resources of concern that are of social, economic and cultural importance). Detailed social, cultural and economic impact assessments are beyond the scope of this NEBA. For this reason, this NEBA was designed specifically to assess the level of concern over *ecological* consequences of various response options and to evaluate response options. It is not intended to estimate potential damages of a spill, but rather to identify what response options (when compared to Natural Attenuation) can minimize oiling of sensitive resources and promote rapid recovery of the ecosystem.

Figure 1. Potential factors in a risk management decisions associated with oil spill response

1.2 Objective

The objective of this NEBA is to evaluate and compare oil spill response options which are being considered in association with an oil spill response plan to support the Project. In addition, the NEBA is intended to support spill response efforts, in the unlikely event of a spill incident, and provide a basis for acquiring approval for the use of Spill Treating Agents (i.e., dispersants) in association with proposed legislation (i.e., Bill C22) on the matter.

The emphasis of this NEBA is on a structured qualitative analysis to identify response options which offer a net environmental improvement over the natural attenuation baseline. It is not intended to be a quantitative analysis. The purpose of the analysis is to help inform decisions. In summary, NEBA is a holistic approach that should:

1. Consider potentially impacted resources of concern.
2. Consider how well they can be protected with the available response techniques under the conditions prevailing at the time of a spill.
3. Seek to identify the response option(s) that provide the best overall outcome to a spill (Stevens and Aurand 2007).

1.3 NEBA Process and Development of a Risk Matrix

When a NEBA approach is used, the analysis should be based on the use of a relative, or comparative, risk framework. The basic premise of the analysis is that appropriate decisions are contingent upon determining how all available response options might be used to minimize impact and encourage recovery to the environmental and socio-economic systems. This should be based on the risk posed by each of the available response options to the identified resources of concern in comparison to all of the other available response options using "natural attenuation" (i.e., no human intervention) as the baseline for comparison. All response options have both limitations and potential benefits. The goal is to identify both, and then realistically evaluate the ecological trade-offs inherent in the use of each response option relative to other options and to the baseline (i.e., natural attenuation). In order to accomplish that goal, IPIECA (2013) identifies four elements associated with the NEBA process:

1. **Collect information on the physical and biological environmental conditions as well as the human use of the area of interest.**
    - *This step was completed via preparation of an EIS and preliminary baseline studies (Stantec 2014a,b,c) which are precursors to this NEBA document.*
2. **Review previous spill case histories and experimental results which are relevant to the area and to the available response methods.**
    - *Best professional judgment by the team of authors was used to cite past scientific studies and learnings from previous offshore spill incidents, as applicable.*
3. **On the basis of previous experience, predict the likely environmental outcomes if the proposed response is used, and compare to if the area is left for natural attenuation.**
    - *Based largely on learnings from previous offshore spill incidents.*
4. **Compare and weigh the advantages and disadvantages of the available response options against the outcome of using natural attenuation.**
    - *This is a semi-qualitative process, at best, and relies heavily on the best professional judgement of the authors, as well as input from regulatory experts in the Nova Scotia region gathered through engagement and review.*

NEBA generally focuses on comparisons between and within the identified resources of concern when various response options are weighted, such as:

- Does the socioeconomic benefit of a particular spill response method outweigh direct ecological impacts?
- Does the benefit to shoreline organisms, seabirds and marine mammals from using oil dispersants at sea outweigh the potential impact to fishery resources from exposure to dispersed oil?
- Does a clean-up method benefit one resource but impact another?

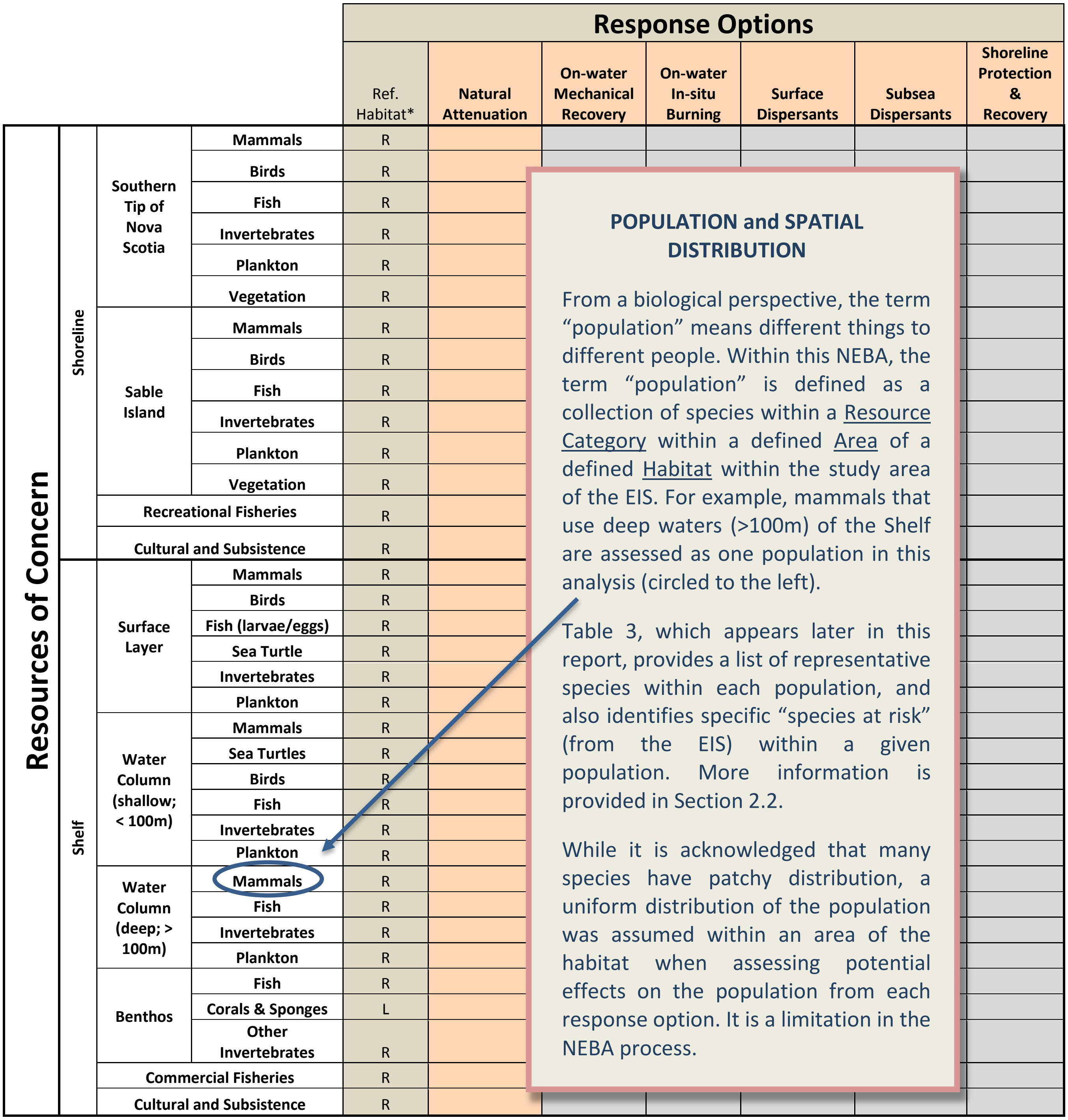
- Do different clean-up methods achieve the same outcome, but at different levels of efficiency, varying levels of impact, or over different spatial and temporal frames?

As summarized by Stevens and Aurand (2007), the NEBA approach can also help to identify potential trade-offs that may arise in the protection of different resources. NEBA is most effective when conducted during the planning phase when potential trade-offs between environmental, social, economic or aesthetic concerns can be discussed and resolved as part of the planning process. Further, when NEBA is conducted in the planning phase, it can help inform oil spill response plans with respect to stockpiling of appropriate equipment, and can help set expectations for response option effectiveness.

Having a defined, understandable methodology for conducting the analysis is critical. It provides the analytical, scientific, and documentary support for relative risk comparisons between effects on the identified resources of concern from various response options. A widely accepted approach to conducting this required comparative analysis is provided in the USCG guidelines for developing CERAs (Aurand *et al*., 2000). This approach utilizes a **risk matrix** and a **risk ranking matrix**.

The completed risk matrix is the key to the NEBA analysis: it allows comparisons between response options as well as across habitats and resource groups. The completed risk matrix provides an overview of the level of concern (i.e., risk) potentially imposed on the various resources of concern from the available response options. The risk matrix designed for this particular NEBA is shown in Figure 2. The resources of concern identified in Figure 2 and used in the NEBA analysis were derived from consideration of the baseline environmental information described in the EIS (Stantec 2014a,b) for the Regional Assessment Area (RAA). See section 5 of the EIS for further details.

In order to complete the risk matrix analysis, a risk ranking matrix is developed and used to assign levels of concern to each resource of concern (row) from the individually considered response options (column) in the risk matrix. Figure 3 presents a simplified example of a risk ranking matrix. Each axis represents a parameter used to describe risk. Here the x-axis evaluates “population recovery” and ranges from “reversible” to “irreversible,” while the y-axis evaluates “magnitude” and ranges from “minor” to “severe”. Each cell is assigned an alphanumeric value to represent relative impact. Thus, in this simplified example, a “1A” represents an irreversible and severe effect, while a “2B” represents a reversible and minor effect. While a simple 2 by 2 matrix is discussed here for illustration of the concept, actual NEBA analysis requires greater resolution. As a result, a NEBA typically employs a 4 by 4 or a 5 by 5 matrix for sufficient resolution and complexity (i.e., it is not overly difficult to complete for a number of response options and resources of concern).



				Response Options						
				Ref. Habitat*	Natural Attenuation	On-water Mechanical Recovery	On-water In-situ Burning	Surface Dispersants	Subsea Dispersants	Shoreline Protection & Recovery
Resources of Concern	Shoreline	Southern Tip of Nova Scotia	Mammals	R						
			Birds	R						
			Fish	R						
			Invertebrates	R						
			Plankton	R						
			Vegetation	R						
		Sable Island	Mammals	R						
			Birds	R						
			Fish	R						
			Invertebrates	R						
			Plankton	R						
			Vegetation	R						
		Recreational Fisheries		R						
		Cultural and Subsistence		R						
	Shelf	Surface Layer	Mammals	R						
			Birds	R						
			Fish (larvae/eggs)	R						
			Sea Turtle	R						
			Invertebrates	R						
			Plankton	R						
		Water Column (shallow; < 100m)	Mammals	R						
			Sea Turtles	R						
			Birds	R						
			Fish	R						
			Invertebrates	R						
			Plankton	R						
		Water Column (deep; > 100m)	Mammals	R						
			Fish	R						
			Invertebrates	R						
			Plankton	R						
		Benthos	Fish	R						
			Corals & Sponges	L						
			Other Invertebrates	R						
		Commercial Fisheries		R						
		Cultural and Subsistence		R						

POPULATION and SPATIAL DISTRIBUTION

From a biological perspective, the term "population" means different things to different people. Within this NEBA, the term "population" is defined as a collection of species within a Resource Category within a defined Area of a defined Habitat within the study area of the EIS. For example, mammals that use deep waters (>100m) of the Shelf are assessed as one population in this analysis (circled to the left).

Table 3, which appears later in this report, provides a list of representative species within each population, and also identifies specific "species at risk" (from the EIS) within a given population. More information is provided in Section 2.2.

While it is acknowledged that many species have patchy distribution, a uniform distribution of the population was assumed within an area of the habitat when assessing potential effects on the population from each response option. It is a limitation in the NEBA process.

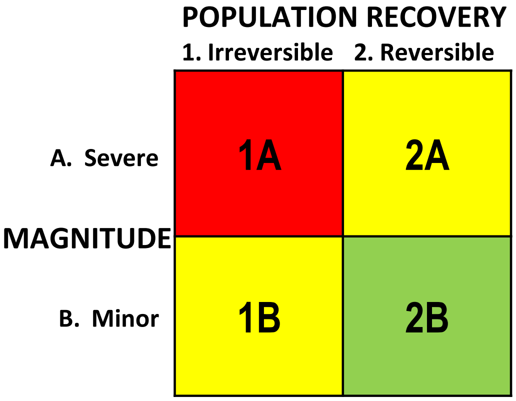
*R – Regional is defined as the entire Nova Scotia region, L – Local was defined as "near field" of the well head (~10 km)

Figure 2. NEBA analysis risk matrix

				Response Options						
				Ref. Habitat*	Natural Attenuation	On-water Mechanical Recovery	On-water In-situ Burning	Surface Dispersants	Subsea Dispersants	Shoreline Protection & Recovery
Resources of Concern	**Slope**	**Surface Layer**	**Mammals**	R						
			Birds	R						
			Fish (larvae/eggs)	R						
			Sea Turtle	R						
			Invertebrates	R						
			Plankton	R						
		Water Column (shallow; < 100m)	**Mammals**	R						
			Sea Turtles	R						
			Birds	R						
			Fish	R						
			Invertebrates	R						
			Plankton	R						
		Water Column (deep; > 100m)	**Mammals**	R						
			Fish	R						
			Invertebrates	R						
			Plankton	R						
		Benthos	**Fish**	R						
			Corals & Sponges	L						
			Other Invertebrates	R						
		Commercial Fisheries		R						
		Cultural and Subsistence		R						
	Special Areas	**Gully Marine Protected Area**		L						
		Roseway Basin		L						

*R - Regional, L – Local

Figure 2. NEBA analysis risk matrix *(cont.)*



	POPULATION RECOVERY	
MAGNITUDE	1. Irreversible	2. Reversible
A. Severe	1A	2A
B. Minor	1B	2B

Figure 3. Basic risk ranking matrix

In the NEBA, response options are considered as a source of potential ecosystem stress relative to stresses caused by the spilled oil. The mechanisms that cause this stress are not always the same, and may differ in magnitude between options. Seven “hazards” determine potential exposure pathways that link the stressors (including natural attenuation) to the resources of concern. The seven hazards are:

1. Air pollution
2. Aquatic toxicity
3. Physical trauma (i.e., mechanical impact from people, boats, etc.)
4. Oiling or smothering
5. Thermal (i.e., heat exposure from ISB)
6. Oil-contaminated waste materials transfer and disposal
7. Indirect (refers to a secondary effect such as ingestion of contaminated food)

For example, on-water recovery may affect mammals through physical injury or disturbance. On-water recovery is the **stressor**, mammals are the **resource of concern**, and physical injury or disturbance is the **hazard** by which the mammals are affected (i.e., a dolphin is struck by a propeller on a workboat handling skimming operations). Consequently, if a NEBA classifies mammals as a resource of concern and on-water recovery is a possible resource option, planners must understand the types, relative abundance and behavior patterns of the mammals in the study area to gauge to what degree the response option may cause physical injury or disturbance relative to that already caused by the oil. It is important to understand that the assessment represents changes from the natural attenuation of an oil spill. For example, the same mammals discussed above could potentially benefit from on-water recovery as a result of reduction in potential for oiling or smothering. The alpha-numerical score attributed in the risk matrix is calculated using the risk ranking matrix and is based on any associated benefit as well as the degree of impact posed by a hazard to the individual resource of concern for a particular response option. When the resource of concern cannot be linked to a response option through a hazard then there is no risk.

As part of the risk ranking process, multiple reference “populations” are defined in order to estimate the percent of a population affected (see text box in Figure 2 for more information). The EIS prepared for the Project served as the basis for the populations that were assessed in this NEBA. Details on the specific risk matrix and risk ranking matrix that were developed for this study are given in Section 3.2 of this report.

In brief, the steps for this overall process are as follows:

- Prepare oil spill scenario (or scenarios) for analysis
- Identify resources of concern and associated toxicity/exposure thresholds of concern
- Prepare a conceptual matrix (response options versus resources of concern) to guide the subsequent analysis
- Characterize resource impact if no response is implemented (e.g., natural attenuation baseline)
- Characterize resource impact from individual response options by relating oil exposure to levels of ecological concern.
- Compare the results to the natural attenuation baseline
- Identify options which improve over baseline
- Identify uncertainties and limitations
- Determine implications and consequences for response planning
- Communicate the results and rationale.

2 Spill Scenarios and Baseline Information

2.1 Geographic Area of Interest and Spill Scenarios

The geographic area of interest for the NEBA analysis includes the Southwest Scotian Slope, Sable Island and the southern tip of Nova Scotia (see Figure 4). The primary reference area used is the Regional Assessment Area (RAA) to maintain consistency with the EIS (Stantec 2014a).

A key feature of this area is defined by the Scotian Shelf/Slope break, which influences the distribution of biological resources as well as the regional hydrodynamic regime. The seaward extent of the RAA is restricted to the 200 nautical mile limit of Canada's Exclusive Economic Zone and includes offshore marine waters of the Scotian Shelf and Slope (see purple outline in Figure 4).

The scenarios considered in this report are based on information provided in the EIS and a series of oil spill simulation studies conducted by RPS ASA (Horn and French McCay, 2014a and 2014b). A brief summary of the salient factors is provided below, including references to specific portions of these documents, where appropriate. These references should be consulted if additional technical detail is desired. Note that the full dispersant modelling report is available upon request. Most of the analytical discussions in this report are based on the geographic area referred to in the EIS RAA. The conclusions outlined in this assessment are based on an analysis of deep water subsea well blowouts (with and without dispersant application) at two exploratory drilling sites (Site 1 and Site 2) located approximately 250 km offshore Nova Scotia (Figure 5). The blowout volumes used were based on calculated Worst Case Credible Discharge for each site.

SELECTING A SCENARIO

The selection of a spill scenario (e.g., oil type, oil volume, location, season and weather) is frequently the topic of debate, with many perspectives on what the "best" scenario is when planning for oil spills. Since the purpose of this NEBA was to evaluate the *ecological* consequences of various response techniques, a summer season was selected with a Worst Case Credible Discharge volume. Since the summer weather conditions support all response options, this scenario allows for an even comparison of each option under a worst case release. The type of oil chosen for the trajectory model was Federated Crude oil, which is considered a representative product with similar chemical and physical properties as that expected in the target reservoir.

The authors recognize that in winter months, some "at sea" response options (e.g., mechanical recovery and ISB) may not be feasible with sea states typically above 2 m. However, the reader is reminded that these higher sea states in winter months (or in storm events) will promote more natural dispersion, which will achieve the same objective of removing oil from the sea surface and preventing oil from approaching near-shore resources.

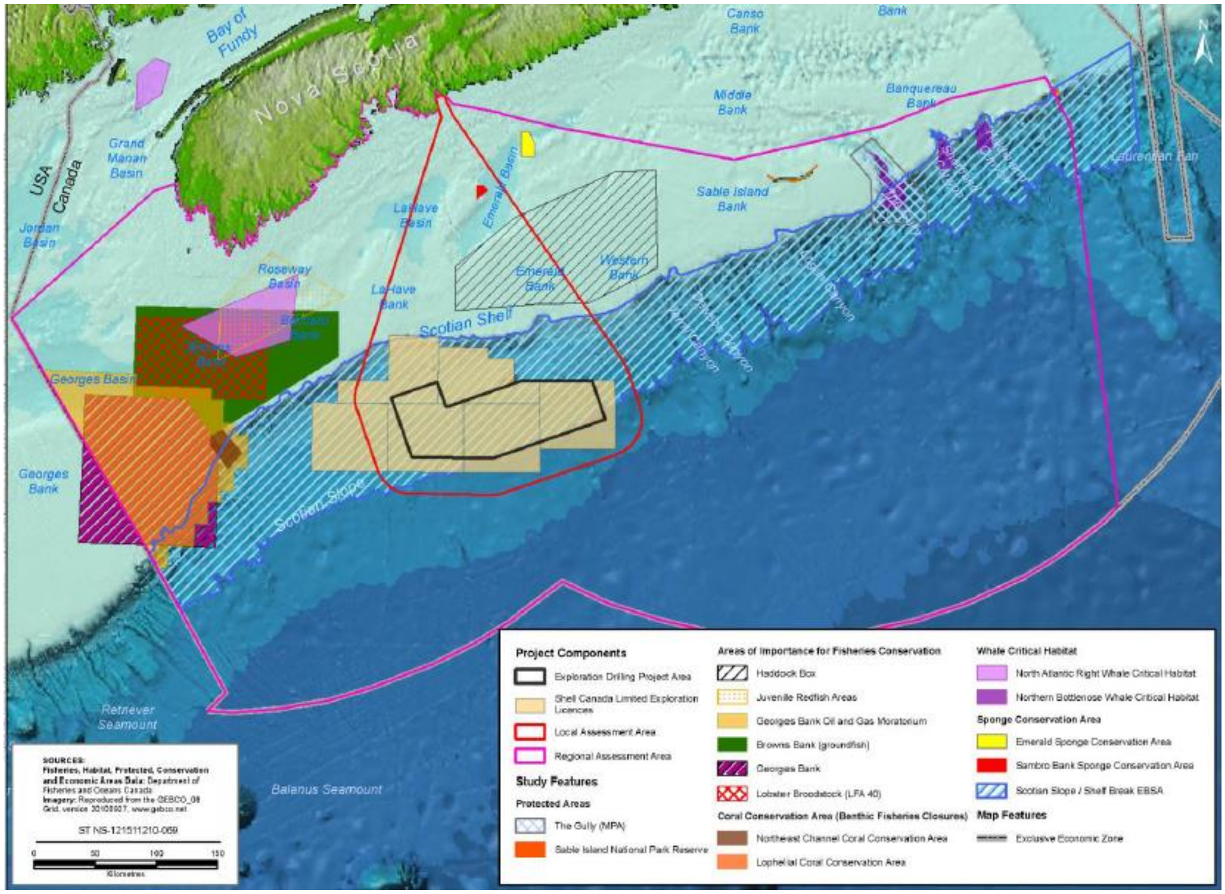


Figure 4. Spatial Boundaries for Environmental Assessment (from Stantec 2014a - Figure 3.1).

RPS ASA was tasked with preparing 3D oil spill trajectory and fate modelling in support of the EIS and also to characterize the expected variation in oil fate and trajectory between unmitigated cases (i.e., no response actions taken) and mitigated (i.e., application of surface dispersant or subsea dispersant). The basic parameters of these efforts are outlined below and the results are summarized in Section 2.4.

As presented by Horn and French McCay (2014a), in the first phase of the study, continuous unmitigated subsurface blowout scenarios were developed at the two sites, which were chosen to consider variations in water depths as well as proximity to sensitive marine features (Table 1). Federated Crude Oil was chosen as a representative product for the modelling given similar chemical and physical properties to that expected for the oil in the target reservoir. Use of this oil type was also considered an additional conservative measure based on the low viscosity and higher aromatic content of this product. Modelled release volumes and rates varied with 747,000 bbl (24,900 bpd) blowouts at Site 1 and 1,474,500 bbl (49,150 bpd) blowouts at Site 2 (Table 1). These modelled parameters were chosen based on estimated well parameters for the various depths chosen and considered to be representative of the wells that would be drilled for the Project. Model and release duration for all modelled scenarios was 30 days (considered worst case scenario duration), with a continuous release of Federated Crude oil. The near-field blowout plume model OILMAPDeep^{TM} characterized the subsurface blowout in 3D (i.e., on the water surface and throughout the water column).

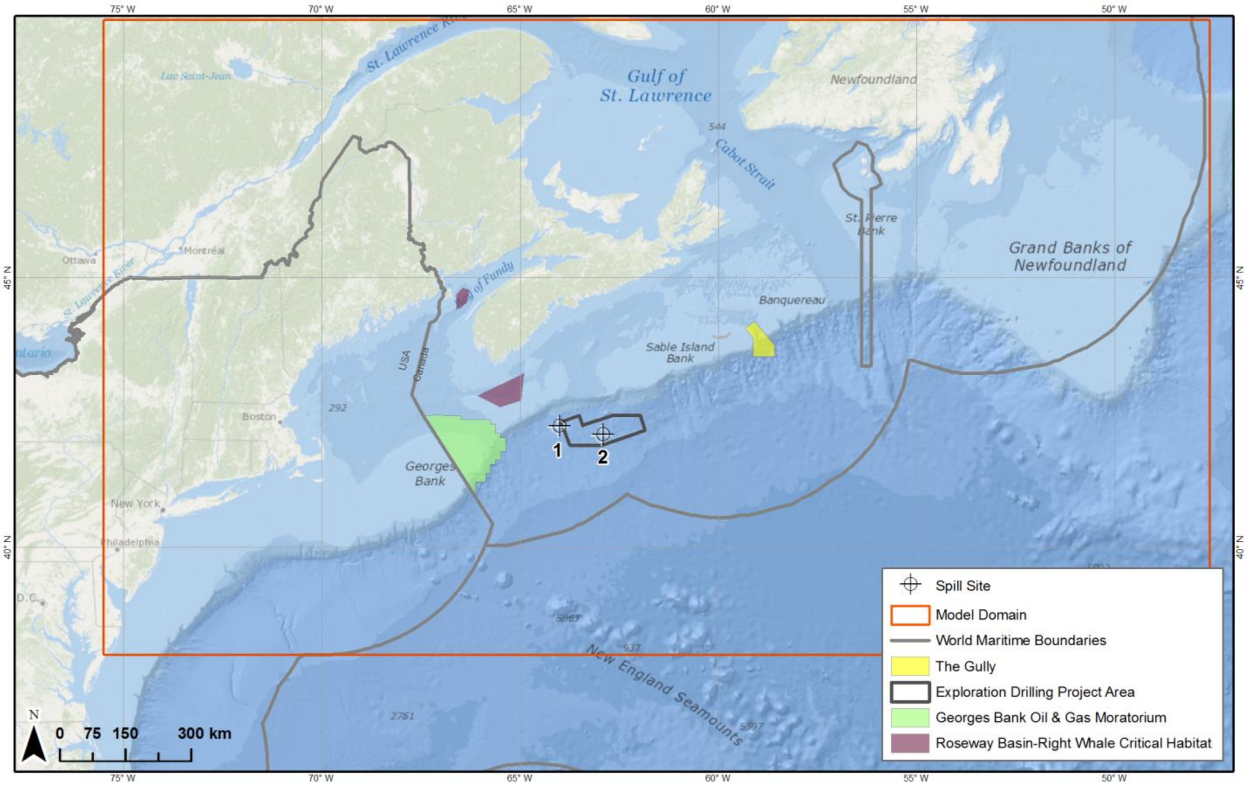


Figure 5. Location of Sites 1 and 2 used in oil spill trajectory modelling in relation to other study area features (from Horn and French McCay 2014b).

In the second phase of the study, the far-field trajectory and fate of four representative dispersant-mediated blowouts were investigated using the SIMAP^{TM} (Spill Impact Model Application Package) model. This model estimated the 3D distribution of the oil in the marine environment from the release, providing individual trajectories, mass balance information, and predicted oil thicknesses and concentrations on and in the water (Table 2). The modelling involved two simulations: subsea dispersant injection at each site from the beginning of the release (to conservatively determine maximum possible concentration of oil in the water column) and a 4-day aerial application of dispersant to the initial unmitigated surface slick until subsea dispersants could be applied (Table 2) (Horn and French McCay 2014b). Scenarios identified for this modelling also included the 95th percentile scenarios (representing maximum surface oiling) using summer season environmental conditions (April through September) for Sites 1 and 2 from the trajectory modelling report (Horn and French McCay 2014a). Summer conditions were identified as candidates for this study, as warmer and more quiescent summer conditions resulted in larger surface oil by both mass and area covered, as compared to winter conditions and previous modelling. These 95th percentile scenarios are representative deterministic cases that were identified from stochastic analyses (480 runs per site; 240 runs per summer/winter season) as having some of the largest areas of surface ocean affected (95th percentile) from spilled oil.

Table 1. Unmitigated Modelled Spill Scenarios (after Horn and French McCay 2014a; modified from Appendix G in Stantec 2014a)

Spill Location	Depth of release	Model Duration	Release Duration	Number of Model Runs	Released Product	Release Type	Oil Release Volume
Site 1 (42.3°N, 64.0°W)	1700 m	30 days	30 days	40 per month x 12 months	Federated Crude Oil	Unmitigated Blowout	747,000 bbl (24,900 bpd)
Site 2 (42.15°N, 62.9°W)	2500 m	30 days	30 days	40 per month x 12 months	Federated Crude Oil	Unmitigated Blowout	1,474,500 bbl (49,150 bpd)

Table 2. Dispersant Mitigated Modelled Spill Scenarios (after Horn and French McCay 2014b)

Spill Location	Depth of release	Release Date & Time	Release Duration & Model Duration	Scenario Type	Released Product	Oil Release Volume	Dispersant to Oil Ratio (DOR)	Dispersant Release Volume
Site 1 (42.3°N, 64.0°W)	1700 m	July 14, 2009 @ 1908	30 days 30 days	Subsea Dispersant Mitigated Blowout	Federated Crude Oil	747,000 bbl (24,900 bpd)	1:60 (effective 1:75)	522,900 gal (17,430 gpd)
Site 2 (42.15°N, 62.9°W)	2500 m	August 7, 2009 @ 0659	30 days 30 days	Subsea Dispersant Mitigated Blowout	Federated Crude Oil	1,474,500 bbl (49,150 bpd)	1:80 (effective 1:100)	774,120 gal (25,804 gpd)
Site 1 (42.3°N, 64.0°W)	1700 m	July 14, 2009 @ 1908	4 days 4 days	Surface Dispersant Mitigated Blowout	Federated Crude Oil	9,960 bbl (24,900 bpd)	1:20	49,012 gal Variable Rate
Site 2 (42.15°N, 62.9°W)	2500 m	August 7, 2009@ 0659	4 days 4 days	Surface Dispersant Mitigated Blowout	Federated Crude Oil	196,600 bbl (49,150 bpd)	1:20	49,012 gal Variable Rate

2.2 Resources of Concern

Detailed information on the biological resources present in the study area is provided in Section 5 (Existing Environment) of the EIS (Stantec 2014a). Based on this information from the EIS and the results of the transport and fate modelling, a resources of concern summary list was identified for the analysis (see Table 3 on the following pages). The species-specific information (especially for Valued Components -VC) in the EIS was taken into account in selecting and characterizing the ecological communities identified as resources of concern. The analysis in this report is based on the generalized ecological communities and/or habitat types present in that affected area, except in instances where one key species or specific community is key to evaluating the level of concern. The resources of concern identified for the analysis in this report include the following:

- Marine Mammals
- Birds
- Fish
- Invertebrates
- Plankton
- Vegetation
- Sea Turtles
- Corals & Sponges
- Cultural & Subsistence
- Commercial Fisheries

The resources of concern table is constructed to emphasize the difference between habitats offshore, on the **slope**, on the **shelf** and on the **shoreline**. The table also includes the resource categories “Cultural and Subsistence” (to denote Aboriginal Use) and “Commercial Fisheries”. These resources of concern were chosen for the NEBA analysis based on the high level of importance attached to them, as identified in the EIS. These particular Resources of Concern are depicted crossing both the Habitat and Resource Category columns in the table. This was purposely done to symbolize their assignment across all resource categories rather than repeating it within each of the Habitat and Resource Category entries. Special Areas such as the Gully and Roseway Basin were also added because of their importance in this Project Area and to consider localized vs. regionalized spatial considerations in regards to the various response options.

Table 3. Resources of Concern Developed for the Nova Scotia NEBA (based on the EIS)

AREA	HABITAT	HABITAT DESCRIPTION	RESOURCE CATEGORY	REPRESENTATIVE SPECIES or SPECIFIC CONCERNS
Shoreline	**Southern tip of Nova Scotia Intertidal**	Marine intertidal zone is defined as the area of the foreshore and seabed that is exposed to the air at low tide and submerged at high tide.	Marine Mammals	Grey and Harbour Seals
			Birds	IBAs: South Shore (Barrington Bay Sector), South Shore (Roseway to Baccaro Sector), South Shore (Port Joli Sector), South Shore (East Queens Co. Sector), The Brothers, Bon Portage Island, Eastern Cape Sable Island, Grassy Complex Area Species at Risk: Piping Plover, Roseate Tern, Harlequin Duck, Red Knot
			Invertebrates	Echinoderm and mollusk (snail, mussel, clam) species.
			Vegetation	Significant eelgrass areas, salt marsh areas, various red, green, and brown algae
	Sable Island Intertidal	Marine intertidal zone is defined as the area of the foreshore and seabed that is exposed to the air at low tide and submerged at high tide.	Marine Mammals	Grey, Harbour, Harp, Hooded and Ringed Seals
			Birds	IBAs: Sable Island Species at Risk: Roseate Tern
			Invertebrates	Various mollusks, echinoderm species
			Vegetation	Various red, green, and brown algae
	Recreational Fisheries			Invertebrates: Bar Clams, Soft Shell Clam, Bay Quahog, Razor Clams, Clams, Oysters, Whelk
	Cultural & Subsistence			DFO Small Craft Harbours Aquaculture sites - Finfish and Shellfish Kejimikujik National Park - Seaside Adjunct Provincial Parks Privately owned Conservation Areas Nature Reserves Wilderness Areas Recreational Beaches

Table 3. Resources of Concern Developed for the Nova Scotia NEBA (based on the EIS) (*cont.*)

AREA	HABITAT	HABITAT DESCRIPTION	RESOURCE CATEGORY	REPRESENTATIVE SPECIES or SPECIFIC CONCERNS
Shelf (from subtidal zone to the shelf break)	**Sea Surface Microlayer**	The sea surface microlayer (SML) is the top 1 millimeter of the ocean surface. This is the boundary layer where exchanges occur between the atmosphere and the ocean surface.	Marine Mammals	Mysticetes: Blue whale, Fin whale, Humpback whale, Minke whale, North Atlantic right whale, Sei whale Odontocetes: Atlantic white-sided dolphin, Harbour porpoise, Killer whale, Long-finned pilot whale, Northern bottlenose whale, Short-beaked common dolphin, Sperm whale, Stripped dolphin, White-beaked dolphin
			Sea Turtles	Leatherback and Loggerhead Sea Turtles
			Birds	Large Alcids, Dovekie, Black Guillemot, Cormorants, Black Legged Kittiwake, Gulls, Jaeggers, Northern Fulmar, Northern Gannet, Phalaropes, Shearwaters, Skuas, Storm Petrels, Terns, Waterfowl
			Fish (larvae/eggs only)	Monkfish
	Water Column (*shallow less than 150m*)	The marine pelagic environment from the surface to the bottom of the photic zone to a depth of 150 m.	Marine Mammals	Mysticetes: Blue whale, Fin whale, Humpback whale, Minke whale, North Atlantic right whale, Sei whale Odontocetes: Atlantic white-sided dolphin, Harbour porpoise, Killer whale, Long-finned pilot whale, Northern bottlenose whale, Short-beaked common dolphin, Sperm whale, Stripped dolphin, White-beaked dolphin
			Sea Turtles	Leatherback and Loggerhead Sea Turtles
			Birds (diving)	Large Alcids, Dovekie, Black Guillemot, Cormorants, Black Legged Kittiwake, Gulls, Northern Fulmar, Northern Gannet, Shearwaters, Storm Petrels, Terns, Waterfowl
			Fish (larvae/eggs only)	Species at Risk: Acadian Redfish, American Plaice, Atlantic Cod Groundfish: Atlantic Halibut, Pollock, Red Hake, Silver Hake, White Hake, Yellowtail Flounder Pelagic: Atlantic Mackerel, Capelin Invertebrates: American Lobster, Scallop, Northern Shrimp, Snow Crab

Table 3. Resources of Concern Developed for the Nova Scotia NEBA (based on the EIS) (*cont.*)

AREA	HABITAT	HABITAT DESCRIPTION	RESOURCE CATEGORY	REPRESENTATIVE SPECIES or SPECIFIC CONCERNS
Shelf (from subtidal zone to the shelf break)	**Water Column (*shallow less than 150m*)**	The marine pelagic environment from the surface to the bottom of the photic zone to a depth of 150 m.	Fish	Species at Risk: American Eel, American Plaice, Atlantic Bluefin Tuna, Atlantic Cod, Atlantic Salmon, Atlantic Sturgeon, Basking Shark, Blue Shark, Cusk, Porbeagle Shark, Shortfin Mako, Spiny Dogfish, Spotted Wolffish, Stripped Bass, Thorny Skate, White Shark, White Hake Groundfish: Haddock, Hagfish, Monkfish, Pollock, Red Hake, Sandlance, Silver Hake, Witch Flounder, Yellowtail Flounder. Pelagic: Atlantic Mackerel, Bigeye Tuna, Black Dogfish, Swordfish, Yellowfin Tuna
			Invertebrates	Northern Shrimp, Shortfin Squid
			Plankton	Phytoplankton, zooplankton, copepods, ctenophores, salps, jellyfish
	Water Column (*deep greater than 150m*)	The marine pelagic environment from the edge of the photic zone (150 m) to the boundary of the benthic zone.	Marine Mammals	Mysticetes: Blue whale, Fin whale, Humpback whale, Minke whale, North Atlantic right whale, Sei whale Odontocetes: Atlantic white-sided dolphin, Harbour porpoise, Killer whale, Long-finned pilot whale, Northern bottlenose whale, Short-beaked common dolphin, Sperm whale, Stripped dolphin, White-beaked dolphin
			Sea Turtles	Leatherback and Loggerhead Sea Turtles
			Fish (larvae/eggs only)	Species at Risk: American Plaice Groundfish: Atlantic Halibut, Silver Hake, Witch Flounder
			Fish	Species at Risk: Acadian Redfish, American Plaice, Atlantic Bluefin Tuna, Atlantic Cod, Atlantic Wolffish, Basking Shark, Blue Shark, Cusk, Deepwater Redfish, Northern Wolffish, Porbeagle Shark, Roughhead Grenadier, Shortfin Mako, Spiny Dogfish, Spotted Wolffish, Thorny Skate, White Shark Groundfish: Atlantic Halibut, Haddock, hagfish, Monkfish, Red Hake, Silver Hake, Witch Flounder Pelagic: Atlantic Herring, Atlantic Mackerel, Black Dogfish, Capelin, Swordfish, Yellowfin Tuna
			Invertebrates	Northern Shrimp, Shortfin Squid
			Plankton	Zooplankton, copepods, ctenophores, salps, jellyfish

Table 3. Resources of Concern Developed for the Nova Scotia NEBA (based on the EIS) (*cont.*)

AREA	HABITAT	HABITAT DESCRIPTION	RESOURCE CATEGORY	REPRESENTATIVE SPECIES or SPECIFIC CONCERNS
Shelf (from subtidal zone to the shelf break)	**Benthos**	The benthic zone is the lowest level in the marine environment which includes the sediment surface as well as sub-surface layers.	Fish (larvae/eggs only)	Species at Risk: Atlantic Wolffish, Smooth Skate, Thorny Skate, Winter Skate Groundfish: Sandlance Pelagic: Atlantic Herring
			Fish	American Plaice, Atlantic Wolffish, Northern Wolffish, Spotted Wolffish, Throny Skate, Atlantic Halibut, Hagfish, Monkfish, Witch Flounder, Sandlance
			Corals & Sponges	Small and large Gorgonacea (Soft corals, Sea pens), Stony Corals, Porifera, Glass sponge
			Invertebrates	American Lobster, Jonah Crab, Scallop, Snow Crab
	Commercial Fisheries			Finfish NAFO 4X, 4W, and 5Ze (Pelagic season is open year round although high fishing activity occurs from July to November. The ground fishery is open year round, with high season from July-Sept)
				Scallop SFA 25, 26, and 27 (Fishery is open year round, with most activity occurring between May and October.)
				Crab CFA 23, 24E, and 24W (Season is open from April to September)
				Lobster LFA 31b and 32 (Season is open from April 19 - June 20)
				Lobster LFA 33/34 (Season is open from the last Monday in November to May 31)
				Lobster LFA 41 (Season is open year round)
	Cultural & Subsistence			Recreational Fishing - Pelagic and Benthic finfish Recreational Diving Recreational Boating Aboriginal Food, Social, and Ceremonial Fisheries : Finfish: American Eel, Atlantic Cod, American Plaice, Atlantic Salmon, Atlantic Herring, Atlantic Halibut, Atlantic Mackerel, Atlantic Redfish, Blue Shark, Capelin, Deepwater Redfish, Gaspereau, Haddock, Striped Bass, Pollock, Silver Hake, Smooth Flounder, Tomcod, Windowpane Flounder, Winter Flounder, Witch Flounder, Yellowtail Flounder. Invertebrates: American Lobster, American Oysters, Bay Quahog, Blue Mussels, Crabs, Scallops, Squid Mammals: Seals

Table 3. Resources of Concern Developed for the Nova Scotia NEBA (based on the EIS) (*cont.*)

AREA	HABITAT	HABITAT DESCRIPTION	RESOURCE CATEGORY	REPRESENTATIVE SPECIES or SPECIFIC CONCERNS
Slope (extending offshore from the shelf break)	**Sea Surface Microlayer**	The sea surface microlayer (SML) is the top 1 millimeter of the ocean surface. This is the boundary layer where exchanges occur between the atmosphere and the ocean surface.	Marine Mammals	Mysticetes: Blue whale, Fin whale, Humpback whale, Minke whale, North Atlantic right whale, Sei whale Odontocetes: Atlantic white-sided dolphin, Harbour porpoise, Killer whale, Long-finned pilot whale, Northern bottlenose whale, Sowerby's beaked whale, Short-beaked common dolphin, Sperm whale, Stripped dolphin, White-beaked dolphin
			Birds	Large Alcids, Dovekie, Cormorants, Black Legged Kittiwake, Gulls, Jaeggers, Northern Fulmar, Northern Gannet, Phalaropes, Shearwaters, Skuas, Storm Petrels, Terns, Waterfowl
			Sea Turtles	Leatherback and Loggerhead Sea Turtles
			Fish (larvae/eggs only)	Monkfish
	Water Column (*shallow; less than 150m*)	The marine pelagic environment from the surface to the edge of the photic zone to a depth of 150 m	Marine Mammals	Mysticetes: Blue whale, Fin whale, Humpback whale, Minke whale, North Atlantic right whale, Sei whale Odontocetes: Atlantic white-sided dolphin, Harbour porpoise, Killer whale, Long-finned pilot whale, Northern bottlenose whale, Sowerby's beaked whale, Short-beaked common dolphin, Sperm whale, Stripped dolphin, White-beaked dolphin
			Sea Turtles	Leatherback and Loggerhead Sea Turtles
			Birds (diving)	Large Alcids, Dovekie, Cormorants, Black Legged Kittiwake, Gulls, Northern Fulmar, Northern Gannet, Shearwaters, Storm Petrels, Terns, Waterfowl
			Fish (larvae/eggs only)	Species at Risk: Acadian Redfish, Deepwater Redfish Groundfish: Turbot-Greenland Flounder, Witch Flounder
			Fish	Species at Risk: American Eel, Atlantic Bluefin Tuna, Atlantic Cod, Basking Shark, Blue Shark, Cusk, Porbeagle Shark, Shortfin Mako, Spiny Dogfish, Spotted Wolffish, Thorny Skate, White Shark Groundfish: Monkfish, Red Hake, Silver Hake, Turbot-Greenland Flounder, Witch Flounder Pelagic: Albacore Tuna, Bigeye Tuna, Swordfish, White Marlin, Yellowfin Tuna

Table 3. Resources of Concern Developed for the Nova Scotia NEBA (based on the EIS) (*cont.*)

AREA	HABITAT	HABITAT DESCRIPTION	RESOURCE CATEGORY	REPRESENTATIVE SPECIES or SPECIFIC CONCERNS
Slope (extending offshore from the shelf break)	**Water Column (*shallow; less than 150m*)**	The marine pelagic environment from the surface to the edge of the photic zone to a depth of 150	Invertebrates	Shortfin Squid
			Plankton	Phytoplankton, zooplankton, copepods, ctenophores, salps, jellyfish
	Water Column (*deep; greater than 150m*)	The Marine pelagic environment from the edge of the photic zone (150 m) to the boundary of the benthic zone.	Marine Mammals	Mysticetes: Blue whale, Fin whale, Humpback whale, Minke whale, North Atlantic right whale, Sei whale Odontocetes: Atlantic white-sided dolphin, Harbour porpoise, Killer whale, Long-finned pilot whale, Northern bottlenose whale, Sowerby's beaked whale, Short-beaked common dolphin, Sperm whale, Stripped dolphin, White-beaked dolphin
			Sea Turtles	Leatherback and Loggerhead Sea Turtles
			Fish (larvae/eggs only)	Species at Risk: Roundnose Grenadier
			Fish	Species at Risk: Acadian Redfish, Atlantic Bluefin Tuna, Atlantic Cod, Atlantic Wolfish, Basking Shark, Blue Shark, Cusk, Deepwater Redfish, Northern Wolffish, Porbeagle Shark, Roughhead Grenadier, Roundnose Grenadier, Shortfin Mako, Spiny Dogfish, Spotted Wolffish, Thorny Skate, White Shark Groundfish: Atlantic Halibut, Hagfish, Monkfish, Red Hake, Silver Hake, Turbot-Greenland Flounder, Witch Flounder Pelagic: Albacore Tuna, Bigeye Tuna, Black Dogfish, Swordfish, Yellowfin Tuna
			Invertebrates	Shortfin Squid
			Plankton	Zooplankton, copepods, ctenophores, salps, jellyfish
	Benthos	The benthic zone is the lowest level in the marine environment which includes the sediment surface as well as sub-surface layers.	Fish	Atlantic Wolffish, Northern Wolffish, Spotted Wolfish, Thorny Skate, Monkfish, Turbot-Greenland Flounder, Witch Flounder
			Corals & Sponges	Small and large Gorgonacea (Sea whilps, Sea pens, Soft corals), Black coral, Stony cup coral
			Invertebrates	Snow Crab
	Commercial Fisheries			Finfish NAFO 4X, 4W, and 5Ze (Pelagic season is open year round although high fishing activity occurs from July to November. The ground fishery is open year round, with high season from July-Sept)

Table 3. Resources of Concern Developed for the Nova Scotia NEBA (based on the EIS) (*cont*.)

AREA	HABITAT	HABITAT DESCRIPTION	RESOURCE CATEGORY	REPRESENTATI/VE SPECIES or SPECIFIC CONCERNS
Slope (extending offshore from the shelf break)	**Cultural & Subsistence**			N/A
Special Areas	**Gully Marine Protected Area**	The Gully Marine Protected Area is located approximately 200 km southeast of Nova Scotia, east of Sable Island, on the edge of the Scotian Shelf. The seafloor drops off to 2500 m into a large submarine canyon which is home to a rich diversity of marine habitats and species.		<u>Mysticetes</u>: Blue whale, Fin whale, Humpback whale, Minke whale, North Atlantic right whale, Sei whale <u>Odontocetes</u>: Atlantic white-sided dolphin, Harbour porpoise, Long-finned pilot whale, Northern bottlenose whale, Sowerby's beaked whale, Short-beaked common dolphin, Sperm whale, Stripped dolphin, White-beaked dolphin <u>Corals and sponges</u>: Small and large Gorgonacea, Black coral, Sea Pens, Soft Coral, Porifera
	Roseway Basin	The Roseway Basin is located on the Scotian Shelf off of Southwest Nova Scotia, between Baccaro and Browns Banks. This Basin is critical habitat for the endangered North Atlantic Right Whale (Schedule 1 of SARA)		<u>Mysticetes</u>: North Atlantic Right Whale

Figure 6 and 7 below provide the reader a general introduction to the Project area. Shoreline classification information, provided through Environment Canada, is captured in Figure 6 to illustrate the varied shoreline habitat along the southern tip of Nova Scotia. Areas noted as important fisheries locations are shown in Figure 7. Spatial information denoted on Figure 7 was gathered as part of stakeholder engagements associated with the EIS and NEBA.

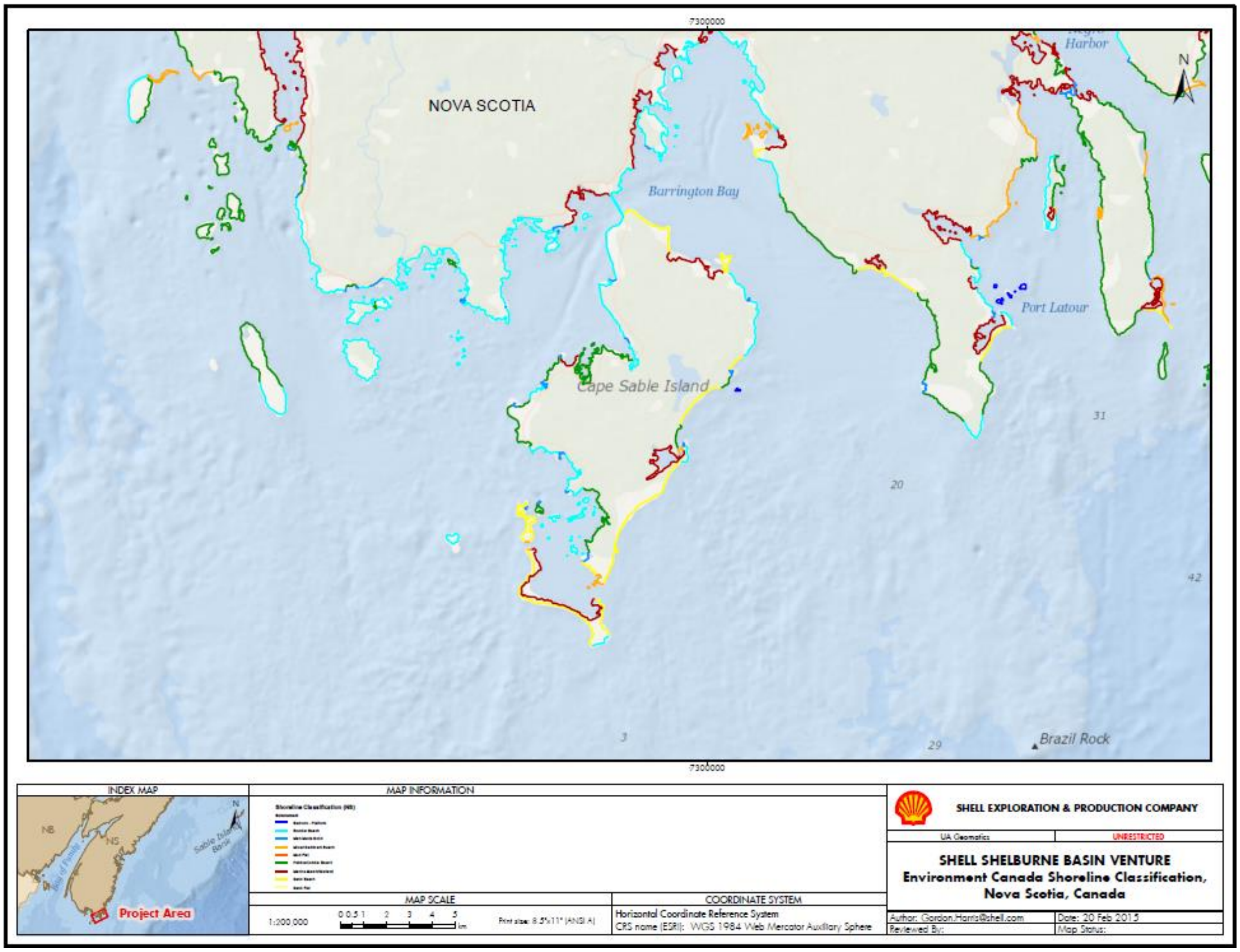


Figure 6. Shoreline classification map for the Nova Scotia region

In association with the NEBA analysis, Shell has engaged with various federal and provincial regulators, as well as Aboriginal peoples and members of the public, regarding Resources of Concern and the associated analysis. Additionally, there was active stakeholder participation in the development of the EIS, and the reader is encouraged to review the detailed information provided in that document (Stantec, 2014a,b). Table 4 provides a summary of stakeholder engagement undertaken in association with the NEBA analysis.

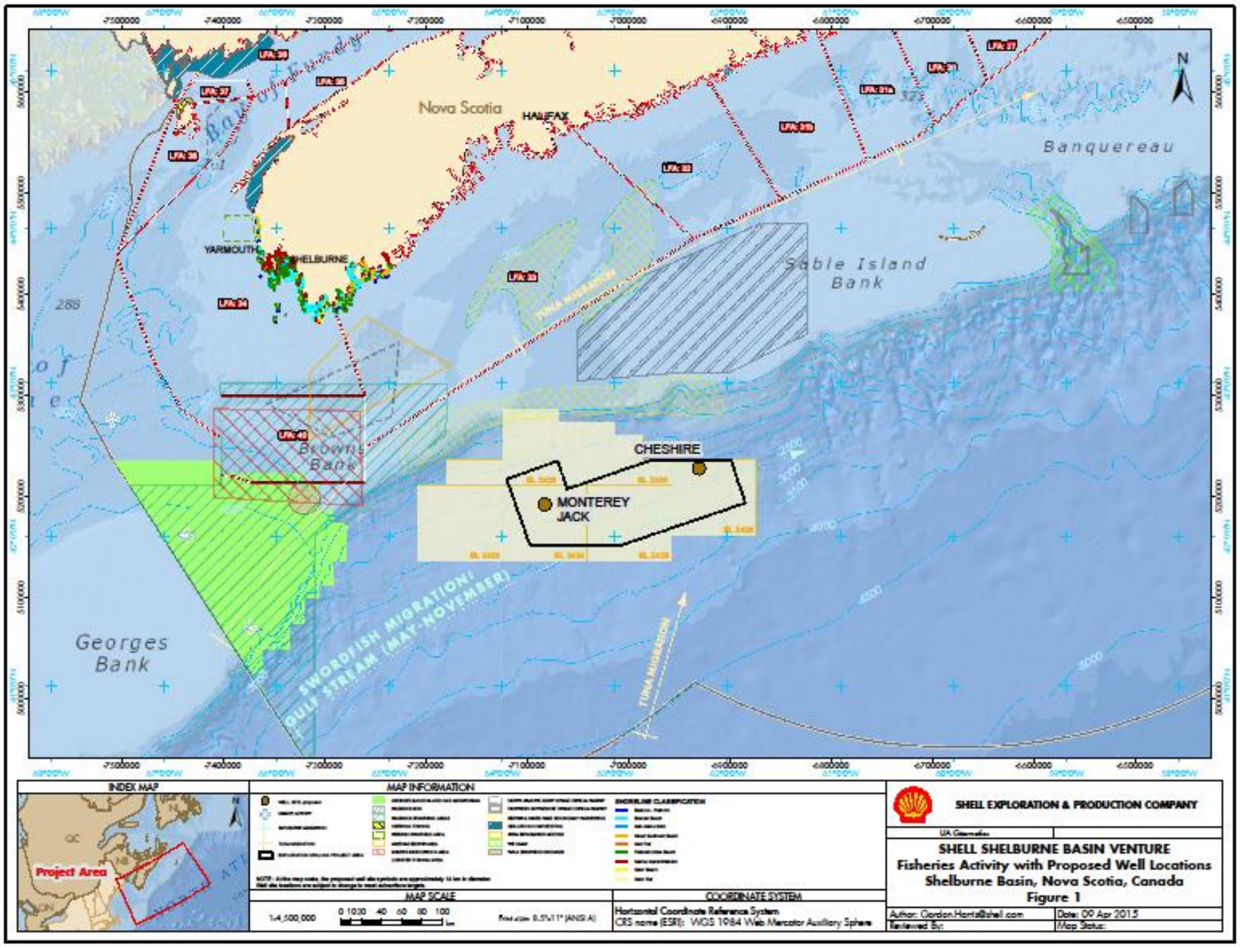


Figure 7. Map depicting important fisheries within the Project area

Table 4. Summary of NEBA Stakeholder and Aboriginal Engagement

Organization	Format	Purpose	Location	Date
Fisheries and Oceans Canada (DFO) DFO – Canadian Coast Guard (CCG)	Workshop	Overview of NEBA Methodology and Results Spill Response Measures	Montreal, QC	Dec 8, 2014
Environment Canada (EC) – National Environmental Emergencies (NEEC) Science Table				
CNSOPB				
Mi'kmaq of Nova Scotia	Workshop	Spill Response Measures NEBA Methodology and Results	Millbrook, NS	Feb 9, 2015
Mi'kmaq of Nova Scotia	Workshop	Spill Response Measures NEBA Methodology and Results	Membertou, NS	Feb 10, 2015
Fisheries Stakeholders (Fisheries Advisory Committee +)	Workshop	Spill Response Measures NEBA Methodology and Results	Halifax, NS	Feb 11, 2015
New Brunswick First Nations (St. Mary's, Woodstock, Fort Folly, Assembly of NB First Nation Chiefs)	Workshop	Spill Response Measures NEBA Methodology and Results	Fredericton, NB	Feb 12, 2015
St. Mary's First Nation	Conference Call	Proposed manner of Consultation	Halifax, NS	Mar 26, 2015
Assembly of New Brunswick First Nation Chiefs (ANBFNC)	Conference Call	Proposed manner of Consultation	Halifax, NS	Mar 27, 2015
KMKNO	Conference Call	Proposed manner of Consultation	Halifax, NS	Mar 30, 2015
Fisheries Stakeholders (FAC +)	Information Session	Spill Response Measures NEBA Methodology and Results	Halifax, NS	Apr 24, 2015
New Brunswick First Nations (Woodstock, St. Mary's, Fort Folly, ANBFNC)	Information Session		Fredericton, NB	Apr 27, 2015
Millbrook Chief and Council	Letter	Request for meeting	Millbrook, NS	May 19, 2015
Eskasoni Chief and Council	Letter	Request for meeting	Eskasoni, NS	May 19, 2015
Acadia Chief and Council	Letter	Request for meeting	Acadia, NS	May 19, 2015
Millbrook First Nation	Information Session	Spill Response Measures NEBA Methodology	Millbrook, NS	May 28, 2015
Mi'kmaq Fisheries Managers	Information Session		Millbrook, NS	Jun 18, 2015

2.3 Response Options

The six response options considered in this analysis are summarized below from an operational and logistics perspective. Shell has prepared a detailed Oil Spill Response Plan (OSRP) as well as an Aerial and Surface Dispersant Operations Plan for the Project. The reader is encouraged to review that plan for further operational information on the individual response options. It is important to recognize that during a spill, the best response almost always results when a combination of response techniques are used together to minimize ecological damage and promote the fastest overall recovery of the ecosystem. So while the response options are considered individually in this document, it is understood that multiple responses will likely be used during a real spill.

Where necessary for the analysis, scenario-specific information is included in the description. The operational benefits and limitations for all of these response options are summarized in Table 5. Potential environmental impacts are the focus of later analysis in the document.

Table 5. Operational Summary of Response Options (Modified from IPIECA 2013)

Response Option	Benefit	Limitation
Natural Attenuation	• No intrusive removal or cleanup techniques that further damage the environment • May be best option if there is little to no threat to human or environmental well-being • When selected for certain areas and conditions, the environment can recover from the spill more effectively than it might when using other response tools	• Winds and currents can change, sending the oil spill toward sensitive areas • Residual oil can impact shoreline ecology, wildlife, and economically relevant resources • Public perception that responders are doing nothing
Shoreline Protection & Recovery	• Booming can be strategically planned to protect sensitive areas • Non-aggressive methods can have minimal impact on shore structure and shore organisms while reducing the amount of stranded oil • Useful for detailed cleaning of near shore environment in specific or sensitive areas • Recovered oil can be recycled	• Aggressive removal methods may impact shoreline and shore organisms (e.g., sand removal and cleaning) • Potential for heavy equipment and high foot traffic (trampling) can cause additional environmental damage • Removal occurs after oil has already impacted shore • Labor-intensive and weather dependent
On-water Mechanical Recovery	• Permanently removes oil from the water, thereby preventing shoreline impacts • Well-accepted, no special approvals needed • Effective for recovery over wide range of spilled products • Large “window of opportunity” • Minimal side effects • Greatest availability of equipment and expertise • Recovered product may be reprocessed	• Inefficient and impractical on thin slicks • Ineffective in inclement weather or high seas • Requires storage capability • Typically recovers no more than 10 percent of the oil spilled in open ocean environments, more may be recovered in other conditions • Labor- and equipment-intensive

Table 5. Operational Summary of Response Options (Modified from IPIECA 2013) *(cont.)*

On-water In-situ Burning	• High oil elimination rate possible • No recovered oil storage requirements • Effective over wide range of oil types and conditions • Specialized equipment (boom) is air transportable • Minimal environmental impact	• Special approvals required • Ineffective in inclement weather or high seas • Black smoke perceived as significant impact on people and the atmosphere • Localized reduction of air quality • Specialized equipment and expertise required • Burn residue can be difficult to recover
Dispersants – Water Surface	• High aerial coverage rate possible at the water surface • Large volumes of oil can be treated • Potentially high oil elimination rate • Reduced vapors at the water surface; improves safety • No recovered oil storage requirements • Lower manpower requirements • Potentially the quickest response option • Prevents oil from spreading to shoreline • Useful in higher wind and sea conditions • Effective over wide range of oil types and conditions	• Special approvals required • Perceived to be unsuitable for calm seas • Short-term, localized reduction in water quality • Potential impact on water column ecology • Specialized equipment and expertise required • Will not work on high viscosity fuel oils in calm, cold seas • Has a limited "window of opportunity" for use
Dispersants – Subsea Injection	• Large volumes of oil can be treated with high efficiency • Potentially high oil elimination rate • Reduced vapors at the water surface; improves safety • No recovered oil storage requirements • Lower manpower requirements • Prevents oil from spreading to shoreline • Useful in wind and sea conditions that would inhibit other response options • Effective over wide range of oil types and conditions • Applications can be performed continuously – 24 hours, 7 days a week	• Less known about long term effects of subsea use • Special approvals required • Short-term, localized reduction in water quality • Potential impact on water column ecology • Specialized equipment and expertise required •

2.3.1 Natural Attenuation

Natural attenuation is a response option involving no human intervention to influence the fate of the spilled product. In association with this analysis, it represents the baseline against which all of the other response options are compared. With natural attenuation, the spilled oil will drift with the winds and currents, gradually weathering 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. Portions of the relatively fresh oil may be released from the shoreline and redistributed several times until it finally degrades, is consumed by organisms, or is deposited permanently.

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 dispersion and may prevent other response options from being 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. It could be necessary where recovery and cleanup are not feasible.

Logistics: 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.

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

Efficiency: The term "efficiency" in oil spill response refers to how well a mobilized response technique will work. In this case, the efficiency of "doing nothing" cannot be measured. However, natural attenuation (sometimes referred to as a "monitor and wait" approach) can be an effective option, especially in extreme weather conditions when high energy can effectively disperse the oil naturally.

2.3.2 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 demonstrates that there is a very low likelihood of spilled oil reaching the shoreline. However, in the unlikely event where it may reach shore, ways to safeguard the shoreline from spill impacts include shoreline protection and recovery. Shoreline protection and recovery are considered important tools when oil cannot be effectively treated or collected on-water prior to encounter with shoreline areas.

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 meters, High winds can also blow the oil past the boom, and tides and currents can also pose a challenge. For the specific spill scenario considered, the remote location of the spill site (i.e., 250 km from shore) and the degree of oil weathering predicted, the options listed below are the most appropriate shoreline recovery options that may be utilized if oil does reach shorelines:

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

Benefits: Protective booming can protect relatively short stretches of the coast and as such should be used strategically in selected areas such as protecting lagoons, backwater entrances, marshes, or other sensitive 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 impact to shorelines, sensitive habitats, birds, mammals, and other wildlife
- Physical removal of oil from the environment
- Recycling or proper disposal of recovered oil.
- Mitigation of impacts to culturally or economically important areas such as those used for nearshore fisheries, gathering, tourism and recreation activities.

OIL AND SEDIMENTS

The concern about the ecological consequences of oil in sediments is valid. Studies from large oil spills (*Exxon Valdez*, *Sea Empress*, and Gulf War spills) have shown that weathered oil that strands in intertidal or subtidal habitats such as mudflats or marshes can persist for years. This can be exacerbated by manual cleanup efforts if personnel walk over sensitive areas and embed the oil deeper into the sediments with their footsteps or tools, or by natural processes that drive the oil below the surface. Once the oil is driven below the surface into anoxic zones, natural weathering and biodegradation processes occur much more slowly (Sauer *et al*., 1998). One experimental study conducted in an Atlantic Canada salt marsh concluded that, once oiled, the best response action is natural attenuation (Lee *et al*., 2003). Typically the public does not respond well to the idea of *not* cleaning up the oil in critical shoreline habitats.

Alternatively, the better response option should be to prevent the oil from approaching these shoreline environments in the first place and instead should focus on responding to the oil while it is still at sea.

Logistics: 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. 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 all make shoreline protection and recovery operationally difficult and it may not be possible to implement such options in all potentially affected areas due to logistical constraints. The reader is referred to the OSRP for equipment, mobilization and deployment planning for the Project.

Limitations: Typically shoreline protection activities can be applied to only relatively short stretches of the coast and as such must be used strategically in selected areas such as protecting lagoons, backwater entrances, marshes and other sensitive, ecologically important, or socially important areas. 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 on some shoreline habitats. 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 in an effort to passively collect any oil that re-floats. Shoreline recovery tends to be more environmentally intrusive than any of the on-water response options. Given the logistics 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.

Efficiency: The efficiency of protective booming is highly variable. The degree of protection afforded depends on factors such as the type of oil, local currents and wave conditions, installation methods, boom maintenance, and the degree to which a shoreline is accessible with equipment and amenable to placement of protective (diversion) booming. Even properly installed booms can protect only relatively short segments of a coastline and cannot provide protection to the entire shoreline if a widespread slick is approaching from the offshore. An additional consideration is that the efficiency of protection commonly decreases as the duration of oiling and amount of oil impinging on the boom increases. Oily booms need to be serviced on a regular basis or they can become a source of oil for the local area it was intended to protect.

Depending on the spill conditions and the response operation used, the shoreline recovery strategies can range from 100% effective in shoreline types such as sandy beaches, where heavy equipment and personnel have easy access, to minimally effective in the case of marshes and sheltered tidal mud flats where any type of access by humans or equipment can drive oil deep into sediments, resulting in no recovery. Additionally, once shoreline recovery begins, determination of “how clean is clean” can make decisions regarding termination difficult. Shoreline cleanup is an extensive topic and documents such as Environment Canada’s “A Field Guide to Oil Spill Response on Marine Shorelines” (Owens and Sergy, 2010), and the Shoreline Assessment Manual, 4th Edition (NOAA, 2013) are valuable references for the reader to gain a better understanding of the various cleanup methods, effectiveness associated with each method, and cleanup endpoints.

2.3.3 On-water Mechanical Recovery

On-water mechanical recovery is defined as the removal of oil from water using mechanical equipment (i.e., skimmers and booms) to redirect and remove oil from the surface of the water. This recovered oil is collected for disposal and possible reuse to prevent or minimize impacts to sensitive near shore and offshore habitats. The success rate of oil removal by means of on-water mechanical recovery is dependent upon factors such as wind, waves, and daylight.

Benefits: This response option permanently removes both fresh and weathered oil states from the water and prevents distribution of the spill in the environment through processes such as natural or chemically induced dispersion, evaporation, or physical transport by currents. When recovered at sea, the threat to shoreline resources is mitigated because less oil becomes stranded and shoreline protection and recovery operations are reduced or eliminated. Recovery operations tend to have minimal side effects on wildlife. Mechanical recovery also provides the greatest range of equipment options and is one of the most practiced and understood of the oil spill response options.

Logistics: The equipment needed to carry out mechanical recovery of a large scale oil spill will involve a large number of skimming vessels, support vessels, storage barges, spotter aircraft and large quantities of collection boom. The equipment will need to be transported to the spill site, which in this instance is approximately 250 km offshore. Collected oil will need to be stored and ultimately returned to shore for disposal. Given the distance offshore, the logistics associated with a large-scale release would be complex and challenging. On water mechanical recovery may have only localized capability and benefit. The reader is referred to the OSRP for equipment mobilization and deployment planning for the Project.

Limitations: Although there will be recovery vessels in the area available to assist with the immediate response, these vessels will have a limited recovery capability. As a result, there will be a lag time from the time of the spill to the time of conducting mechanical recovery on a large scale, reducing the window of opportunity to conduct mechanical recovery. Light oil rising to the surface is likely to form very thin sheens which will reduce efficiency of oil collection at the surface. The longer the oil is left in the water, the more it disperses and thins making it more difficult to recover. Besides the encounter rate, weather conditions and day length would also be critical in this area. Open water boom begins to fail in sea states with waves over approximately 2 m, which occur approximately 80% of the time in the winter and 20 to 25% of the time in the summer within the RAA (Stantec 2014a). While day length is not an issue in the summer, it will be in the winter, reducing the window of opportunity even more. When sea states are conducive for booming and on-water skimming, mechanical recovery techniques typically recover no more than approximately 10%of the oil spilled in open ocean environments.

Efficiency: On-water mechanical recovery on the open ocean is limited by climatic and hydrographic conditions, oil weathering and the encounter rate. Even when conditions are favorable, after action reports from previous large offshore spills indicate recovery of 5 to 10% of spilled volume is the maximum that can be expected. At Deepwater Horizon (DWH) the estimate was less than 5%.[1]

2.3.4 On-Water In-situ Burning

On-water in-situ burning (ISB) involves the collection of oil in specially designed fireproof booms (as in on-water recovery), followed by removal of the oil from the water surface through burning. This response option is advantageous in the fact that it reduces oil storage and disposal. ISB has the same weather and day light condition limitations as on-water mechanical recovery. It is preferentially conducted under even lower wave heights (less than 1.2 m), and with plenty of available daylight to monitor and track the burn as well as to allow for ignition and control.

Benefits: This response option can permanently remove encountered oil from the water at high rates (if there are prevailing low sea states of less than 1.2 m to maintain the oil in the boom) and reduces the amount of oil remaining for collection and disposal. The technique is effective for a wide range of oils. As a result, ISB can minimize the spread of a spill and the resources and time needed for a response.

Logistics: Equipment needs are similar to on-water mechanical recovery, with the addition of fire boom and ignition capability. It should be noted that the approval process for ISB may also require either an enhanced monitoring aircraft or ground-based smoke-plume air quality monitoring to be implemented, so logistics consideration should be given to mobilizing scientific teams and equipment for this purpose. The reader is referred to the OSRP for equipment mobilization and deployment planning for the Project.

Limitations: The decision to use ISB is dependent on the feasibility under existent environmental conditions at the time of an incident and regional government policies- some guidance is available in the "British Columbia/Canada In-situ Oil Burning Policy and Decision Guidelines" (DFO, EC, BC Ministry of Environment, Lands and Parks 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. Limitations related to weather, encounter rates and day length are similar to on-water mechanical recovery. It is preferentially conducted in low wave heights (less than 1.2m), and with plenty of availably daylight to monitor and track the burn as well as to allow for ignition and control. The availability of fire boom, which becomes unusable over time, would be a factor in a spill of the extent and duration assumed for this study. Oil is likely to be easily ignitable when fresh, but will become less suitable for burning as it weathers and emulsifies. Additionally this response option is inefficient and impractical on thin slicks.

Efficiency: ISB is a response technique that is highly dependent on the prevailing environmental conditions and the encounter rate. For these reasons, ISB would not likely result in the removal of large amounts of oil in this Project area because wave heights in the North Atlantic are typically above the 1.2 m needed to maintain the oil in a fire boom. At DWH, where sea states were typically quite low throughout the response, estimates were that 5% of the oil was removed by burning, which is more

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[1] Estimate based on "Oil Budget Calculator: Deepwater Horizon" report by The Federal Interagency Solutions Group, Oil Budget Calculator Science and Engineering Team (November 2010).

than would be expected offshore Nova Scotia where sea states would typically not support the fire booming operation (Allen *et al.*, 2011).

2.3.5 Dispersant Application at Water Surface

A general overview of dispersants was provided in the EIS, and a primer on dispersants is provided in Appendix A. The reader is referred to this appendix for a broader discussion on this topic. Dispersants may be applied to the affected water surface from airplanes, helicopters and/or vessels. Dispersant spray systems are designed to provide the correct droplet size and dosage, as both are important factors in effective oil dispersal. The volume of dispersant applied is a fraction of the volume of oil treated. Responders make a judgment on what dispersant to oil ratio (DOR) should be employed based on the type of oil spilled, its thickness, and its degree of weathering. When the oil is treated with dispersants at the water surface, it disperses within the upper 10 m of the water column due to natural mixing processes. This mixing is primarily driven by wave action and winds, and to a lesser degree rain and possibly surface currents. If these dispersed oil droplets are small enough (generally 10-100 micrometer) the droplets will remain dispersed in the water column, and serves as a positive indication of effective oil dispersion (Lunel, 1993; Li *et al.*, 2009 a,b). Chemically dispersed oil droplets are typically smaller than naturally dispersed oil droplets and have a reduced interfacial tension (due to the surfactant provided by the dispersant). These smaller chemically dispersed droplets form stable oil-in-water emulsions which are much less likely to re-coalesce into a surface slick (compared to naturally dispersed oil droplets). The dispersed oil will then be rapidly diluted due to spreading both horizontally and vertically by tides and currents and will naturally biodegrade. Additional information on biodegradation

DILUTION RATES RESULTING FROM DISPERSANT APPLICATION

Much of the literature on the toxicity of dispersants and dispersed oil is based on 48- or 96-hr LC50 studies where the test organisms are exposed to a constant concentration of dispersant or dispersed oil for relatively prolonged periods. Prolonged and constant exposure to very high concentrations of dispersed oil in a laboratory setting (in order calculate LC50 values) is considerably different from the likely exposure regime experienced by marine organisms in the open sea following an oil spill, as evidenced by analytical results from several field trials conducted in the North Sea to assess fate and effects of dispersant use on an open ocean oil slick.

These field experiments and the subsequent chemical characterization conducted in 1994 (AEA Technology, 1994), 1995 (AEA Technology, 1995; Jones and Petch, 1995), and 1996 (Strøm-Kristiansen *et al.*, 1997; Coelho *et al.*, 1998) showed rapid (within one hour) dilution of dispersed oil concentrations following dispersant application. Further evidence of the rapid dilution of dispersed oil can be found from extensive studies during the DWH spill (OSAT*, 2010), in which more than 11,397 water and sediment samples were analyzed, and findings indicate that less than 1% water and sediment samples exceeded aquatic toxicity benchmarks.

** OSAT is the inter-agency team formed to compile, analyze and interpret the data generated from the DWH large-scale sampling and monitoring program.*

processes is provided in Appendix A. Historically, initial dispersed oil concentrations of 20 to 50 parts per million (ppm) have been reported in the upper 10 m of the water column directly under the slick. These concentrations dilute rapidly as the oil moves through time and space in the water column and degrade. Within 2-4 hours, concentrations typically decrease to below 10 ppm, which is approaching the threshold limit below which adverse ecological effects are not anticipated, even to sensitive species (NRC, 2005).

Benefits: The use of dispersants on the surface of the water applied from either vessels or aircraft can substantially reduce the amount of oil that may impact shorelines or has to be recovered. It reduces the potential smothering of or oil ingestion by wildlife that use surface waters in or near a spill. The application of dispersants can also be performed on a large areal scale and in high sea conditions, thereby increasing the response time and effectiveness for reducing a spill's impact. When a surface spill has been treated with chemical dispersants, the oil can be rapidly diluted in a large volume of water to very low concentrations. Finally, the dispersed oil is also more susceptible to biodegradation – hence, it is removed more quickly from the environment.

Logistics: In the spill scenario analyzed for the NEBA, dispersant application from large, fixed wing aircraft is the most likely mode of application. Spotter aircraft will also be important for this response option to assist in spatial and situational awareness. Sufficient aircraft, dispersant supplies, and maintenance capabilities, along with multiple trained crews and observers will be needed to maintain continuous daylight operations. Staging of aircraft will be on the mainland, a minimum of 250 km away. The reader is referred to the OSRP for equipment mobilization and deployment planning for this Project. It should be noted that the aerial dispersant approval process may also require a surface dispersant monitoring plan to be implemented, so logistics consideration should be given to mobilizing scientific teams and equipment for this purpose. There are SMART guidelines available for monitoring surface dispersant operations (USCG *et al.*, 2006), and the reader is referred to a publication by Trudel *et al.* (2009) for other considerations on aerial dispersant monitoring.

DISPERSANT EFFECTIVENESS ON COLD WATER SPILLS

There has some skepticism about the effectiveness of dispersant use in cold water environments. However, both open ocean field studies and mesocosm studies have indicated that modern day dispersant formulations work very well in these conditions. Several studies have been conducted in the North Sea (AEA Technology 1994, 1995; Brandvik *et al.,* 1996) measuring high dispersant effectiveness on Forties Crude oil, which is a light crude similar to what is expected in this Project area. Not only did the study show high effectiveness, it also measured rapid dilution in the top 10 m of the water column within two hours of aerial application. More recently, a study conducted in the Ohmsett* facility tested four different oils and two different dispersants in very cold water conditions. The authors of this study reported 85-99% effectiveness of the dispersant on both fresh and weathered oil in very cold water conditions (Belore *et al.,* 2009).

** Ohmsett refers to the National Oil Spill Response Research & Renewable Energy Test Facility located in New Jersey, USA. It is the*

Limitations: Aerial dispersant operations require 1000 feet (~300 m) minimum cloud ceiling, 3 statute miles (~5 km) forward visibility, daylight, and wind speeds less than 40 mph (~ 65 km/hr) to ensure safety of aircraft. Special approvals may be required by the Canadian regulating agency for aerial dispersant application. While Canadian policy is not yet established at the time this document has been prepared, regulatory policy in other parts of the world frequently require a minimum distance from shore (approximately 3 nautical miles) and a minimum water depth (approximately 10 m) for aerial dispersant application. Other “exclusion zones or conditions” may be set by regulatory policy. Surface dispersant application also has a limited “window of opportunity” and may be less effective in calm waters (when no wave action is present).

Efficiency: Dispersant effectiveness is dependent on the type of oil and environmental conditions present during the scenario. Dispersant effectiveness can approach 100% when the freshest oil closer to the source is targeted. Note that this high effectiveness is for oil that is actually treated with the dispersant, not for the slick as a whole, so while the effectiveness is high, the encounter rate for a large spill may be low. Effectiveness can be difficult to verify because the dispersant action may occur over a long period of time, and wind and currents may carry the oil from the application area. Trained observers must be used to verify effectiveness. In this scenario, factors such as weather, visibility, day length and logistics will limit the encounter rate of aerial application and the overall efficiency. Despite these limitations, modelling assumptions for this scenario use a 100% dispersant efficiency (for that oil that can be treated, or encountered, by aerial dispersant sorties) in order to analyze the maximum amount of dispersed oil that could be present in the water column and the potential associated ecological effects.

2.3.6 Subsea Dispersant Injection

The DWH spill in 2010 represents the first application of subsea dispersants where dispersants were applied at the well head opening on the sea floor. The same general chemical dispersion principles that were discussed in Section 2.3.5 apply here as well, except for a few key distinctions. The flow rate of oil in a deepsea release will vary on reservoir pressure, gas-oil-ratio, and orifice size. Near the release source, intense turbulence and high pressures will result in the oil flow quickly separating into a wide variety of oil droplet sizes. The dispersant injection is focused at the release point and is intended to rapidly reduce those droplet sizes to a range where the droplets are neutrally buoyant, and to prevent those droplets from re-coalescing and quickly rising to the surface. The complex processes are a focus of ongoing research, but the reader is directed to a recent publication by Brandvik *et al.* (2014) for an overview of subsurface oil release behavior and droplet size distribution (at depth) with and without dispersant treatment.

Benefits: With subsea injection the encounter rate is extremely high because the dispersant is being applied directly to the oil source as it is released into the water, before the oil begins to rise and spread horizontally and vertically within the water column. Because of the high encounter rate, DORs of 1:50 to 1:100 should be sufficient to effectively disperse the oil. The higher DOR means that less dispersant (and therefore less solvent) is required for subsea dispersant injection versus aerial dispersant application. Because the injection is occurring at the sea floor, the dispersed oil will dilute vertically over a much greater volume of water. The spill’s transit at depth will be driven by buoyancy of the dispersed oil droplets (vertically) as well as by the influence of deep ocean currents (horizontally). This 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). The dispersed oil will naturally biodegrade in these cold, deep waters. Additional information on biodegradation processes is provided in Appendix A. During the DWH spill event, measured dispersed oil concentrations at about 1 km distance from the well head at 1200 m depth were consistently well below 5 ppm (Coelho *et al*., 2012). Subsea dispersants may be an ideal response tool as the operations can run at all hours with little impact from severe weather. It also provides dispersant application at one manageable location with control and precision and with a DOR that is less than that needed for surface applications.

Subsea dispersant injection also provides a human health protection factor. It reduces the need for surface recovery, in-situ burning, and surface dispersant operations, thereby reducing the potential for accidents during these operations. In addition, the importance of maintaining a safe source control environmental for workers operating above the oil release site is paramount to an effective response. Use of subsea dispersant injection (SSDI) can substantially reduce surface volatile organic compounds (VOCs) and reduce the likelihood of exceeding the Lower Explosive Limits. Consequently, it is an important tool that helps to safely sustain well-capping and source containment operations during a blow-out situation.

Logistics: Subsea dispersant injection requires additional deployment time to initiate as compared to an aerial application. Vessels equipped with remote operated vehicles (ROVs) must be deployed to the well location for installation and operation of the subsea dispersant injection system. A dispersant manifold (subsea dispersant distribution panel) needs to be positioned on the supply vessel, and coiled tubing is then deployed to the seafloor using the vessel’s crane and placed into position by the ROV. If a Cap and Containment system has already been installed on the well head, it is possible to inject dispersant directly through an injection port on the capping stack, or via an ROV-held application wand positioned outside of the capping stack. Given the substantial distance from shore, it is anticipated that the specialized equipment would take approximately seven to ten days to be mobilized and set up at the source control location. Once deployed and connected, the system is designed to operate continuously via remote monitoring. It should be noted that the subsea dispersant injection approval process may also require a subsea dispersant monitoring plan to be implemented, so logistics consideration should be given to mobilizing scientific teams and equipment for this purpose. The reader is referred to the 2013 API Technical Report 1152, “Industry Recommended Subsea Dispersant Monitoring Plan – Version 1.0” (available for download at http://www.oilspillprevention.org/) for more information on water quality monitoring objectives.

Limitations: Unlike most other response options, which are limited to daylight hours for aviation and vessel safety reasons, subsea dispersant injection can virtually be maintained 24-hours per day, seven days per week, provided that required dispersant volumes can be supplied to the site. A disruption to the dispersant stockpile would likely only occur during extreme weather events when dispersant tote transfers could not be conducted, or when ROV support vessels were recalled to port due to safety considerations. Safety limitations can vary from vessel to vessel and are set at the discretion of the vessel’s Captain and the Incident Command Safety Officer. It is important to note that high seas caused by extreme weather events will result in natural dispersion of oil at the surface, so dispersion will still be occurring. It should be noted that an approval process may also require a subsea dispersant monitoring plan to be implemented.

Efficiency: Results from laboratory testing on similar crude oils have indicated that effectiveness may approach 100% if proper injection methods and DORs are used. While DOR of 1:20 is usually used for surface dispersant application, ratios as low as 1:50 to 1:100 can be used subsea with a high efficiency. This is due to the fact that dispersants are delivered directly into the oil stream exiting the well where oil is fresh, not emulsified, warm (low viscosity), and in a region of high turbulence. For the purposes of this scenario and NEBA, subsea dispersant 'application efficiency' was assumed at 80% as a modelling assumption. It means that 20% of dispersant is lost and the remaining dispersant treats the oil with 100% efficiency. This conservative assumption allows for the evaluation of the maximum amount of oil that may enter the water column and resulting environmental impacts. Effectiveness for subsea dispersant injection can be qualitatively assessed by trained observers looking at real-time video feeds provided by ROV video cameras that are positioned adjacent to the dispersant injection wand. Droplet size analysis by means of a particle size analyzer located just above the dispersant injection point could provide quantitative confirmation of effective dispersion by confirming that the droplet size is being reduced. It should be noted however, that it may not always be feasible to place an instrumentation package just above the well bore as it may interfere with other critical Source Control response activities geared towards capping the well. Subsea dispersant effectiveness can also be assessed by comparing the surface expression (after the oil has risen to the surface) when left untreated, compared to the surface expression of the oil slick once dispersants have been applied subsea. Since it takes time for the oil to rise to the surface from the sea floor release point, there will be a delay in any changes to surface expression of the slick. Slick size can be assessed either by aerial spotting teams or via satellite or other remote imagery devices.

2.4 Spill Modelling

2.4.1 Background and Approach

A combination of stochastic and deterministic modelling approaches were used to estimate both near and far field fate and effects of oil from unmitigated subsea release scenarios (Horn and French McCay 2014a). These same subsea blowout scenarios were then considered and assessed with surface and subsea dispersant application in a separate modelling report (Horn and French McCay 2014b). A thorough description, and detailed modelling results are available in *Trajectory Modelling in Support of the Shelburne Basin Exploration Drilling Program: Model Description, Approach, and Summary of Results,* and the subsequent *Analysis of Subsurface and Surface Dispersant Application* (Horn and French McCay 2014a and b) reports. Note that this first modelling report (Horn and French McCay 2014a) is provided as Appendix G in the EIS (Stantec 2014a). The dispersant modelling report (Horn and French McCay 2014b) is available upon request.

Stochastic modelling, which was conducted in the initial trajectory modelling report, is comprised of numerous individual trajectories at each site (i.e., 480 trajectories) of the same spill scenario, released under varying conditions such as weather and sea state, to produce probabilistic distributions of the released oil for the unmitigated release scenarios considered. Stochastic analyses are used to provide information regarding probability of areas to be affected, as well as the shortest time frame for the oil to reach any of the predicted areas. This modelling represents an important tool in spill response planning, as it provides an understanding of where the oil could go and what its characteristics may be over the course of an incident. The results of the stochastic modelling illustrate the full potential spatial extent of oil and the potentially impacted areas. However, it is important to note that the potentially affected areas do not indicate distribution of oil from any single release, but instead demonstrate generally where the oil could go, based upon environmental variability. While such maps do not provide information on the quantity of oil in a given area, they denote the probability of oil exceeding a given threshold, even if this threshold was exceeded for as short as 15 minutes. Additionally, stochastic maps (not shown in the body of this report) showing areas affected by total petroleum hydrocarbons (TPH) and dissolved aromatics depict oiling frequency, but do not indicate the specific depth at which this occurs, or imply that the entire water column will experience a concentration above a threshold (Horn and French McCay 2014a).

Deterministic modelling was performed in addition to stochastic modelling for this study. Horn and French McCay (2014a) write: “While the stochastic analysis provides insight into the probable behavior of oil spills given historic wind and current data for the region, it does not provide an individual trajectory, oil weathering information, expected concentrations and thickness of oil contamination, mass balance, and other information related to a single spill at a given location time.” Deterministic modelling uses single runs to help provide some of this additional information.

The model thresholds used for the trajectory modelling studies are provided in Table 6. Trajectory modelling was performed to assess the behaviour and fate of dispersed oil following the surface and subsea dispersant applications. Subsea and surface dispersant applications will result in changes in oil distribution within the environment including the deep water column, surface mixing layer, water surface, and the atmosphere. Even without dispersant injection, a certain amount of water column entrainment will occur, and will vary with the oil type, release conditions, and plume turbulence. Entrained oil typically remains within depth boundaries that are based on density. Oil that is not entrained will rise to the surface, where surface slicks will form. Nearly half the oil volume released under modelled conditions (with no dispersant addition) may be expected to become naturally dispersed in the water column.

The addition of dispersant is intended to reduce oil droplet sizes, increase the amount of oil that becomes entrained in the water column, and reduce the amount of oil that surfaces. Any resurfacing oil would form slicks that are smaller in the area, thinner, patchier and less persistent than they would be in unmitigated case. Reduction of surface oil slicks also reduces the amount of oil lost through evaporation to the atmosphere. To support the subsea dispersant modelling, a range of subsea dispersant treatment scenarios were simulated for each spill site to identify the optimum DOR, using the minimum volume of dispersant, resulting in the largest amount of oil in the water column. The identified DOR for each site was then applied to the individual model runs conducted as part of the dispersant modelling report (Horn and French McCay 2014b). The potential effects of dispersant use on the previously modelled spill scenarios were also modelled in a separate report (Horn and French McCay 2014b).

Scenarios considered in the dispersant application modelling report included the 50th percentile and the 95th percentile surface oiling scenarios for Sites 1 and 2 from the main trajectory modelling report (Horn and French McCay 2014a). These 50th and 95th percentile scenarios are representative deterministic cases that were identified from stochastic analyses (480 runs per site; 240 by summer/winter season). The 50th percentile case was chosen to illustrate average/typical environmental conditions resulting in median surface oiling and to put the 95th percentile case into context. The 95th percentile case was identified as having some of the largest areas of ocean surface affected by spilled oil and thus a conservative basis to consider dispersant application and potential environmental consequences. The 95th percentile surface oiling scenario occurred during the summer season (April through September) as warmer and more quiescent summer conditions resulted in increased surface oil by both mass and area covered, as compared to winter conditions. The areas affected were defined as the surface area of ocean experiencing surface oil thicknesses in excess of 0.04 µm for at least 15 minutes. Models were run for each scenario for a period of 30 days to reflect the maximum time expected to cap and contain the well.

Table 6. Modelled Thresholds (Horn and French McCay 2014b)

Oil Type	Oil Thickness / Concentration Cut-off Threshold	Rationale
Surface Oil Thickness	0.04 µm	Visible threshold used to determine impacts on socioeconomic resources (e.g., possibility of fisheries closure). This minimum thickness would relate to a slick being barely visible as a colourless or silver sheen (French-McCay *et al*., 2011; Lewis, 2007 – Bonn Agreement).
	10 µm	Biological threshold for ecological impacts to the water surface (e.g., birds) (French *et al*., 1996 & French-McCay 2009 oil spill fate and effects model). Oil would appear as a dark brown colour.
Shoreline Oil Mass	1.0 g/m^2	This thickness is the threshold for potential effects on socio-economic resource uses, as this amount of oil would conservatively trigger the need for shoreline cleanup on amenity beaches. Oil would appear as a dull brown sheen (French-McCay *et al*., 2011).
	10.0 g/m^2	This thickness provides a more conservative screening threshold for potential ecological effects to shoreline habitats, which has typically been 100 g/m^2, based upon a synthesis of the literature showing that shoreline life has been affected by this degree of oiling (French *et al*., 1996; French McCay 2009). The oil would appear as dark brown coat or opaque/black oil.
In Water Concentration	1.0 ppb of dissolved aromatics	Exposure concentration below which no noteworthy biological effects are expected for sensitive marine resources (Trudel, 1989 and French-McCay, 2004) in S.L. Ross 2011 modelling for Old Harry in Gulf of St. Lawrence). This value is a conservative threshold for early contact on herring larvae.
	1 ppm TPH	Exposure concentration deemed a low level of concern for sensitive life stages in marine organisms (Kraly *et al*., 2001; NAS NRC 2005). This conservative approximation is at the low end of lethal and sub-lethal impacts expected from acute exposure.

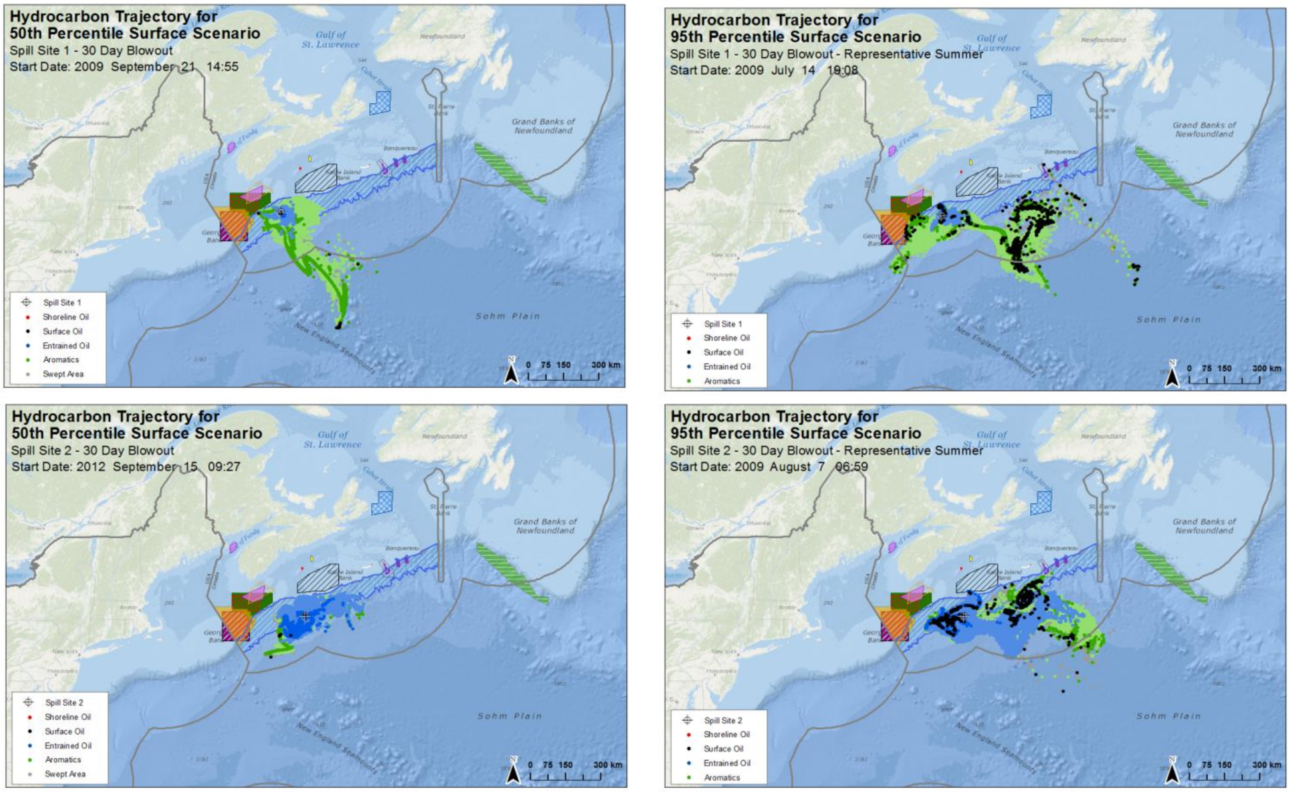
	15 ppm TPH	Canada-Nova Scotia Offshore Petroleum Board – Offshore Waste Treatment Guidelines (CNSOPB OWTG 2010) performance target for TPH in deck drainage / bilge water discharged at sea.
	30 ppm TPH	Canada-Nova Scotia Offshore Petroleum Board – Offshore Waste Treatment Guidelines (CNSOPB OWTG 2010) 30 day weighted average performance target for TPH in produced water discharged to sea.

The hydrocarbon trajectories produced provided a history of modelled oil in time and space. Components of the oil were tracked as entrained droplets of oil, dissolved aromatic constituents, floating surface oil, and stranded shoreline oil. In addition to the trajectories, supporting information and figures related to the fate and effects were provided in the reports including:

1. Mass Balance – The mass balance charts provide an estimate of the oil's weathering and fate for a specific run for the entire model duration as a fraction of the oil spilled up to that point. Components of the oil tracked over time include the amount of oil on the sea surface, the total entrained or dissolved hydrocarbons in the water column, amount of oil ashore, oil evaporated into the atmosphere, and that which has decayed (accounts for both photo-oxidation and biodegradation).
2. Surface Oil Time Series Maps – Maps showing the cumulative footprint of maximum floating surface oil and the associated thicknesses (µm) at all time steps during the individual 30-day spill simulation. Surface oil figures show only thicknesses greater than 0.04 µm.
3. Water Column Time Series Maps – Maps showing the cumulative footprint of maximum water column concentration of dissolved aromatics (ppb) at all time steps during the individual 30-day spill simulation. Dissolved aromatics are the portion of the oil having the greatest potential to affect water column biota, and the footprints were typically smaller than the extent of total oil contamination in the water column. Water column contamination figures show only concentrations ≥1 ppb. Concentrations below 1 ppb are considered low and result in little water column impact.
4. Shoreline Impact - Figure showing mass of oil deposited onto shoreline. Only shoreline oiling exceeding 1 µm, which is equivalent to 1 g/m^2, was depicted.
5. Additional maps were created to illustrate extent of a slick at 0.5, 1, 2, 5, 10, 15 and 30 days, maximum water column TPH concentrations exceeding 1 ppm over 30 days as well as vertical profiles illustrating distribution of hydrocarbons in the water column.

2.4.2 Modelling Results

In general, the modelling studies used in this NEBA (Horn and French McCay 2014a) predicted low likelihood of shoreline oiling (less than 2% chance). The modelling for Sites 1 and 2 resulted in shoreline oiling in 9 out of 480 scenarios and 4 out of 480 scenarios respectively. All shoreline oiling cases occurred during the summer season, limited to the months of May, June, and July, where more quiescent conditions result in a higher percentage of oil remaining on the water surface (Horn and French McCay 2014a). In scenarios where shoreline oiling was shown to occur from an unmitigated blowout scenario, it is expected that the stranded oil would be highly weathered, as the minimum time to shore would be between 20-30 days. The regions shown to be susceptible to potential shoreline oiling within 30 days from an unmitigated release at Site 1 include the southern tip of Nova Scotia, including Yarmouth, Barrington and Shelburne region, as well as Sable Island National Park Reserve. The region susceptible to potential shoreline oiling within 30 days from an unmitigated release at Site 2 includes only Sable Island National Park Reserve (Stantec 2014a; Horn and French McCay 2014a). Figure 8 illustrates the unmitigated modelling results of the 50th and 95th percentile scenarios for predicted oil distributions over the entire 30 day period (cumulative) for Sites 1 and 2.



Hydrocarbon Trajectory for 50th Percentile Surface Scenario
Spill Site 1 - 30 Day Blowout
Start Date: 2009 September 21 14:55

Hydrocarbon Trajectory for 95th Percentile Surface Scenario
Spill Site 1 - 30 Day Blowout - Representative Summer
Start Date: 2009 July 14 19:08

Hydrocarbon Trajectory for 50th Percentile Surface Scenario
Spill Site 2 - 30 Day Blowout
Start Date: 2012 September 15 09:27

Hydrocarbon Trajectory for 95th Percentile Surface Scenario
Spill Site 2 - 30 Day Blowout - Representative Summer
Start Date: 2009 August 7 06:59

Figure 8. Unmitigated Releases for Sites 1 (top 2 panels) and 2 (bottom two panels) for 50th (panels on the left) and 95th (panels on the right) percentile scenarios (Horn and French McKay 2014b). Refer to Figure 4 for identification of spatial boundaries.

It is important to note that these figures represent the cumulative distribution of all areas affected by oil at any time during the 30 day period. They illustrate a single oil spill over the full 30 days modelled. The 95th percentile unmitigated release results in more oiling on the surface (shown in black), when compared to the dispersant mediated scenario. Darker shades represent oil that was present at the end of the 30 day period (the last time step), while lighter shades cover the "swept area", where oil occurred at some time during the 30 day period.

Figures 9 and 10 suggest that less surface oil and more entrained oil is likely when dispersants are applied at both sites.

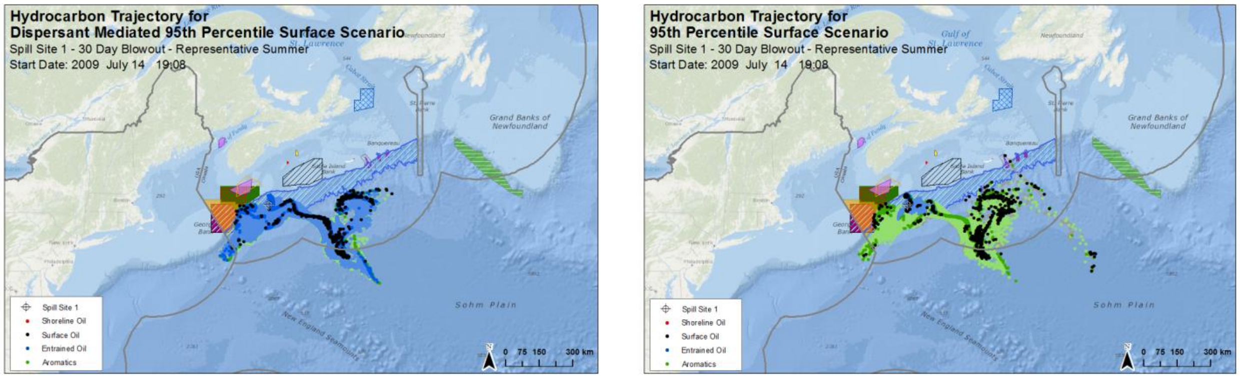


Figure 9. Hydrocarbon trajectories for dispersant mediated (left) vs. unmitigated releases (right) for the 95th percentile surface scenario at Site 1 (Horn and French McCay 2014b). Refer to Figure 4 for identification of spatial boundaries.

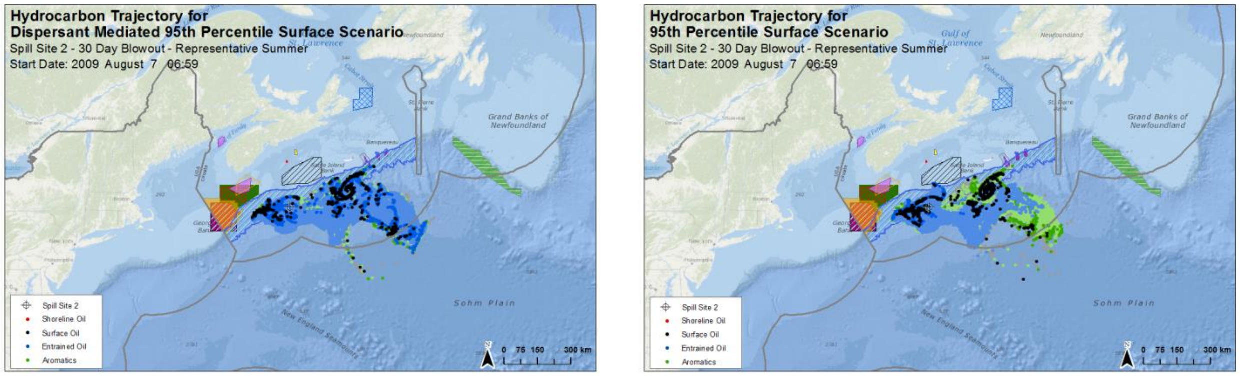


Figure 10. Hydrocarbon trajectories for dispersant mediated (left) vs. unmitigated releases (right) for the 95th percentile surface scenario at Site 2 (Horn and French McCay 2014b). Refer to Figure 4 for identification of spatial boundaries.

In comparison to the cumulative model results shown and described above, which illustrated all areas affected by oil over the entire 30 day period, model results for individual time snapshots throughout the 30 days yielded much smaller oil spill footprints as they show an actual location of a specific slick at each selected point in time. Figure 11 displays results for Day 5 at Site 1, for both the dispersant mediated scenario (left), where all oil is entrained, and the unmitigated scenario (right), where surface oil is observed.

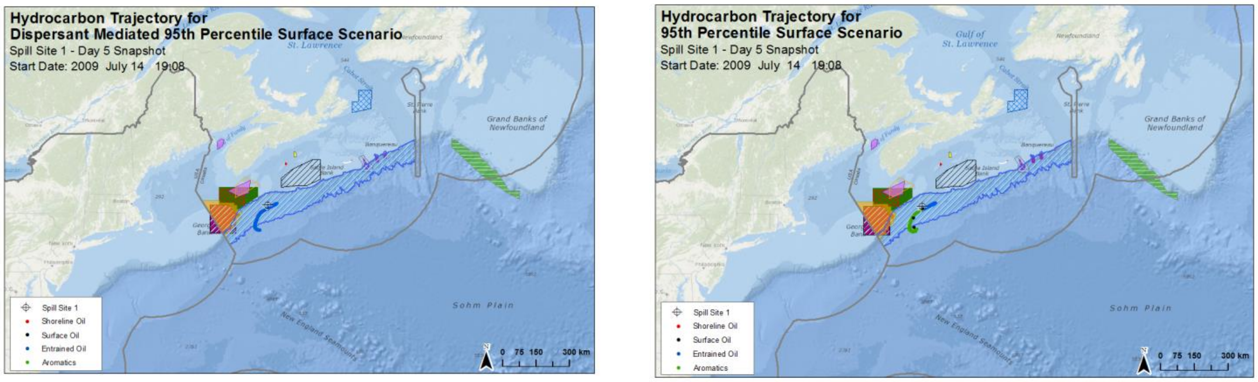


Figure 11. Hydrocarbon particle trajectories predicted for Day 5 of a subsea blowout in the summer season (July) at Site 1 with subsea dispersant application (left) and without (right). (Horn and French McCay 2014b). Refer to Figure 4 for identification of spatial boundaries.

Although the spill footprint shown in the maps in Figure 11 is much smaller than those shown in the cumulative maps in Figures 9 and 10, the effect of subsea dispersant application remains the same (reduction in surface hydrocarbons and aromatics, and a corresponding increase in entrained oil).

Mass Balance calculations were also performed for both the unmitigated and dispersant mediated scenarios shown above. For example, Figure 12 shows the resulting mass balances and illustrates the effect of subsea dispersant application (shown on the left) versus the unmitigated release (shown on the right) on the distribution of oil into the environment at Site 1. Fate categories shown include: Atmosphere (dark blue); shoreline (maroon); surface (green); entrained (purple), and biologically degraded, or "decayed" (light blue). A much smaller percentage of the oil is present on the sea surface in the dispersant mitigated case, compared to the unmitigated scenario.

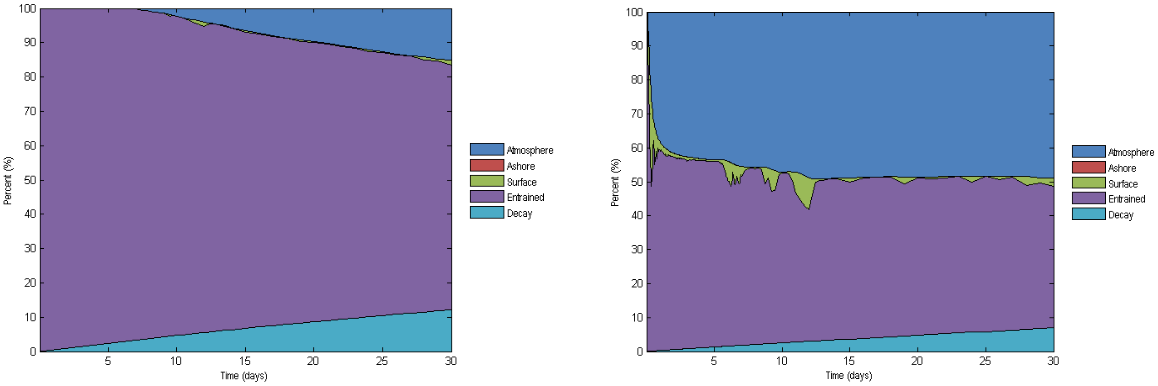


Figure 12. Impact of subsea dispersant injection on mass balance of oil at Site 1 (Horn and French McCay 2014b).

Subsea dispersant application resulted in a much larger portion of the spilled oil being entrained in the water column (75% for Site 1) when compared to unmitigated cases (40% for Site 1). As a result the volume of water experiencing total petroleum hydrocarbon (TPH) concentrations exceeding 15 and 30 ppm were 3 to 6 and 30 to 60 times greater, respectively. It is important to note that with subsea dispersant application, this entrained oil tended to remain at depth (>1000 m), when compared to the unmitigated scenario. As a result, a smaller volume of water was observed to experience dissolved aromatic concentrations exceeding 1 ppb than with the unmitigated case. Additionally, the dispersant mediated scenarios showed a sizeable reduction in surface oil (12%) by mass as well as a reduction in evaporated oil (35 to 40%) lost to the atmosphere when compared to unmitigated scenarios. This reduction in volatile oil components released to the atmosphere results in a reduced risk and threat to the health and safety of response personnel working near the spill source (i.e., lower VOC concentrations). Surface oiling footprints in dispersant-mediated scenarios took longer to appear, were smaller in area, and less continuous when compared to unmitigated releases (Horn and French McCay, 2014b).

Each of the figures presented above depict oil distributions across the various modelled parameters (i.e., shoreline, surface, entrained, and dissolved aromatics). The effect of subsea dispersant application on hydrocarbon distributions in the water column can be seen more clearly when these parameters are examined individually. Figures 13 and 14 illustrate the effect of subsea dispersant application (left) on water column TPH concentrations in the droplet phase as compared to the unmitigated scenario (right) for Sites 1 and 2.

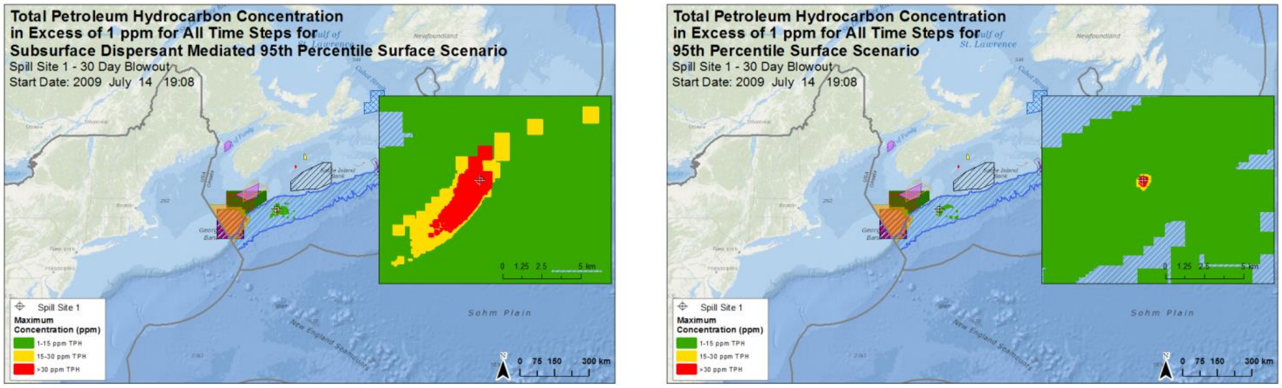


Figure 13. Impact of subsea dispersant injection (left image) versus unmitigated release (right image) on TPH maximum concentrations at Site 1 (Horn and French McCay 2014b). Refer to Figure 4 for identification of spatial boundaries.

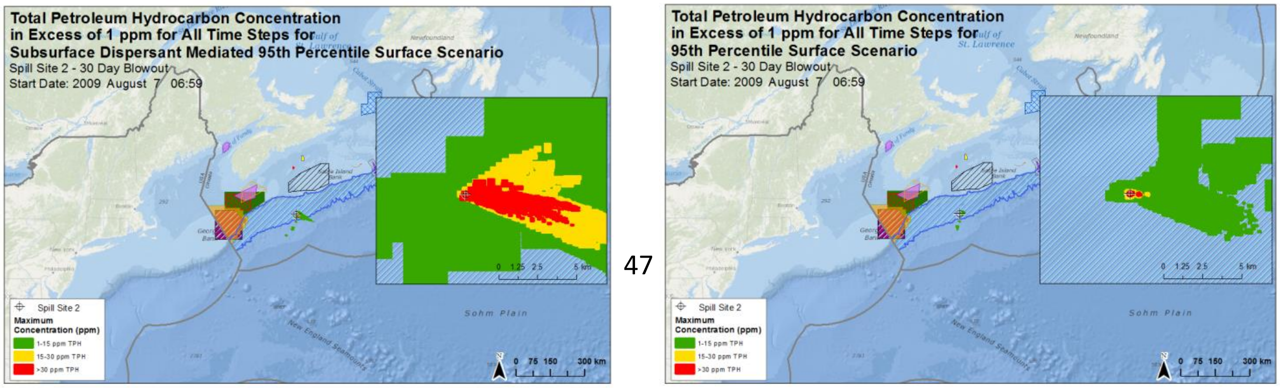


Figure 14. Impact of subsea dispersant injection on TPH distribution at Site 2 (Horn and French McCay 2014b). Refer to Figure 4 for identification of spatial boundaries.

The areas or volumes that experienced oiling above the established thresholds for unmitigated releases, surface dispersant treatment, and subsea dispersant treatment are presented in Table 7. The use of subsea dispersant reduces the area of exceedance for each surface thickness threshold by approximately 4 to 50 times. Similarly, the use of dispersant at the surface reduces surface slicks by over 20% under optimal weather conditions and daylight hours.

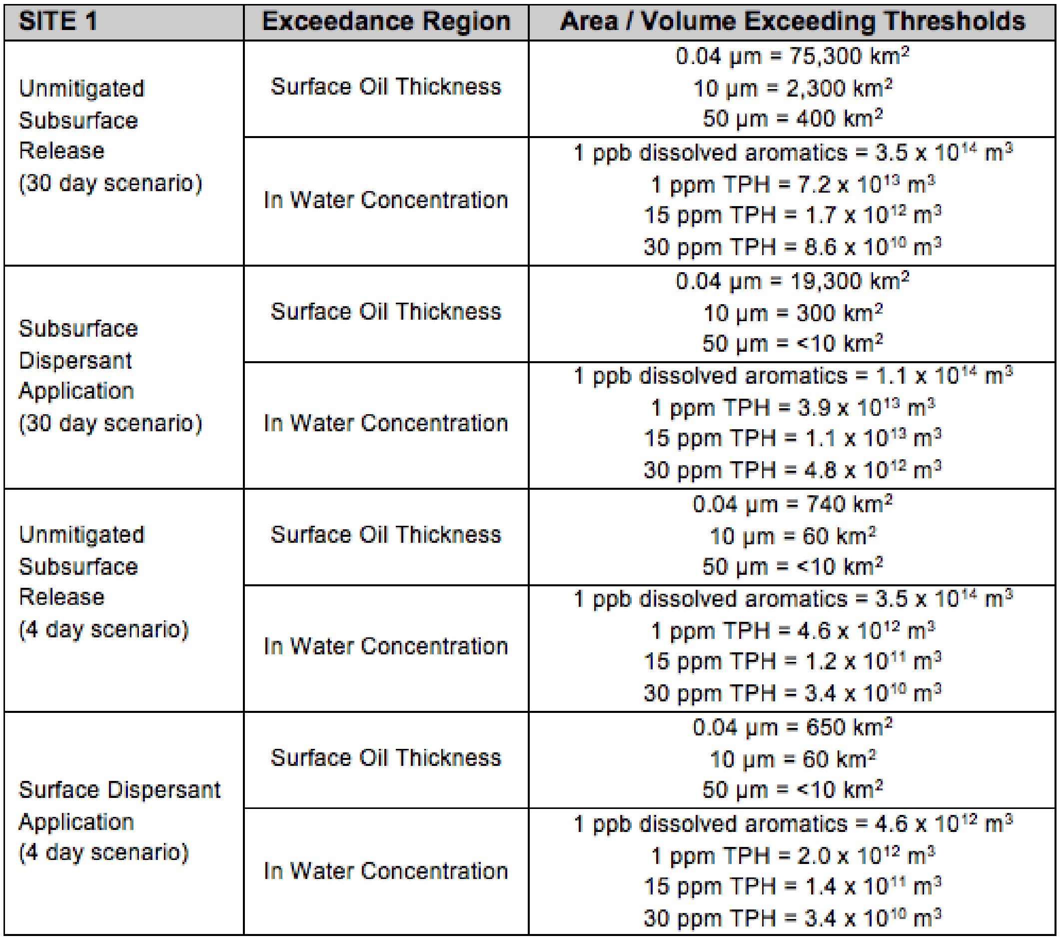
Subsea dispersant-mediated trajectory model results indicate that the application of subsea dispersants will result in a larger fraction of oil becoming entrained in the water column and a reduced amount of oil reaching the surface. Subsea dispersant application resulted in smaller surface oiling footprints that took longer to appear, were smaller in area, and less continuous (more dispersed), when compared to untreated releases. Approximately 75% of the spilled oil remained in the water column for the subsea dispersant-mediated case at Site 1, relative to the predicted approximate 40% in the unmitigated release for the same site. Nearly 80% of the dispersant-mediated Site 2 release remained in the water column, relative to ~45% for the same, unmitigated release.

Smaller differences were observed in mass balance for surface dispersant application scenarios, with a 2-5% reduction in surface oil, and corresponding gain in the water column. This relatively smaller impact may be the result of naturally high sea states and resulting high levels of physical oil dispersion at the surface in the unmitigated case. The data provided by Horn and French McCay (2014b) suggests that for both surface and subsea dispersant treatments, surface slicks were thinner, patchier, and less persistent than for untreated slicks.

As more oil remains entrained in the water column and less oil surfaces, evaporative loss at the surface decreases. Only 10-15% of the total oil was observed to evaporate in the subsea dispersant mediated scenarios, relative to nearly 50% observed in the unmitigated cases. TPH values above 1 ppm may occur out to roughly 50-100 km from the release location in 30 day release scenarios. Concentrations of dissolved aromatic hydrocarbons may exceed 500 ppb (0.5 ppm total petroleum hydrocarbons) in patches within the vicinity (~75 km) of the release location, at localized depths between roughly 1000-2000 m depth. However, much lower concentrations (roughly 5-50 ppb) would be more common throughout the affected area.

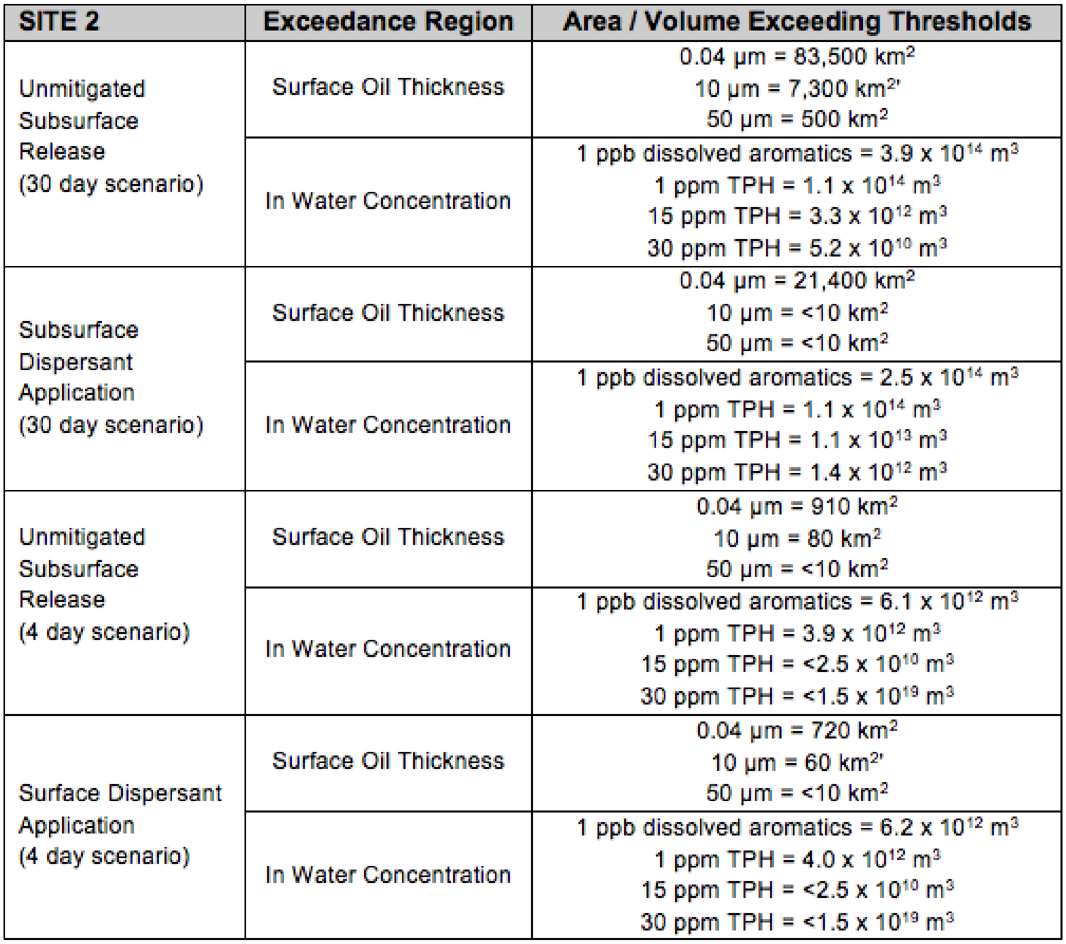
As hydrodynamic forcing (e.g., currents, winds, etc.) was the same between cases, the areal footprints were very similar between dispersant-mediated and unmitigated releases. However, as indicated, for both subsurface and subsea dispersant treatments, surface slicks were thinner, patchier and less persistent than for untreated areas.

Table 7. Threshold Exceedances for Modelled Scenarios: Site 1



SITE 1	Exceedance Region	Area / Volume Exceeding Thresholds
Unmitigated Subsurface Release (30 day scenario)	Surface Oil Thickness	0.04 µm = 75,300 km^2 10 µm = 2,300 km^2 50 µm = 400 km^2
	In Water Concentration	1 ppb dissolved aromatics = 3.5 x 10^{14} m^3 1 ppm TPH = 7.2 x 10^{13} m^3 15 ppm TPH = 1.7 x 10^{12} m^3 30 ppm TPH = 8.6 x 10^{10} m^3
Subsurface Dispersant Application (30 day scenario)	Surface Oil Thickness	0.04 µm = 19,300 km^2 10 µm = 300 km^2 50 µm = <10 km^2
	In Water Concentration	1 ppb dissolved aromatics = 1.1 x 10^{14} m^3 1 ppm TPH = 3.9 x 10^{13} m^3 15 ppm TPH = 1.1 x 10^{13} m^3 30 ppm TPH = 4.8 x 10^{12} m^3
Unmitigated Subsurface Release (4 day scenario)	Surface Oil Thickness	0.04 µm = 740 km^2 10 µm = 60 km^2 50 µm = <10 km^2
	In Water Concentration	1 ppb dissolved aromatics = 3.5 x 10^{14} m^3 1 ppm TPH = 4.6 x 10^{12} m^3 15 ppm TPH = 1.2 x 10^{11} m^3 30 ppm TPH = 3.4 x 10^{10} m^3
Surface Dispersant Application (4 day scenario)	Surface Oil Thickness	0.04 µm = 650 km^2 10 µm = 60 km^2 50 µm = <10 km^2
	In Water Concentration	1 ppb dissolved aromatics = 4.6 x 10^{12} m^3 1 ppm TPH = 2.0 x 10^{12} m^3 15 ppm TPH = 1.4 x 10^{11} m^3 30 ppm TPH = 3.4 x 10^{10} m^3

Table 8. Threshold Exceedances for Modelled Scenarios: Site 2



SITE 2	Exceedance Region	Area / Volume Exceeding Thresholds
Unmitigated Subsurface Release (30 day scenario)	Surface Oil Thickness	0.04 µm = 83,500 km^2 10 µm = 7,300 km^{2}' 50 µm = 500 km^2
	In Water Concentration	1 ppb dissolved aromatics = 3.9 x 10^{14} m^3 1 ppm TPH = 1.1 x 10^{14} m^3 15 ppm TPH = 3.3 x 10^{12} m^3 30 ppm TPH = 5.2 x 10^{10} m^3
Subsurface Dispersant Application (30 day scenario)	Surface Oil Thickness	0.04 µm = 21,400 km^2 10 µm = <10 km^2 50 µm = <10 km^2
	In Water Concentration	1 ppb dissolved aromatics = 2.5 x 10^{14} m^3 1 ppm TPH = 1.1 x 10^{14} m^3 15 ppm TPH = 1.1 x 10^{13} m^3 30 ppm TPH = 1.4 x 10^{12} m^3
Unmitigated Subsurface Release (4 day scenario)	Surface Oil Thickness	0.04 µm = 910 km^2 10 µm = 80 km^2 50 µm = <10 km^2
	In Water Concentration	1 ppb dissolved aromatics = 6.1 x 10^{12} m^3 1 ppm TPH = 3.9 x 10^{12} m^3 15 ppm TPH = <2.5 x 10^{10} m^3 30 ppm TPH = <1.5 x 10^{19} m^3
Surface Dispersant Application (4 day scenario)	Surface Oil Thickness	0.04 µm = 720 km^2 10 µm = 60 km^{2}' 50 µm = <10 km^2
	In Water Concentration	1 ppb dissolved aromatics = 6.2 x 10^{12} m^3 1 ppm TPH = 4.0 x 10^{12} m^3 15 ppm TPH = <2.5 x 10^{10} m^3 30 ppm TPH = <1.5 x 10^{19} m^3

Surface dispersant application increased the entrainment of surface oil into the upper, mixed layer of the water column, within roughly 1 km of the wellhead, with concentrations exceeding 1 ppm out to 5-10 km in these 4-day release scenarios. Similarly, concentrations of dissolved aromatics exceeded 500 ppb in small patches within the vicinity (<10 km) of the release location throughout the surface layer (<50-100 m depth). However, much lower concentrations (roughly 5- 50 ppb) would be more common throughout the affected area.

The timing of surface dispersant application had a large effect on the mass balance of surface oil, and maximum differences in mass balance occurred during the daytime, and periods of lower sea states. Oil accumulated on the surface at night, when dispersants were not applied.

No shoreline oiling was observed in any of the dispersant mediated or unmitigated release trajectories run in association with the dispersant modelling report and used to support the NEBA.

2.4.3 Conclusions from Modelling

In summary, the use of subsea dispersants reduces the area exceeding surface thickness thresholds by over 75%, when compared to unmitigated cases. Similarly, the targeted use of dispersants at the surface may reduce areal coverage of surface oil by 10-20% in the first few days of the release. Dispersing oil into water column results in an increase in the region of potential oil exposure for marine organisms, although exposure concentrations are expected to be relatively small in most of the areas. Higher concentrations of dissolved aromatics and total TPH were found in the upper water column in unmitigated cases, while they were typically found at localized depths between roughly 1000-2000 m in the subsea dispersant application cases.

Unmitigated release scenarios resulted in the largest footprints for surface oil exceeding 0.04 µm thickness, with 3-4 times more coverage when compared to the subsea dispersant application scenarios. The biological thresholds of 10 and 50 µm surface oil were 2-4 orders of magnitude lower, by area, than the highly conservative 0.04 µm threshold representing the first appearance of a barely visible sheen.

The application of subsea dispersant results in roughly 25% the area of surface oil thickness exceeding 0.04 µm and approximately 10% or less exceeding 10 and 50 µm, when compared to unmitigated scenarios. However, subsea dispersant treatment resulted in water column hydrocarbon concentrations 1-2 orders of magnitude higher (e.g., exceeding 15 and 30 ppm TPH than observed for unmitigated release scenarios).

The smallest extent observed for surface oiling occurred in the surface dispersant scenarios. This was due to the shorter period modelled (limited to 4 days), the effects of the dispersant, and weather conditions conducive to physical dispersion.

Evaporative loss of oil components to the atmosphere was considerably reduced by surface and subsea dispersant application. While protection of human health and safety was not a specific focus of this study, the potential reduction in exposure to hydrocarbons could have important benefits to first responders and emergency response operations.

3 The Risk Analysis Process

3.1 The Risks Associated with Oil Exposure

The Shelburne Basin Venture Exploration Drilling Project Environmental Impact Statement (Stantec 2014a), provides a detailed overview of the existing biological environment as well as the effects of hydrocarbons to various species. Section 5 of the EIS provides an overview of the existing environment and Section 8 provides a thorough review of the impacts of untreated oil to marine and avian species. In summary, surface oil poses a variety of risks to birds, marine mammals and other species utilizing the top layer of the ocean surface to live, feed, rest, and breathe. Surface oil can saturate feathers and fur which can reduce the ability of animals to thermo-regulate, which can often result in death if not treated immediately with veterinary care. In cases where these animals escape direct lethal exposure, pelagic and coastal seabirds and marine mammals can sustain sub-lethal damages such as skin, eye and respiratory irritation from exposure to surface oil. The sea surface microlayer also serves as an important habit for many fish species eggs and larvae, which are sensitive to oil.

Once oil is spilled into the water and spreads over the surface, a number of physical, chemical and biological processes immediately begin to alter the oil’s characteristics which may prohibit the effectiveness of some response options. If untreated, the surface oil will begin to weather over time, and processes such as evaporation, spreading, and emulsification will cause the oil to form a “mousse” and eventually tar balls. A mousse in this context is a water-in-oil emulsion that is resistant to dispersant effects and difficult to burn or recover with skimmers. Emulsified oil may persist for a long time serving as a continuous source of contamination to the top portion of the water column. Consequently, the weathering process necessitates a rapid response to mitigate a spill.

Chemical interactions between the atmosphere and the slick can cause the formation of gaseous vapours, and the oil chemistry can be further altered by sunlight. Aerosols may be formed when high wind and wave conditions beat water through the oil slick. These dynamic processes as well as oil persisting on the surface increases the risk of exposure to birds, marine mammals, and human receptors in the area.

Chemical processes assisted by wave action and current mixing are also underway beneath the surface of an oil slick. These natural processes drive bulk oil and soluble constituents into the water column, increasing exposure to marine life. It is important to consider that a portion of the oil will be present in the water column in dissolved and dispersed form even if dispersants are not used. Natural oil entrainment is especially likely for light oils, deep water blowouts, and high sea conditions. Oil weathering processes also cause the viscosity of the oil to increase, initially making it more difficult to disperse, and eventually making it more difficult to retain and recover with mechanical equipment, or to burn in place. These weathering dynamics put further pressure on responders to make a timely decision about deploying the appropriate mix of response options. Waiting too long to make a decision limits the response tools that will work. A decision to use aerial dispersants must be made in a timely manner, since dispersants are most effective in the first few days before the oil becomes more highly weathered,

In the case of an oil spill from a subsea blowout, the same physical and chemical processes as those in a surface spill influence the environmental fate of the oil, but to different degrees. Oil released under pressure at the sea floor tends to rise due to the buoyancy of the droplets. The oil rises in liquid droplets of varying size, and the droplets that reach the surface coalesce, forming an oil slick that is subject to the weathering processes for a surface oil spill. However, the subsea spill's travel through the water column can affect the oil, as the gas components will quickly dissolve into the water column. The smallest oil droplets may be trapped at lower depths, as their buoyancy cannot overcome the horizontal forces in the water column. Their small size however, increases the likelihood that they will be broken down through biodegradation processes. Conversely, larger droplets will continue to rise and will lose their soluble oil components through dissolution during the ascent. Currents mix and spread these droplets in the water column, complicating the formation of an intact oil slick, and increasing the likelihood that the oil will surface in a weathered state, perhaps appearing as a mousse.

These processes have their largest impact within the initial hours of release, and these challenges are the basis for development of methods for injecting dispersants directly into the subsea oil release. Subsea injection of dispersants during a response can greatly increase the percentage of oil that is entrained in the water column as small droplets, thereby preventing the formation of large surface slicks, and facilitating the biodegradation process.

The toxicity of dispersants and dispersed oil has been a source of controversy and misunderstandings since dispersants were first used. Modern day dispersant products (e.g., Corexit 9500, Finasol OSR52, and Dasic Slickgone) have very low toxicity. In fact, Corexit 9500 is classified as only "slightly toxic" according to the EPA Toxicity Guide (US Environmental Protection Agency, 2014). Studies conducted by the EPA during the DWH spill in 2010 reported results of Corexit 9500 toxicity to several species as being "practically non-toxic" Guide (US Environmental Protection Agency, 2010). As a result the real issue for dispersant use is the toxicity of the dispersed oil (National Research Council, 2005).

Before addressing the topic of dispersed oil toxicity, it is helpful to acknowledge that any of the spill scenarios in which dispersant application would be considered as a response option already represent some degree of marine toxicity risk due to the toxicity of the oil itself. Studies also indicate that with dispersed oil, any toxicity of the oil dispersant mix results primarily from the oil and not the dispersant. This is because unmitigated floating slicks pose significant toxicity risk via physical coating of marine mammals and birds, especially to those species which feed or rest on the waters' surface. Additionally, natural dispersion of untreated surface oil is expected in this Project area when higher sea states are present (refer to trajectory models), so there will be elevated hydrocarbon concentrations present even if dispersants are not applied. For these reasons, the decision to use dispersants is based on the assessment of the risks posed by dispersed oil, as compared to the risks of not dispersing the oil.

The toxicity of dispersed oil in the water column is related to three factors:

1. Whether the concentration exceeds known acute or chronic toxicity thresholds for the oil type that was spilled;
2. The length of time that the concentrations persist above toxic thresholds; and,
3. The toxicological sensitivity of the species exposed to oil above the acute or chronic toxicity thresholds.

The ability of habitats and populations to recover after initial impact is also an important consideration. There is a wide range of sensitivity among species, and at different life stages of the same species. It is important to identify the species living in the area that will be treated with dispersants, and the life stages they are in order to make sound decisions, based on local environmental conditions.

Controlled studies have shown:

- The most notable environmental impact considerations for dispersed oil exposures occur in the water column; and
- Sediments on the seafloor rarely have accumulations of chemically dispersed oil at levels that pose environmental concerns (see text box in Section 2.3.2).

As previously mentioned, marine toxicity is a function of exposure — which includes the concentration of dispersed oil in the water column for a specific duration — and the sensitivity of the marine species present in the environment. Figure 15 illustrates a high level summary of many data points from standard laboratory toxicity tests. From a review of toxicity databases (NRC, 2005; DTox, 2014), “more sensitive species” are defined as those laboratory tested species (or life stages) that were lethally affected (LC50) in the 1-10 ppm dispersed oil range. “Less sensitive species” are identified as those laboratory tested species (or life stages) that were lethally affected (LC50) above 10 ppm dispersed oil. The lab tests also measure short-term impairment in growth, reproduction, respiration rates, etc. — changes that may be serious to overall health but do not immediately kill a test subject. These changes are called sub-lethal effects. Previous laboratory results indicate that more sensitive species and life stages demonstrate sub-lethal effects at short duration exposures beginning at lower concentrations (0.5 ppm). As a result, when examining the expected initial concentrations of dispersed oil, it is important that both lethal and sub-lethal effects are considered.

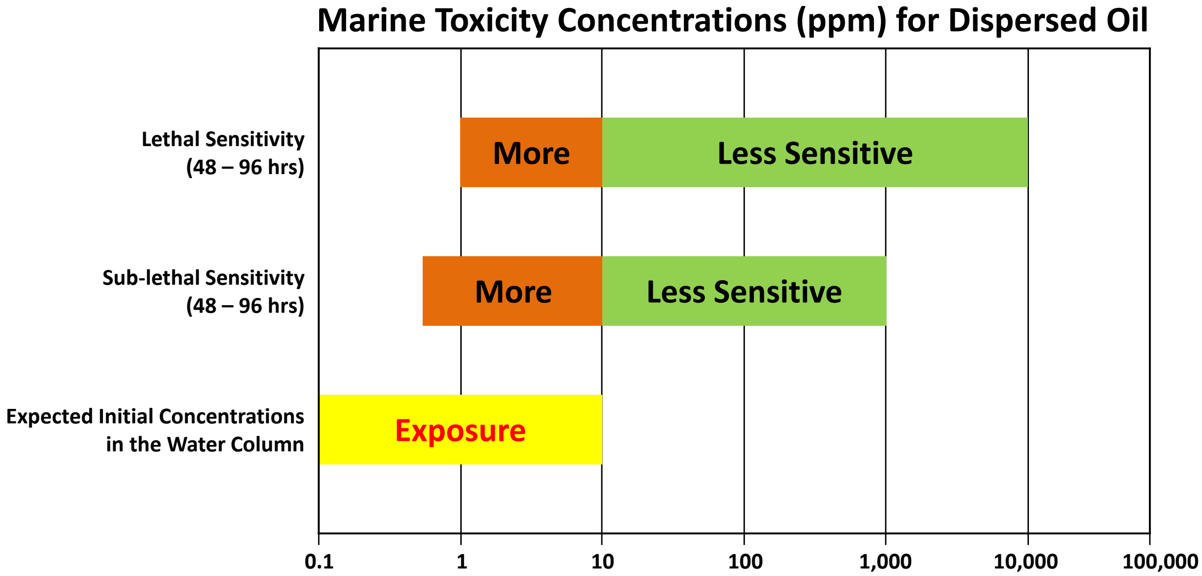


Figure 15. Species sensitivity to dispersed oil exposures. The top row indicates typical LC50 range to organisms following an exposure duration of 48 to 96 hours. The middle row depicts sub-lethal effects

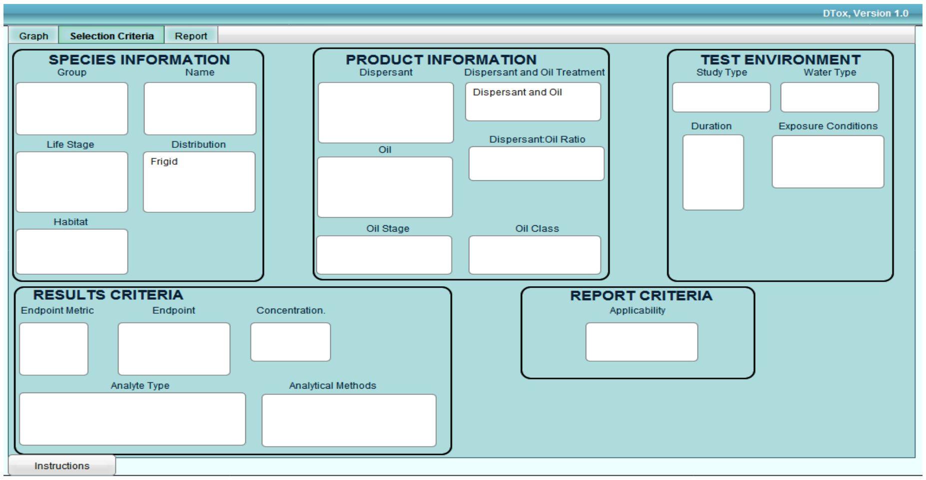
concentrations during the same time duration. The lowest bar indicates typical dissolved oil concentrations in the water following a spill. Normally, these concentrations diminish quickly (within hours) because of rapid dilution (after National Research Council, 2005)

It is important to note that using existing laboratory data to assess the potential risks to marine life from dispersed oil does not provide a full understanding of the potential effects in the ocean since the laboratory data may not accurately model exposure in the field. Some of the specific limitations of applying laboratory toxicity testing results to real-world spill response include the following (IPIECA, 2015b):

- Most standard laboratory tests are designed to report the concentrations that result in mortality of half the test organisms during a constant exposure over four days. In a real world scenario, oil that has been treated with dispersants will typically disperse, dilute and start to biodegrade in the water column in less than four days. In addition, many marine organisms are mobile and will not remain in a region with continual exposure to dispersed oil for four days. Therefore the comparison on Figure 15 may be somewhat misleading as it compares sensitivities of the organisms to constant exposure for an extended period of time with a concentration that only occurs for a short period of time (for surface application) and in a limited area.
- There are few tests using short-term exposure durations that focus on anything but lethal endpoints, so little is reported about impairments that are sub-lethal. While very useful for screening different dispersants against each other and against different oils, this laboratory data should not be used as a reliable assessment of what happens (e.g., real-world exposure concentrations, dilution, biodegradation) under dynamic field conditions.
- Lab tests routinely focus on the most sensitive species and their most sensitive life stages, and those few species that are amenable to laboratory testing conditions. Data are not available for all species and all life stages, or for all oil types.

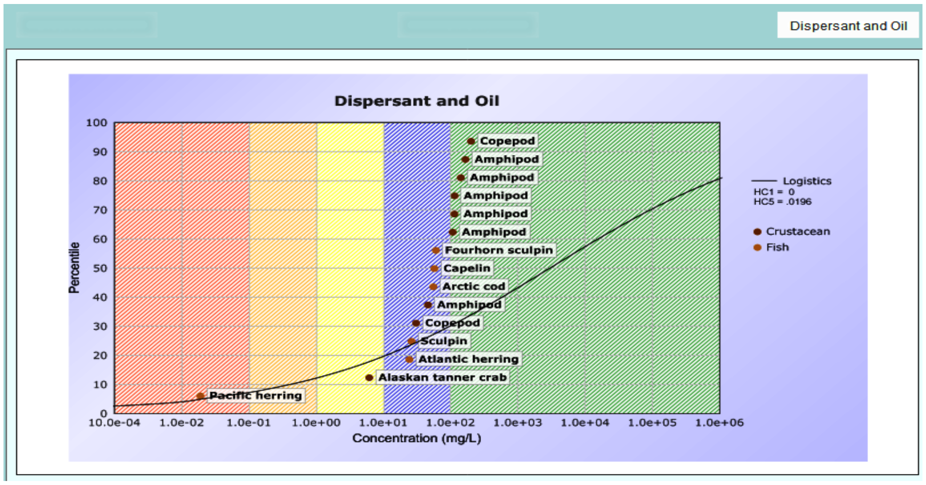
The technical literature often involves the calculation of lethal effect concentrations based on the nominal volume of oil added and not what was actually incorporated into the water column to which the test species was exposed. Since many oil components are poorly soluble, some readily evaporate, and some stick to test system surfaces, it is difficult to compare available data that did not follow standardized testing protocols and quantify actual exposure concentrations in these tests (Coelho *et al.,* 2013).

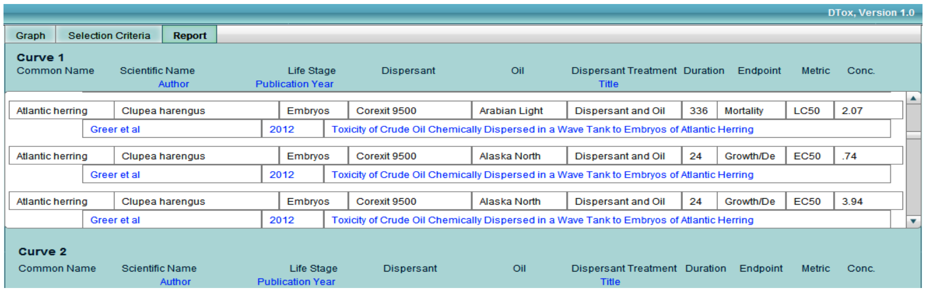
In 2013, the NOAA-funded Coastal Response Research Center sponsored a project to rapidly assess the toxicity of physically and chemically dispersed oils. The project, known as DTox, involved the development of a dispersant and chemically dispersed oil toxicity database, and was completed in early 2014. The result is a new quantitative data compilation that provides the basis for a more thorough assessment of levels of concern for dispersants and chemically dispersed oil (Bejarano, 2014). End-users of this new tool can develop Species Sensitivity Distribution (SSD) curves that will likely improve risk estimates during oil spill response exercises or spill events by allowing the user to select data that specifically relates to particular oils or dispersant. It provides rapid access to centralized toxicity data so that data from past research can be applied in a meaningful way to current spill planning events and can aid in the threshold and risk ranking process. The reader is encouraged to view the DTox video at http://www.researchplanning.com/wp-content/uploads/2014/02/DTox_Tutorial.mp4 to gain an understanding of the capabilities of DTox. Users can query the system to quickly access toxicity information on specific dispersants, oils, or species of interest. Further, it allows the user to directly link data in the curve to the original publication. Sample screen shots from DTox are provided in Figure 16.



Distribution: Frigid

Dispersant and Oil Treatment: Dispersant and Oil





Curve 1

Common Name	Scientific Name Author	Life Stage Publication Year	Dispersant	Oil	Dispersant Treatment Title	Duration	Endpoint	Metric	Conc.
Atlantic herring	Clupea harengus	Embryos	Corexit 9500	Arabian Light	Dispersant and Oil	336	Mortality	LC50	2.07
	Greer et al	2012			Toxicity of Crude Oil Chemically Dispersed in a Wave Tank to Embryos of Atlantic Herring				
Atlantic herring	Clupea harengus	Embryos	Corexit 9500	Alaska North	Dispersant and Oil	24	Growth/De	EC50	.74
	Greer et al	2012			Toxicity of Crude Oil Chemically Dispersed in a Wave Tank to Embryos of Atlantic Herring				
Atlantic herring	Clupea harengus	Embryos	Corexit 9500	Alaska North	Dispersant and Oil	24	Growth/De	EC50	3.94
	Greer et al	2012			Toxicity of Crude Oil Chemically Dispersed in a Wave Tank to Embryos of Atlantic Herring				

Curve 2

Common Name	Scientific Name Author	Life Stage Publication Year	Dispersant	Oil	Dispersant Treatment Title	Duration	Endpoint	Metric	Conc.

Figure 16. DTox database tool showing input query screen (top) and an example curve for some arctic species (middle). End-users can also retrieve the original source citation (bottom). (Bejarano, 2014)

The advantage to using SSD curves in lieu of conducting new species-specific testing was highlighted in a second paper by Bejarano *et al*. (2014), which concluded:

- SSDs have been shown to provide useful information of potential significance for decisions makers involved in oil spill response decision-making.
- SSDs can provide scientifically defensible benchmark values for use in dispersant use decision making and related oil spill issues, even when the SSDs are based on standard exposure regimes rather than real world, dynamic exposure tests.
- It is not necessary to continue testing new species (or extreme condition species – such as cold water) because cold water species fell within the range of sensitivities of commonly tested species, mostly of temperate climates.

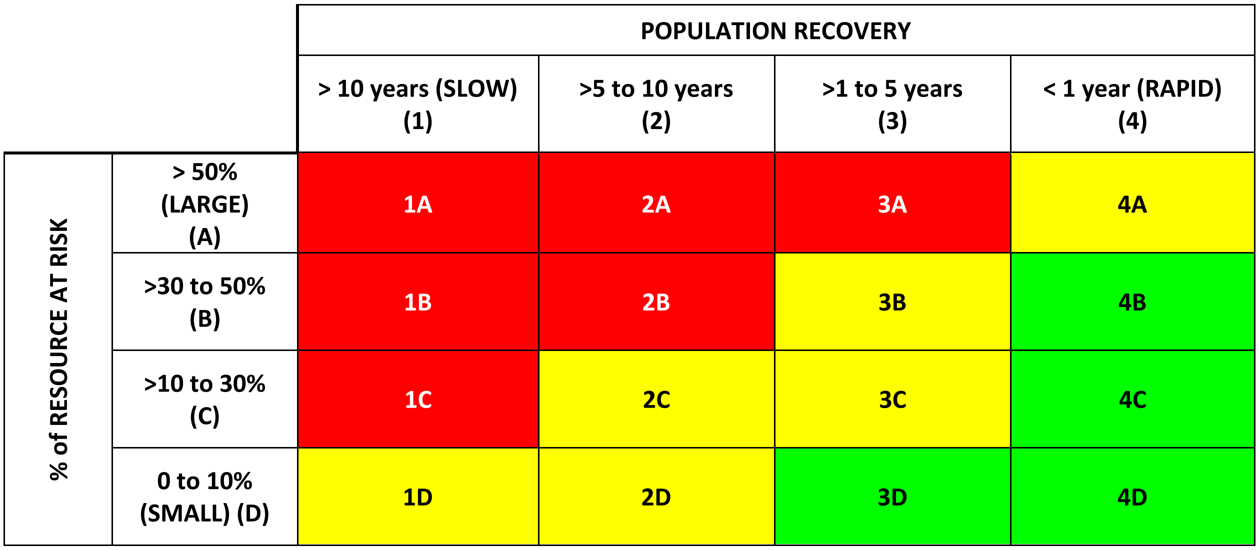
It is noteworthy that the general species sensitivity brackets for dispersed oil that are identified in Figure 15, as published in the National Research Council (2005) report on dispersants, were originally derived by preparing SSD curves more than a decade ago. As new dispersed oil toxicity data has been produced since that time, there is additional evidence that many species (and life-stages) from diverse aquatic systems (from tropical to arctic) tend to respond similarly to benchmark species that have already been extensively studied.

3.2 The Risk Ranking Process

Once the risk matrix has been compiled and the resource and trajectory data evaluated, the study team used a “risk ranking matrix” in order to assign a **level of concern** to each cell in the risk matrix (Figure 17). Each axis of the risk ranking matrix represents a parameter used to describe risk: the x-axis rates duration in terms of “population recovery” and the y-axis evaluates magnitude in relation to “% of resource at risk” affected. Each cell in the risk matrix is assigned an alphanumeric value to represent relative impact. For this analysis, a 4 by 4 matrix offers sufficient resolution.

The study team divided the “population recovery” time ranges into four categories ranging from less than 1 year (rapid recovery) to more than 10 years (slow recovery). Likewise, the “% Resources at Risk” were also divided into four categories with less than 10% representing a small percentage of the population and more than 50% as a large percentage of the population. The intermediary ranges for both axes were then further divided to provide some more definition to the matrix. The risk ranking matrix for this NEBA was based on summarizing 14 consensus ecological risk assessment (CERA) matrices generated through numerous CERA workshops throughout the United States, Mexico, the Caribbean and New Zealand.

The first step in the NEBA process was to evaluate the consequences of Natural Attenuation, which serves as a baseline. All subsequent rankings are relative to the baseline, i.e., are conditions better or worse for each resource when using each individual response options. Using the risk ranking matrix requires estimating the proportion of the resource affected, and how long it will take the resource to recover. Based on the initial alphanumeric score, a level of concern ranking of High (red), Moderate (yellow) or Low (green) can be assigned.



		POPULATION RECOVERY			
		> 10 years (SLOW) (1)	>5 to 10 years (2)	>1 to 5 years (3)	< 1 year (RAPID) (4)
% of RESOURCE AT RISK	> 50% (LARGE) (A)	🟥 1A	🟥 2A	🟥 3A	🟨 4A
	>30 to 50% (B)	🟥 1B	🟥 2B	🟨 3B	🟩 4B
	>10 to 30% (C)	🟥 1C	🟨 2C	🟨 3C	🟩 4C
	0 to 10% (SMALL) (D)	🟨 1D	🟨 2D	🟩 3D	🟩 4D

Figure 17. Risk Ranking Matrix used in this analysis

A key factor in determining whether or not a resource is affected is to apply thresholds at which impacts, either acute or chronic, would be expected to occur for the various resource groups under consideration. In this case, two sets of thresholds, based on conservative (protective) assumptions were considered. The first set, used by Horn and French McCay (2014a and b), is shown in Table 9. In this approach, damage to shoreline ecological resources and habitats was assumed if oil contacted the habitat at a modelled concentration above 10.0 g/m^2. Impacts to birds, mammals and turtles on the water surface were assumed if there was a high probability of any contact with the modelled surface oil slick at slick thicknesses above 10 µm.

In the second approach shown in Table 10, the thresholds that can be most clearly quantified are those related to aquatic toxicity. This table which was first provided in Kraly *et al*. (2001) presents a series of concentration thresholds developed to address a range of organisms. These values are based on a qualitative review of published toxicity information initially developed for early CERA workshops. This table was included in the material reviewed by the Ocean Studies Board of the National Research Council (NRC) and included in their study (NRC, 2005). Additionally, a review of existing data from NRC and the DTox database (Bejarano, 2014) was conducted to compare the range of sensitivities reported for marine species tested for lethal and sub-lethal impacts from acute exposures to expected initial concentrations of dispersed oils following dispersant application in open waters, as well as in laboratory tests. Figure 15 was developed from this review. The more conservative threshold of 1 ppm is used in this analysis to conservatively protect sensitive species and juvenile life stages.

Table 9. Modelling Threshold Used to Define Regions with Potential Effects (Horn and French McCay 2014b)

Stochastic Threshold	Cut-Off Threshold	Rationale
Surface Oil Thickness	10 µm	Biological threshold for ecological impacts to the water surface (e.g., birds) (French *et al*., 1996 & French-McCay 2009 oil spill fate and effects model). Oil would appear as a dark brown colour.
Shoreline Oil Mass	10.0 g/m^2	This thickness provides a more conservative screening threshold for potential ecological effects to shoreline habitats, which has typically been 100 g/m^2, based upon a synthesis of the literature showing that shoreline life has been affected by this degree of oiling (French *et al*., 1996; French McCay 2009). The oil would appear as dark brown coat or opaque/black oil.
In Water Concentration	1.0 ppb of dissolved aromatics	Exposure concentration below which no noteworthy biological effects are expected for sensitive marine resources (Trudel, 1989 and French-McCay, 2004) in S.L. Ross 2011 modelling for Old Harry in Gulf of St. Lawrence). This value is a conservative threshold for early contact on herring larvae.

Table 10. Water Column Thresholds in ppm of Total Petroleum Hydrocarbons (Kraly *et al*., 2001)

Exposure	Level of Concern	Protective of Sensitive Life Stages	More Protective Criteria	Protective of Adult Fish	More Protective Criteria	Adult Crustacea/ Invertebrates	More Protective Criteria
0-3 hours	Low	<5	<1-5	<10	<10	<5	<5
	Medium	5-10	5-10	10-100	10-100	5-50	5-50
	High	>10	>10	>100	>100	>50	>50
0-24hours	Low	<1	<0.5	<2	<0.5	<2	<0.5
	Medium	1-5	.5-5	2-10	.5-10	2-5	.5-5
	High	>5	>5	>10	>10	>5	>5
0-96 hours	Low	<1	<0.5	<1	<0.5	<1	<0.5
	Medium			1-5	.0-5	1-5	.5-1
	High	>1	>0.5	>5	>5	>5	>1

The study team used all of the available information about the existing biological environment from the EIS and the oil trajectory analysis in the modelling reports, along with these toxicity thresholds, to develop ***levels of concern*** about the risk. The risk scores assigned in the risk matrix do not represent a prediction of actual impacts. Instead, they represent the level of risk assigned to a particular resource of concern from the different proposed response options.

3.3 Risk Analysis Results

As mentioned previously in Section 2.3, the best overall response to most large oil spills will almost always involve the integration of multiple response options. The reader is reminded that every response option has varying operational and logistics constraints that affect how quickly it can be deployed, and how much the particular response option can be "scaled up" based on many factors including access to remote areas, transit times for personnel and equipment. In addition, the decision-makers will need to set realistic expectations on how well each response option will work for the specific spill conditions. This NEBA is not suggesting that only one response option should be used, rather it is intended to consider the potential ecological consequences of each option (individually) to assist decision-makers in devising a response that minimizes overall ecosystem exposure to persistent oil, and promotes the most rapid overall ecosystem recovery.

The detailed results from the risk analysis are shown in Figure 18 and further detailed in the subsections that follow. As discussed in Section 2.4, the modelling results indicate that shoreline impact is an extremely low probability event. Therefore, the shoreline risk ranking results only apply to those circumstances where impacts to the shoreline (less than 2% of the modelled trajectories) are predicted.

			Reference Habitat*	Natural Attenuation	On-water Mechanical Recovery	On-water In-situ Burning	Surface Dispersants	Subsea Dispersants	Shoreline Protection & Recovery
Shoreline	**Southern Tip of Nova Scotia**	**Mammals**	R	3D	3D	3D	3D	4D	3D
		Birds	R	1A	1A	1A	1A	4D	1A
		Fish	R	4D	4D	4D	4D	4D	4D
		Invertebrates	R	4D	4D	4D	4D	4D	4D
		Plankton	R	4D	4D	4D	4D	4D	4D
		Vegetation	R	4D	4D	4D	4D	4D	4D
	Sable Island	**Mammals**	R	3A	3A	3A	3C	3D	2C
		Birds	R	1A	1A	1A	3B	3D	1A
		Fish	R	4D	4D	4D	4D	4D	4D
		Invertebrates	R	4D	4D	4D	4D	4D	4D
		Plankton	R	4D	4D	4D	4D	4D	4D
		Vegetation	R	4D	4D	4D	4D	4D	4D
	Recreational Fisheries		R	2A	2A	2A	2B	2C	2C
	Cultural and Subsistence		R	2A	2A	2A	2B	2C	2C
Shelf	**Surface Layer**	**Mammals**	R	2C	2C	2C	2C	3D	2C
		Birds	R	1A	1A	1A	1A	3D	1A
		Fish (larvae/eggs only)	R	4D	4D	4D	4D	4D	4D
		Sea Turtle	R	3D	3D	3D	3D	4D	3D
		Invertebrates	R	4D	4D	4D	4D	4D	4D
		Plankton	R	4D	4D	4D	4D	4D	4D
	Water Column (shallow; < 100m)	**Mammals**	R	4D	4D	4D	4D	4D	4D
		Sea Turtles	R	4D	4D	4D	4D	4D	4D
		Birds	R	4D	4D	4D	4D	4D	4D
		Fish	R	3D	3D	3D	3D	4D	3D
		Invertebrates	R	3D	3D	3D	3D	4D	3D
		Plankton	R	4D	4D	4D	4D	4D	4D
	Water Column (deep; > 100m)	**Mammals**	R	4D	4D	4D	4D	4D	4D
		Fish	R	4D	4D	4D	4D	4D	4D
		Invertebrates	R	4D	4D	4D	4D	4D	4D
		Plankton	R	4D	4D	4D	4D	4D	4D
	Benthos	**Fish**	R	4D	4D	4D	4D	4D	4D
		Corals & Sponges	L	4D	4D	4D	4D	4D	4D
		Other Invertebrates	R	4D	4D	4D	4D	4D	4D
	Commercial Fisheries		R	2A	2A	2A	2B	2C	2A
	Cultural and Subsistence		R	2A	2A	2A	2B	2C	2A
Slope	**Surface Layer**	**Mammals**	R	2C	2C	2C	2C	3D	2C
		Birds	R	1A	1A	1A	1A	3D	1A
		Fish (larvae/eggs only)	R	4D	4D	4D	4D	4D	4D
		Sea Turtle	R	3D	3D	3D	3D	4D	3D
		Invertebrates	R	4D	4D	4D	4D	4D	4D
		Plankton	R	4D	4D	4D	4D	4D	4D
	Water Column (shallow; < 100m)	**Mammals**	R	4D	4D	4D	4D	4D	4D
		Sea Turtles	R	4D	4D	4D	4D	4D	4D
		Birds	R	4D	4D	4D	4D	4D	4D
		Fish	R	3D	3D	3D	3D	4D	3D
		Invertebrates	R	3D	3D	3D	3D	4D	3D
		Plankton	R	4D	4D	4D	4D	4D	4D
	Water Column (deep; > 100m)	**Mammals**	R	4D	4D	4D	4D	4D	4D
		Fish	R	4D	4D	4D	4D	4D	4D
		Invertebrates	R	4D	4D	4D	4D	4C	4D
		Plankton	R	4D	4D	4D	4D	4C	4D
	Benthos	**Fish**	R	4D	4D	4D	4D	4D	4D
		Corals & Sponges	L	4D	4D	4D	4D	4D	4D
		Other Invertebrates	R	4D	4D	4D	4D	4D	4D
	Commercial Fisheries		R	2A	2A	2A	2B	2C	2A
	Cultural and Subsistence		R	2A	2A	2A	2B	2C	2A
Special Areas	**Gully Marine Protected Area**		L	2D	2D	2D	3D	4D	2D
	Roseway Basin		L	2C	2C	2C	3C	4D	2C

Figure 18. Results for the Risk Analysis (*R - Regional, L – Local)

3.3.1 Natural Attenuation

In approximately 95% of the modelling cases where oil does not reach the shoreline, the “level of concern” associated with natural attenuation is estimated to be low (recovery in less than one year), except for birds and marine mammals on the sea surface on both the shelf and slope, and recreational/commercial fisheries and cultural and subsistence use in all areas. The low level of concern for water column resources is based on low exposure levels given that the oil would remain largely on the water surface. However, even though it is evaluated as a low level of concern, naturally dispersed oil levels in the upper 10 to 20 m of the water column in the vicinity of surface slicks could pose a risk to plankton and fish eggs and larvae, if present in offshore locales and the spill occurs during spawning season. However, the anticipated area of effect in the water column for the total spill is not expected to be substantial (see Sections 2.4 and 3.1).

The level of concern for birds and fur-bearing mammals is judged to be much higher based on the following considerations drawn from the EIS, the oil spill modelling completed for this study, and past CERA findings:

- The largest concentrations of both birds and mammals occur over the continental shelf, while the oil trajectory stays mainly over the continental slope and the deep ocean. However the critical importance of these species, and the recognized patchy distribution of protected species, increased the level of concern for both percentage affected and time for population recovery.
- Federated Crude Oil weathers rapidly and during much of the year, especially in the winter, disperses rapidly into the upper water column.
- While the predicted area potentially affected by a surface slick is large, the actual footprint of the slick at any given time is relatively small (less than 10% of the reference area or RAA) and the oil older than several days would be highly weathered (emulsified and/or tar balls) and would pose less of a risk.
- Species vary throughout the year, but are present in all months.
- Individuals could contact oil and if so population recovery could take several years.

The level of concern for commercial fisheries in all regions is judged to be high based on the following:

- There will likely be an immediate closure of most, if not all, fisheries by Fisheries and Oceans Canada (with likely input or advice from Environment Canada and/or Canadian Food Inspection Agency) in the areas and/or for the resources considered affected by the spill.
- The affected fisheries are unlikely to reopen until monitoring of both oil distribution and tissue samples of species of concern reach acceptable levels, based on standards set by Canadian regulatory agencies.
- Fisheries closures in the Gulf of Mexico associated with the DWH incident were lifted within a year. Long-term population recovery studies are still ongoing.
- Typically, public trust tends to take a long time to recover.

The level of concern for cultural and subsistence uses in all regions (1A, concern for entire resource, recovey more than ten years) is judged to be high based on the following:

- This consideration has already been raised by First Nation stakeholders in association with the Project.

- Typically, trust levels by the public take a long time to recover.
- Experience from other incidents (i.e., Exxon Valdez) indicates that cultural and subsistence use concerns can remain a factor after more than 20 years, mostly due to chronic effects from shoreline impacts and persistance of oil in shoreline sediments. Oil at sea is expected to dissipate much more rapidly and produce less chronic effects.

Although shoreline oiling was determined to be a low probability event (i.e., less than 2% probability for both scenarios), the modelled trajectories suggested two areas at risk, the southern tip of Nova Scotia and Sable Island. The two highest concerns in these areas is for birds in the Important Bird Areas (IBAs) and marine mammals. The important bird species include the Leach’s storm petrel and the Roseate tern (a critically endangered species). Surface oiling on Sable Island National Park Reserve has the potential to affect these populations. As a result, the level of concern score for these bird resources is 1A (more than 50% of the population at risk, more than ten years to recover). While surface oiling is expected to impact birds to a lesser extent on the tip of Nova Scotia given the lower concentration of these populations than on Sable Island National Park Reserve, the Level of Concern score is still a 1A because of the patchy distribution, meaning that oiling of even a small area could possibly hit the only patch of protected birds.

The important mammal species was identified as the grey seal on Sable Island where a sizeable portion of the North Atlantic population could be at risk. The level of concern score for this resource is 3A (more than 50% of the population at risk, recovery in one to five years). Other shoreline resources are at low risk (3D or 4D, recovery in less than one year) based on:

- Any oil reaching shore after 20 to 30 days (or more) will be extremely weathered (mostly tarballs) and represents less of a threat than fresh oil.
- High energy levels (especially in winter) in many areas will aid in rapid dilution, biodegredation and recovery.
- The available shoreline habitat potentially at risk is only a small portion.

3.3.2 Shoreline Protection and Recovery

Shoreline protection and recovery will not change any of the scores associated with habitats or resources of concern on the shelf or the slope relative to natural attenuation. Shoreline protection and recovery techniques may prevent some localized shoreline contamination, and will reduce the persistence of oil in treatable shoreline areas. However, the overall regional effect is not considered significant because the effectiveness of these options is heavily influenced by topographic and climatic conditions. The remote conditions along the Nova Scotia coastline, limited shoreline accessibility as well as the local weather conditions can pose formidable challenges to large-scale shoreline protection and recovery operations. The reader is refered to the OSRP for further information on Shoreline protection and recovery.

In low energy habitats care must be used to avoid exacerbating the damage caused by the oil. With appropriate response planning and implementation, a net improvement should be possible over natural attenuation, particularly in localized areas. Shoreline protection and recovery operations will be especially important and beneficial for marine mammals on Sable Island. For the island, the risk ranking was reduced from 3A (greater than 50% of the resource at risk, recovery in one to five years) to 2C (10-30% of the population at risk, recovery in five to ten years) because given 20 to 30 days to prepare effective shoreline protection, which followed by aggressive shoreline removal and seal deterrance, could reduce exposure considerably. This was not the case for birds, where it was judged that a large human presence could disturb the bird populations negatively, especially during nesting season, where eggs and chicks in non-oiled supratidal zones could be damaged by foot traffic. All shoreline activities in the area will have to be planned in conjunction with wildlfe specialists.

Other shoreline risk rankings were already low and are not expected to change, given that operations are expected to be localized and limited and some oil will still be present on shorelines that cannot be protected or completley cleaned. The levels of concern for cultural and subsistences uses, both on Sable Island and the southern tip of Nova Scotia are expected to improve with shoreline protection and recovery operations based on the visible activity and expected localized beneficial results. Shoreline protection and recovery efforts could also be targeted to areas of importance on southern tip of Nova Scotia where conditions permit. The levels of concern for these areas are reduced from 2A to 2C, with shoreline protection reducing percentages affected, but still resulting in a recovery time of five to ten years.

3.3.3 On-water Mechanical Recovery

The levels of concern scores associated with on-water mechanical recovery are unchanged from the natural attenuation baseline, based on the logistic and weather limitations discussed in Section 2.3.3. The limited ability to utilize this option is expected to limit the overall regional ecological benefits over natural attenuation. Nevertheless, a worst case discharge may trigger the use of this response option which can remove a small amount of surface oil in localized areas where it is deployed (i.e., localized benefits). While not enough to appreciably change the regional ecological consequences, it does provide some potential for surface oil removal in localized areas, and as a result does potentially provide a small net environmental benefit over natural attenuation.

3.3.4 On Water In-Situ Burning

The levels of concern scores associated with ISB are unchanged from the natural attenuation baseline, based on the logistic and weather limitations discussed in Section 2.3.4, as was the case for on-water mechanical recovery. The effectiveness of ISB is anticipted to be even less than on-water mechanical recovery because of prevailing sea state conditions in the Project area, which limits the ecological benefits provided. However, this option could remove some small amount of the oil from the sea surface. While not enough to appreciably change the regional ecological consequences, it does provide potential for localized surface oil removal, and as a result does potentially provide a small net environmental benefit over natural attenuation.

Given the great distance from shoreline, air quality concerns over the rising plume were not considered a threat to human populated areas, and it is assumed that birds would avoid the smoke plume. Some small by-products from ISB can result in sinking burn residue. Components in the burn residue matrix is thought to have a low bioavailability and a review of bioassays from the Newfoundland Offshore Burn Experiment show little or no acute toxicity to aquatic organisms (Blenkinsopp *et al.,* 1997; Daykin *et al.,* 1994). Studies with several benthic organisms also indicated no acute toxicity and very low sublethal toxicity from burn residues generated in a laboratory (Gulec and Holdway, 1999). As a result of these past studies it was concluded that sinking burn residue does not present an appreciable ecological concern.

3.3.5 Dispersant Application at Water Surface

Compared with an unmitigated spill, surface dispersant application is expected to result in net environmental benefits for marine mammals and birds on the sea surface by reducing surface oil slicks. The trajectory modelling results indicate that the addition of surface dispersants is expected to reduce oil droplet size, increase the amount of oil that becomes entrained in the water column, and reduce the amount of oil at the surface. Any resurfacing oil would form slicks that are smaller in area, thinner, patchier and less persistent than they would be in an unmitigated case. Although surface dispersant use is expected to provide a net environmental benefit for marine mammals and birds, it it not expected to change the levels of concern for resources other than birds and mammals on Sable Island. Based on the natural resource information provided in the EIS and the limitations on surface dispersant application given the prevailing environmental conditions, the risk ranking for marine mammals and birds on both the shelf and the slope (in surface waters) are considered likely to remain unchanged between the unmitigated and surface dispersant scenarios. While aerial dispersant application should be highly effective on encountered oil, the combination of weather conditions, day length (particularly in winter), and the difficult logistics given distance offshore, the ability to apply surface dispersants is expected to be limited. It is expected that the application of surface dispersants would result in only a 10-20% reduction in surface oil in the first four days (i.e., the modelled duration). As more dispersant operational resources became available, the percentage of surface oil that can be treated by aerial dispersants will increase, but the impacts of untreated surface oil will continue to cause potential impacts.

Surface dispersant application is also not considered to change the levels of concern for water column resources for reasons similar to those provided above. This includes the limited ability to deploy given environmental conditions and distance offshore, as well the limited total reduction in surface oil given these contraints. Although the use of surface dispersants is not expected to change the levels of concern to resources of concern on a regional scale, they may result in localized benefits in the areas where they are successfully deployed.

Using surface dispersant applications on surface oil will have localized benefits to organisms using the surface layers of the water column given its effects of reducing the surface slick and entraining oil in the water column. Although it will increase the amount of oil dispersed in the upper 10 to 20 m of the water column, oil will likely already be present in the water column through natural attenuation given prevailing environmental conditions in Nova Scotia. Thus, additional entrainment due to chemical dispersion will be incremental. Concentrations of chemically dispersed oil will dilute rapidly as the oil moves through the water column over time. Within 2-4 hours, concentrations typically decrease to below 10 ppm, which is approaching the threshold limit below which adverse ecological effects are not anticipated, even to sensitive species. The use of surface dispersants is therefore considered to provide a localized benefit to organisms such as birds and mammals using surface waters, and is not expected materially impact resources using the water column given the rapid dilution of dispersed oil and the low toxicity of the dispersants themselves (see Appendix A for a discussion of dispersant toxicity).

The levels of concern for cultural and subsistence uses and commercial fisheries remain high because of a lack of accurate information on long-term recovery times, and the fact that public “perception” of damages may persist for decades. A common perception is that chemical dispersants are highly toxic and cause the entrained oil/dispersant mix to persist in the environment. Although scientific studies have demontrated this is not the case, the public perception still remains. The reader is referred to Appendix A for a general discussion on the fate and effects of dispersants.

Shoreline impacts are rare and have low levels of concern in the natural attenuation case, and these would not change with surface dispersant application. There are two exceptions to this. First, the level of concern for marine mammals on the shoreline of Sable Island, where a major reduction in the percentage of the population of grey seals at risk is anticipated following the surface application of dispersants (new ranking 3C, down from 3A, recovery still in one to five year range). Second, the level of concern for birds at risk in the IBA is reduced from 1A to 3B, since less individuals would be affected, the population should recover in less time. Impacts to Sable Island are rare (see Section 2.4) but if they do occur they could be severe. As a result, surface dispersant application could lower, and even potentially eliminate, the risks to mammals and birds where it limits or prevents the surface slick from reaching the area.

3.3.6 Subsea Dispersant Injection

Subsea dispersant injection provides the greatest decrease in levels of concern assigned to resources at risk as compared to the levels of concern generated from natural attenuation. The lower levels of concern stem from the fact that subsea dispersants can be effectively deployed with continuos operation, and their use does not cause a material increase in risk to the water column resources while greatly reducing the quantity of oil in shallower waters and on the water surface and shorelines. Dispersant use also reduced the likelihood that oil reaches shorelines and sensitive areas such as Sable Island National Park Reserve. Modelling indicates that this response option has the greatest potential to reduce surface oil, as well as reduce dispersed oil concentrations in the sensitive upper water column (surface to 100 m) where a variety of sensitive meroplanktonic resources are found.

Given that the application occurs at the spill's source, the exposures to dispersed oil in the deeper water column of the slope do increase, but the results from the trajectory modelling indicate areas exceeding the evaluation thresholds rarely occur (see Section 2.4). Dispersant injection occurs in an offshore area and at depths where sensitive resources are less common than in nearshore and shoreline environments. The area at the greatest risk is in the immediate vicinity (few kilometres) of the application point. Monitoring of subsea dispersant application during the DWH spill (Coelho *et al.,* 2012) indicated that concentrations of dispersed oil quickly diluted to below 1 ppm TPH within a few kilometres of the DWH well site, which is below nearly all conservative lethal thresholds and below most sub-lethal thresholds for sensitive marine species (NRC, 2005; see Figure 15). Additionally, while there were initially concerns during the DWH spill that the subsea dispersant injection could cause anoxic conditions at depth due to increased respiration from biodegradation, an extensive dissolved oxygen (DO) monitoring study was conducted over a three month period during the response. More than 1,500 DO concentration measurements were recorded, and while a minor reduction of DO was reported in the dispersed oil plume (from biodegradation that was taking place), levels never dropped below the ecologically significant threshold of 2.0 mg/L. Refer to Figure 19 for a summary of the DO results. These data suggest that subsea dispersant injection did not create any “oxygen depleted zones” in the Gulf of Mexico (Coelho *et al.,* 2012).

Underwater photographs collected as part of the Shelburne Basin Venture Seabed Survey conducted in 2014 around prospective wellsite locations, did not identify the presence of any aggregations of corals, sponges or other benthic epifauna (Stantec, 2014c). No species of conservation interest were noted within the seabed study area, however the authors of this NEBA recognize that limited at-sea observations of the benthic environment is not a full characterization of species/resources in the deep waters of the slope.

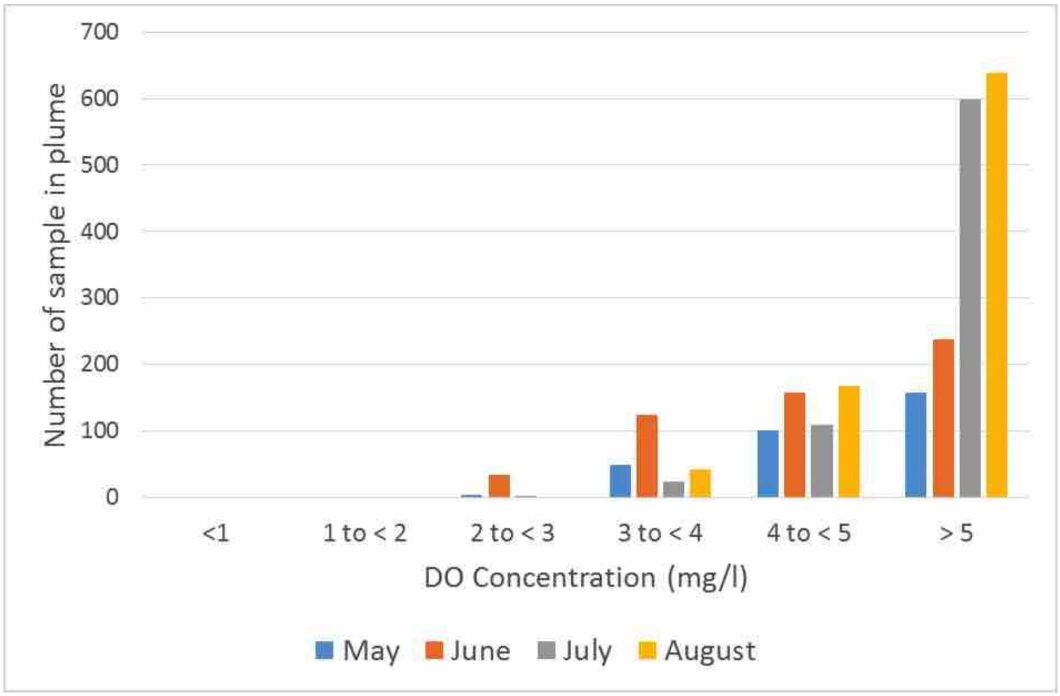


Figure 19. DO data from water samples collected during DWH spill (Coelho *et al.,* 2012)

Water column resources on the slope are not expected to be affected except in the upper water column, which would see less naturally dispersed oil. The changes to the levels of concern are as follows:

- Marine mammals and bird scores on the water surface in both the shelf and slope are reduced based on the decreased surface oil. This reduction is a conservative estimate because the smaller amount of surface oil could be such that natural weathering could eliminate it within days or less.
- The risk to sea turtles on the water surface in both the shelf and slope is reduced from 3D (less than 10% of the population at risk, recovery in one to five years) to 4D (less than 10% of the population at risk, recovery in less than one year) for the same reasons as described above.
- The risk to invertebrates in the shallow water column is reduced from 3D (less than 10% of the population at risk, recovery in one to five years) to 4D (less than 10% of the population at risk, recovery in less than one year) due to the reduction in naturally dispersed oil in the upper water column.

- The localized risk to invertebrates and plankton in the deep water column on the slope is increased based on the increase in exposure to dispersed oil in proximity to the discharge plume and application point. However, this is highly localized the the near vicinity of the well head.
- Finally, the perceived risk to fisheries and cultural and subsistence uses on the shelf should decrease from high to moderate as it becomes clear there is less oil, but public perception will still be slow to recover.

The remaining changes to the risk scores occur in shoreline habitats. Subsea dispersant injection has the potential to completely prevent this already rare event. With the application of subsea dispersant, no shoreline impacts would be expected to occur. Even if some surface oil remains, natural weathering processes would reduce the amount reaching shore, and this outcome is evaluated here. Important changes to the natural attenuation scenario occur for cultural and subsistence uses and for marine mammals and birds, as follows:

- The perceived risk to Cultural & Subsistence (both areas) is estimated to be reduced from due to the reduction in oiling. The benefit is greater here than on the shelf because the change will be more visible and obvious. However, even if the actual physical oiling approaches zero, public concerns will still remain, albeit lessened.
- The risk to marine mammals on the southern tip of Nova Scotia was reduced from 3D (less than 10% of the population at risk, recovery in one to five years) to 4D (less than 10% of the population at risk, recovery in less than one year) on the assumption that even less oiling will occur and impacts will essentially be restricted to a few individuals, without a measurable population impact.
- Similary, the level of concern for birds in the southern tip of Nova Scotia was reduced from 1A to 4D, and on Sable Island it was reduced from 1A to 3D for the same reason.
- The risk to marine mammals (grey seals) on Sable Island was reduced from 3A (greater than 50% of the resource at risk, one to five years to recover) to 3D (less than 10% of the population at risk, recovery in one to five years) because of the dramatically lowered exposure risk to a large population.

While a spill during breeding season for both the birds and mammals in shoreline habitats may critically affect the numbers impacted, especially in Sable Island, it is clear that dispersant application will always improve the condition over unmitigated surface oiling. As stated earlier, in the optimal case the rare impacts to shoreline resources could be completely eliminated by an effective subsea dispersant injection program. It is the only option which appears to realistically offer this outcome (see Section 2.3).

4 Summary

4.1 Critical Factors in the Analysis

This qualitative, NEBA analysis was conducted for oil spill contingency planning purposes, and is dependent upon a variety of input sources. It is intended to address the overall risk of a large scale subsea blowout event. Because it is intended to be a broad analysis of a large scale event, there is no specific season or trajectory analysis that will account for every possible spill scenario. However, it should represent likely exposure risks and levels of concern.

To conduct this study, the following important factors were considered and/or employed:

- the comprehensive environmental analysis conducted by Stantec;
- the comprehensive trajectory modelling using state-of-the-art models and including stochastic and deterministic scenario provided by ASA;
- reliance on the risk matrix which has been validated through numerous other studies;
- design of a scenario representing a high volume discharge incident for this area; and
- use of assumptions that were conservative and evaluated maximum extent of the impact.

4.2 Key Findings Related to Ecological Impacts

The most noteworthy result of the modelling analysis is the lack of shoreline impact in the vast majority of simulations for both treated and untreated slicks. Other summary results are as follows:

- Overall, the “level of concern” for long-term ecological harm from the modelled releases is low, in large part because of the great distance offshore and low predicted amount of oil that would encounter shorelines or nearshore environments (approx. 2%)
- Surface oil stays offshore (beyond the shelf/slope break) in most cases (over 95% of the time).
- Because of the characteristics of the oil and the environmental conditions in the North Atlantic, large amounts of hydrocarbons enter the upper water column due to natural dispersion. However, water column concentrations of hydrocarbons are unlikely to exceed relevant thresholds, except in limited areas.
- Weathering of the surface oil is relatively rapid.
- Oil that reaches the shoreline (after 20 to 30 days) will be highly weathered (tar balls) and therefore adverse effects on resources will be less than with fresher oil.
- In the few instances where oil might reach the shoreline, the long travel time means that protective booming and shoreline recovery (done properly) could be planned and performed efficiently, but would not prevent all shoreline impacts.
- On-water mechanical recovery and in-situ burning are unlikely to substantially reduce adverse effects on ecological resources at a regional level. Some localized benefits may be provided from this activity.
- Natural dispersion and evaporation limit the area affected by surface oil.
- Aerial dispersant application to the sea surface will provide some benefit, especially early in the response, since it can be mobilized to the Source Control area faster than any other “at sea” response technique. Chemically dispersed oil droplets are preferred (over naturally dispersed

droplets) because they are smaller and form a stable oil-in-water emulsion that will not re-coalesce into a slick (because the dispersant lowers the interfacial tension of the droplet). As a result, chemically dispersed oil droplets will more readily and rapid biodegradation.

- Subsea injection of dispersants provides the greatest ecological benefit by retaining oil at depths and reducing the extent and concentration of surface oil and oil in the upper water column.
- Subsea dispersant injection increases hydrocarbon concentrations of oil in deep waters (close to the well site), but the affected areas are small relative to the overall Project area. The concentrations predicted do not represent a high level of concern to sensitive biological resources in those deep waters, and the concentrations should reduce fairly rapidly through biodegradation processes. It also lowers the level of naturally dispersed oil in the upper 10 to 20 m of the water column and at the surface.
- Aerial dispersant application may reduce surface impacts in treated slicks without a substantial increase in shallow water hydrocarbon concentrations, but the option can have logistical limitations given environmental conditions in Nova Scotia and will be less effective on highly weathered oil. As a result, aerial dispersants should be focused at relatively fresh oil at sea, since oil approaching shoreline areas will be too weathered for effective dispersant use.
- The risk to cultural and subsistence resources can be reduced by the use of subsea dispersants given that it reduces the likelihood that oil will reach the shoreline or sensitive areas such as Sable Island National Park Reserve. Further, SSDI is expected to promote more rapid biodegradation in deepwater, thereby removing oil from the ecosystem more quickly than other response options. However, the concerns from First Nations will likely remain high.
- The actual risk of various response options (specifically dispersants) to species that are important to commercial fisheries is low, but concern may remain high. Fisheries closures are likely to result from the spill itself, irrespective of whether dispersants or any other methods are used to assist in the response. The lengths of the closures may not change as a result of any of the response options, though subsurface dispersants may reduce the length of closures due to their potential effectiveness. Dispersant use may increase public concerns over seafood safety, though studies indicate their low toxicity.

4.3 Consideration of Other Scenarios

Since the purpose of this NEBA was to evaluate the ecological consequences of various response techniques, a summer season was selected with a Worst Case Credible Discharge volume. Since the summer weather conditions support all response options, this scenario allows for an even comparison of each option under a worst case release. During the winter season or during a storm event, it is reasonable to expect that higher sea states will exist and that some of these response options (e.g., on-water mechanical recovery, ISB and possibly protective shoreline booming) will no longer be operationally viable. As such, the feasible response options “at sea” during the winter (or a storm) may be limited to Natural Attenuation and Dispersant Use (surface or subsea). In higher sea state conditions, it is important to remember that while some response options may be suspended, natural dispersion from higher surface water mixing energy will play a larger role in the Natural Attenuation response option. In this case, monitoring activities can help provide valuable information on the degree of natural dispersion that is taking place, and can help inform decision-making as to the necessity for using chemical dispersants to further enhance the dispersion processes.

4.4 Recommendations Concerning Response Options

All of the response options evaluated offer the potential for a net improvement over natural attenuation, and none have material adverse consequences. All of them should be discussed and considered when developing an oil spill response plan. It is always assumed that a combination of response techniques will be used, as appropriate, to minimize oil exposure to sensitive resources and to promote rapid recovery of the ecosystem as a whole. The OSRP provides information on the integration and activation of multiple response options for this Project Area.

However, the response options vary greatly in their potential effectiveness in association with a large scale subsea blowout scenario, as summarized below
(from least to most beneficial):

THE ROLE OF MONITORING

While the topic of response monitoring is outside the scope of this NEBA, it is noteworthy that implementation of appropriate operational (near real-time) monitoring* plans is needed to confirm efficacy of various response options and to modify response operations, as needed (e.g., adjusting DOR or skimming patterns).

In addition, environmental effects (longer term) monitoring studies are useful to assess the overall ecosystem recovery. Both operational and environmental monitoring are addressed in more detail in the OSRP.

** See Coelho et al. (2014) and API Technical Report 1152 (2013) for background information on operational monitoring.*

- **On-water In-situ Burning (ISB)** – This response option is severely restricted by seasonal day length, year-round weather conditions and logistical constraints. As a result, it is unlikely to offer substantial ecological benefits.
- **On-water mechanical recovery** – While this response option is constrained by factors similarly to those for ISB, on-water mechanical recovery resources are generally easier to obtain and deploy in larger numbers. Although this option is effective for smaller, confined spills, the estimated oil recovery for large-volume scenarios is generally associated with low ecological benefit.
- **Shoreline protection and recovery** – As a result of the low probability of shoreline contact indicated in trajectory spill modelling completed for the Project, this response option will have little overall effect, except in the rare cases where shoreline contact occurs. In these cases, this response option is essential. An effective response plan for protection of the ecological resources on Sable Island is the most important consideration.
- **Aerial dispersant application** – This response option was shown to be effective in substantially reducing surface oil in treated areas (the modelled oil is highly dispersible) but suffers from weather and logistic limitations. While it can be very effective in treating fresh oil, surface oil reduction is predicted to be 10-20% in the first 4 days of the spill. Hydrocarbon concentrations in the upper 10 to 20 m of the water column would increase in treated areas for a very short period, but would rapidly dilute and therefore not pose a long-term risk to the ecosystem (see text box in Section 2.3.5 on dilution rates). A water quality monitoring program would help define the spatial scale and longevity of dispersed oil plumes. This option could be very valuable

early in the release scenario while other response options, such as subsea dispersant injection equipment, is enroute.

- **Subsea dispersant injection** – This response option leads to the greatest net environmental benefit, and is recommended as a primary response option. The option provides the most improvement in risk scores for resources on the water surface and on the shoreline, without a major increase in risk to water column resources. While the predicted shoreline oiling was quite low in this scenario (approx. 2%), there is still considerable value in removing oil from the sea surface. Subsea dispersant injection has the potential to substantially reduce floating oil (potentially near zero, once implemented), as well as reduce dispersed oil concentrations in the sensitive upper water column (surface to 100 m). This dispersion at sea will enhance biodegradation in deeper waters farther offshore. Once in place, subsea dispersant injection is less sensitive to weather limitations than other available response options, and is the only one with the potential to operate 24 hours, seven days per week. Finally, this response option reduces the potential for exposure of surface vessels to volatile components of the oil; reduces the need for surface recovery, in-situ burning, and surface dispersant operations, thereby reducing the potential for personnel exposure and accidents during these operations.

FOR MORE INFORMATION ON DISPERSANTS…

Dispersant research and development has been advancing for more than four decades, and there is a vast amount of information available on the topic. A more in depth discussion on dispersants, dispersant use, and the effects of dispersed oil can be found in these comprehensive documents which provide excellent overviews on the topic.

- IPIECA Dispersants: Surface Application - Good practice guidelines for incident management and emergency response personnel (72 pages; published April 2015) available for free download at: *http://www.ipieca.org/publication/dispersants-surface-application*

- IPIECA Dispersants: Subsea Application - Good practice guidelines for incident management and emergency response personnel (published in June 2015) which will be available from: *http://www.ipieca.org/publication/*

- BP Oil Spill Dispersant Use Manual (129 pages; published in 2014) which is available as a free hard copy upon request.

- ExxonMobil Oil Spill Dispersant Guidelines (200 pages; published in 2008) available for free download at: *http://crrc.unh.edu/sites/crrc.unh.edu/files/exxonmobil_dispersant_guidelines_2008.pdf*

- Oil Spill Dispersants Efficacy and Effects, produced by the National Research Council (378 pages; published in 2005) available for free download at: *http://www.nap.edu/openbook.php?isbn=030909562X*

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APPENDIX A: An Overview of Dispersants

An overview on dispersants was included in the EIS (Stantec, 2014a), but has been included in this appendix for reference.

Operational Considerations

Oil spill response strategies can include well control, remote sensing, mechanical on-water recovery, surface, aerial and subsea dispersants, in-situ burning, and shoreline protection and recovery. In many regions, the preferred method is to mechanically remove oil from the surface of the water when environmental conditions permit. However, past experience with offshore oil spills has demonstrated that mechanical equipment alone may not be sufficient for effective offshore oil recovery due to low encounter rates and reduced efficiency due to rough sea conditions. Operating in deeper waters and farther offshore brings challenges related to greater transit distances for boats supporting the response, and adverse weather conditions that can hamper safe operations and return to port. An effective response in a fast changing offshore environment requires access to all response options to be adaptable to a specific response scenario and to ensure maximum response effectiveness and environmental protection.

While mechanical recovery can be used on small operational spills, dispersants become a critical response tool for larger and spread out spills offshore. Surface application of dispersants offers the following advantages:

- Dispersants can be used over a wider range of environmental/ meteorological/ oceanographic conditions than other response options. They can be applied in rough seas (up to 3 m) and on thinner oil slicks (<<1 mm).
- Dispersant aircraft can typically travel to spill locations at speeds over 150 knots (170 mph; 275 kph) compared to 7 knots (8 mph; 13 kph) which is the typical speed of a response vessel transiting to a spill location. Arriving at the spill location quicker allows an effective response to start before slicks have spread, moved, or broken apart into smaller surface slicks.
- Large oiled areas can be rapidly treated by aircraft compared to alternative response methods.
- Aircraft are also able to travel between slicks located few kilometres apart in a matter of minutes, while vessel-based response options may require many hours to haul in the equipment, move to a new location, and redeploy the equipment.
- Dispersants remove oil from the water surface, therefore decreasing the risk for marine birds and mammals to come into contract with oil. 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. Dispersants use is usually recommended in the offshore areas deeper than 10 m.
- Dispersants protect shorelines. Surface oil may be driven by winds towards shorelines, while dispersed oil is typically carried away by currents.
- Dispersants delay/prevent formation of stable water-in-oil emulsions and, in some cases, break emulsions already formed.

Subsea dispersants application offers several additional advantages (API, 2013):

- Safety — subsea injection reduces the amount of oil coming to the surface and this in turn:
  (a) reduces the potential for exposure of surface vessels and personnel to volatile components of the oil and
  (b) reduces the need for surface recovery, in-situ burn, and surface dispersant operations, thereby reducing the potential for exposure of response personnel to accidents during these operations.
  Subsea application can reduce the potential for worker and public exposures by treating the oil where it is being discharged and preventing it from spreading or coming closer to shore.
- Oil Removal — Natural biodegradation processes will remove the oil from the environment as petroleum-degrading bacteria found world-wide consume the oil as a food source. Dispersant treated oil is rapidly diluted in the water column to the point that biodegradation can occur at very low concentrations without depleting oxygen or nutrient levels.
- Efficiency — Subsea injection may require markedly less dispersant compared to dispersing at the surface.
- Precision — Subsea application ensures that all dispersant is mixed with the oil at one manageable location before it spreads; instead of trying to treat widely spread oil slicks at the surface.
- Application — Surface dispersant applications require favorable weather conditions, while subsea dispersant injection from a vessel can proceed in a much broader range of conditions.
- Timing — Application can occur around the clock, whereas surface (aerial and vessel) applications are usually restricted to daylight hours.
- Effectiveness — The operational effectiveness of dispersant applications subsea is likely to be more effective as the oil being treated has not undergone extensive weathering. Turbulence naturally associated with the blowout jet could create droplets more effectively than breaking waves at the surface.
- Encounter Rates - Subsea injection has higher oil encounter rates than any other response technique.

For these reasons, in addition to mechanical recovery, the appropriate use of dispersants, applied either at the ocean’s surface or subsea, may provide the means of removing sizeable quantities of oil from the surface quickly, therefore reducing overall environmental impacts from the spill to the sensitive near shore and shoreline environments. It is important to note that dispersants are most effective on fresh and unemulsified oil, so time in securing the approvals for dispersants use is critical to ensure that oil is still amendable to dispersion. This is less relevant for a blowout scenario as fresh oil comes to the surface every day, but approval timing becomes critical for batch spill responses as dispersants use may have a very narrow “window of opportunity”. To facilitate decision making, industry and government agencies are working together prior to the spill to use Net Environmental Benefit Analysis (NEBA) principles to consider the consequences of using dispersants to move the oil into the water column where it can rapidly dilute and biodegrade, against the impacts of oil left on the water surface or oil stranding on shoreline if mechanical containment and recovery efforts are ineffective or inefficient.

Dispersants have traditionally been applied at the water surface by properly equipped vessels, helicopters, and fixed-wing aircraft. There are many examples of dispersant use in North America in the past fifteen years 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 large 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.

Prior to this, the largest use of dispersant was during the 1979 IXTOC-1 spill in the Bay of Campeche, Mexico where 1 to 2.5 million gallons (~4 to 10 million litres) of dispersants were applied over a five-month period (EPA online, 2011)

The DWH incident was the first response 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 subsea dispersant injection during the DWH incident, new techniques for subsea dispersant use are now available and the knowledge on this topic is evolving rapidly.

Principles of Chemical Dispersion

Some portion of released oil will likely disperse into water column whether chemical dispersants were used or not. 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 100 micrometers in diameter) generally tend to stay suspended in the water column and eventually biodegrade, 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 and is largely dependent on droplet size which, in turn, is dependent on discharge velocity, release rate, and oil to gas ratio. Like surface spills, droplet sizes less than 100 micrometers in diameter typically remain dispersed in the water column and degrade whereas larger droplets are more buoyant and will generally float to the surface and form floating oil slicks.

Chemical dispersants are surfactants. While there are a few dispersants formulated for use in fresh or brackish water, these are uncommon and not relevant to this Project Area, so this discussion will focus on the majority of dispersants which are formulated for use in marine environments. They enhance natural oil 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) in a solvent. The solvent has two functions: it reduces the viscosity of the surfactant which enables it to be sprayed and it promotes 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.

As an example of dispersant composition Table A1 lists ingredients of Corexit® EC9500A as well as alternative daily uses of its components.

Table A1. Corexit® EC9500A Ingredients.

CAS #	Name	Common Day-to-Day Use Examples
1338-43-8	Sorbitan, mono-(9Z)-9-octadecenoate	Skin cream, body shampoo, emulsifier in juice
9005-65-6	Sorbitan, mono-(9Z)-9-octadecenoate, poly(oxy-1,2-ethanediyl) derivs.	Baby bath, mouth wash, face lotion, emulsifier in food
9005-70-3	Sorbitan, tri-(9Z)-9-octadecenoate, poly(oxy-1,2-ethanediyl) derivs	Body/Face lotion, tanning lotions
577-11-7	* Butanedioic acid, 2-sulfo-, 1,4-bis(2-ethylhexyl) ester, sodium salt (1:1)	Wetting agent in cosmetic products, gelatin, beverages
29911-28-2	Propanol, 1-(2-butoxy-1-methylethoxy)	Household cleaning products
64742-47-8	Distillates (petroleum), hydrotreated light	Air freshener, cleaner

* Contains 2-Propanediol

Factors that Affect Dispersant Effectiveness

Surface Application

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 products tend to form stable emulsions over time when mixed with water by wave action, which 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 usually 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 dispersant droplet size is generally considered to be about 600 to 800 µm. The targeted initial dispersant-to-oil ratio (DOR) for surface application of modern dispersants is generally around 1:20. This ratio may need to be adjusted down to a lower DOR for heavy crudes or more heavily weathered oil. Likewise, a higher DOR may be appropriate for particularly light crude oils. Operational efficacy monitoring during aerial dispersant application will help inform decision-makers on the optimum DOR needed for a specific set of spill conditions.

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 coalesce, float to the surface, and form an oil slick. 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.

It is important to note some key distinctions between chemical dispersion and natural dispersion. First, natural dispersion will begin to occur at breaking wave heights (i.e., when white caps form), which can translate to varying wave heights depending on many factors including the speed and direction of both ocean currents and wind. As a result, in lower wave heights of approximately 2 metres or less, natural dispersion will not be as dominate a factor as in higher sea states. Naturally dispersed oil droplets are not as small as chemically dispersed oil droplets and are not as stable in the water column. In other words, naturally dispersed droplets have a much greater likelihood of re-coalescing into a surface slick when wave action calms, reducing chances of biodegradation. When dispersants are applied, the interfacial tension of the oil droplets is permanently reduced, resulting in smaller chemically dispersed oil droplets that are more stable as an oil-in-water emulsion, and therefore will not likely re-coalesce. These smaller, stable chemically dispersed oil droplets will promote faster biodegradation.

The viscosity and pour point of a given oil provide a good indication of its dispersibility. 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[2]). 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. Pour point is also an important parameter. Any oil with a pour point higher than the ambient temperature may become very viscous or semi-solid and loose its dispersibility.

Subsea Application

Subsea dispersant application was first used in the DWH response in 2010 and information on the associated scientific monitoring can be found in Coelho *et al.,* 2012. Currently 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 deepwater environment. Research is underway to determine how the 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.

Several of the limitations that apply to surface application may not affect subsea dispersant injection. 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 needed to promote effective dispersion is much lower. Optimum DORs for subsea use are still the subject of ongoing research, but based on the DWH incident and recent research, an initial application rate of 1:100 is thought to be an appropriate target, as opposed to 1:20 for surface use. The rate can be adjusted during a response event to optimize the effectiveness, based on real-time subsea dispersant monitoring data. Efficiency of subsea dispersant injection is likely to be higher than surface dispersion as dispersants are applied directly into fresh, warm oil with low viscosity in a zone of high turbulence facilitating formation of small droplets.

Laboratory Testing of Dispersants Efficiency

In September, 1994, the US Environmental Protection Agency (EPA) officially adopted the swirling flask test (SFT) as its official laboratory screening methodology for testing the effectiveness of dispersants in seawater. The SFT is based on the protocol first developed and adopted by Environment Canada in the 1980s. It essentially consists of a procedure in which a pre-mixed solution of crude oil and dispersant is added to a specially designed glass side-arm flask containing 100 ml artificial seawater and the contents of the flask mixed on an orbital shaker for 10 min followed by a settling time of 10 min. The dispersed oil mixture is then extracted and measured in a spectrophotometer to determine the quantity of oil that had been dispersed into the water column. Listing of a dispersant on the US national contingency plan (NCP) product schedule has been contingent on the dispersant being at least 45% effective (50 ± 5%) in dispersing Prudhoe Bay and South Louisiana crude oils in the laboratory test. The procedure is simple, inexpensive, and straightforward. After the SFT was adopted in the final EPA regulation promulgated in September 1994 and described in Appendix C, Subpart J of 40 CFR 300.900, it was re-examined after its first year of use. Re-examination was pursued because of the discovery that unexpectedly large

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[2] 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.

discrepancies had been observed between the data submitted by dispersant manufacturers and those generated by EPA contract laboratories for numerous products on the NCP product schedule. Thus, in 1999, EPA decided to rigorously investigate the SFT to understand and resolve its apparent ambiguities and possibly come up with a better, more reproducible protocol. The results of the research have been submitted, and a new methodology was developed based on a new flask design. The flask is a 150 ml baffled trypsinizing flask used in biological science research and clinical laboratory testing. The new protocol was named the baffled flask test (BFT) (Venosa *et al.*, 2002).

Neither of these tests has been designed to simulate dispersion under actual offshore conditions, however, they do provide a sufficient rationale to screen candidate dispersants without quantitatively predicting efficiency under real world conditions. For the assessment of oil dispersant effectiveness under real sea state conditions, test protocols are required to have hydrodynamic conditions closer to the natural environment, including transport and dilution effects. To achieve this goal, Fisheries and Oceans Canada and the US Environmental Protection Agency (EPA) designed and constructed a wave tank system to study chemical dispersant effectiveness under controlled mixing energy conditions (regular non-breaking, spilling breaking, and plunging breaking waves). Several dispersion tests conducted in this tank demonstrated high effectiveness of dispersants far exceeding those observed in bench-scale tests.

The U.S. Minerals Management Service (MMS) funded and conducted two series of large-scale dispersant experiments in cold water at Ohmsett – The National Oil Spill Response Test Facility, in February–March 2006 and January–March 2007. Alaska North Slope, Endicott, Northstar and Pt. McIntyre crude oils and Corexit 9500 and Corexit 9527 dispersants were used in the two test series. The crude oils were tested both when fresh and after weathering. Results demonstrated that both Corexit 9500 and Corexit 9527 dispersants were 85–99% effective in dispersing the fresh and weathered crude oils tested at cold temperatures. (Belore *et al*., 2009)

While existing tests can be used to select dispersants for subsea application, several projects are under way to develop new equipment and protocols to more closely simulate specifics of subsea dispersants injection and evaluate dispersants under broader range of conditions.

Toxicity of Dispersants and Dispersed Oil

In general, the toxicity of modern dispersants (those maintained within the Global Response Network) is much less than the toxicity of the crude oil itself. Aquatic toxicity for short-term exposures is usually described using LC50 (Lethal Concentration) endpoints. The LC50 is the concentration that causes acute mortality in 50% of test organisms in a specified time period (usually 48 or 96 hours). The greater the LC50 value, the lower the toxicity; that is, a higher concentration is required to produce a specified adverse effect.

Environment Canada has done extensive testing of dispersants and chemical cleaners (Fingas, *et al*., 1991, 1995) using standard tests with rainbow trout to assess the toxicity of more than 60 products. Common household detergents were included for comparative purposes and to help provide the proper perspective on dispersant toxicity. Table A2 shows that today's dispersants are an order of magnitude less toxic to rainbow trout than common household detergents are.

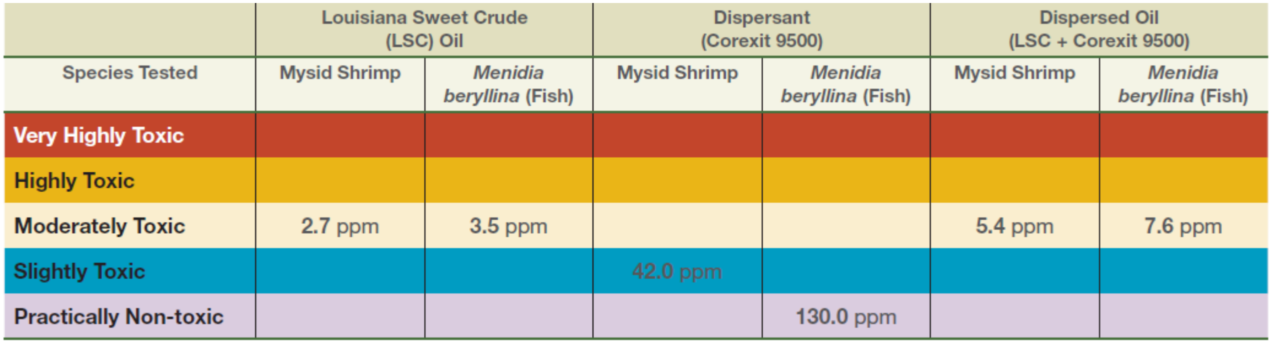
Table A2. Environment Canada Aquatic Toxicity Comparison of Household Cleaners and Dispersants (dispersants are shown in red)

PRODUCT	RAINBOW TROUT 96 HOUR LC50 (PPM)
Palmolive	13
Sunlight	13
Bioorganic (surface washing agent)	18
Mr. Clean	30
Citrikleen XPC (surface washing agent)	34
Enersperse 700	50
Corexit 9527	108
Corexit 9500	354

Furthermore, the US EPA evaluated the eight commercially available dispersants and found that the dispersants tested had different levels of toxicity, but Corexit® EC9500A, was among the least toxic. Ultimately, the crude oil by itself was found to be more toxic to the test species than the dispersants alone; the dispersants alone were less toxic than the dispersant-oil mixture; and the oil alone displayed toxicity results similar to the dispersant-oil mixtures (EPA ORD, 2010).

The US EPA has established a scale (Table A3) for interpreting laboratory-generated aquatic toxicity information using LC50 values (mg/L = ppm). The aquatic toxicity results for two key test species (mysid shrimp and silverside, a small fish also known as Menidia) as determined by EPA for Macondo crude oil, the dispersant Corexit® EC9500A, and the oil-dispersant mix are shown in Table 3.

Table A3. EPA Aquatic Toxicity Testing Summary for Oil, Dispersant, and Dispersed Oil (EPA ORD, 2010)



	Louisiana Sweet Crude (LSC) Oil		Dispersant (Corexit 9500)		Dispersed Oil (LSC + Corexit 9500)	
Species Tested	Mysid Shrimp	*Menidia beryllina* (Fish)	Mysid Shrimp	*Menidia beryllina* (Fish)	Mysid Shrimp	*Menidia beryllina* (Fish)
Very Highly Toxic						
Highly Toxic						
Moderately Toxic	2.7 ppm	3.5 ppm			5.4 ppm	7.6 ppm
Slightly Toxic			42.0 ppm			
Practically Non-toxic				130.0 ppm		

The toxicity of dispersed oil varies considerably among different types of organisms, and also among life stages for some organisms. In general, for most aquatic organisms, the 96hr LC50 for dispersed oil is on the order of 20-50 ppm. Larval and embryonic life stages for some organisms can be much more sensitive, and may be adversely affected by concentrations as low as a 1-5 ppm. While some sub-lethal impacts could take place even at low hydrocarbon concentrations, due to fast dilution of dispersed oil in the ocean noteworthy adult mortality effects on adult fish populations from dispersant use in the last 40 years have not been observed.

Although standard toxicity tests can be used to produce a numerical measure of a substance's aquatic toxicity and provide important information about the effects of oil and dispersants, many of these tests do not accurately reproduce the different types of exposures organisms may experience during an actual oil spill.

The magnitude of toxic effects is determined by the exposure that organisms receive, which is governed by:

- The concentration of dispersed oil to which they are exposed; and
- The duration of time for which the exposure persists.

Available data suggest that, following initial dispersion, maximum dispersed oil concentrations are less than 50 mg/L and that dispersed oil concentrations reduce to 1 to 2 mg/L in less than 2 hours (Cormack and Nichols, 1977; McAuliffe *et al*., 1980 and 1981; Lunel, 1994; Strom-Kristiansen *et al*., 1997; Daling and Indrebo, 1996). Trudel *et al*. (2009) showed that, even in closed wave tanks, concentrations of dispersed oil are rarely higher than 100 mg/L. With time, dispersed oil plumes continue to dilute and offshore concentrations of dispersed oil are estimated to fall below a threshold for acute impacts in less than a day (Cormack and Nichols, 1977; McAuliffe *et al*., 1980; IPIECA, 2001; French McCay and Payne, 2001; French McCay *et al*., 2006). As a result, exposure of water column organisms to offshore dispersed oil (chemically or physically) is short and limited to the top few metres of the water column during application of dispersants at the water surface (vessel/aerial) (Potter *et al*., 2012). Small-scale field tests have indicated that dispersants also rapidly dilute even in the absence of dispersed oil. Concentrations of dispersant in water have been shown to reduce to less than 1 mg/L within hours, which are generally below estimated toxicity levels derived from experiments with constant exposure (NRC, 1989). These concentrations are very different from typical laboratory test protocols which typically use a constant concentration over a fixed amount of time (typically 48 to 96 hours), making it difficult to extrapolate results of laboratory experiments into realistic impacts in the field. Bejarano *et al.* (2014) discussed the large variety in exposure methods, oil type and treatments and the complications when interpreting and applying these data for impact assessments. During the DWH incident, subsea dispersant injection occurred more or less continuously, and concentrations of dispersant and 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 an exclusion zone of 1 km from the well head. Beyond the 1 km exclusion zone, a subsea dispersed oil plume usually existed but was typically narrow, trended away from the site in the direction of very slight subsea currents, and was bounded by depths of about 1100-1300 m. According to Lee (2013), from 2779 individual samples collected in that area only 33 samples had TPH concentration higher than 10ppb.

While some short term toxicity to certain species can occur in the immediate vicinity of oil dispersant application operations, it is important that the resultant toxicity be considered within the context of the overall impacts of dispersed and undispersed oil on all potentially affected ecosystems (NEBA approach).

Comparative sensitivity of cold water and temperate species

There has been a considerable effort in the past five to ten years to better understand the sensitivity of cold water species to dispersed oil. The majority of studies have been conducted with crude oil or individual polycyclic aromatic compounds exposing mainly copepods and fish larvae. (e.g., Christiansen *et al*., 1996; Ingebritsen *et al*., 2000; Perkins *et al*., 2005; Jensen *et al*., 2008; Baussant *et al*., 2009; Skadsheim *et al*., 2009; Jensen and Carroll, 2010; Hansen *et al*., 2011; Hjorth and Nielsen, 2011; Grenvald *et al*., 2013). Several studies addressed the toxicity of chemically and physically dispersed oil (e.g., Hansen *et al*., 2012; Gardiner *et al*., 2013; McFarlin *et al*., 2011). These studies showed that while dispersants temporarily increase the concentration of oil in the water column, for field-relevant concentrations, the same concentration of chemically dispersed oil is no more toxic than physically dispersed oil and that the dispersants' acute toxicity only occurs at much higher water column concentrations than expected with any proposed use of the dispersant product.

Although regionally specific toxicity data are sometimes desired, there are several practical challenges with testing arctic species in standard laboratory tests. A number of studies have, therefore, assessed the potential relevance of temperate species toxicity data for assessing cold water species' sensitivity (De Hoop *et al*., 2011; Olsen *et al*., 2011; Word and Gardiner, in prep). There is a body of evidence that indicates that, based on acute effects, cold water species are no more sensitive than temperate species to petroleum related compounds. Several studies indicated that cold water species require a longer period of time to exhibit effects associated with petroleum exposures (Chapman and Riddle, 2005; Olsen *et al*., 2011, Gardiner *et al*., 2013; Hansen *et al*., 2013). Many factors can explain the increased response time of cold water species as they have a number of morphological and physiological adaptations to survive at cold temperatures (e.g., lipid stores, decreased metabolic rates for some larger body size compared to temperate counterparts, and slower digestion) that may affect toxic responses (De Hoop *et al*., 2011). Olsen *et al*. (2011) and De Hoop *et al*. (2011) concluded that toxicity data for temperate regions are transferrable to the cold regions for the chemical 2-methyl naphthalene, naphthalene, and physically and chemically dispersed oil, as long as extrapolation techniques are properly applied and uncertainties are taken into consideration. These findings are supported by Word and Gardiner (in preparation) who compare the relative sensitivity of arctic and non-arctic species using measured and literature data. A report from the Norwegian Research Council that reviews 10 years of research on long-term environmental effects of the oil and gas industry (NFR, 2012) concludes that cold water organisms themselves are not necessarily more sensitive to oil discharges than temperate organisms.

Dispersed Oil Biodegradation

Chemical dispersants are specifically designed to enhance natural dispersion by reducing the surface tension at the oil/water interface and making it easier for waves to create small oil droplets with larger surface area. This provides naturally occurring oil degrading bacteria greater access to the oil by creating a dilute mixture of oil droplets with high surface area rather than a thick surface accumulation with less surface area relative to volume. Fortunately, oil degrading bacteria are present in all marine environments (Prince *et al*., 2010a, 2010b; Atlas and Hazen, 2011). To date, there are over 500 microbial species of bacteria, fungi and algae that have been recognized to be capable of degrading petroleum hydrocarbons (Head *et al.*, 2006; Yakimov *et al*., 2005). Biodegradation by indigenous microbial communities is the major process for weathering and eventual removal of oil from marine environments (Atlas, 1995; Atlas and Bartha, 1992; Atlas and Hazen, 2011; Leahy and Colwell, 1990). Studies have shown that oil degrading microbes colonize dispersed oil droplets within a few days. This is a natural process by which hydrocarbons are transformed into less harmful compounds through the metabolic or enzymatic activity of microorganisms that are able to 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).

Bacteria in cold environments have metabolic rates comparable to those observed in more temperate climates and the rates of microbial growth in different environments are relatively similar despite temperature difference. Zahed *et al*. (2011) found a 'half-life' of approximately 30 days for a light oil in seawater from Malaysia at 28°C. Similar experiments with New Jersey seawater at 8°C suggested a 'half-life' of 14 days (Prince *et al*., 2013) while others with Arctic seawater at -1°C yielded a 'half-life of approximately 60 days (McFarlin *et al*., 2014). Bagi *et al*. (2014) followed naphthalene biodegradation in pristine water samples collected from the North Sea and the Arctic Ocean, and found three-fold faster naphthalene degradation rate coefficients in the latter at temperatures from 0.5 to 15°C.

The EPA recently conducted a study on dispersed oil biodegradation using concentrations approaching expected field concentrations (Venosa and Holder, 2007). They studied the biodegradation of dispersed Alaska North Slope crude oil at two temperatures and two concentration ranges: nominally 50 mg/L and 5 mg/L. They found rapid biodegradation at 20°C (greater than 80% of the alkanes consumed in 30 days) and only slightly reduced biodegradation rates at 5°C (greater than 80% of the alkanes consumed in 40 days).

Studies conducted during Deepwater Horizon oil spill in deep cold waters of the Gulf of Mexico showed that microbial respiration within the oil slick was higher by approximately a factor of five compared to respiration rates observed outside the oil slick (Edwards *et al*., 2011). The average half-life of alkanes was found to be the range of 1.2-6.1 days while decreases in aromatic hydrocarbons were observed to be on the scale of weeks to months (Hazen *et al*., 2010; Boehm *et al*., 2011).

These and many other studies prove that crude oil can be effectively biodegraded by bacteria naturally present in the sea water even in cold water environments like those in Nova Scotia. Dispersing oil in the water column facilitates natural biodegradation by increasing the surface area available for bacterial colonization and ensuring fast dilution of the plume to the levels that bacteria always have access to sufficient amount of nutrients and dissolved oxygen. Biodegradation of oil, and especially emulsified oil, at water surface and biodegradation of oil stranded on the shoreline is expected to have much slower biodegradation rates due to limited surface area available for bacterial colonization, high oil concentration, and as a result potential deficiency in nutrients.

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APPENDIX B: Biographies for NEBA Authors

Dr. Gina Coelho is a Principal Professional Associate and Subject Matter Expert for HDR. She has over 25 years' experience in environmental research, consulting, program management, group facilitation and regulatory compliance. Since joining EM&A as one of the founding members in 1996, she has worked extensively in the field of dispersant and dispersed oil research. After starting EM&A, Dr. Coelho completed her Ph.D. dissertation which focused on dispersant use and response policy for 22 countries and territories around the world. She has conducted open ocean oil field trials (Norway and UK), mesocosm research (Coastal Oil Spill Simulation System, TX and SINTEF Tank Testing, Norway) and laboratory experiments (at the EM&A toxicity testing laboratory, MD) on the efficacy and biological effects of oil, dispersant, and dispersed oil. She has worked as a co-facilitator (with Dr. Aurand) on more than a dozen Ecological Risk Assessments for the US Coast Guard, has set up three dispersed oil testing facilities (in the US, Brazil, and New Zealand), and has taught several courses, including "Understanding Oil Spill Response" and "Dispersant Use and Planning." Dr. Coelho served as a HazMat Response Incident Commander to McMurdo Station, Antarctica, for the National Science Foundation during the 1999-2000 austral summer. She has served as Environmental Unit leader and Chief Scientist on other oil spill responses. From 2005 to 2008 she served as co-Principal investigator on a NOAA Coastal Response Research Center (CRRC) funded project to examine life-cycle and multi-generational effects of oil and dispersed oil on a marine organism, and again in 2012-2013 on a second NOAA CRRC project to develop a dispersed oil toxicity database to support oil spill response decision-making.

During the BP DWH spill, Dr. Coelho served as BP's chief scientist to design and conduct the two subsea dispersant injection tests to assess the feasibility and efficacy of a long-term subsea operational dispersant response. She developed the associated subsea monitoring operation in support of this dispersant injection strategy, and under USEPA Directive, retested all of the USEPA NCP dispersants to develop efficacy and toxicity data specific to MC252 oil. She has continued to serve in an oversight capacity for BP on mesocosm research to elucidate the effects of pressure on atomizing spray formation flow of oil that is dispersed at depth.

In July 2010, Dr. Coelho facilitated a Joint Industry Task Force (JITF) Workshop for the American Petroleum Institute (API) to identify future areas for research in the fields of dispersants, mechanical recovery, cap and containment, policy, and risk communication research. In 2011, Dr. Coelho became the Program Manager of a JITF to study subsea dispersant injection systems, efficacy, fate and effects, modelling and communication. She is also serving as a subject matter expert on this JITF and drafted an industry paper entitled "Discharging Oil in U.S. Waters to Enhance the Study of Subsurface Dispersant Injections: Field Study Preparation and Considerations". She continues to be involved in JITF research coordination with specific emphasis on deep sea dispersion and dissolution of dispersed oil.

Prior to joining EM&A in January 1996, she was a consultant in marine toxicology and environmental project management for Scientific and Environmental Associates, Inc. (SEA). In this capacity, she participated in a number of field and laboratory projects related to the toxicity of crude oil to marine organisms. She also served as a project management consultant for the Marine Spill Response Corporation, during which time she provided oversight on research programs being conducted by various US and international research organizations related to evaluating ecological impacts from oil spills.

Dr. Don Aurand is a Subject Matter Expert with more than 40 years of experience in oil spill planning, research, and experimental field design. Dr. Aurand serves as a technical expert on oil spill impacts, dispersant use planning, and ecological risk assessment and risk communication. As a project manager and senior facilitator under previous contracts, Dr. Aurand successfully led nearly 20 Ecological Risk Assessment consensus development workshops related to the environmental effects of oil spill response technologies for the USCG. In addition to his 17-year career with HDR|EM&A, Dr. Aurand has worked as the Director of Environmental Health Research in the MSRC Research and Development Program, served as Program Manager for the Offshore Oil and Gas Environmental Studies Program (US Department of the Interior), and was a Group Leader (Environmental) at the MITRE Corporation. During the latter part of his career, he has focused on issues related to the environmental consequences of oil spills, particularly the role of dispersants. While at MSRC, he developed the concept of using the USEPA ecological risk assessment approach as a tool to develop consensus in oil spill response planning, and later co-authored the Coast Guard guidance manual on conducting consensus ecological risk assessments. After the 1991 Gulf War, he managed and participated in a joint industry-NOAA effort to characterize shoreline oil spill impacts in Saudi Arabia, Kuwait and Iran. Subsequently, he was part of a consulting team which advised the United Nations Compensation Commission on war-related oil spill damage claims.

Dr. Aurand has presented several oil spill response and dispersant use planning courses, including to the USCG (Sector Delaware Bay and District 1), RRT 3 and industry, among others. Dr. Aurand has served as the Secretary of the Potomac Regional Chapter of the Society of Environmental Chemistry and Toxicology (SETAC), where he interacted with members from Federal agencies, state agencies, academia, and the private sector.

During the DWH incident, Dr. Aurand served as Chief Scientist on a number of the oceanographic cruises monitoring the ecological consequences of the deep water dispersant injection. Additionally, he coordinated EM&A's participation by providing Chief Scientists and toxicity testing staff for the cruises. More recently, Dr. Aurand has assisted the Oil Spill Joint Industry Task Force (JITF) under contract to API to examine industry's ability to respond to a "Spill of National Significance (SONS)" based on the actual response to the DWH subsea release, which led to a series of recommendations to the National Commission on the BP DWH Oil Spill and Offshore Oil Drilling (Presidential Commission). He also assisted the JITF in their analysis of the Presidential Commission's final report and the related issue papers to evaluate their potential impact on industry. Dr. Aurand has over 50 technical and peer-reviewed publications related to pollution studies, oil spill response efforts and environmental conflict resolution.

Mr. James Staves joined HDR as a project Scientist in September 2012. He is responsible for providing technical, scientific, and regulatory support to HDR clients, on areas including laws and regulations pertaining to the U.S. National Response System for Oil and Hazardous Substances, chemical dispersant use, and net Environment Benefit Analysis. He has conducted training and workshops on subsea dispersant use, prepared contingency plans required by U.S. regulations for use of subsea dispersants, and participated in several Incident Management Team exercises for HDR client companies operating in the Gulf of Mexico. He has also performed a comprehensive review of information and research needs to support broader use of Net Environmental Benefit Analyses (NEBA) in the Arctic Circle, and provided technical and administrative support to the API D3 program for advancing the state of science and technology available for subsea dispersant use.

Prior to joining HDR, Mr. Staves spent more than 25 years in the U.S. Environmental Protection Agency where he held positions ranging from Federal On-Scene Coordinator to Co-Chair of the Regional Response Team. He has extensive experience in developing regional programs to implement the emergency prevention, preparedness, and response requirements of the National Environmental Policy Act (NEPA), Clean Water Act (CWA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Superfund Amendments and Reauthorization Act (SARA), Oil Pollution Act (OPA), and Clean Air Act (CAA). As an On-Scene Coordinator, he was responsible for Superfund site assessments, Superfund Removal Actions, and on-scene coordination of emergency response actions for accidental releases of oil and hazardous chemicals. He also served as the Agency's representative during emergency response actions for major oil and hazardous chemical spills including the Mega Borg oil spill of 1990, and the Deep Water Horizon incident of 2010. He has held Incident Command System positions ranging from Environmental Unit Leader, to Incident Commander in disasters including Hurricanes Andrew, Katrina, Gustav, and Ike. He has also led multi-agency teams on Chemical Safety Audits of facilities that had experienced catastrophic hazardous material releases.

During his tenure at the EPA, he served as the first Director for the Emergency Preparedness Center at the University of Texas at Dallas, where he managed technical and administrative staff in developing and promoting the use of innovative information management technologies in the fields of emergency preparedness and response. Mr. Staves was also a Preventive Medicine Officer in the U.S. Army Reserves, and served in Northeastern Saudi Arabia throughout the duration of Operation Desert Storm.

Mr. Eric Miller joined HDR as a Project Scientist in June 2014 after retiring as a commissioned officer with the rank of Commander from the United States Coast Guard (USCG). He is a researcher, program manager, and professional educator possessing over 20 years’ experience leading emergency responses and coordinating interagency and industry roles in protecting the environment and promoting public safety. He possesses extensive operational, policy, and teaching experience in pollution response, environmental protection, and disaster preparedness and recovery. Consequently he is well-versed on United States environmental laws and their regulatory responsibilities outlined under the National Oil and Hazardous Substances Pollution Contingency Plan and National Response Framework.

During his tenure with the USCG, he served as a Marine Pollution Investigator, Assistant Professor of Chemistry at the USCG Academy, and as the U.S. Coast Guard’s Liaison to the Federal Emergency Management Agency (FEMA). In his last assignment, he served as the Chief of the Industry and Interagency Coordination Division in the Office of the Marine Environmental Response Policy at USCG Headquarters. He was also appointed as the Program Chair for the 2011 and 2014 International Oil Spill Conferences (IOSC) where he led a diverse team of industry, governmental and academic volunteers in developing the technical program for the world’s largest oil spill conference. He is particularly well-versed on the federal government’s responsibilities and structures for conducting research and development and technology evaluation for oil spill prevention and response needs based on his education and experience as the Executive Director for the Interagency Coordination Committee on Oil Pollution Research (ICCOPR).

Ms. Ann Slaughter is a Project Scientist with HDR, and has served as the laboratory manager for HDR's oil and dispersed oil aquatic toxicity testing laboratory since 2006. She holds a BS in chemistry and has more than 25 years of experience in the field of environmental consulting. She was actively involved as a facilitator in a prior Ecological Risk Assessment conducted by HDR for the United States Coast Guard involving a joint effort with the Mexican Navy in the Gulf of Mexico. During the 2010 DWH spill, she served as the lead laboratory supervisor for several dispersant studies and analyses conducted by the company after the United States Environmental Protection Agency directed the re-testing of all dispersants identified on the U.S. National Contingency Plan's Product Schedule. She has also conducted and provided oversight on other Federally-funded and private sector studies related to dispersant, oil, and dispersed oil impacts to marine species.