APPENDIX H

Oil Spill Trajectory Modelling

UpstreamHSE

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Technical Report

Fate and Effects Oil Spill Trajectory Modelling Report for Scotian Basin Exploration Drilling Project: Well NS-1

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Executive Summary

BP Canada Energy Group ULC is proposing to conduct an exploration drilling program on Exploration Licences (ELs) 2431, 2432, 2433, and 2434, known as the Scotian Basin Exploration Drilling Project (SBEDP).

BP proposes to drill up to seven wells on the aforementioned Exploration Licenses which cover 13,982 km^2 and are located approximately 230 to 370 km southeast of Halifax and 48 km from Sable Island National Park Reserve. Sable Island is also the nearest permanent, seasonal or temporary residence to the Project Area except for workers inhabiting offshore platforms at the Sable Offshore Energy Project and the Deep Panuke developments. Water depths in the licences range from 100 metres (m) to more than 3,000 m. Several major currents, including the Labrador Current and Gulf Stream, influence the circulation in the region.

Oil spill trajectory and fate modelling has been performed to support an Environmental Assessment for the Project.

The possible spill events selected for modelling include large scale, worst case credible discharge (WCCD) deep water subsea blowouts at the well head and smaller batch spills of marine diesel at the surface representing accidental spill events from the Mobile Offshore Drilling Unit (MODU) associated with hose or tank failure scenarios. The scenarios are summarised in Table E1.

Table E1 Modelled oil spill scenarios

Scenario	Location	Water Depth	Modelled Scenario	Released Product	Release Duration	Release Volume	Modelling Type
Scenario 1	Site 1	2,104m	Blowout	Crude Oil (Sture Blend)	30 days	733,000 bbl (24,890 bpd)	Stochastic & deterministic
Scenario 2	Site 2	2,652m	Blowout	Crude Oil (Sture Blend)	30 days	1,056,000 bbl (35,914 bpd)	Stochastic & deterministic
Scenario 3	Site 1	2,104m	Batch Spill	Marine Diesel	Instantaneous	10 bbl	Stochastic & deterministic
Scenario 4	Site 1	2,104m	Batch Spill	Marine Diesel	Instantaneous	100 bbl	Stochastic & deterministic

Oil spill trajectory and fate modelling was conducted using the SINTEF Oil Spill Contingency And Response model (OSCAR). OSCAR is a 3-dimensional model that calculates and records the distribution (as mass and concentrations) of contaminants on the water surface, on shorelines, in the water column, and in sediments. The model allows multiple release sites, each with a specified beginning and end to the release. This allows time-variable releases at a given location, as well as throughout the study area. For subsurface releases (e.g. blowouts or pipeline leakages), the near field part of the simulation is conducted with a multi-component integral plume model that is embedded in the OSCAR model. The near field model accounts for buoyancy effects of oil and gas, as well as effects of ambient stratification and cross flow on the dilution and rise time of the plume.

Using the multivariate analysis best fit approach developed by SINTEF, Sture Blend oil was selected as the analogue oil for the modelling of subsea blowout releases as it was shown to provide the best overall match of oil properties to those predicted for NS-1 well prospect.

BP commissioned an independent, assurance review of potential metocean models to use in modelling work to support the Scotian Basin EIS. The review compared hindcast data of two potential metocean models to published data to identify which model provided the better representation of the expected conditions in the Scotian Basin. The conclusion was to obtain hydrodynamic data comprised of daily HYCOM current speeds with Bedford Institute Tides linearly superimposed. The HYCOM currents are from the Navy Research Laboratory experiment 91.1 (HYCOM GLBu0.08) and were interpolated onto a three hourly time step for the period 1st January 2006 and 31st December. The spatial resolution was 1/12.5 degrees. Three hourly wind speed and direction data was obtained from the National Centre for Atmospheric Research (NCAR) / National Centre for Environmental Protection (NCEP) Climate Forecast System Reanalysis (CFSR).

Utilising these models and inputs stochastic simulations were conducted for the following weather "seasons":

- Winter season (November - April)
- Summer season (May to October)

The simulations were run at varying start times to cover each 6 month season using data for winds and currents from January 2006 through December 2010, thus ensuring that the predicted transport and oil weathering for each oil spill simulation is subjected to a range of prevailing wind and current conditions that is historically representative of the time period in question.

The OSCAR model is able to track oil on the sea surface, on the shoreline and water column to levels that have little relevance from a response or environmental impact perspective. Therefore, threshold levels were applied in the modelling of each of these impact compartments as follows:

- surface oil thickness > 0.04 µm (barely visible or silver sheen on the water surface)
- stranded oil thickness > 1 µm (equivalent to 1.0 g/m^2) ("stain/film" oiling)
- In-water total hydrocarbon (dispersed and dissolved oil) concentrations > 58 ppb

In stochastic modelling of subsea blowout releases a total of 210 individual, 30-day unmitigated releases were modelled for 120 day periods for both Sites 1 and 2. Site 1 is a smaller volume and shallower water release of modelled spilled oil (24,890 bpd at a water depth of 2,104 m), while Site 2 was a larger volume of modelled spilled oil at a greater water depth (35,914 bpd at a depth of 2,652 m).

The stochastic model output does not represent the extent of any one oil spill event (which would be significantly smaller) but rather provides a summary of the total individual simulations for a given scenario or oil type. Stochastic models are used for planning purposes.

While the modelling demonstrates a potentially large affected area, it is important to note that many of the areas delineated through the modelling have low probabilities of occurrence and that results are based on an unmitigated capping stack release scenario with no other response mitigation measures implemented. In an actual incident, emergency response measures inclusive of containment and recovery operations are likely to have some effect on limiting the magnitude and duration of the spill event, thereby limiting the geographic extent and potential environmental effects of a blowout.

The modelling results predict that the majority of oil will remain in offshore waters with a <20% probability that surface oil exceeding the 0.04 µm (Bonn Agreement Oil Appearance Code (BAOAC) “Sheen”) will enter near shore waters of Nova Scotia for both the summer and winter scenarios. In the event that surface oil was to enter the near shore area of Nova Scotia, it would take a minimum of between 30 to 50 days to arrive.

In the summer season, the extent of the area with greater than 50% probability of contamination measured approximately 920 km by 465 km in the respective E - W and N - S directions at its maximum extent for Site 2.

The duration of surface exposure for near shore waters of Nova Scotia was 0 to 2 days. The low surface exposure times suggests that the complex coastal circulation patterns and the turbulent nature of the sea in the region are continually mixing any surface oil into the upper water column reducing exposure time on surface. Exposure times increase on approaching the release site. For example, in the worst exposure scenario (Site 2, summer season) the area where oil might be present on the surface for > 7 days measures 1,010 km by 450 km in the respective SW – NE and NW to SE directions at its maximum extent.

Some seasonal variation in the movement of oil following a release is expected. Oil is more likely to be transported further towards the South and Southwest under winter conditions, due to the stronger South Westerly surface currents in winter. In summer, the trajectory movement is more uniform, but still with multi-directional transport patterns and a higher frequency of transport towards the South and East, especially for Site 2. In summer, the prevailing winds from the West have more of an influence in transporting surface oil to the East.

The higher wind speeds and associated waves in winter result in significantly more entrainment and reducing the spatial extent of thick oil on the sea surface. The stochastic results have demonstrated the potential locations for spill effects exceeding threshold levels beyond the RAA boundary, and in some cases, beyond Canadian jurisdiction. For example, the stochastic results from modelling an unmitigated spill from Site 1 during the summer season indicate there is a 16% probability of surface oil being present as a sheen (0.04 µm surface layer thickness) within the international boundaries of Saint-Pierre and Miquelon (France), which could occur in a minimum of 12 days of a blowout event, but would generally average 34 days for the minimum arrival time. For Site 1 in the summer, the average probability of an unmitigated spill resulting in surface oiling exceeding the threshold level within the US waters is approximately 7% (with a minimal arrival time of approximately 22 days but on average a minimum of 55 days); this average probability increases to 14% for Site 2 in winter with similar minimum arrival times. The average probability of an unmitigated spill resulting in surface oiling exceeding the threshold level within the waters of Bermuda is approximately 2%, with a minimum arrival time of approximately 44 days, but on average a minimum of 60 days.

There is also potential for surface oil to intersect Protected Areas and EBSAs.

For Sable Island where there is a 28% probability of surface oiling exceeding the 0.04 µm sheen thickness threshold, based on stochastic modelling results for Site 1 (summer season) which is the worst-case scenario. The average minimal arrival time for the oil to reach Sable Island using this threshold is predicted to be 8 days with an average maximum exposure time of 4 days. The maximum time-averaged thickness of surface oil may reach more than 200 µm; however, the average time-averaged thickness is predicted to be less than 50 µm.

The average probability of surface oiling (exceeding a thickness of 0.4 µm) reaching the Gully marine protected area (MPA) is 61% during the summer season (worst case scenario). The maximum exposure time for surface oil exceeding the 0.04 µm threshold in the Gully is 4 to 7 days. The maximum time-averaged thickness of surface oil predicted in the Gully MPA may reach more than 200 µm (BAOAC “Continuous True Oil Colour”); however, the average time-averaged thickness is predicted to be less than 50 µm.

There is a moderate probability of surface oiling (in excess of 0.04 µm) reaching the Emerald Basin (45 – 58%) and Georges Bank (0 – 30%). Predictive modelling indicates that the length of time for an unmitigated blowout event to reach threshold thicknesses at Emerald Basin or Georges Bank would range between approximately 6 to 20 days for Emerald Basin and 30 to 42 days for George’s Bank.

The in-water dispersed and dissolved oil threshold exceedance of 58 ppb for total hydrocarbons (THC) is expected to remain in offshore waters with a smaller areal extent than for surface oil thicker than 0.04 µm. The modelling results indicate that the in-water oil exceedance will not reach the near shore waters of mainland Nova Scotia.

The results indicate that the minimum time for in-water oil concentrations >58 ppb to arrive at the maximum distance from the well is between 50 and 75 days. As mentioned earlier, the well intervention response assumptions used in the modelling are conservative (30 days to cap the well) and consider no other emergency response measures. For example, BOP intervention could be implemented within 2 to 5 days and the well could be capped between 13 and 25 days. Exposure time to oil concentrations above 58 ppb is also contingent on spill response time.

For these unmitigated scenarios, the predicted distance from the well site where exposure to in-water concentrations of oil > 58 ppb may exceed 14 days ranges from circa 50 to 100 km, while in-water exposure time of <1 day may be expected at the outer extent of the predicted threshold exceedance area..

Although the winter (November to April) scenario predicts that no in-water oil will reach Sable Island, there is a 5% probability that in-water oil concentrations will exceed the threshold around Sable Island for the summer (May to October) scenario. The minimum arrival times for in-water oil concentrations exceeding the threshold to waters surrounding Sable Island in the summer is predicted to be between 10 and 20 days.

Applying the 58 ppb total hydrocarbon threshold for effects to fish (an in-water concentration of dissolved and entrained oil in the top 100 m), these levels are most likely to be encountered on the Scotian Slope, with 7 to 11% average probability of these levels occurring in the Haddock Box and 9 to 13% average probability of these levels reaching the Emerald, Western, and Sable Banks on the shelf.

When considering shoreline oiling within the entire modelling domain, the stochastic results for the Site 1 scenario predict a maximum accumulated oil mass on the shoreline of 666 and 255 tonnes for the summer and winter seasons respectively, with peak oiling occurring between 20 and 50 days. These amounts of oil represent 0.7% and 0.2% of the total amount of oil released. For Site 2, the maximum amounts of accumulated oil on the shoreline were 666 tonnes in the summer and 220 tonnes in the winter, with peak oil occurring within a slightly longer timeframe of 35 to 100 days.

However, there was a wide range in the maximum amount of oil accumulated on the shoreline, with <1 tonne occurring in 56% of the cases during the winter season for Site 1 and 67% of the cases for Site 2. In the summer season, < 1 tonne of stranded oil occurred in 31% of the cases for Site 1 and 36% of the cases for Site 2.

There are several coastline areas (including those outside of the Regional Assessment Area) that could potentially be exposed to shoreline oiling above the 1.0 g/m^2 threshold.

At Sable Island shoreline oiling is possible for both scenarios (Sites 1 and 2) for both seasons (summer and winter), with the summer season resulting in the most oil stranded. Site 1 also results in more shoreline oiling than Site 2, which is in deeper water and further offshore. The probability of shoreline oiling exceeding the 1 µm threshold ("stain/film" oiling) ranges from 55% up to a maximum of 66% (Site 1 summer season). The earliest arrival time for shoreline oil exceeding the threshold for Site 1 occurs during the summer with an arrival time of approximately 3.8 days to the nearest shoreline (Sable Island). In the winter season, the earliest arrival time is approximately 5.8 days to Sable Island. For Site 2, the earliest arrival time for shoreline oiling (Sable Island) above the threshold occurs during the summer approximately 6.6 days following the start of the release. During the winter, the earliest arrival time occurs after approximately 10.5 days.

Stochastic modelling indicates a low potential (0 to10%) for shoreline oiling along the Nova Scotia coastline, with most predicted contact locations being less than 1%. A higher probability for shoreline emulsion mass exceeding 1 µm ("stain/film" oiling) is predicted to occur during the summer season (May to October). It is expected that the oil would be highly weathered, as the minimal arrival time for this coastline interaction ranges from 20 to 100 days. This timeframe would provide sufficient time to mobilize spill response in these areas.

Shoreline oiling may occur along portions of the Eastern Shore and Southern tip of Nova Scotia including the Yarmouth, Barrington, Shelbourne region, Brier Island and the Canso Coastal Barrens although the likelihood of this occurring is low (less than 5% in most cases. The only heavy oiling (>10 mm thickness of emulsified oil on the shoreline), that potentially occurs on the mainland is associated with the Site 2 scenario in the summer season and is predicted to take place around Riverport, Kinsburg, La Have Islands and West Dublin areas.

Some moderate to light oiling may also occur on the islands of Saint Pierre and Miquelon in the summer season from both Site 1 and Site 2 scenarios although the probability of oiling was low (<5%). Arrival times ranged from 30 to 75 days. In the winter season the probability of oiling is < 1%.

The stochastic results for the Site 2 scenario indicate that some occasional beaching events can occur along the USA coastline of Maine (from Bar Harbor to the Canadian border at Saint Andrews) during the winter season with probabilities < 5% and arrival times > 75 days. These events are associated with the stranding of weathered tar balls (mostly stain/film thickness (0.1 to 0.001 mm)). A few isolated tar ball stranding events also occur in the Cape Cod Bay region near Rhodes Island albeit with a very low probability of occurrence (<1%).

Individual or "deterministic" trajectories were identified and selected from the stochastic results that represented the maximum shoreline oiling for each well site and season. These representative worst credible case scenarios were then rerun deterministically to establish near-field and far-field fate and transport. The deterministic simulations provide insight to the individual trajectories, oil weathering behavior, the mass of oil in each environmental compartment (air, water, surface, land and sediment) and other information (area of oil slick, length of shoreline oiled etc.) related to each single spill at a given location and time which cannot be assessed using stochastic models.

Near-field deterministic simulations of the NS-1 blowout event at Site 1 indicate that the central core of the subsea plume (comprising dispersed and dissolved oil) does not extend more than 15 km radially away from the release location.

The oil droplet size model in OSCAR predicts a d95 droplet size of 8.8 mm and d50 (median) droplet size of 4.1 mm for the Site 1 release. It will take the largest oil droplets (8.8 mm) 5 hours to rise to the surface, with 50% having arrived after 10 hours.

The results of near-field modelling at Site 2 were broadly similar to those for Site 1, although the central core of the dispersed oil plume was more constrained, suggesting that cross currents velocities were smaller than those experienced during the Site 1 simulation. The central core of the plume does not extend more than 5 km radially away from the release location until the upper 300 m of the water column, where cross currents increase the radial extent of the dispersed oil to around 10 km. Similar oil droplet sizes are predicted, but the rise times to surface were 1 -2 hours longer due to the well location being in deeper water.

Far-field deterministic modelling results for both sites predict the water content of the oil emulsion arriving on the shoreline would be 78%. At the end of the "worst" shoreline oiling simulation for the summer season about 38% of the total oil released will have biodegraded and 30% evaporated. After 120 days, 0.01% of the release is reported on the surface and 19% in the water column; with that remaining in the water column dispersed to negligible concentrations (< 10 ppb THC dispersed oil).

The modelling results for Site 1 predict that the majority of oil would remain offshore. In the event that surface oil was to enter the near shore area of Nova Scotia, it is predicted to have a thickness of between 0.04 and 0.3 µm. Exceedances of the in-water oil threshold is predicted to also be limited to offshore waters; however, the area impacted is smaller than that of surface oiling. Shoreline oiling exceeding the threshold level is expected to be limited to the coastline of Sable Island. Unmitigated oiling on Sable Island is predicted to be heavy with a thickness of > 10 mm. The maximum length of shoreline impacted would occur after 7 days with 27.8 km of coastline being affected. The maximum mass of oil on the shoreline occurs later (after 42 days) and is associated with 670 tonnes of oil accumulated on the shoreline.

The results for Site 2 illustrate that surface oiling exceeding the 0.04 µm threshold will occur in the near shore waters of Nova Scotia, with surface thicknesses ranging from 0.04 µm to 200 µm. The in-water oil threshold follows the same trend with in-water oil concentrations ranging from 58 ppb to 1,000 ppb in the near shore waters around Nova Scotia. The maximum length of shoreline impacted would occur after 101 days with 80 km of coastline affected including the coastlines of both Sable Island and mainland Nova Scotia The maximum mass of oil on the shoreline occurs earlier (after 32 days) with 669 tonnes of oil accumulated on the shoreline.

Modelling results indicated that the accidental batch release of marine diesel would have limited effects. The results show that the location of threshold exceedances for surface effects are expected to occur over a greater area if a spill occurs during the summer than for winter. For a 100 bbl spill, the locations for oiling in excess of 0.04 µm could extend approximately 100 km to the west and southeast and 30 km in all other directions, with a small portion of weathered diesel continuing beyond these distances.

The maximum time-averaged emulsified oil thickness on the sea surface exceeding the 0.04 µm threshold for both spill scenarios ranged from 0.04 µm to 50 µm. In-water dispersed and dissolved oil threshold exceedance of 58 ppb for total hydrocarbons (THC) was not exceeded in any of the simulations and no oil from the batch spills reached the coastline of Sable Island or Nova Scotia. Deterministic simulations indicate that approximately 65% of the spill evaporates from the surface within 3 days following the release, with remaining proportions dispersing or biodegrading within the same period.

1 Introduction

BP Canada Energy Group ULC is proposing to conduct an exploration drilling program on Exploration Licences (ELs) 2431, 2432, 2433, and 2434, known as the Scotian Basin Exploration Drilling Project (SBEDP). BP holds a 40% interest in the Nova Scotia Offshore ELs and will operate the exploration program. Partners Hess Canada Oil and Gas ULC and Woodside Energy International (Canada) Limited hold a 40% and 20% interest, respectively. (see Figure 1.1)

BP proposes to drill up to seven wells on the aforementioned Exploration Licenses which cover 13,982 km^2 and are located approximately 230 to 370 km southeast of Halifax and 48 km from Sable Island National Park Reserve. Sable Island is also the nearest permanent, seasonal or temporary residence to the Project Area except for workers inhabiting offshore platforms at the Sable Offshore Energy Project and the Deep Panuke developments. Water depths in the licences range from 100 metres (m) to more than 3,000 m. Several major currents, including the Labrador Current and Gulf Stream, influence the circulation in the region.

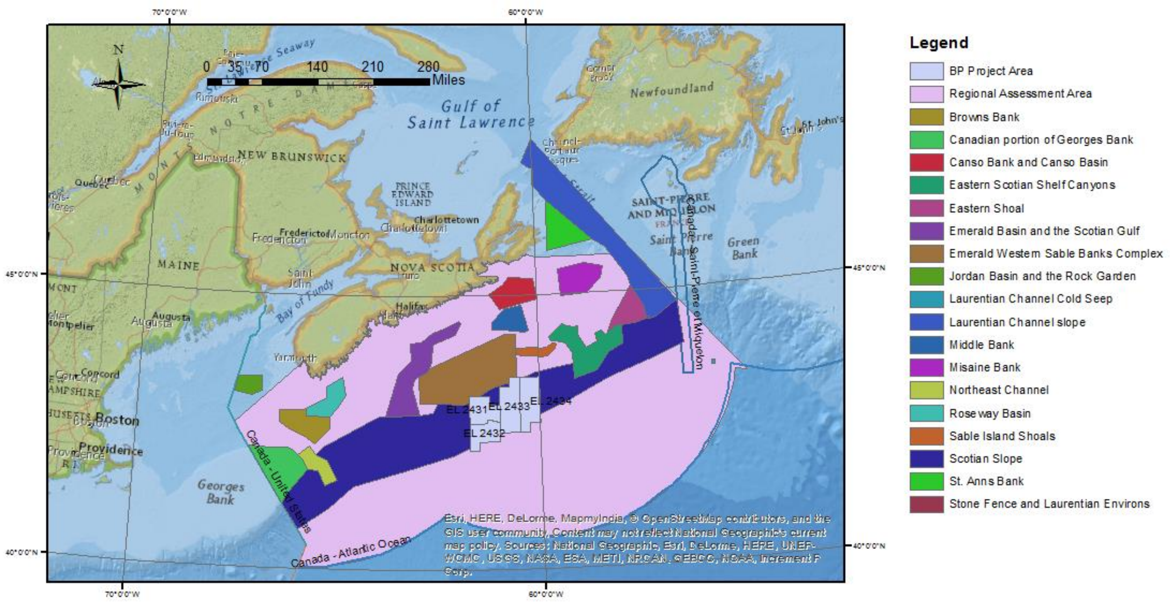


Figure 1.1 Scotian Basin Exploration Drilling Project Location

1.1 Scope of Work

Environmental and social screening for the SCEDP, carried out in March 2015 to conform with the requirements of GDP 3.6-0001 (Environmental and Social Requirements for New Access Projects, Major Projects, International Protected Area Projects and Acquisition Negotiations) (1), identified that an unintended release of oil during drilling, has the potential to affect Internationally Protected Areas (IPAs) in the Scotian Basin region. As a follow up action to better define the potential to affect IPAs, oil spill modelling of an unintended release associated with a potential loss of well control has been carried out to gain a better understanding of the fate and potential environmental and social impacts so that appropriate response strategies can be defined. Group Guide (GG) 3.6-0004, ("International Protected

Area Projects" [(2)]), provides additional guidance in relation to interpreting and implementing the requirements of Section 5.6 of GDP 3.6-0001.

In addition, as part of the oil spill contingency planning process, GP 10-90 ("Oil Spill Preparedness and Response for Deepwater Operations") [(3)] requires that any BP entity drilling a well in deep-water carries out oil spill fate and effects modelling of worst credible case discharge scenario(s) selected by a multidisciplinary team. This is to conform with the requirements of Section 8.1 (Identify, assess and prioritise oil spill planning scenarios), which is aimed at gaining a better understanding of the fate and potential environmental and social impacts of an unintended release so that appropriate response strategies can be defined. Section 8.1i also specifies that modelling is conducted using either the SINTEF OSCAR oil spill model or an alternate that is endorsed by the BP Technical Authority for oil spill preparedness and response in addition to any other modelling programme required by applicable country-specific legal and regulatory requirements.

The results of this study will also be used in support of an Environmental Assessment for the Project, which must be accepted by the regulator (Canada-Nova Scotia Offshore Petroleum Board (CNSOPB)) before drilling activities can commence.

The possible spill events selected for modelling include large scale, worst case credible discharge (WCCD) deep water subsea blowout events at the well head and smaller batch spills of marine diesel at the surface representing accidental spill events from the Mobile Offshore Drilling Unit (MODU) associated with hose or tank failure scenarios (see Section 3).

The scope of work for oil spill trajectory modelling included the following components:

- Use spatial wind data, current data and specific hydrocarbon properties as input into OSCAR, to predict the movement and weathering of the oil originating from the oil spill release site;
- Use stochastic (or probabilistic) modelling to predict the fate of the spilt diesel over time, including and probability of contamination and travel time of oil on the sea surface, water column and shoreline;
- Determine the maximum exposure time, concentration / thickness of weathered oil on the sea surface and in the water column for each scenario;
- Calculate the probability of shoreline contact, the shortest arrival time and degree of oiling on the shoreline for each scenario.
- Review the stochastic results and present the single spill trajectories with the highest amount of oil reaching the shore for each scenario.
- Quantify the exposure of key environmental resources in the event of an accidental spill.

2 The Oil Spill Contingency and Response (OSCAR) Model

The SINTEF Oil Spill Contingency And Response model (OSCAR) is the Segment preferred oil spill fate and trajectory model for Upstream. The use of this model is mandatory for deep-water operations as defined in GDPs 4.6-0002 Annex 2 [(3)].

OSCAR is a 3-dimensional model that calculates and records the distribution (as mass and concentrations) of contaminants on the water surface, on shorelines, in the water column, and in sediments. The model allows multiple release sites, each with a specified beginning and end to the release. This allows time-variable releases at a given location, as well as throughout the study area. For subsurface releases (e.g. blowouts or pipeline leakages), the near field part of the simulation is conducted with a multi-component integral plume model that is embedded in the OSCAR model. The near field model accounts for buoyancy effects of oil and gas, as well as effects of ambient stratification and cross flow on the dilution and rise time of the plume.

The model output is recorded in three physical dimensions plus time. The model databases supply values for water depth, sediment type, ecological habitat, and shoreline type. The system has an oil physical-chemical database that supplies physical and chemical parameters required by the model.

The model computes surface spreading, slick transport, entrainment into the water column, evaporation, emulsification and shoreline interactions to determine oil drift and fate at the surface. In the water column, horizontal and vertical transport by currents, dissolution, adsorption, settling and degradation are simulated. An Ekman model integrated into OSCAR computes a wind-driven current which transports entrained oil on the surface. The varying solubility, volatility, and aquatic toxicity of oil components are accounted by representing the oil in terms of a number of pseudo-components. By modelling the fate of individual pseudo-components, changes in the oil composition due to evaporation and degradation may be accounted for in the toxicity of the dissolved oil fraction.

OSCAR may compute oil weathering from crude assay data, although results that are more reliable are produced if the target oil has been through a standardized set of laboratory weathering procedures established by the SINTEF laboratories. Alternatively, the model may use oil weathering properties from oils for which data already exists, selecting the crude oil in the oil database that most closely matches the composition of the oil of concern.

2.1 Input Data to run OSCAR

OSCAR accepts as input both 2- and 3-dimensional current data from hydrodynamic models, and single point or gridded wind data from meteorological models. The surface spreading, slick transport, entrainment into the water column, evaporation, emulsification and shoreline interactions processes that determine oil drift and fate are linked to the oil properties database within OSCAR. Each oil stored in the database is characterised by 25 key hydrocarbon component groups analysed in accordance with the SINTEF oil weathering protocols. This ensures accurate representation of physical, chemical and biological behaviour of each hydrocarbon as it is released into the model.

2.2 Outputs from OSCAR

2.2.1 Types of Output

There are two types of model simulations that can be generated: stochastic simulations and deterministic simulations. Both simulation types are used in different ways during the modelling process to inform the various stages of assessing the severity and risk posed by the scenarios. Together the two model types give an indication of both likelihood and magnitude of any potential effects.

Stochastic Modelling Simulations

Stochastic modelling is used to predict the probability of sea surface, shoreline or water column contact that may occur following an oil spill event. It accounts for the variability of meteorological and oceanographic conditions in the study area over the anticipated operational period to provide an insight into the probable behaviour of the potential spills.

It involves running numerous individual spill trajectory simulations using a range of prevailing wind and current conditions that are historically representative during which the spill event may occur. The set of individual simulations may be performed within a specified time period (seasonal single year statistics), or by specifying the number of simulations to be run each year in a specified season (seasonal multiyear statistics). The trajectory results are then combined to produce statistical outputs that include the probability of where oil might travel and the time taken for the oil to reach a given shoreline. The stochastic model output does not represent the extent of any one oil spill event (which would be significantly smaller) but rather provides a summary of the total individual simulations for a given scenario or oil type. Stochastic models are used for planning purposes.

Deterministic Modelling Simulations

Deterministic modelling (or single spill trajectory analysis) is used to predict the fate (transport and weathering behaviour) of spilled oil over time under predefined hydrodynamic and meteorological conditions.

When carrying out deterministic modelling, BP typically selects the conditions that gave rise to the simulation with the worst environmental effects from the stochastic modelling (i.e. meteorological conditions).

2.2.2 Stochastic modelling and probabilistic results

The following section describes some of the technical details regarding the statistical output from OSCAR.

The notion of a grid cell will be used, referring to the two-dimensional surface or shoreline grid, or the three-dimensional concentration grid. Each of these grids consists of cells, which represent the smallest area (highest spatial resolution) on which OSCAR operates when producing statistics.

Statistics

OSCAR produces a set of statistics in its output, including a) maximum or minimum, b) time-averaged, c) maximum time-averaged and d) probability. The metrics are defined in terms of exceeding certain threshold values for oil concentration, thickness or mass and presented as maps for different environmental compartments (sea surface, water column or shoreline).

A map of **maximum or minimum** values can be produced from a stochastic simulation (for example maximum accumulated oil or minimum arrival time). This means that for all time steps and for all simulations, OSCAR has kept a record of the maximum or minimum for that particular value in each grid cell.

For example, the maximum accumulated shoreline oil map, the oil mass in every shoreline cell is checked every time step for every simulation. Whenever OSCAR detects that a shoreline cell has more oil than previously recorded, it will record this new value as the maximum. After all simulations have been performed, this maximum can then be reported for each cell.

Time-averaged statistics are used to produce an average value for a variable. For each simulation, OSCAR monitors each grid cell and records its value unless it has no impact (for example no surface oil or no total concentration). At the end of the simulation, these values are then averaged to produce the time-average. Whenever thresholds are applied pre-processing, the time-average will also exclude values below these specified thresholds.

Maximum time-averaged values can be presented as maps (such as the maximum time-averaged value total concentration). This means that for each grid cell, the value from the simulation with the largest time-average is selected and reported.

Probability maps can also be produced by the stochastic simulation. These maps indicate in the fraction or percentage of the stochastic simulations that reported the specified event (for example oil thicker than some threshold) for each cell. This can be oil on the surface, oil on the shoreline etc.

For example, the shoreline impact probability records each simulation that has some oil that hits a specific grid cell. If then three out of a total of ten simulations record oil hitting this shore cell, the probability for shoreline impact for this cell is 30%. Here there is no weighting for the frequency of oil coming ashore within each scenario.

Threshold calculations

OSCAR has two ways of applying thresholds to statistical model output, pre-processing thresholds and post-processing thresholds.

Pre-processing thresholds consist of applying lower thresholds for simulation outputs before statistical simulations are performed. OSCAR will then, for each time step, filter out values to output based on these thresholds.

For example, using a 5 µm thickness as a minimum surface limit will ensure that no thickness below 5 µm will be included and used in any of the statistics.

The disadvantage of this approach is that it has to be applied before running stochastic simulations. This can be time-consuming if this limit has later to be revised, since the entire set of simulations needs to be re-run. This is also the method used when filtering out threshold values in deterministic simulations.

Post-processing thresholds are applied to simulation outputs after the statistical simulations are performed. OSCAR will then, for each grid cell in a simulation, compute a time-averaged value for the entire simulation. This average value is then compared to the threshold and the statistical contribution for this simulation is either removed or accepted.

For example, using a 5 µm thickness limit post-processing will ensure that no surface grid cell with an average thickness less than 5 µm will contribute to the statistics. Note, however, that lower thicknesses can still contribute to the statistics as long as the average value is above the threshold.

The disadvantage of this approach is that although it is less time-consuming to apply, it can under-estimate the actual impact in particular where the average values are close to the threshold values.

3 Oil Spill Scenarios

Two key spill scenarios were modelled as part of this study representing both a low probability, large scale event (i.e. a subsea well blowout) and an instantaneous, small scale spill scenario (i.e. a surface release of diesel). For all scenarios, the OSCAR model (a module within the SINTEF Marine Environmental Modelling Workbench (MEMW) 7.0.1 software package) was run until the amount of oil in the system fell below the significance thresholds described in Section 4.5.

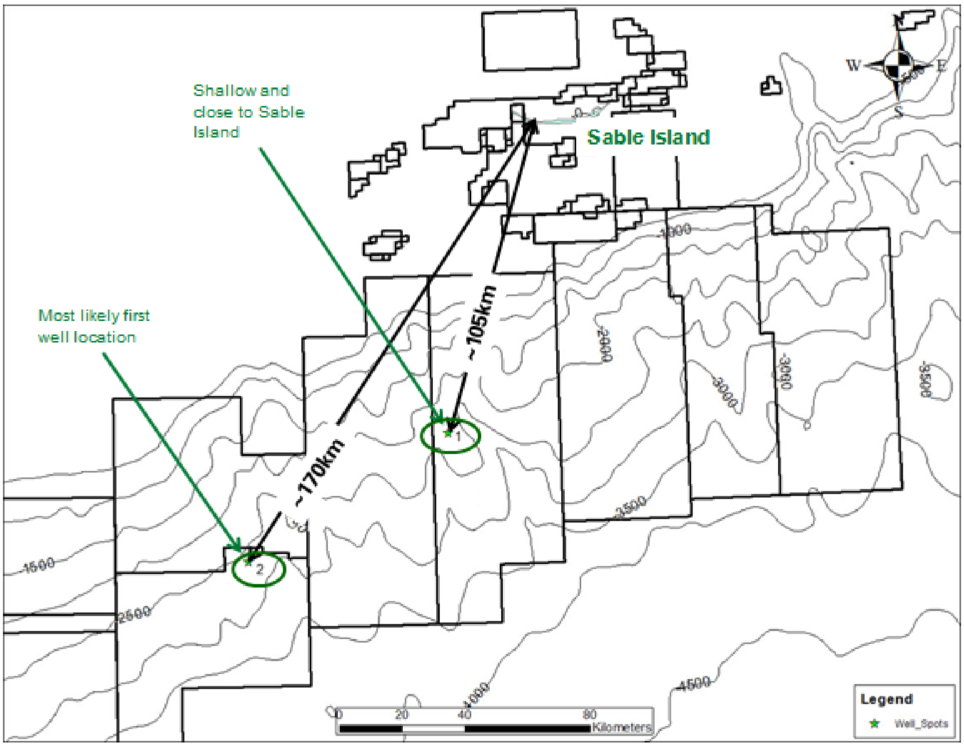
3.1 Model Scenarios

For the subsea well blowout scenarios final well locations have not yet been identified and therefore two potential locations were selected at different water depths and at varying distances to sensitive receptors within and around the ELs (shown in Figure 3.1). Both locations represent viable drilling prospects.

Table 3.1: Release Locations

Location	Block	Water Depth	Longitude	Latitude	Distance from Sable Island
Site 1	EL 2434	2,104 km	60.434610	43.046428	105 m
Site 2	EL 2432	2,652 km	61.229314	42.692076	170 m

Figure 3.1 Release Locations



The scenarios modelled were as follows:

1. A subsea blowout of crude oil

A subsea blowout scenario was modelled at the two locations described above. In line with the precautionary principle, BP has selected the worst credible case (WCD) for each location. Steady state uncontrolled well discharge modelling was undertaken to assess the potential WCD that could arise as a result of a blowout event. The WCD rate calculations were carried out according to BP Segment guidelines [(4)]. Production forecasts were performed using a reservoir material balance calculation (MBAL from Petroleum Experts Ltd). Individual steady state uncontrolled well discharge rates were calculated in accordance with the methodology described in EP SG 4.6-0001 using the approved BP application “Prosper” developed by Petroleum Experts Ltd.

The provisional well design presented in Figure 3.2 was used as the casing configuration for the well discharge modelling. It has been assumed that if two sands are exposed then it will be in 12.1/4” open hole.

As a precautionary measure, in both well locations, 100% oil content in the reservoir sands was assumed (i.e. 0% water cut in the formations). Each case also assumes the presence of two high pressure sands which are both exposed in the blowout scenario. Fluid flow rate and cumulative volumes profiles for the two WCD subsea well blowout cases are shown in Figures 3.3 and 3.4. Table 3.2 details all the release conditions for both release scenarios. Release volumes varied between the two locations. The first location (Site 1) at 2,104 m water depth has an initial flow rate of 24,890 barrels per day (bpd). The second location (Site 2), at 2,652 m water depth, has an initial flow rate of 35,914 bpd.

For modelling purposes, BP has assumed a conservative release duration of 30 days. BP will mobilise and deploy cap and containment equipment and tools as soon as possible and current estimates indicate that the capping stack can be delivered to the well location within 12 to 19 days with rapid deployment thereafter.

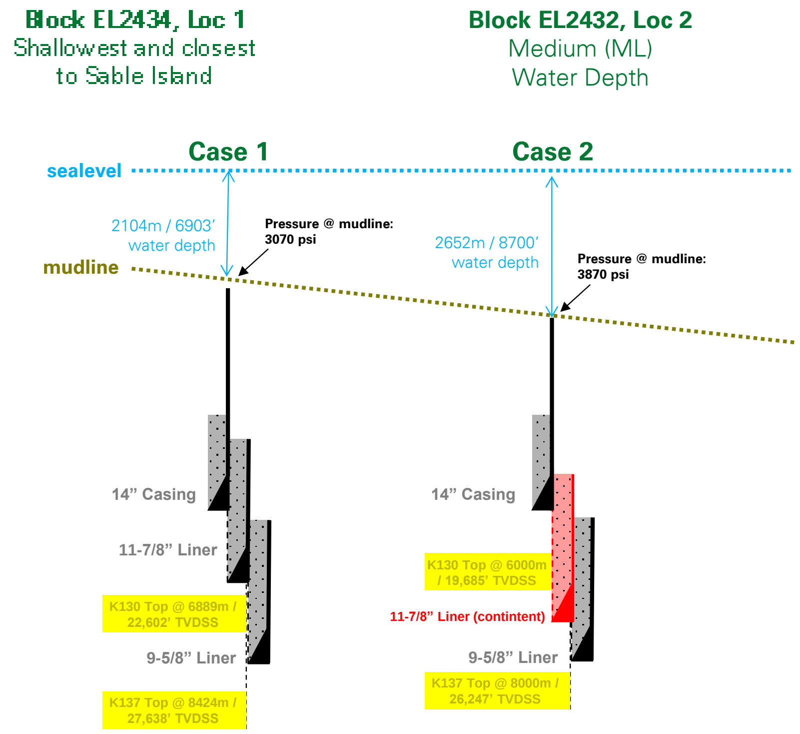
A Technical File Note (TFN) has been written which documents in more detail all the input parameters and assumptions used in the rate calculations [(5)].

2. A surface batch release of diesel

Two surface diesel release scenarios were also modelled to represent a loss of containment at the MODU. This scenario represents the most likely spill scenario that could occur on the MODU.

The spill volumes modelled included 10 bbl, to represent a hose failure, and 100 bbl, to represent a tank failure. For a conservative assessment, it was assumed the diesel release occurred at Site 1 which falls closer to Sable Island.

Figure 3.2 Expected well intervals used in the WCD modelling for well NS-1



Scenarios for each Case:
A: two sands , catastrophic failure at 9-5/8" shoe or 2 sands in 12-1/4" open hole
B: one sand (upper only), occurs before 9-5/8" shoe is set
C: one sand (lower only), 9-5/8" shoe holds

Figure 3.3 Steady state uncontrolled discharge rates for the NS-1 subsea well blowout scenarios over the 30 days estimated to cap and contain the well.

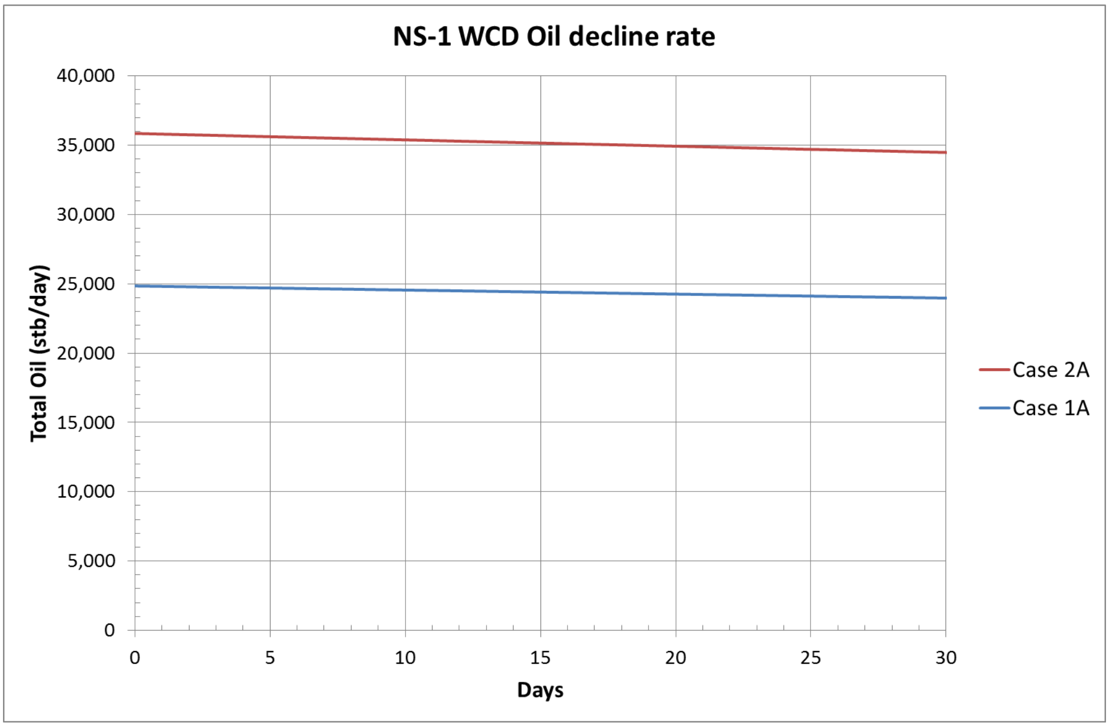
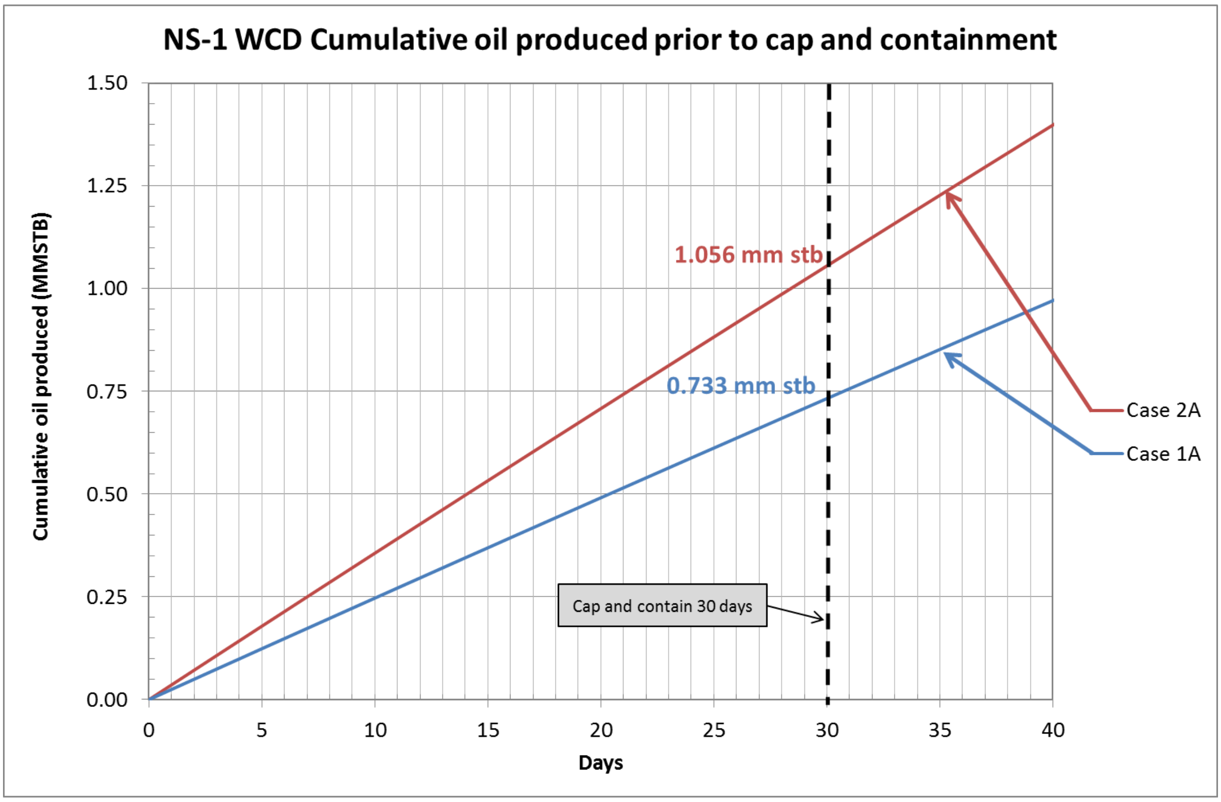


Figure 3.4 Cumulative production forecasts for the for the NS-1 subsea well blowout scenarios over the 30 days estimated to cap and contain the well.



All modelled scenarios were run without any oil spill tactical response methods as mitigation measures. In reality, spill mitigation measures such as oil spill containment, recovery and shoreline protection measures would be implemented in the event of a spill to reduce the adverse effects to marine and coastal resources, thereby mitigating the full impact of a spill.

4 Data Inputs and model set-up parameters

The following sections detail the OSCAR set-up used to complete modelling run for the release scenarios outlined in Section 3.

4.1 Predicted fluid characteristics and analogue oil selection for modelling

The oil types modelled include marine diesel and crude oil.

Oil and chemical databases supply chemical and toxicological parameters required by the OSCAR model. A unique strength of the model is its foundation on an observational database of oil weathering properties. The laboratory and field methods developed at SINTEF for weathering of crude oils and petroleum products are described in Daling et al. (1990, 1997)[7,8]. Numerous field tests have verified the reliability of weathering predictions based on this methodology, in order to avoid unrealistic results.

The oil database contains complete weathering information for more than 50 crude oils and petroleum products. It also contains crude assay data for approximately 150 other crude oils. These latter data are derived from the HPI database [9]. Since no empirical observations of weathering are available for these oils, model estimates of oil weathering are less reliable than for oil for which oil weathering studies have been carried out.

SINTEF (Aamo et al.[10] and Daling et al.[8]) uses a multivariate approach to group oil types based on a limited data set available from crude oil assays (wax/asphaltene content, viscosity, density, pour point and the true boiling point curve). This approach can be used to match new oil types to oils where their weathering properties are already mapped or characterised to select analogue oils for OSCAR modelling.

4.1.1 Crude Oil

Given that the wells to be drilled for this project are exploratory, the exact nature of the well hydrocarbon fluids that may be encountered is unknown. The crude oil characteristics were selected to align with the expected reservoir characteristics using a bottom up petroleum system analysis approach. Specific properties of the petroleum fluid will depend on the richness, quality and thermal maturity of the source rocks. Where available, top down observations on petroleum fluid analogues from offset wells or nearby areas were used to further constrain expected fluid properties.

Table 4.1 summarizes the predicted fluid properties at reservoir pressure and temperatures for two potential formations which could be encountered during drilling operations. The fluid properties were predicted by matching analogous fluid properties (measured in the laboratory at stock tank conditions) using the Petrosky correlations in Prosper™.

Using the multivariate analysis best fit approach developed by SINTEF described above, Sture Blend oil was shown to provide the best overall match of oil properties to those predicted for NS-1 well prospect. The analogue oil properties are presented in Table 4.2.

Table 4.1 Summary of reservoir fluid properties predicted from laboratory characterisation of an analogous oil at surface stock tank conditions

	Lower Sand @ Reservoir Conditions	Upper Sand @ Reservoir Conditions	Surface @ Standard Conditions
Reference Pressure (psi)	13,000	10,000	15.025
Reference Temperature ($^oF/^oC$)	356 / 180	257 / 125	60 / 16
Oil Form'n Vol Factor, B_{oi} (rvb/stb)	1.23	1.24	
Solution GOR, R_{si} (scf/stb)	756	756	
Viscosity (cp)	0.643	0.738	12.5*
Compressibility (10^{-5} psi^{-1})	1.0757	1.0087	
Density (g/cc)	0.8852	0.8757	
Saturation Pressure, P_{sat} (psi)	2,581	2,077	
API Gravity (Single Stage Flash)			34.1
Paraffin Content (wt%)			4.1
Asphaltene Content (wt%)			4.6
Sulphur Content (wt%)			0.58
Wax Appearance Temp ($^oF/^oC$)			100 / 37.7
Pour Point ($^oF/^oC$)			23 / -5

*Viscosity was not measured in the laboratory at surface conditions for the analogous oil sample, but was extrapolated using the trend of five viscosities measured at varying temperatures and pressures in the laboratory..

Table 4.2 Oil property predictions for the NS-1 well prospect and fluid properties for the best oil analogue match from the SINTEF OSCAR oil database

Fluid Properties:	Estimated NS-1 Fluid Properties	Analogue oil - Sture Blend	Units
API Gravity	34.1	35.5	
Specific gravity	0.854	0.847	
Pour Point	-5	-3	deg C
Wax Content	4.1	4	wt%
Asphaltene Content	4.6	0.2	wt%
Nickel	5.7	n/a	ppm
Vanadium	4.7	n/a	ppm
Dead oil viscosity at reference (surface) temperature	12.5	10	cP
Reference temperature	16	13	deg C
Live oil viscosity at reservoir temperature	0.7		cP
Reservoir temperature	115		deg C

Predictions of the surface oil weathering behaviour of the Sture Blend analogue oil under a range of wind and sea temperature conditions was carried out using the SINTEF Oil Weathering Model. The results are presented in Appendix 1.

4.1.2 Marine Diesel:

Marine diesel is a standard diesel used widely in offshore activity including shipping and oil and gas activity. It has a low viscosity and high aromatic content. Its characteristics are well known and tested. The oil properties of marine diesel derived from the SINTEF OSCAR oil database are as follows:

Table 4.3 Fluid properties of Marine Diesel extracted from the SINTEF OSCAR oil database

Fluid Properties:	Marine Diesel	Units
API Gravity	36.4	
Specific gravity	0.843	
Pour Point	-36	deg C
Dead oil viscosity at reference (surface)	3	cP
Reference temperature	13	deg C

4.2 Oil spill release rate, release volume and release duration

The release conditions for the NS-1 oil spill modelling scenarios are presented in Tables 4.4 and Tables 4.5.

Table 4.4 Release information for NS-1 subsea well blowout scenarios

Well Name:	NS-1

Release Site:		Scenario - Case 1A	Scenario - Case 2A
Well Location:	Geographic Latitude:	43 deg	42 deg
		2 min	41 min
		47.14 sec	31.47 sec
		North	North
	Geographic Longitude:	60 deg	61 deg
		26 min	13 min
		4.60 sec	45.53 sec
		West	West
Water depth:		6,903 ft	8,700 ft
		2,104 m	2,652 m

Release Information:		Scenario - Case 1A (Stochastic - Winter Season)	Scenario - Case 1A (Deterministic - Winter Season)	Scenario - Case 1A (Stochastic - Summer Season)	Scenario - Case 1A (Deterministic - Summer Season)	Scenario - Case 2A (Stochastic - Winter Season)	Scenario - Case 2A (Deterministic - Winter Season)	Scenario - Case 2A (Stochastic - Summer Season)	Scenario - Case 2A (Deterministic - Summer Season)
		24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)	24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)	24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)	24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)	35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)	35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)	35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)	35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)
"Pipe" ID diameter of the last casing string at the seabed release point for the WCD (14" OD):		0.315 m	0.315 m	0.315 m	0.315 m	0.315 m	0.315 m	0.315 m	0.315 m
		12.4 ins	12.4 ins	12.4 ins	12.4 ins	12.4 ins	12.4 ins	12.4 ins	12.4 ins
Release duration:	P90 time:	30 days	30 days	30 days	30 days	30 days	30 days	30 days	30 days
Start time for release (deterministic simulations)			01 April 2008 00:00		04 October 2008 12:00		09 February 2008 01:00		04 October 2008 12:00
Time window for blowout event:	Earliest (P95) date for blowout event:	n/a	n/a	12 October 2012	n/a	12 October 2012	n/a	12 October 2012	
	Latest (P5) date for blowout event:	n/a	n/a	03 March 2013	n/a	03 March 2013	n/a	03 March 2013	n/a
	Time window (P90) for blowout event:	November - April	n/a	May - October	n/a	November - April	n/a	May - October	n/a
Temperature of release as it leaves wellbore:		20 deg C	20 deg C	20 deg C	20 deg C	20 deg C	20 deg C	20 deg C	20 deg C
Salinity of release as it leaves wellbore:		115 ppt	12.4 ppt	12.4 ppt	12.4 ppt	12.4 ppt	12.4 ppt	12.4 ppt	12.4 ppt
		1.08 g/cm^3	1.08 g/cm^3	1.08 g/cm^3	1.08 g/cm^3	1.08 g/cm^3	1.08 g/cm^3	1.08 g/cm^3	1.08 g/cm^3
Air temperature:		2 deg C	2 deg C	13 deg C	13 deg C	2 deg C	2 deg C	13 deg C	13 deg C
Oil volume release rate:	Initial P90 value for worst case discharge (WCD):	24,890 bpd	24,890 bpd	24,890 bpd	24,890 bpd	35,914 bpd	35,914 bpd	35,914 bpd	35,914 bpd
		3,957 m^3/d	3,957 m^3/d	3,957 m^3/d	3,957 m^3/d	5,710 m^3/d	5,710 m^3/d	5,710 m^3/d	5,710 m^3/d
	Release rate after 30 days (capping Stack) for worst case discharge (WCD):	24,005 bpd	24,005 bpd	24,005 bpd	24,005 bpd	34,532 bpd	34,532 bpd	34,532 bpd	34,532 bpd
		3,816 m^3/d	3,816 m^3/d	3,816 m^3/d	3,816 m^3/d	5,490 m^3/d	5,490 m^3/d	5,490 m^3/d	5,490 m^3/d
Total oil released:		733,000 bbls	733,000 bbls	733,000 bbls	733,000 bbls	1,056,000 bbls	1,056,000 bbls	1,056,000 bbls	1,056,000 bbls
		116,538 m^3	116,538 m^3	116,538 m^3	116,538 m^3	167,891 m^3	167,891 m^3	167,891 m^3	167,891 m^3
		98,743 tonnes	98,743 tonnes	98,743 tonnes	98,743 tonnes	142,255 tonnes	142,255 tonnes	142,255 tonnes	142,255 tonnes
Water volume release rate:	Initial P90 value for worst case discharge (WCD):	- bpd	- bpd	- bpd	- bpd	- bpd	- bpd	- bpd	- bpd
		- m^3/d	- m^3/d	- m^3/d	- m^3/d	- m^3/d	- m^3/d	- m^3/d	- m^3/d
	Release rate after 30 days (capping Stack) for worst case discharge (WCD):	2 bpd	2 bpd	2 bpd	2 bpd	4 bpd	4 bpd	4 bpd	4 bpd
		0.3 m^3/d	0.3 m^3/d	0.3 m^3/d	0.3 m^3/d	0.6 m^3/d	0.6 m^3/d	0.6 m^3/d	0.6 m^3/d
Total water released:		26 bbls	26 bbls	26 bbls	26 bbls	53 bbls	53 bbls	53 bbls	53 bbls
		4.1 m^3	4.1 m^3	4.1 m^3	4.1 m^3	8 m^3	8 m^3	8 m^3	8 m^3
		4.5 tonnes	4.5 tonnes	4.5 tonnes	4.5 tonnes	9 tonnes	9 tonnes	9 tonnes	9 tonnes
Gas-Oil Ratio:	GOR	756 scf/bbl	756 scf/bbl	756 scf/bbl	756 scf/bbl	756 scf/bbl	756 scf/bbl	756 scf/bbl	756 scf/bbl
		135 sm^3/m^3	135 sm^3/m^3	135 sm^3/m^3	135 sm^3/m^3	135 sm^3/m^3	135 sm^3/m^3	135 sm^3/m^3	135 sm^3/m^3
Gas density:		0.67 kg/Sm^3	0.67 kg/Sm^3	0.67 kg/Sm^3	0.67 kg/Sm^3	0.67 kg/Sm^3	0.67 kg/Sm^3	0.67 kg/Sm^3	0.67 kg/Sm^3
Calculated gas volume release rate:	Initial P90 value for worst case discharge (WCD):	18.8 MMscf/d	18.8 MMscf/d	18.8 MMscf/d	18.8 MMscf/d	27.1 MMscf/d	27.1 MMscf/d	27.1 MMscf/d	27.1 MMscf/d
		0.53 MMsm^3/d	0.53 MMsm^3/d	0.53 MMsm^3/d	0.53 MMsm^3/d	0.77 MMsm^3/d	0.77 MMsm^3/d	0.77 MMsm^3/d	0.77 MMsm^3/d
	Release rate after 30 days (capping Stack) for worst case discharge (WCD):	18.1 MMscf/d	18.1 MMscf/d	18.1 MMscf/d	18.1 MMscf/d	26.1 MMscf/d	26.1 MMscf/d	26.1 MMscf/d	26.1 MMscf/d
		0.51 MMsm^3/d	0.51 MMsm^3/d	0.51 MMsm^3/d	0.51 MMsm^3/d	0.74 MMsm^3/d	0.74 MMsm^3/d	0.74 MMsm^3/d	0.74 MMsm^3/d
Calculated mass flow rate of gas released:	Initial P90 value for worst case discharge (WCD):	4.1 kg/s	4.1 kg/s	4.1 kg/s	4.1 kg/s	6.0 kg/s	6.0 kg/s	6.0 kg/s	6.0 kg/s
	Release rate after 30 days (capping Stack) for worst case discharge (WCD):	4.0 kg/s	4.0 kg/s	4.0 kg/s	4.0 kg/s	5.7 kg/s	5.7 kg/s	5.7 kg/s	5.7 kg/s
Total gas released:		554 MMscf	554 MMscf	554 MMscf	554 MMscf	798 MMscf	798 MMscf	798 MMscf	798 MMscf
		16 MMsm^3	16 MMsm^3	16 MMsm^3	16 MMsm^3	23 MMsm^3	23 MMsm^3	23 MMsm^3	23 MMsm^3
		10,511 tonnes	10,511 tonnes	10,511 tonnes	10,511 tonnes	15,140 tonnes	15,140 tonnes	15,140 tonnes	15,140 tonnes

Table 4.5 Release information for NS-1 accidental hydrocarbon (diesel) spill scenarios

Well Name:	NS-1

Release Site:		Well Site 1
Well Location:	Geographic Latitude:	43 deg
		2 min
		47.14 sec
		North
	Geographic Longitude:	60 deg
		26 min
		4.60 sec
		W East / West
Water depth:		6,903 ft
		2,104 m

Release Information:	Scenario - Surface release Hose Failure (Stochastic - Winter Season)	Scenario - Surface release Hose Failure (Stochastic - Winter Season)	Scenario - Surface release Hose Failure (Stochastic - Summer Season)	Scenario - Surface release Hose Failure (Stochastic - Summer Season)	Scenario - Surface release Tank Failure (Stochastic - Winter Season)	Scenario - Surface release Tank Failure (Stochastic - Winter Season)	Scenario - Surface release Tank Failure (Stochastic - Winter Season)	Scenario - Surface release Tank Failure (Stochastic - Winter Season)
	10 bbls diesel release	10 bbls diesel release	10 bbls diesel release	10 bbls diesel release	100 bbls diesel release	100 bbls diesel release	100 bbls diesel release	100 bbls diesel release
Release duration:	1 hour	1 hour	1 hour	1 hour	6 hour	6 hour	6 hour	6 hour
Start time for release (deterministic simulations)		03 June 2009 05:00		03 June 2009 05:00		03 June 2009 05:00		03 June 2009 05:00
Time window for surface release:	November - April	n/a	May - October	n/a	November - April	n/a	May - October	n/a
Temperature of release:	20 deg C	20 deg C	20 deg C	20 deg C	20 deg C	20 deg C	20 deg C	20 deg C
Air temperature:	2 deg C	2 deg C	13 deg C	13 deg C	2 deg C	2 deg C	13 deg C	13 deg C
Total oil released:	10 bbls	10 bbls	10	10 bbls	100 bbls	100	100 bbls	100 bbls
	1.6 m^3	1.6 m^3	1.6 m^3	1.6 m^3	15.9 m^3	15.9 m^3	15.9 m^3	15.9 m^3
	1.3 tonnes	1.3 tonnes	1.3 tonnes	1.3 tonnes	13.4 tonnes	13.4 tonnes	13.4 tonnes	13.4 tonnes

4.3 Hydrodynamic and wind data

Currents, winds and other meteorological and oceanographic factors are critical parameters which can influence the fate and behaviour of oil following a spill. Meteorological and oceanographic data is available from a number of sources and can be formatted to work in the OSCAR model.

4.3.1 Nova Scotia Currents

The regional current processes offshore Nova Scotia are dominated by the cold Labrador current that flows from the north along the continental shelf-break, and the warm North Atlantic current that flows towards the northeast and is located further offshore. The Labrador Current is shown in Figure 4.1, which indicates that its principle source is the West Greenland Current; however, flows through the Davis and Hudson straits are also important. The Figure also shows that the Labrador Current splits into two branches: an inshore and an offshore flow. The North Atlantic Current (Gulf Stream) is shown in Figure 4.2 which also shows the circulation across the shelves offshore Nova Scotia.

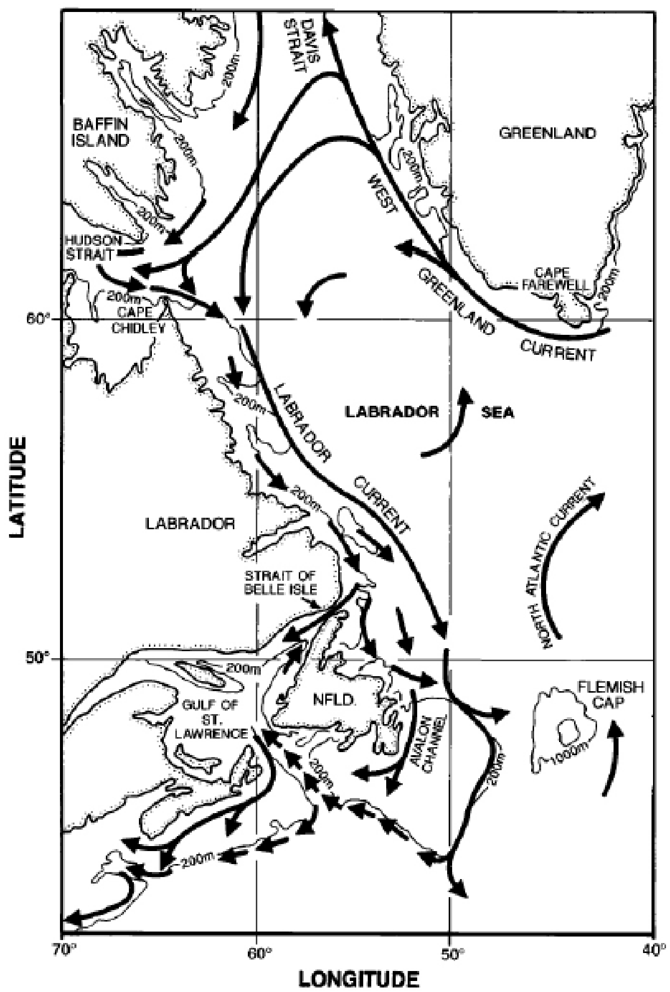


Figure 4.1 General circulation in the North West Atlantic showing major current systems (from Colbourne et al.[11] and adapted from Chapman and Beardsley [12].

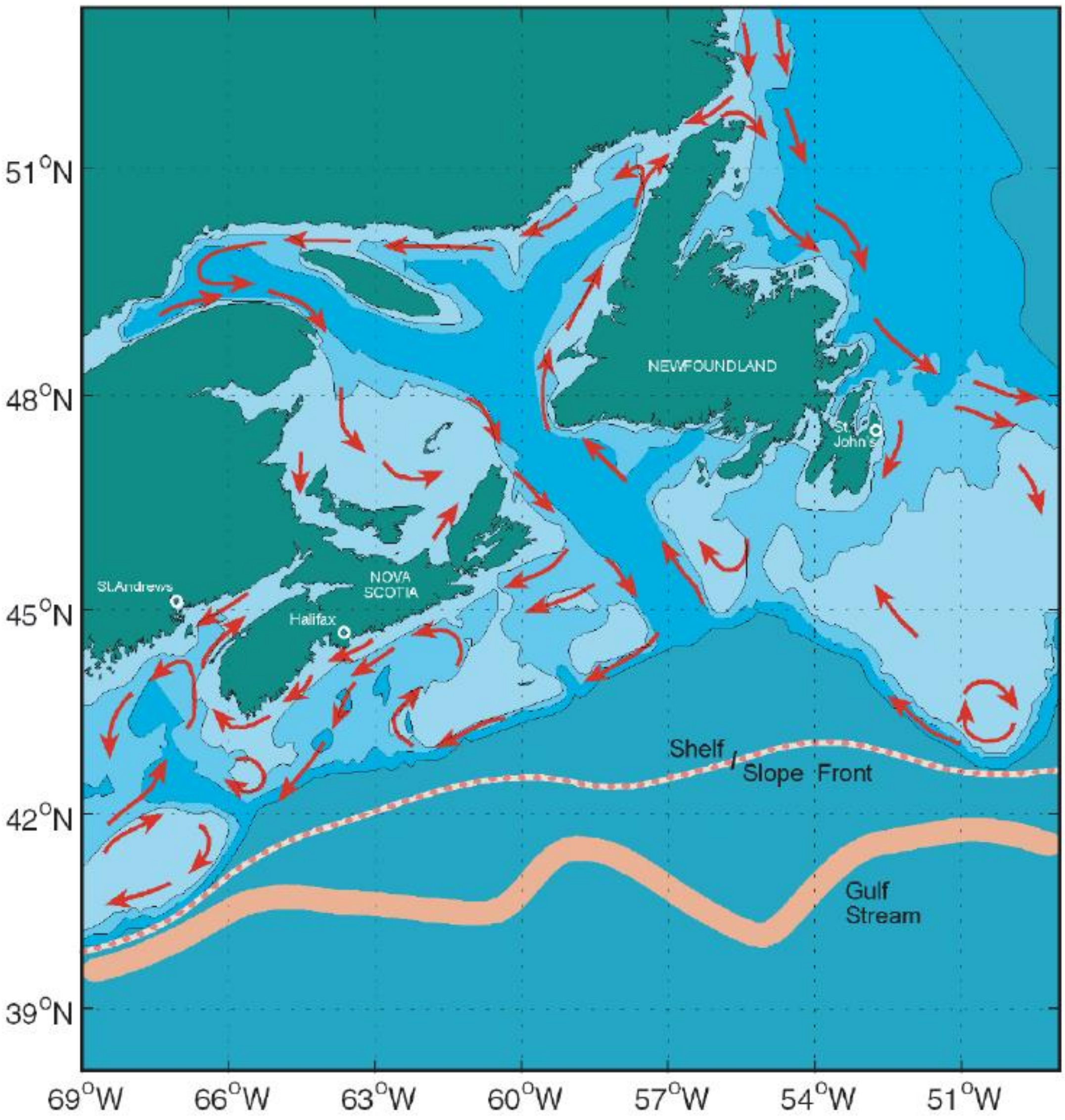


Figure 4.2 Schematic showing the surface circulation and the positions of the Shelf/Slope Front and the Gulf Stream (from Drinkwater and Gilbert [13]).

BP commissioned an independent, assurance review of potential metocean models to use in modelling work to support the Scotian Basin EIS. The review compared hindcast data of two potential metocean models to published data to identify which is the better representation of the expected conditions in the Scotian Basin[6].

The assurance work was designed to take account of the following features:

- **Regional:** circulation, sea surface height, sea surface temperature
- **Sub-regional:** circulation, temperature and salinity transects, tides, drifters
- **Scotian Shelf:** hydrography, moorings

The independent assurance assessment has demonstrated that the metocean model parameters listed in Table 4.6 provide the most accurate representation of the anticipated conditions in offshore Nova Scotia.

The hydrodynamic dataset used in OSCAR modelling comprised of daily HYCOM current speeds with Bedford Institute Tides linearly superimposed. The HYCOM currents are from the Navy Research Laboratory experiment 91.1 (HYCOM GLBu0.08) and were interpolated onto a three hourly time step for the period 1st January 2006 and 31st December 2010. The spatial resolution is 1/12.5 degrees and the results were extracted onto a domain that spans: longitude 45 to 75 degrees West and latitude 35 to 55 degrees North. The HYCOM currents were provided on forty depth levels, from the surface to 5,000 m. HYCOM uses Gebco 30 minute bathymetry, Climate Forecast System Reanalysis (CFSR) atmospheric forcing and assimilates data from a variety of sources. The tidal currents have been derived from the constituents in the BIO WebTide module (from the Scotian Shelf, North West Atlantic and Global grids) and the profile through depth was reconstructed by assuming a 1/7 power law.

Snapshot maps showing examples of the wind and current fields generated from the National Centre for Atmospheric Research (NCAR) / National Centre for Environmental Protection (NCEP) CFSR and HYCOM datasets respectively are presented in Figures 4.3 – 4.5.

Table 4.6 Metocean Data Parameter Inputs

	Input Data	**Reference**
Bathymetry	GEBCO-1 minute	http://www.gebco.net/
Current velocity components	HYCOM	https://hycom.org/
Sea-surface elevation	HYCOM	https://hycom.org/
Temperature	HYCOM	https://hycom.org/
Salinity	HYCOM	https://hycom.org/
Tides	Bedford Institute Tides	http://www.tide-forecast.com/locations/Bedford-Institute-Nova-Scotia/tides/latest
Winds	NCAR /NCEP (CFSR)	http://rda.ucar.edu/pub/cfsr.html
Atmospheric forcing	NCAR/NCEP (CFSR)	http://rda.ucar.edu/pub/cfsr.html
Wave heights	Calculated in OSCAR	n/a
Wind induced current	Calculated in OSCAR	n/a

Figure 4.3 Snapshot map showing an example of the 2-dimensional wind field generated from the NCAR / NCEP (CFSR) dataset

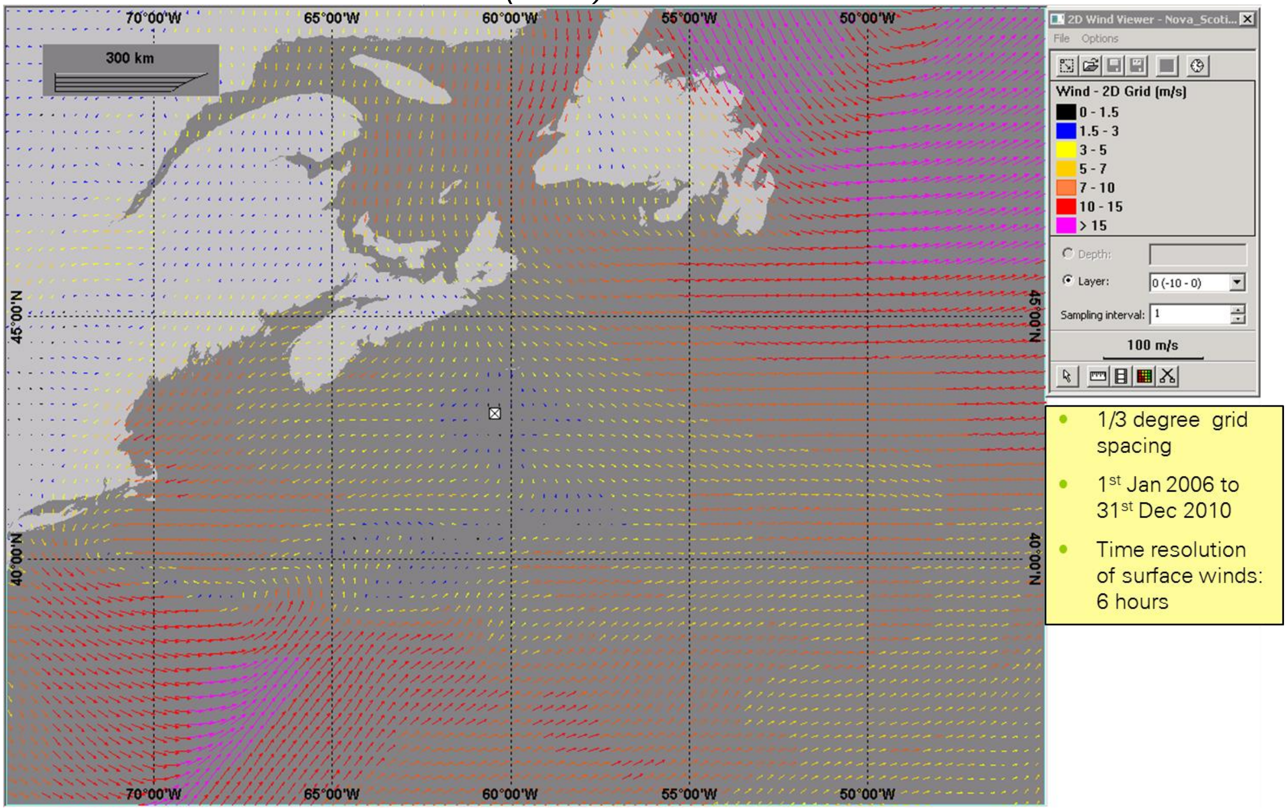


Figure 4.4 Snapshot map showing an example of the surface current field from 3-dimensional HYCOM generated dataset

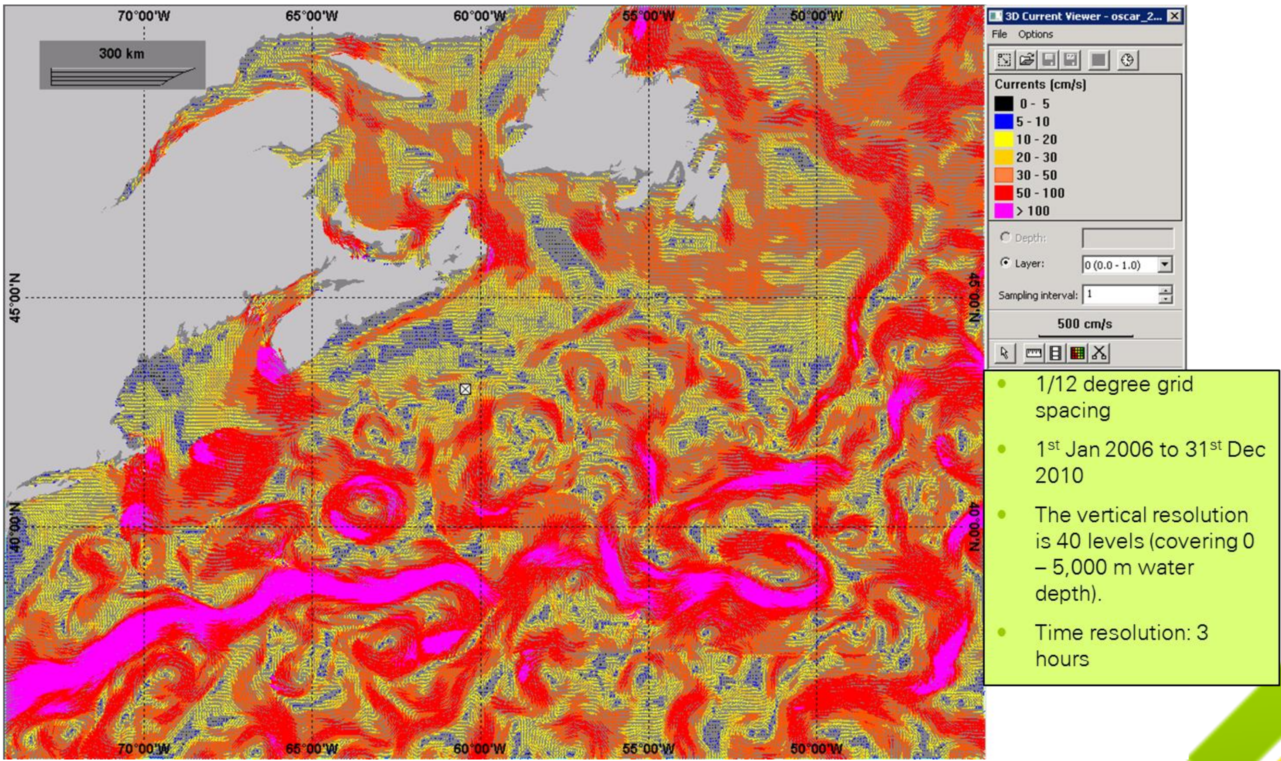
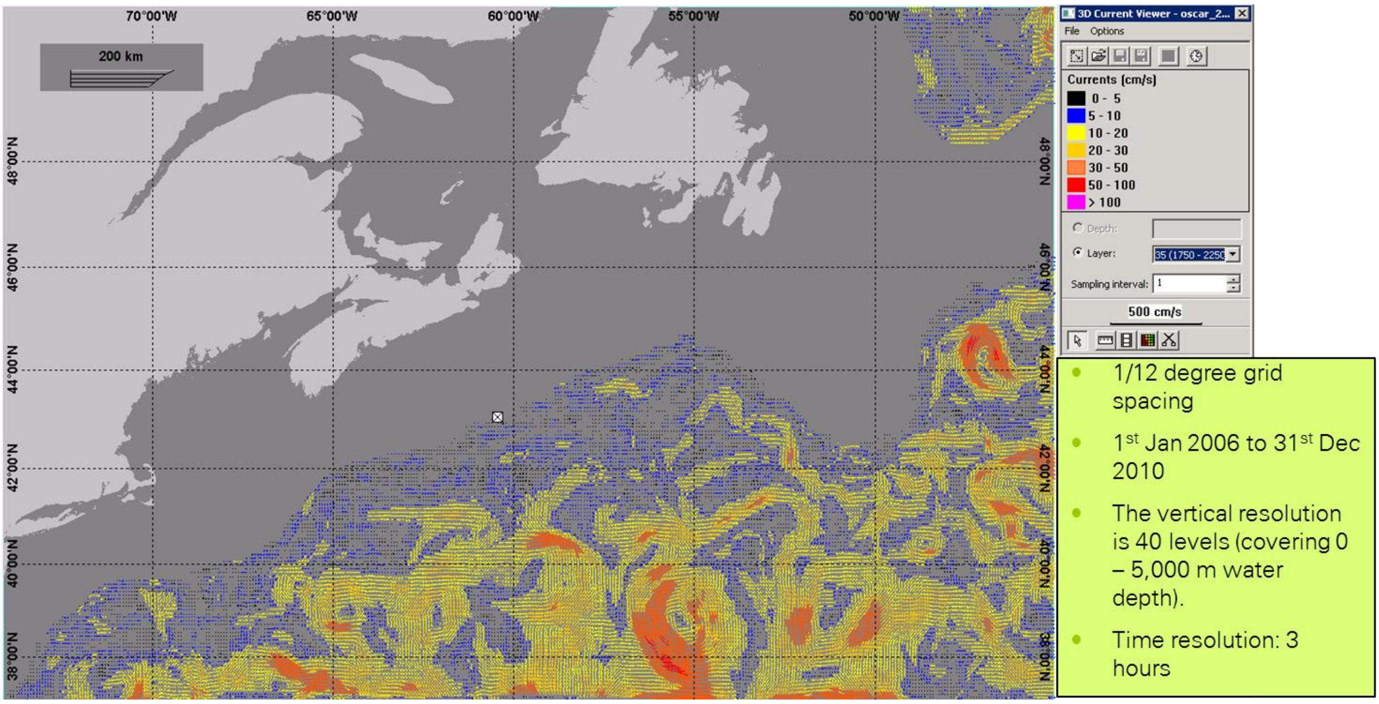


Figure 4.5 Snapshot map showing an example of the current field for the water depth range 1,750 - 2,250 m extracted from the 3-dimensional HYCOM generated dataset



4.3.2 Predicted winds and currents at the NS-1 well locations

Hindcast model predictions of surface wind and currents at the NS-1 well locations are presented in Appendix 2.

The current intensity decreases with water depth in the water column as shown in Figures 4.4 and 4.5, with average currents speeds < 5 cm/s near the seabed at the NS-1 well locations. Surface currents are highly variable at both well locations (see Figures A2.5 and A2.6). However, seasonal current roses indicate stronger currents with a more South Westerly distribution during the winter months (November – April, see Figure A2.1). The strongest surface currents (> 30 cm s-1), occur during the winter season, but current speeds are on average 10 % faster during the winter months (Figure A2.2).

According to the CFSR model, wind speeds at well site locations 1 and 2 averaged around 9.9 ms^{-1} (19 knots) during the winter season and 7.3 ms^{-1} (14 knots) during the summer season (April – October) over the entire 2006 – 2010 time period. However, maximum wind speeds were much higher, with a maximum daily average wind speed of 19.5 ms^{-1} (38 knots) in the summer and 25.5 ms^{-1} (57 knots) in the winter.

Seasonal wind roses showed very similar wind directions and at sites 1 and 2 (Figure A2.8), with stronger wind speeds during the winter, when compared to the summer (Figure A2.9). In winter, winds were predominantly from the W to WNW (Figure A2.10) and in the summer from the W to SW.

4.3.3 Hydrographical profiles

The HYCOM model was used to extract average monthly temperature and salinity vs. depth profiles (over the period 2006 to 2010) for the NS-1 well locations. The data was then used to produce hydrographical profiles for each “seasonal” time period employed in the stochastic simulations (see Appendix 3).

4.4 Model set-up parameters

4.4.1 Model area

To confirm that the simulations captured both the physical extent and time duration of each oil spill event, the simulations were set up as follows:

1. The user-defined habitat grid for the release area (i.e. the physical geography boundary conditions) used in both stochastic and deterministic modelling was created to retain at least 95% of the total mass of the release within the grid boundary during any given simulation (see Figure 4.6 and 4.7 for geographical maps).

2. The model simulation period for a given scenario was selected so that the amounts of oil exceeding the threshold limit values for surface oil thickness and total dispersed oil concentration in the water column were negligible at the end of the simulation.

Figure 4.6 Map showing habitat grid boundaries used in stochastic / deterministic simulations for the NS-1 subsea well blowout scenarios

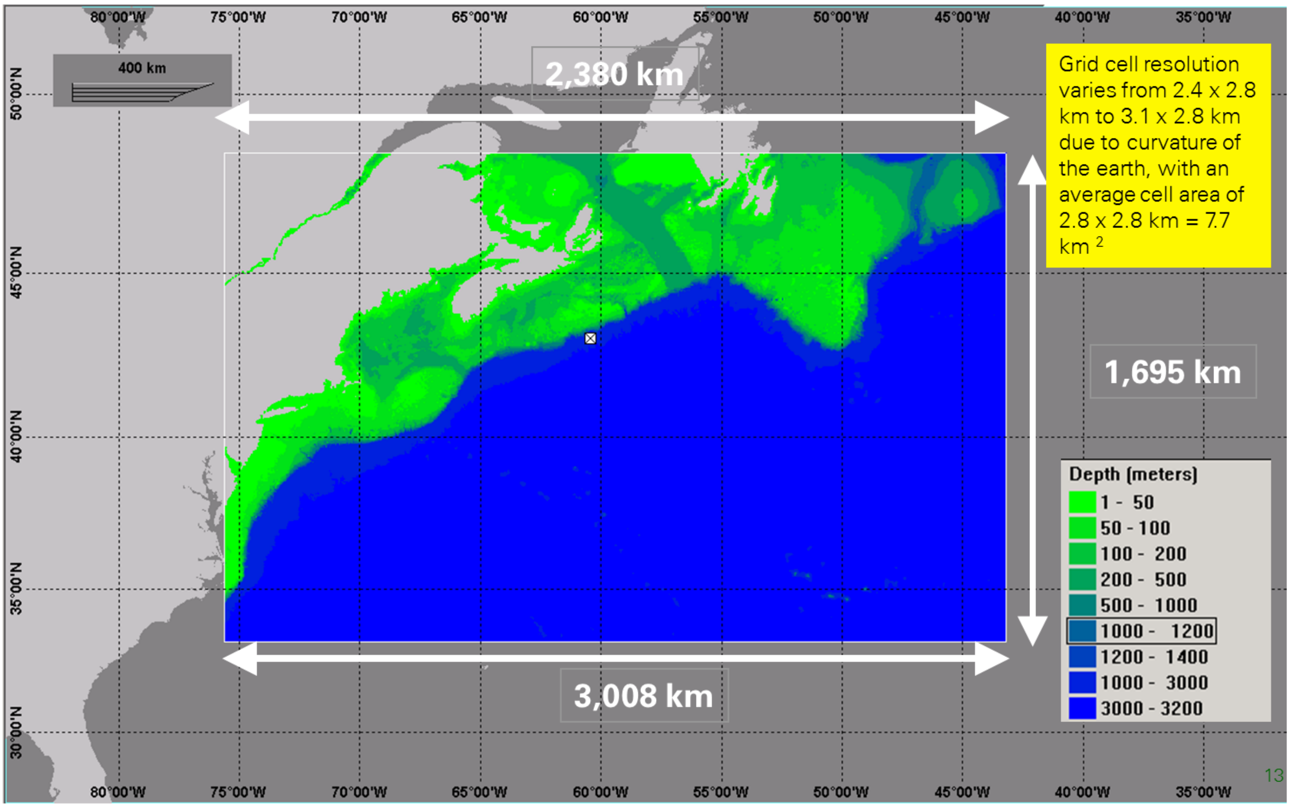


Figure 4.7 Map showing habitat grid boundaries used in stochastic / deterministic simulations for the 10 bbl surface release of diesel (hose failure) scenario

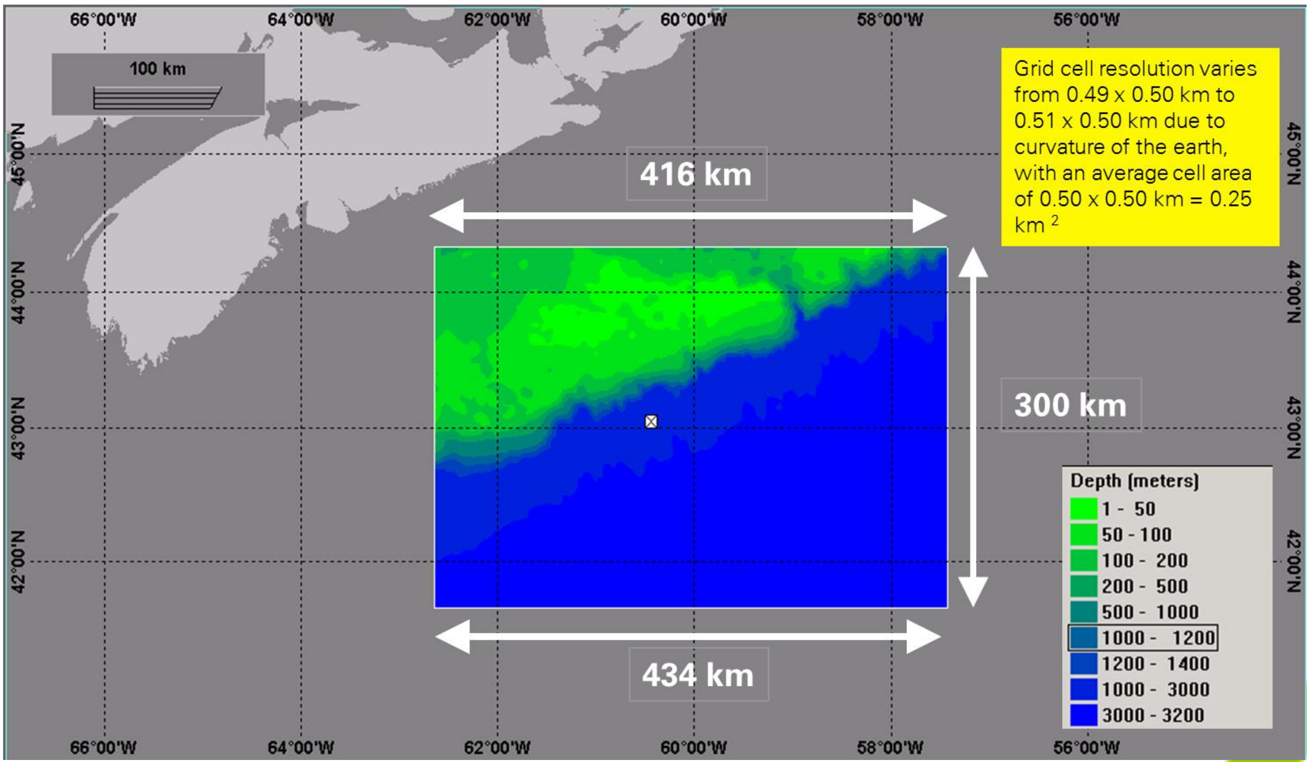
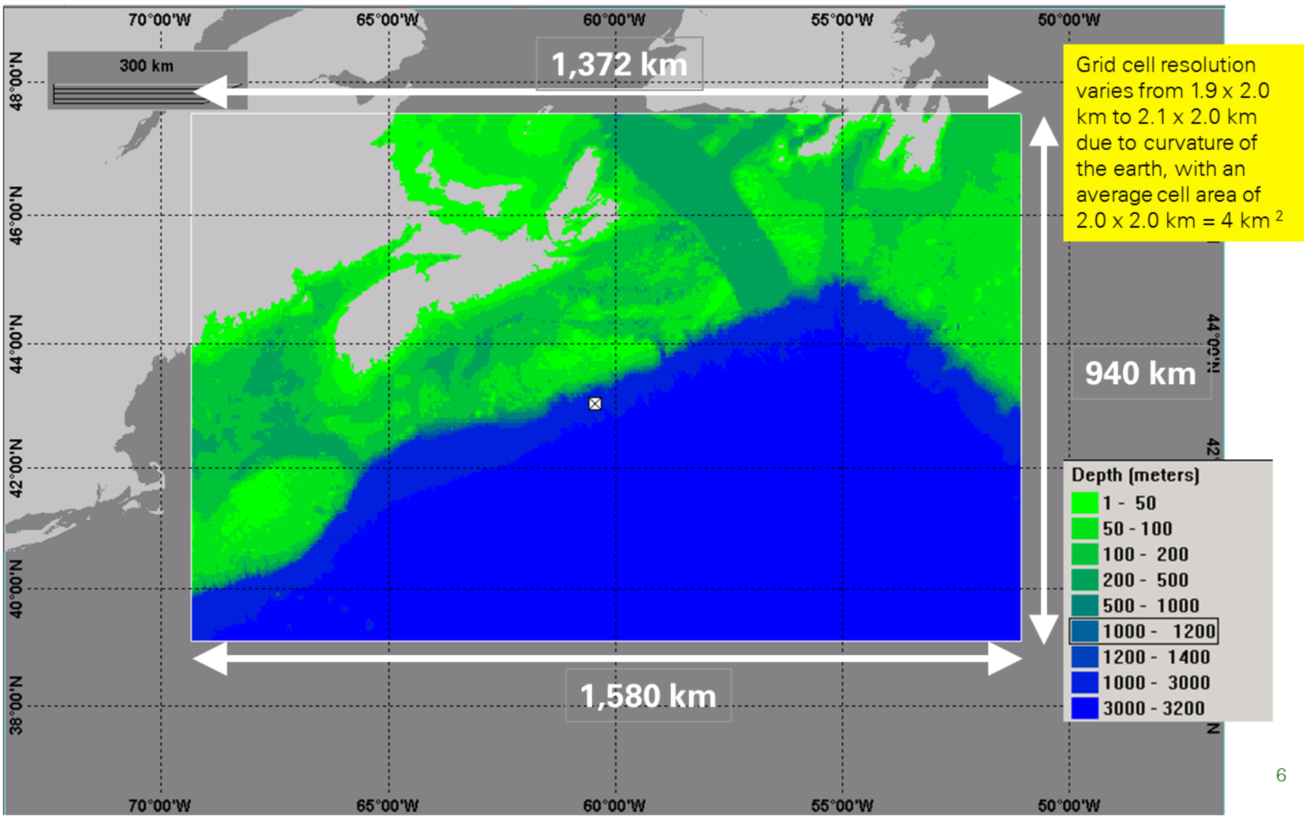


Figure 4.8 Map showing habitat grid boundaries used in stochastic / deterministic simulations for the 100 bbl surface release of diesel (tank failure) scenario



6

4.4.2 Model settings and assumptions

Tables 4.7 and 4.8 provide a summary of the model settings and assumptions used in the stochastic and deterministic simulations.

Film thickness

The default initial film thickness was set to the default of 4 mm and the oil was tracked on the sea surface to a terminal thickness of 0.04 µm.

Simulation time

The simulation periods for blowout and diesel release scenarios we set to 120 days and 30 / 50 days respectively (see section 4.4.1).

Particle number

The number of particles representing oil droplets and dissolved contaminants was set to 10.000 for both the stochastic and deterministic simulations to provide good resolution.

Table 4.5 Summary of the model settings and assumptions used in the stochastic and deterministic simulations for the NS-1 subsea well blowout scenarios

Model Parameters:		Scenario - Case 1A (Stochastic - Winter Season)	Scenario - Case 1A (Deterministic - Winter Season)	Scenario - Case 1A (Stochastic - Summer Season)	Scenario - Case 1A (Deterministic - Summer Season)	Scenario - Case 2A (Stochastic - Winter Season)	Scenario - Case 2A (Deterministic - Winter Season)	Scenario - Case 2A (Stochastic - Summer Season)	Scenario - Case 2A (Deterministic - Summer Season)
		24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)	24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)	24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)	24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)	35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)	35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)	35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)	35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)
Number of particles	Droplet	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
	Dissolved	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Habitat Grid dimensions	Average Grid Width	2,700 km 1,678 miles	2,700 km 1,678 miles	2,700 km 1,678 miles	2,700 km 1,678 miles	2,700 km 1,678 miles	2,700 km 1,678 miles	2,700 km 1,678 miles	2,700 km 1,678 miles
	Grid height	1,695 km 1,053 miles	1,695 km 1,053 miles	1,695 km 1,053 miles	1,695 km 1,053 miles	1,695 km 1,053 miles	1,695 km 1,053 miles	1,695 km 1,053 miles	1,695 km 1,053 miles
The spatial resolution of the Habitat Grid	Average Resolution in the x-direction (longitude)	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km
	Resolution in the y-direction (latitude)	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km
The spatial resolution of the concentration grid in the horizontal and vertical	Average Resolution in the x-direction (longitude)	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km
	Resolution in the y-direction (latitude)	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km
	Resolution in the z-direction (depth)	10 m	10 m	10 m	10 m	10 m	10 m	10 m	10 m
The spatial resolution of the surface grid	Average Resolution in the x-direction (longitude)	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km
	Resolution in the y-direction (latitude)	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km	2.8 km
Depth for concentration grid	Min:	0 m	0 m	0 m	0 m	0 m	0 m	0 m	0 m
	Max	100 m	100 m	100 m	100 m	100 m	100 m	100 m	100 m
Lower concentration limit (water soluble fraction):		1 ppb	1 ppb	1 ppb	1 ppb	1 ppb	1 ppb	1 ppb	1 ppb
Terminal surface film thickness:		0.04 microns	0.04 microns	0.04 microns	0.04 microns	0.04 microns	0.04 microns	0.04 microns	0.04 microns
The oil droplet size distribution min / max and median droplet size	Min:	1 µm	1 µm	1 µm	1 µm	1 µm	1 µm	1 µm	1 µm
	Median:	4,105 µm	4,105 µm	4,105 µm	4,105 µm	4,105 µm	4,105 µm	4,105 µm	4,105 µm
	Max	8,830 µm	8,830 µm	8,830 µm	8,830 µm	8,830 µm	8,830 µm	8,830 µm	8,830 µm
Computation time-step and output time-step	Time-step	20 min	20 min	20 min	20 min	20 min	20 min	20 min	20 min
	Output interval	1 day	1 day	1 day	1 day	1 day	1 day	1 day	1 day
Simulation period:		120 days	120 days	120 days	120 days	120 days	120 days	120 days	120 days
Number of stochastic simulations:		210 (2006 - 2010)	n/a	210 (2006 - 2010)	n/a	210 (2006 - 2010)	n/a	210 (2006 - 2010)	n/a

Table 4.5 Summary of the model settings and assumptions used in the stochastic and deterministic simulations for the NS-1 accidental hydrocarbon (diesel) discharge scenarios

Model Parameters:		Scenario - Surface release Hose Failure (Stochastic - Winter Season)	Scenario - Surface release Hose Failure (Stochastic - Winter Season)	Scenario - Surface release Hose Failure (Stochastic - Summer Season)	Scenario - Surface release Hose Failure (Stochastic - Summer Season)	Scenario - Surface release Tank Failure (Stochastic - Winter Season)	Scenario - Surface release Tank Failure (Stochastic - Winter Season)	Scenario - Surface release Tank Failure (Stochastic - Winter Season)	Scenario - Surface release Tank Failure (Stochastic - Winter Season)
		10 bbls diesel release	10 bbls diesel release	10 bbls diesel release	10 bbls diesel release	100 bbls diesel release	100 bbls diesel release	100 bbls diesel release	100 bbls diesel release
Number of particles	Droplet	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
	Dissolved	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Habitat Grid dimensions	Average Grid Width	425 km 264 miles	425 km 264 miles	425 km 264 miles	425 km 264 miles	1,476 km 917 miles	1,476 km 917 miles	1,476 km 917 miles	1,476 km 917 miles
	Grid height	300 km 186 miles	300 km 186 miles	300 km 186 miles	300 km 186 miles	940 km 584 miles	940 km 584 miles	940 km 584 miles	940 km 584 miles
The spatial resolution of the Habitat Grid	Average Resolution in the x-direction (longitude)	0.5 km	0.5 km	0.5 km	0.5 km	2.0 km	2.0 km	2.0 km	2.0 km
	Resolution in the y-direction (latitude)	0.5 km	0.5 km	0.5 km	0.5 km	2.0 km	2.0 km	2.0 km	2.0 km
The spatial resolution of the concentration grid in the horizontal and vertical	Average Resolution in the x-direction (longitude)	0.5 km	0.5 km	0.5 km	0.5 km	2.0 km	2.0 km	2.0 km	2.0 km
	Resolution in the y-direction (latitude)	0.5 km	0.5 km	0.5 km	0.5 km	2.0 km	2.0 km	2.0 km	2.0 km
	Resolution in the z-direction (depth)	10 m	10 m	10 m	10 m	10 m	10 m	10 m	10 m
The spatial resolution of the surface grid	Average Resolution in the x-direction (longitude)	0.5 km	0.5 km	0.5 km	0.5 km	2.0 km	2.0 km	2.0 km	2.0 km
	Resolution in the y-direction (latitude)	0.5 km	0.5 km	0.5 km	0.5 km	2.0 km	2.0 km	2.0 km	2.0 km
Depth for concentration grid	Min:	0 m	0 m	0 m	0 m	0 m	0 m	0 m	0 m
	Max	100 m	100 m	100 m	100 m	100 m	100 m	100 m	100 m
Lower concentration limit (water soluble fraction):		1 ppb	1 ppb	1 ppb	1 ppb	1 ppb	1 ppb	1 ppb	1 ppb
Terminal surface film thickness:		0.04 microns	0.04 microns	0.04 microns	0.04 microns	0.04 microns	0.04 microns	0.04 microns	0.04 microns
Computation time-step and output time-step	Time-step	10 min	10 min	10 min	10 min	10 min	10 min	10 min	10 min
	Output interval	6 hours	6 hours	6 hours	6 hours	6 hours	6 hours	6 hours	6 hours
Simulation period:		30 days	30 days	30 days	30 days	50 days	50 days	50 days	50 days
Number of stochastic simulations:		225 (2006 - 2010)	n/a	225 (2006 - 2010)	n/a	225 (2006 - 2010)	n/a	225 (2006 - 2010)	n/a

4.5 Response and environmental thresholds

The OSCAR model is able to track oil on the sea surface, on the shoreline and water column to levels that have little relevance from a response or environmental impact perspective. Therefore, threshold levels have been specified for each of these impact compartments as follows:

4.5.1 Surface: thickness of emulsified oil on the water surface

The minimum thickness of oil that may result in harm to seabirds through ingestion from preening of contaminated feathers, or loss of thermal protection from their feathers, has been estimated by different researchers to range between 10 µm (10 g/m^2) to 25 µm (25 g/m^2) (French-McCay, 2009[(15)]). However, visible sheens on the water surface can have a socio-economic impact as commercial resources can be affected. For example, fisheries are closed when a visible sheen is detected. Therefore, a conservative surface thickness threshold of 0.04 µm was used in the modelling, which relates to a barely visible or silver sheen on the water surface[(16)].

4.5.2 Shoreline: volume of oil reaching the shoreline

Oil on the shoreline can have an impact on environmental and socio-economic receptors. French-McCay (2011 [(15)]) review paper quotes shoreline impact lethal thresholds of 1 kg/m^2 (1 mm) for vegetation growing along flat shorelines with soft sediments and 100 g/m^2 (0.1 mm) for epifaunal invertebrates (mussels, crabs, starfish etc.). However, a conservative stranded oil threshold 1.0 g/m^2 was used in the stochastic modelling as that amount of oil would conservatively trigger the need for shoreline clean-up. This is equivalent to a density of 1” diameter tar balls of @ 0.12 – 0.14 tar balls per m^2 of shoreline [(20)].

4.5.3 Water column concentration: concentration of oil in the water column

Carls et al (2002[(17)]) found that the acute toxicity of water-soluble fraction of oil (LC50) varies from 200 to 5,000 ppb THC. Based on extensive toxicity tests of crude oils and oil components on marine organisms, the OLF (the Norwegian Oil Industry Association) Guideline for risk assessment of effects on fish from acute oil pollution (2008)[(18)] concluded that threshold concentration for an expected NOEC for acute exposure for THC ranges from 50 - 300 ppb. Work undertaken by Neilson et al (2005, as reported in OLF, 2008) proposed a value for acute exposure to dispersed oil of 58 ppb, based on the toxicity of chemically dispersed oil to various aquatic species, which showed the 5% effect level is 58 ppb (see Figure 4.9). The 58 ppb threshold for the NOEC for oil dissolved and entrained oil in the water column was thus selected for stochastic modelling based on the conclusion in the OLF guideline.

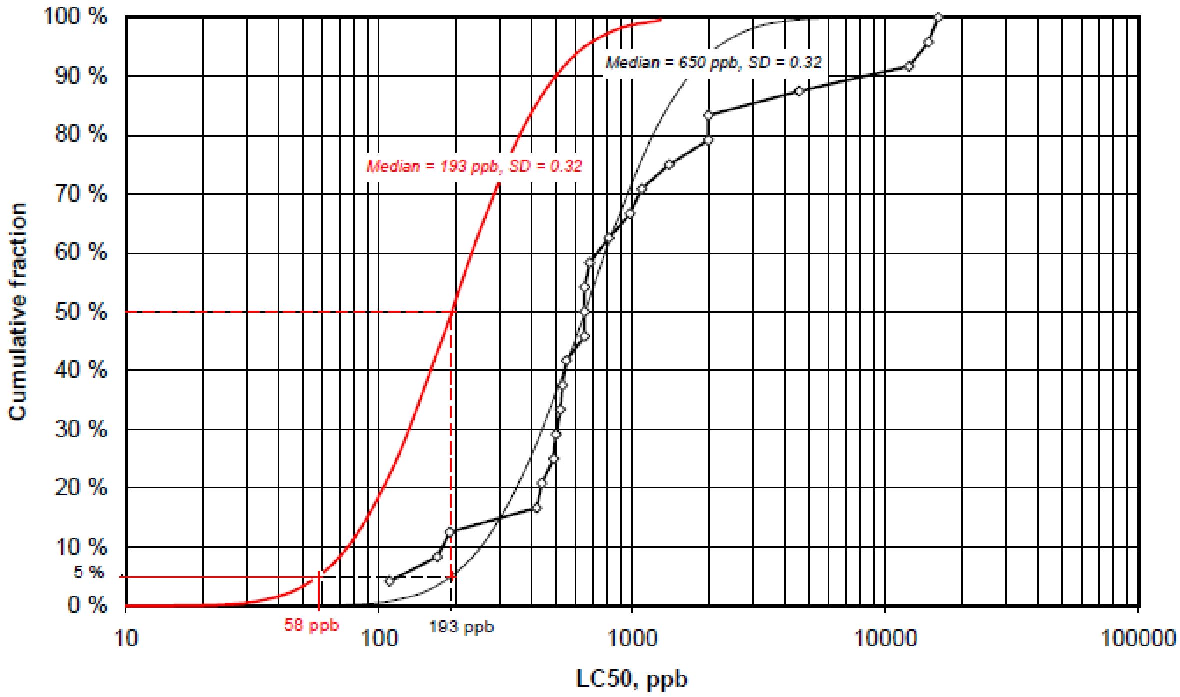


Figure 4.9 *LC50 values from toxicity studies on dispersed oil on various aquatic species. The red line is the cumulative distribution curve of interest. This sensitive species dose-response curve shows the 5 % percentile LC50 value and SD = 0.32. From this dose-response curve, the threshold value (5 % lethal risk) is found to be 58 ppb.*

In this study all thresholds were applied pre-processing as described in Section 2.2.2).

5 Protected and Environmentally Sensitive Areas

The potential impact of an oil release from the NS-1 well locations was assessed by geospatial analysis using ArcGIS to identify where probabilistic outputs from OSCAR (exceeding the oil thickness and concentration threshold values detailed in Section 4.5) overlap with Designated Protected and Environmentally Sensitive Areas.

5.1 Protected Areas

Protected Areas (PAs) included in the geospatial analysis were as follows:

- IUCN Category Ia: Strict Nature Reserves
- IUCN Category Ib: Wilderness Areas
- IUCN Category II: National Parks
- IUCN Category III: Natural Monument or Feature
- IUCN Category IV: Habitat/Species Management Areas
- IUCN Category V: Protected Landscape/Seascape
- IUCN Category VI: Protected Areas with Sustainable Use of Natural Resources
- RAMSAR Sites
- World Heritage Sites
- UNESCO-MAB Biosphere Reserve

Designated Protected Areas present in the region are shown in Figure 5.1, with two PAs (Sable Island National Park Reserve and The Gully Marine Protected Area), falling within the 150 km of the Project Area.

5.2 Ecologically and Biologically Sensitive Areas

In addition to the PAs, there are several Ecologically and Biologically Significant Areas (EBSAs) that have been designated on the Scotian Shelf and Slope that would fall within a 150 km radius of the Project Area. EBSAs have no formal designation or regulatory protection but are recognized by scientific experts as playing a key role in marine protected areas planning. Of particular relevance are the following EBSAs which overlap with the Project Area:

- Scotian Slope EBSA
- Emerald-Western-Sable Island Bank Complex EBSA
- Haddock Box (Haddock spawning area – Fisheries Closure Area)
- Sambro Bank and Emerald Bank Sponge Conservation Areas (Fisheries Closure Areas)

The Scotian Slope is the largest EBSA offshore Nova Scotia (72,800 km2), extending the length of the Scotian Slope. It is recognized for its high productivity and fish species diversity, small fish and small invertebrate species richness, unique habitats and sensitive benthic communities. It is also recognized as being important for groundfish and seabirds, and is a migratory route for cetaceans and large pelagic fishes (DFO 2014 [(21)]).

The Emerald-Western-Sable Island Bank Complex is another large EBSA (17,900 km2) which contains important habitat for groundfish (spawning and nursery areas), invertebrates, seabirds, and cetaceans. It is recognized for its high larval fish abundance and diversity, and has high fish and invertebrate biomass and species diversity. The Western Gully area of the EBSA is of potential significance to cetaceans (DFO 2014 [(21)]). The EBSAs considered in this assessment are listed in Table 5.1 and presented as polygons in in Figures 5.2 and 5.3.

Table 5.1 Ecological and Biological Sensitive Areas (EBSAs) considered in the oil spill exposure assessment

Scotian Shelf Offshore EBSAs	Area (Sq km)
Browns Bank	4,308
Canadian portion of Georges Bank	7,014
Canso Bank and Canso Basin	4,113
Eastern Scotian Shelf Canyons	7,434
Eastern Shoal	3,397
Emerald Basin and the Scotian Gulf	8,513
Emerald Western Sable Banks Complex	17,900
Jordan Basin and the Rock Garden	1,824
Laurentian Channel Cold Seep	50
Laurentian Channel slope	21,484
Middle Bank	2,748
Misaine Bank	4,599
Northeast Channel	2,589
Roseway Basin	3,158
Sable Island Shoals	1,297
Scotian Slope	72,569
St. Anns Bank	4,661
Stone Fence and Laurentian Environs	44
Other EBSAs	**Area (Sq km)**
Bowtie	4,063
Emerald Sponge Conservation Area	197
Haddock Box	12,776
NAFO Fishing Closure Area (1) Sponge, Coral & Seapen Protected Areas	14,287
NAFO Fishing Closure Area (2) Seamount Areas	16,335
NAFO Fishing Closure Area (3) Seamount Areas	41,645
NAFO Fishing Closure Area (4) Seamount Areas	16,213
NAFO Fishing Closure Area (5) Seamount Areas	276,731
Northeast Channel Coral Conservation Area	425.00
Northeast Channel Coral Conservation Area - NEC limited bottom fishing zone	34
Northeast Channel Coral Conservation Area - NEC restricted bottom fishing zone	391
Sambro Bank Sponge Conservation Area	62
St Anns Bank Area of Interest	4,381
Stone Fence coral conservation area	15
Laurentian Channel (AOI)	16,528
Lobster Fisheries Act Closure Area	6,554
Georges Bank	14,514
North Atlantic Right Whale - Grand Manan Basin	739
North Atlantic Right Whale - Roseway Basin	3,315

Figure 5.1 Map showing Protected Areas in the Scotian Basin region

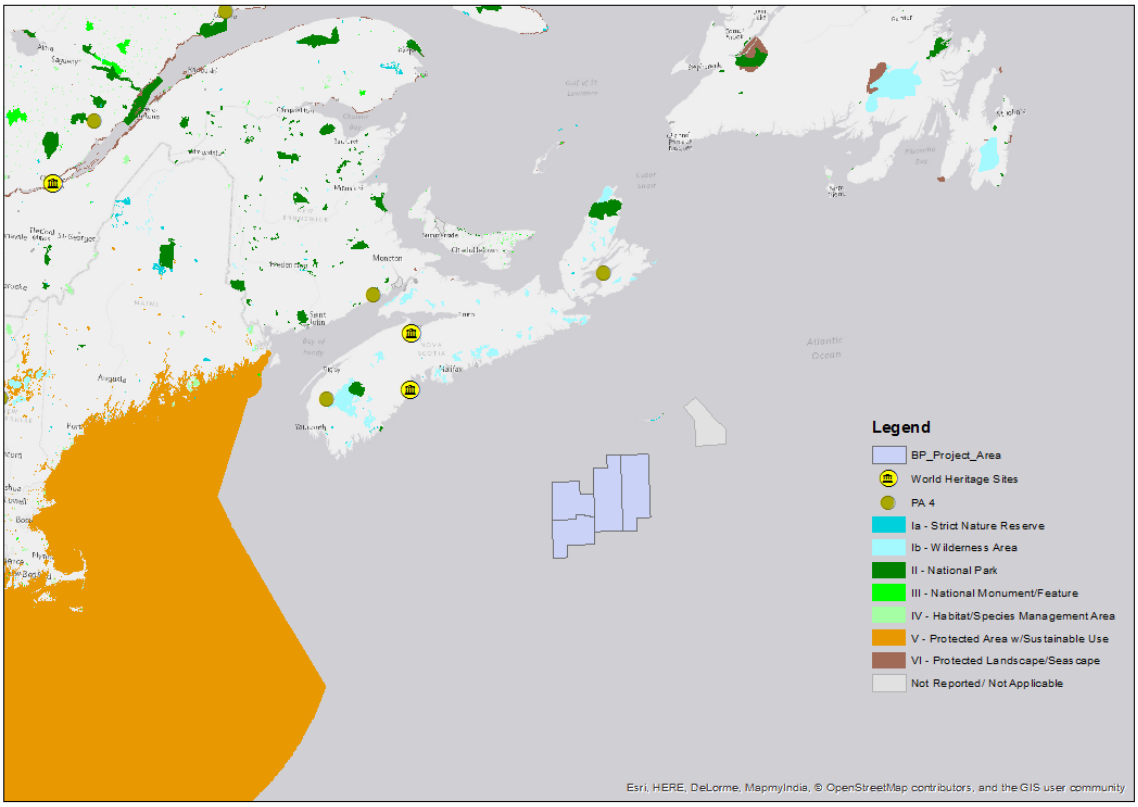


Figure 5.2 Scotian Shelf Offshore EBSAs

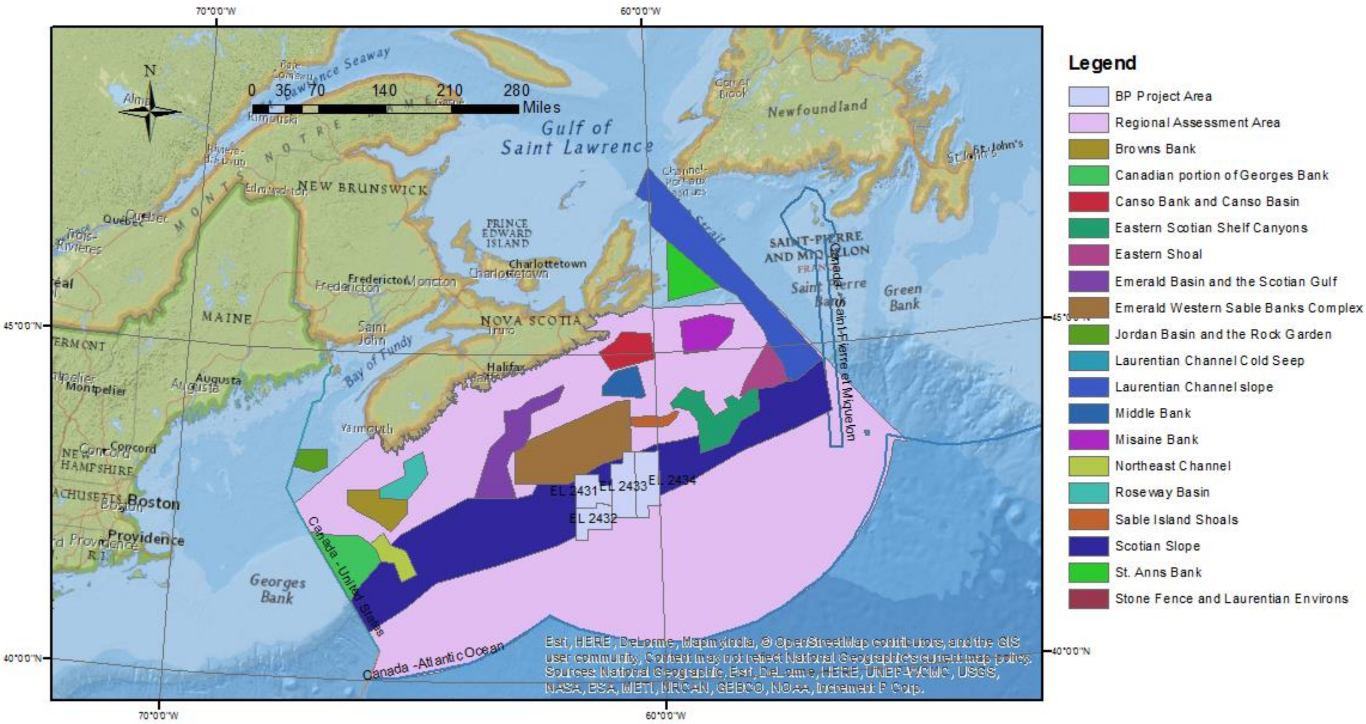
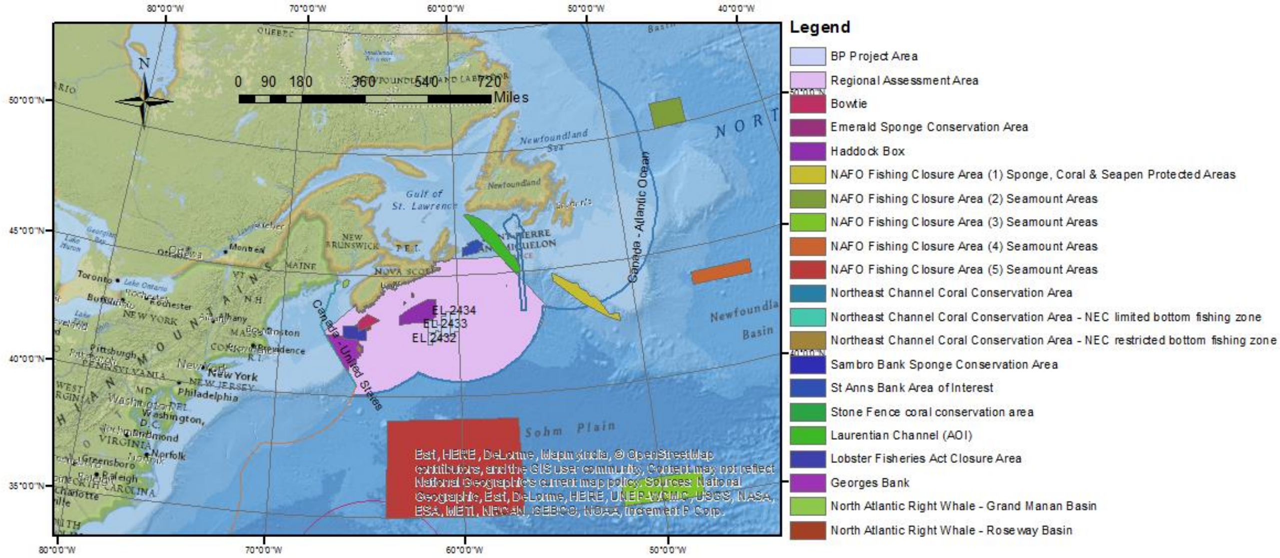
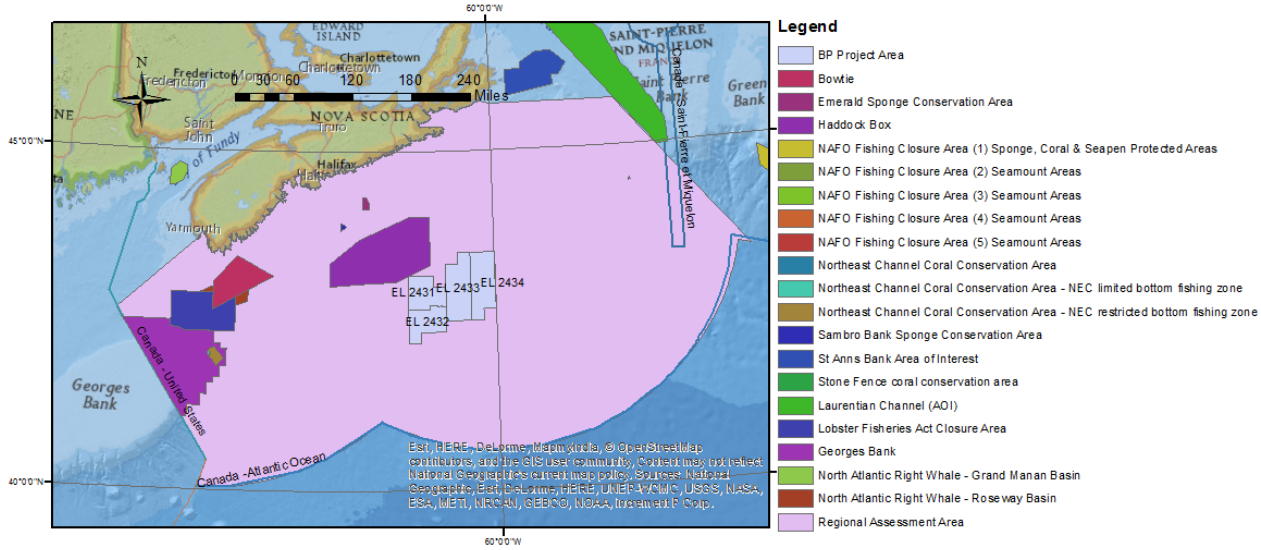


Figure 5.3 Other EBSAs considered in the Assessment

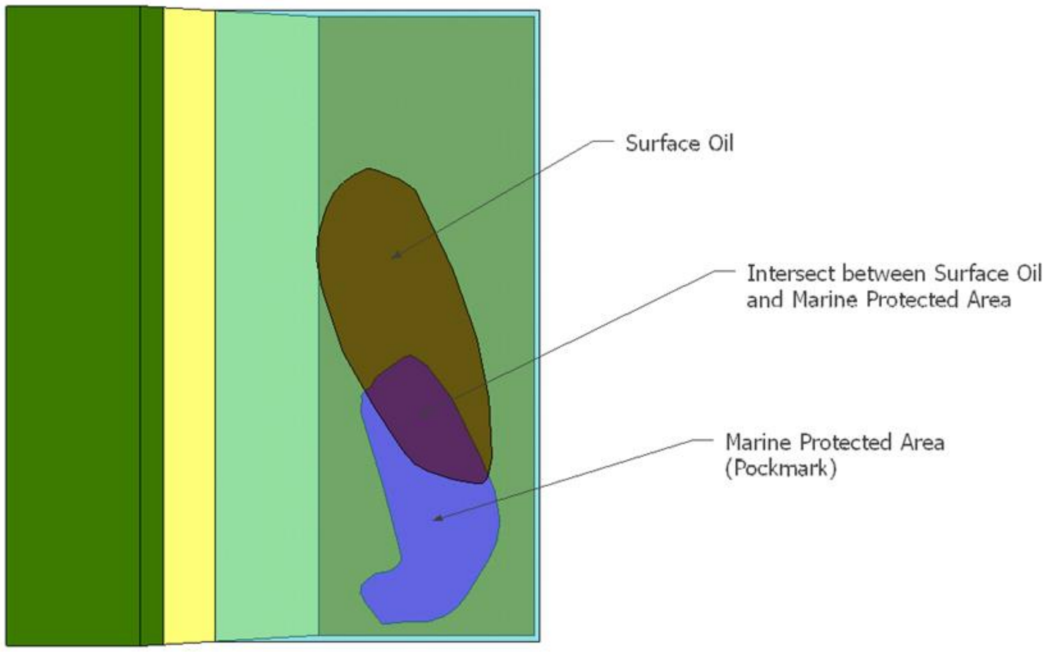


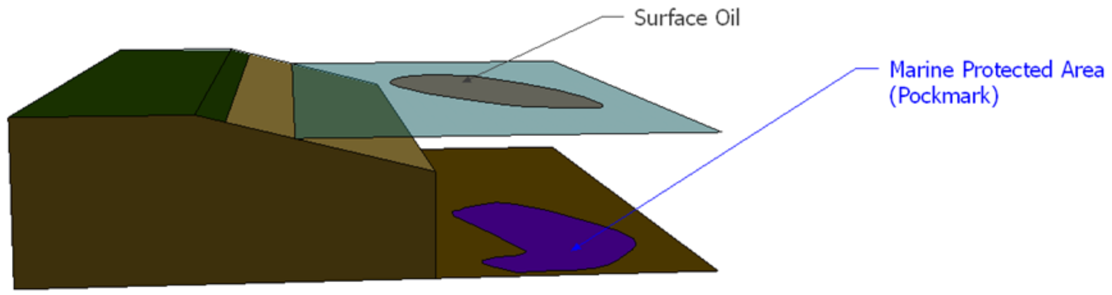


5.3 GIS Analysis

It should be noted that the approach for identifying marine protected/sensitive areas at risk from surface oiling is very conservative. Marine protected / sensitive areas may be designated for seabed features (such as pockmarks, trenches, corals etc.) and will not be directly impacted by the presence of surface oil or oil entrained in the upper water column. However, the intersection routines in the GIS analysis show locations where surface oil and upper water column probability outputs from OSCAR spatially overlap any protected/sensitive areas (Latitude and Longitude). This is the case even when the OSCAR outputs are vertically separated from the Marine protected / sensitive area (see Figure 5.4).

Figure 5.4 Diagram showing the representation of intersection function between surface oil and marine protected areas (top) and possible errors due to vertical separation between surface oil and marine protected areas on the seabed (bottom).

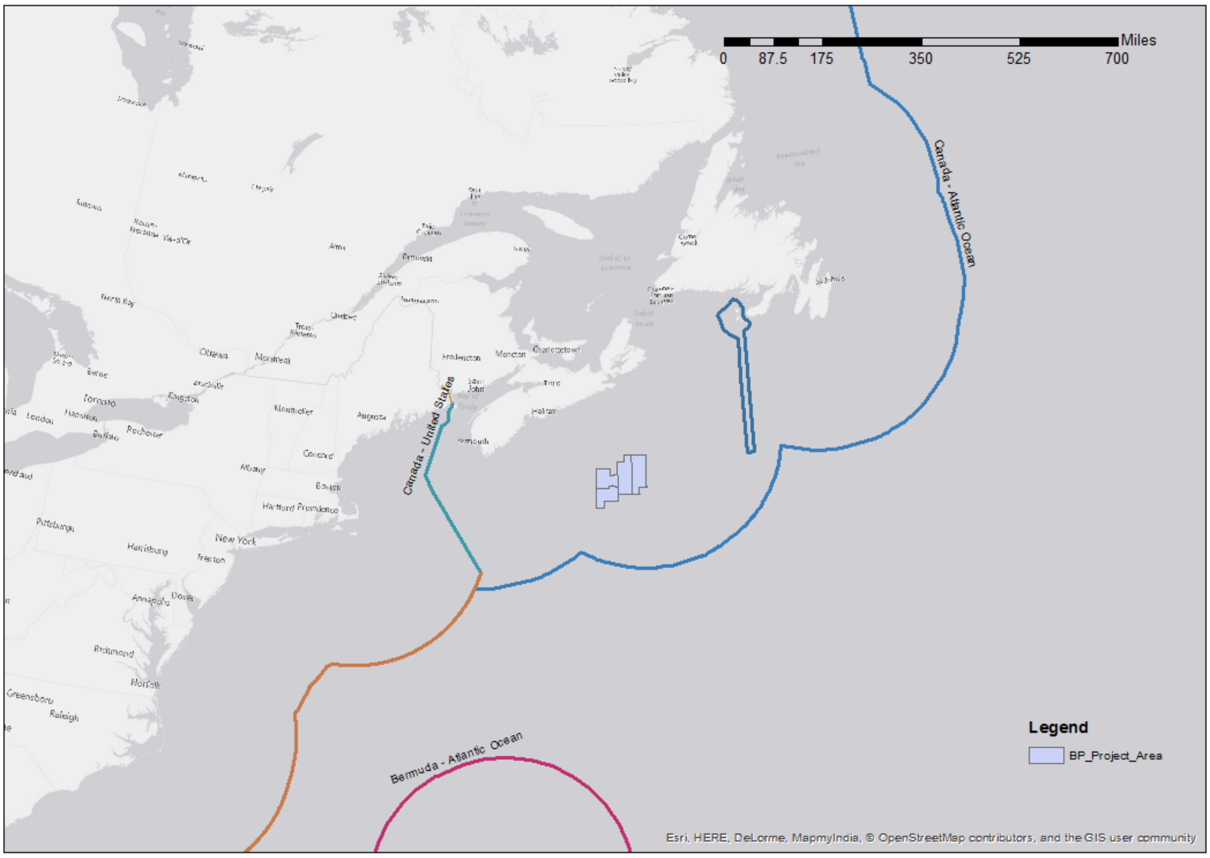




5.4 World Maritime Boundaries

A map showing the location of all relevant World Maritime Boundaries (WMBs) is provided in Figure 5.5.

Figure 5.5 Map showing Maritime Boundaries



6 NS-1 subsea well blowout modelling results

6.1 Stochastic results

A total of 210 individual, 30-day unmitigated releases were modelled for 120 day periods for both Site 1 (Case 1A) and Site 2 (Case 2A). Site 1 is a smaller volume and shallower water release of modelled spilled oil (24,890 bpd at a water depth of 2,104 m), while Site 2 was a larger volume of modelled spilled oil at a greater water depth (35,914 bpd at a depth of 2,652 m).

Separate stochastic simulations were carried out to represent the following weather "seasons":

- Winter season (November - April)
- Summer season (May to October)

The simulations were run at varying start times to cover each 6 month season using data for winds and currents from January 2006 through December 2010, thus ensuring that the predicted transport and oil weathering for each oil spill simulation is subjected to a range of prevailing wind and current conditions that is historically representative of the time period in question. Although each simulation has the same release information, they have differing trajectory paths, due to the varying start times and associated conditions.

During each simulation, the model records the grid cells contacted by the oil spill trajectory, as well as the time elapsed. Once the stochastic modelling is complete, OSCAR produces statistical outputs (see Section 2.2.2) that includes:

- Probability of sea surface, shoreline, or water column contact that may occur at a given grid cell;
- Minimum time before contact could occur at a given a grid cell
- Exposure time - duration of oil presence within a given grid cell
- Maximum mass / thickness / concentration of oil within a given grid cell

These model output estimators (probability and time) are calculated independently for each location in the grid. The stochastic model output does not represent the extent of any one oil spill event (which would be significantly smaller) but rather provides a summation of all possible extents and exposure risks above specified threshold levels for a given scenario.

Lower threshold limits on the surface thickness (0.04 µm), total concentration in the water column (58 ppb) and shoreline concentration (0.001 litres per sq. m) were applied pre-processing, i.e. thresholds were applied to each stochastic simulation output before statistical calculations were performed.

The following sections present a variety of statistical results from the simulations. Seasonal summaries of the stochastic analyses of potential surface oiling (Section 6.1.1) and water column dispersed and dissolved oil concentrations (Section 6.1.2) illustrate the locations of potential oil contamination in Canadian waters surrounding Nova Scotia and Newfoundland, US waters to the east of New England, and international waters south of Canada for Sites 1 and 2. Seasonal summaries of potential shoreline oiling statistics are presented in Section 6.1.3, with detailed maps for key areas (Sable Island, Nova Scotia, Maine coastline (USA) Saint Pierre and Miquelon (France), Grand Bank / Fortune Bay (Newfoundland)) presented in Appendix 4.

While the modelling demonstrates a potentially large affected area, it is important to note that many of the areas delineated through the modelling have low probabilities of occurrence and that results are based on an unmitigated capping stack release scenario with no other response mitigation measures implemented. In an actual incident, emergency response measures inclusive of containment and recovery operations are likely to have some effect on limiting the magnitude and duration of the spill event and thereby limiting the geographic extent and potential environmental effects of a blowout event.

6.1.1 Sea Surface Results

Statistical results from the stochastic simulations are presented in the following statistical maps based on all 210 runs completed for the summer and winter scenarios:

- Probability of Surface Oiling (Figures 6.1 and 6.2)
    - Contour map showing the probability of emulsified oil being present on the sea surface at the sheen thickness threshold >0.04 µm (lower limit of visible oil on the sea surface)
- Minimum Travel Time of Surface Emulsified Oil (Figures 6.3 and 6.4)
    - Contour map showing the quickest time (from all the stochastic trajectories) before emulsified oil is present on the sea surface at thicknesses > 0.04µm.
- Maximum Exposure Time of Surface Emulsified Oil (Figures 6.5 and 6.6)
    - Contour map showing the longest time (from all the stochastic simulations) that emulsified oil is present within a surface grid cell at thicknesses > 0.04 µm.
- Maximum Emulsified Oil Thickness (Figures 6.7 and 6.8)
    - Contour map showing the maximum of time-averaged emulsified oil thicknesses calculated for each surface grid cell at the end of each stochastic trajectory (only surface oil thickness values exceeding the 0.04 µm thickness threshold are included in the time-average calculation. Thicknesses are presented as groups accounting to the Bonn Agreement Oil Appearance Code (BAOAC).
- Average of Time-Averaged Emulsified Oil Thickness (Figures 6.9 and 6.10)
    - Contour map showing the average of time-averaged emulsified oil thicknesses calculated for each surface grid cell at the end of each stochastic trajectory (only surface oil thickness values exceeding the 0.04 µm thickness threshold are included in the time-average calculation. Thicknesses are presented as groups accounting to the Bonn Agreement Oil Appearance Code (BAOAC).

The modelling results predict that the majority of oil will remain in offshore waters with a <20% probability that surface oil exceeding the 0.04 µm (Bonn Agreement Oil Appearance

Code (BAOAC) "Sheen") will enter near shore waters of Nova Scotia for both the summer and winter scenarios (Figure 6.1 and 6.2). In the event that surface oil was to enter the near-shore area of Nova Scotia, it would take a minimum of between 30 to 50 days to arrive (Figures 6.3 and 6.4).

In the summer season, the extent of the area with greater than 50% probability of contamination measured approximately 920 km by 465 km in the respective E - W and N - S directions at its maximum extent for Site 2.

The duration of surface exposure for near shore waters of Nova Scotia was 0 to 2 days. The low surface exposure times suggests that the complex coastal circulation patterns and the turbulent nature of the sea in the region are continually mixing any surface oil into the upper water column reducing exposure time on surface. Exposure times increase on approaching the release site. For example, in the worst exposure scenario (Site 2, summer season) Figure 6.6 shows that the area where oil might be present on the surface for > 7 days measures 1,010 km by 450 km in the respective SW – NE and NW to SE directions at its maximum extent.

Some seasonal variation in the movement of oil following a release is expected. Oil is more likely to be transported further towards the South and Southwest under winter conditions (Figures 6.1 and 6.2), due to the stronger South Westerly surface currents in winter (see Section 4.3.2 and Appendix 2, Figure A2.1). In summer, the trajectory movement is more uniform, but still with multi-directional transport patterns and a higher frequency of transport towards the South and East, especially for Site 2. In summer, the prevailing winds from the West have more of an influence in transporting surface oil to the East.

The higher wind speeds and associated waves in winter result in significantly more entrainment, reducing the spatial extent of thick oil on the sea surface (Figures 6.7 – 6.10).

The stochastic results have demonstrated the potential locations for spill effects exceeding threshold levels beyond the RAA boundary, and in some cases, beyond Canadian jurisdiction (See Section 6.3 and Appendix 5). Figure 6.61 illustrates the average probability of transboundary effects from an unmitigated spill (Site 1 summer season). Assuming no mitigation, the model estimates a 16% probability of surface oil resulting as a sheen (0.04 µm surface layer thickness) within the international boundaries of Saint-Pierre and Miquelon (France), which could occur in a minimum of 12 days of a blowout event, but would generally average 34 days for the minimum arrival time. For Site 1 in the summer, the average probability of an unmitigated spill resulting in surface oiling exceeding the threshold level within the US waters is approximately 7% (with a minimal arrival time of approximately 22 days but on average a minimum of 55 days); this average probability increases to 14% for Site 2 in winter with similar minimum arrival times (Figure 6.68). The average probability of an unmitigated spill resulting in surface oiling exceeding the threshold level within the waters of Bermuda is approximately 2%, with a minimum arrival time of approximately 44 days but on average a minimum of 60 days.

The potential for surface oil to intersect Protected Areas and EBSAs is presented in Section 6.3 and Appendix 5.

For Sable Island where there is a 28% probability of surface oiling exceeding the 0.04 µm sheen thickness threshold, based on stochastic modelling results for Site 1 (summer season), which is the worst-case scenario. The average minimal arrival time for the oil to reach Sable Island using this threshold is predicted to be 8 days with an average maximum exposure time of 4 days. The maximum time-averaged thickness of surface oil may reach more than 200 µm (BAOAC "Continuous True Oil Colour"); however, the average time-averaged thickness is predicted to be less than 50 µm (see Appendix 5 Table A5.9).

Stochastic modelling predicts the average probability of surface oiling (exceeding a thickness of 0.4 µm) reaching the Gully marine protected area (MPA) to be approximately 61% during the summer season (worst case scenario). The maximum exposure time for surface oil exceeding the 0.04 µm threshold in the Gully is 4 to 7 days. The maximum time-averaged thickness of surface oil predicted in the Gully MPA may reach more than 200 µm; however, the average time-averaged thickness is predicted to be less than 50 µm.

There is a moderate probability of surface oiling (in excess of 0.04 µm) reaching the Emerald Basin (45 – 58%) and Georges Bank (0 – 30%). Predictive modelling indicates that the length of time for an unmitigated blowout event to reach threshold thicknesses (0.04 µm for surface oiling) at Emerald Basin or Georges Bank would be between approximately 6 to 20 days for Emerald Basin and 30 to 42 days for George's Bank.

Figure 6.1 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical contour maps showing the probability of sea surface emulsified oil thicknesses exceeding the 0.04 μm (BAOAC "Sheen") thickness threshold for probabilities > 5%

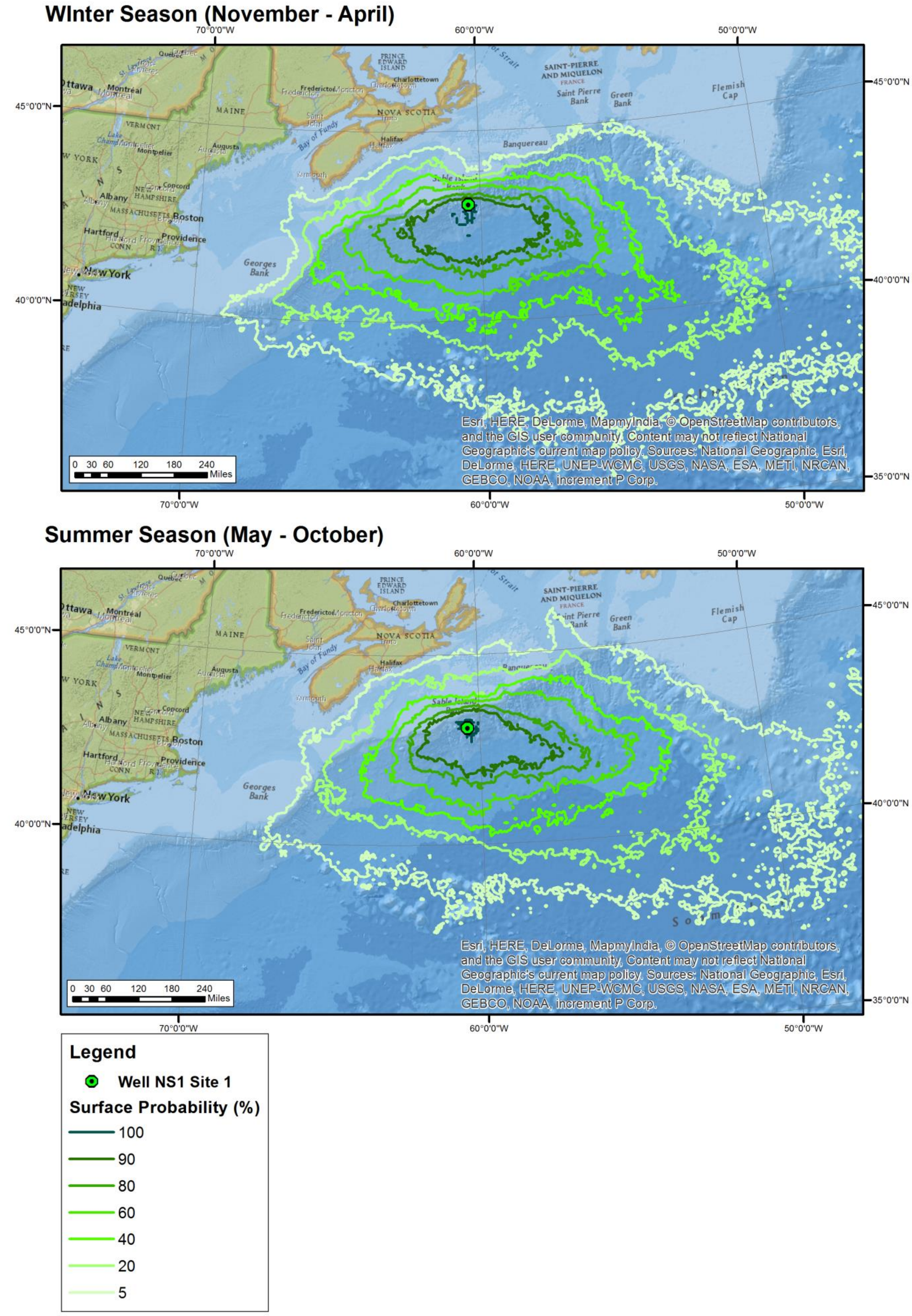


Figure 6.2 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical contour maps showing the probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold for probabilities > 5%

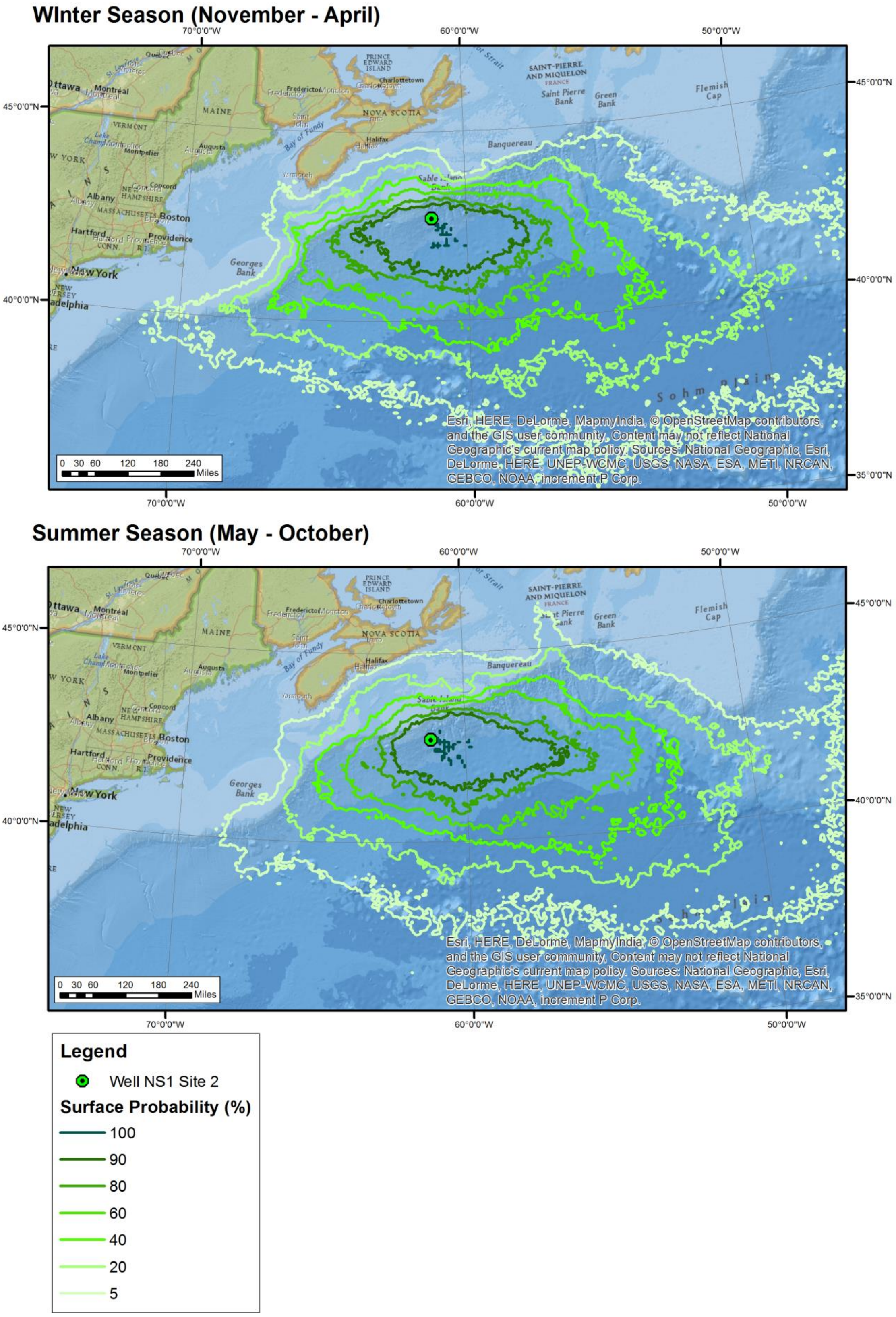


Figure 6.3 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical contour maps showing the minimum travel time before the emulsified oil thicknesses on the sea surface exceed the 0.04µm (BAOAC “Sheen”) thickness threshold. No probability threshold is applied due to limited functionality in OSCAR. This explains the slightly larger extent than shown in the surface emulsified oil probability maps

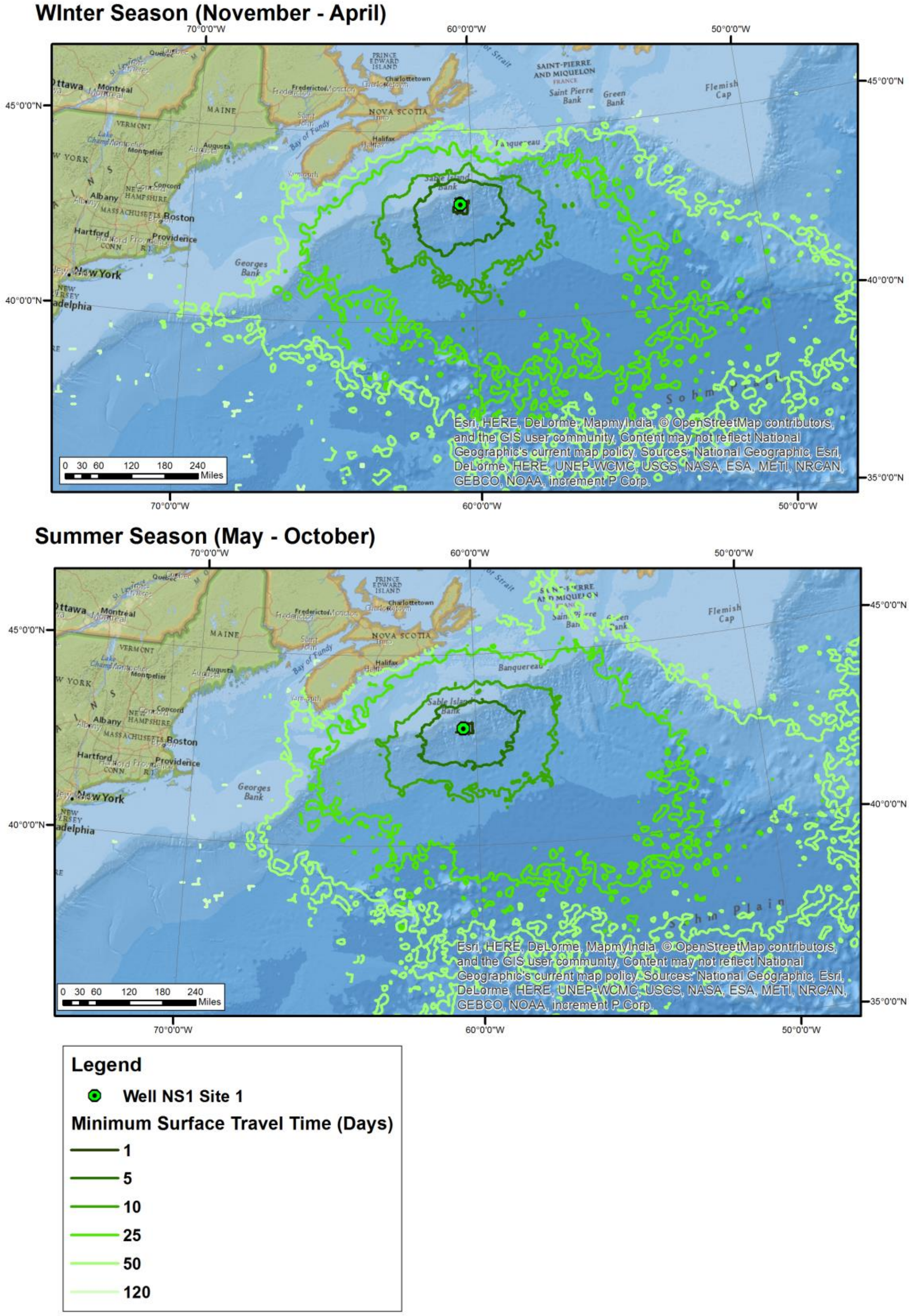


Figure 6.4 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical contour maps showing the minimum travel time before the emulsified oil thicknesses on the sea surface exceed the 0.04µm (BAOAC "Sheen") thickness threshold. No probability threshold is applied due to limited functionality in OSCAR. This explains the slightly larger extent than shown in the surface emulsified oil probability maps

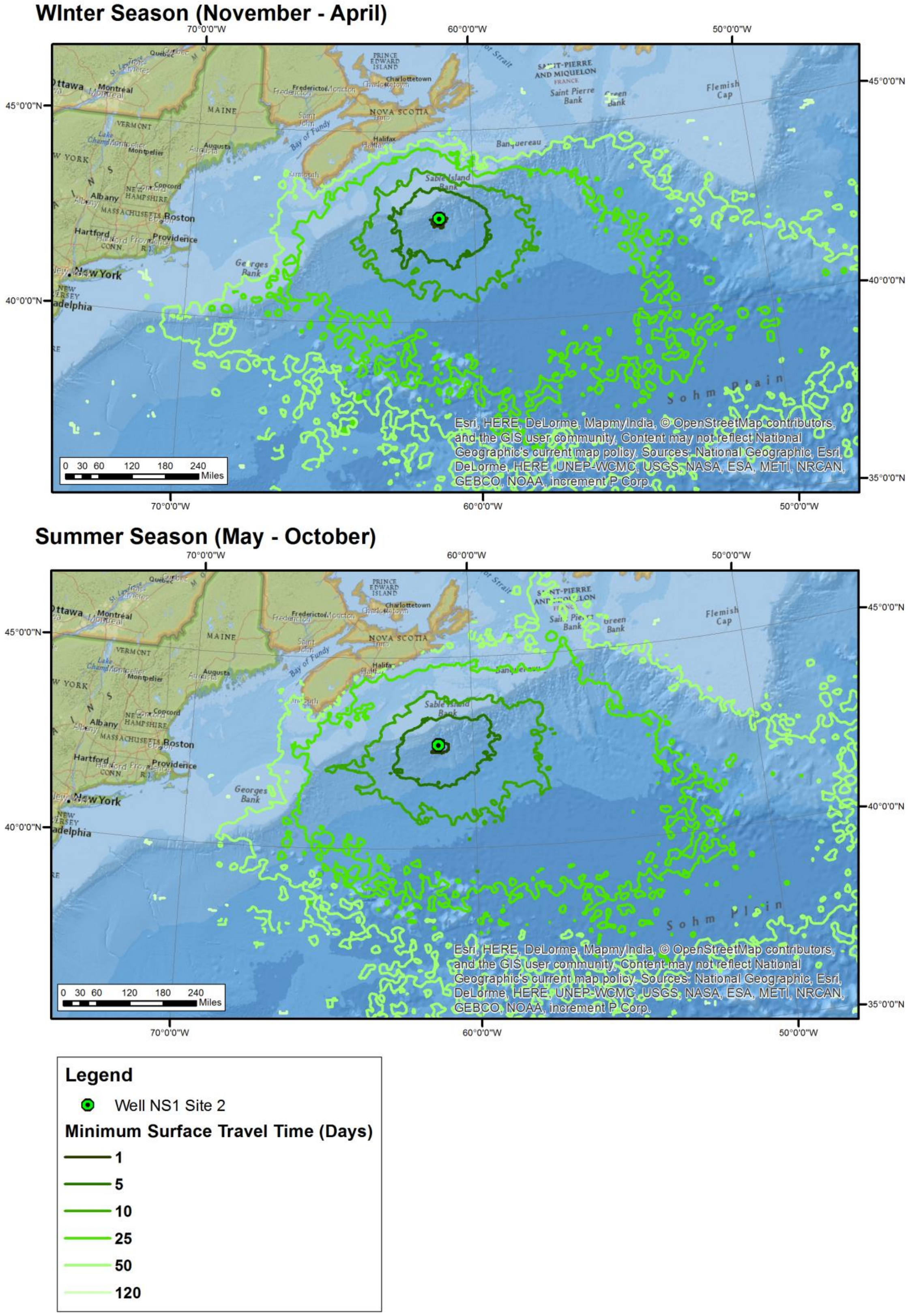


Figure 6.5 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the maximum exposure time for emulsified oil thicknesses on the sea surface which exceed the 0.04µm (BAOAC “Sheen”) thickness threshold. No probability threshold is applied due to limited functionality in OSCAR. This explains the slightly larger extent than shown in the surface emulsified oil probability maps

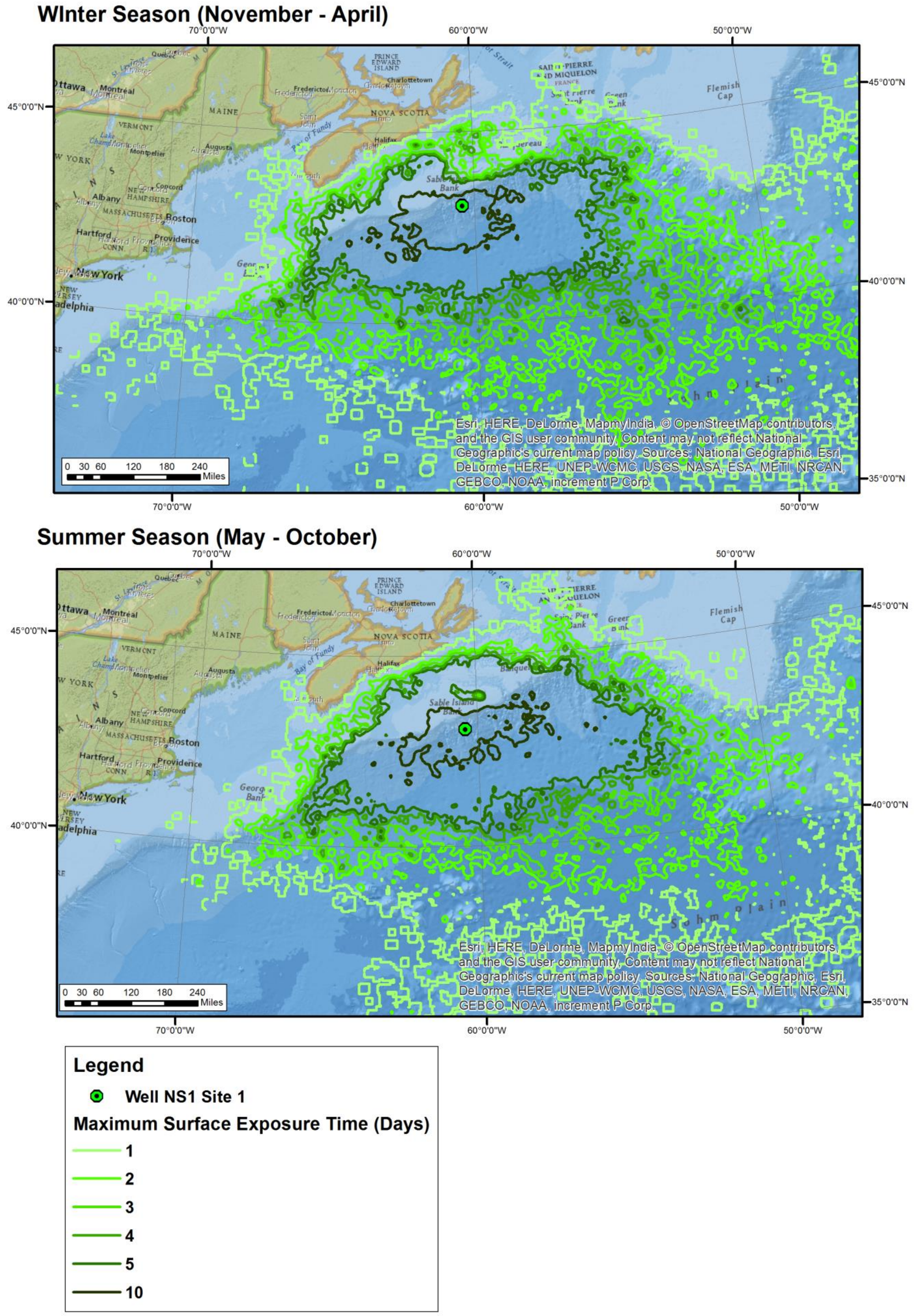


Figure 6.6 Case 2A: Well NS- capping stack containment scenario (30 day duration). Statistical contour maps showing the maximum exposure time for emulsified oil thicknesses on the sea surface which exceed the 0.04µm (BAOAC "Sheen") thickness threshold. No probability threshold is applied due to limited functionality in OSCAR. This explains the slightly larger extent than shown in the surface emulsified oil probability maps

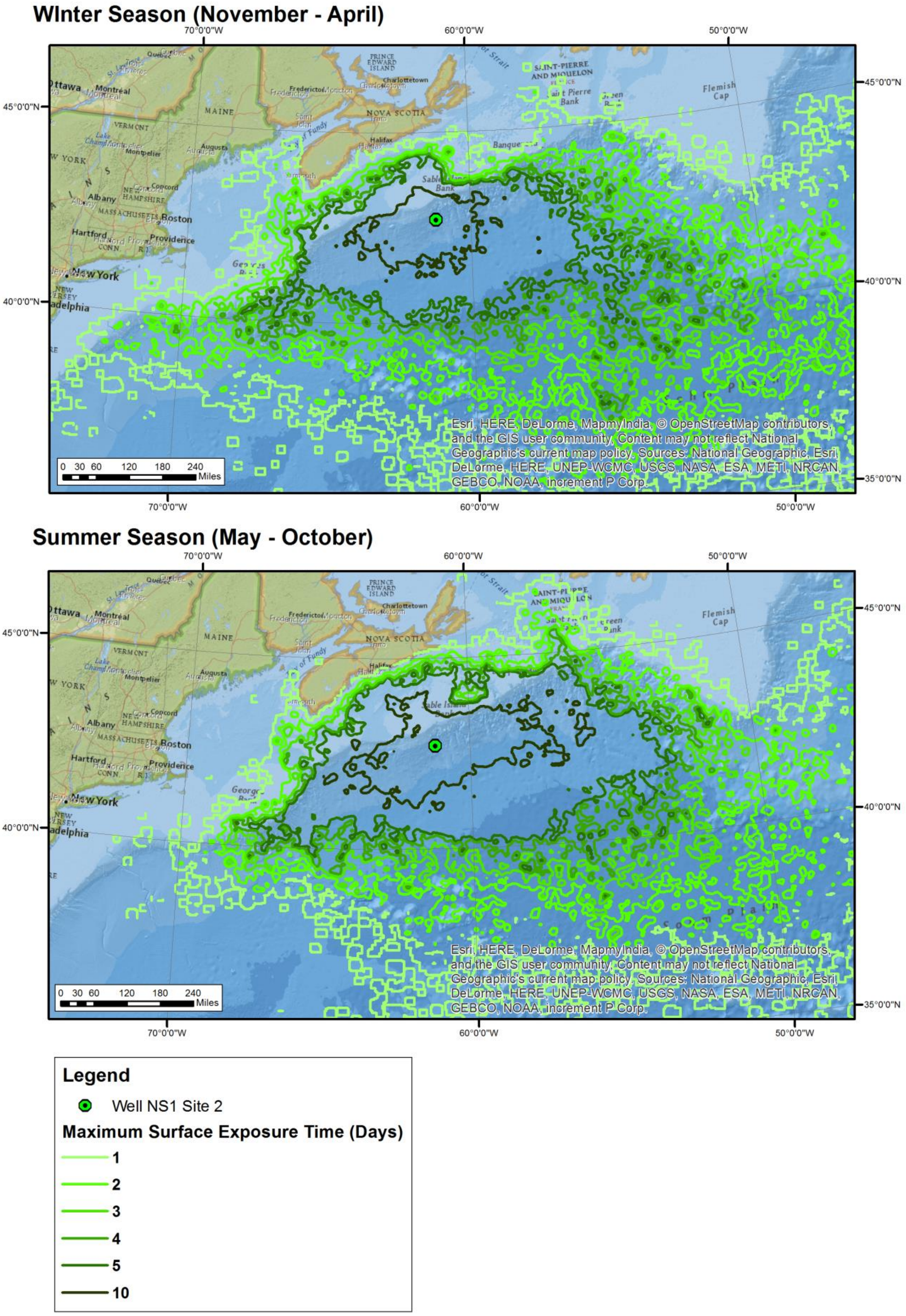
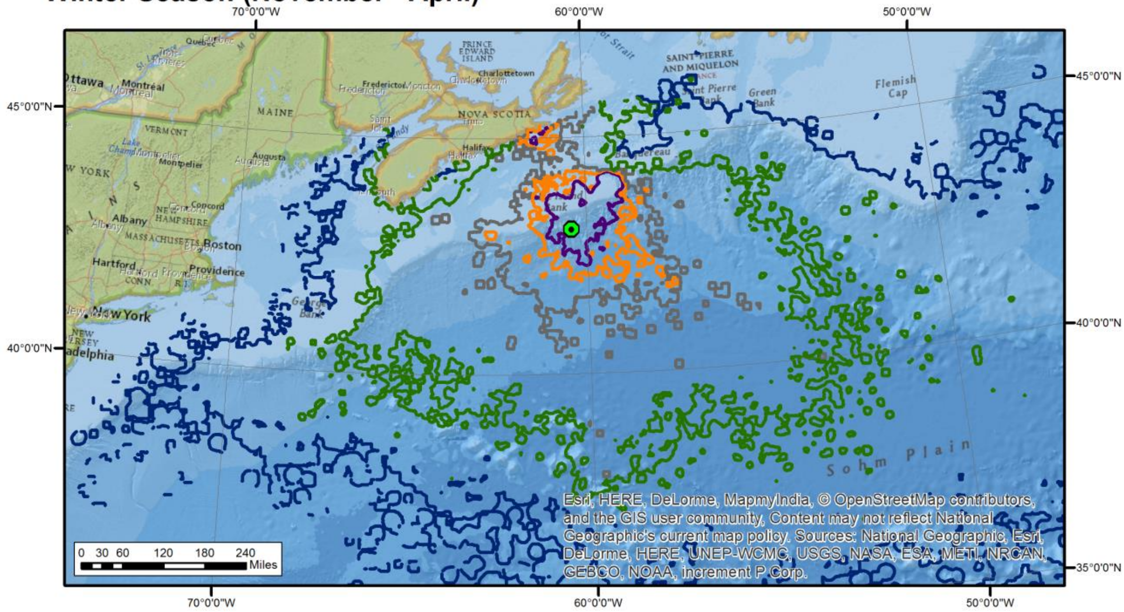


Figure 6.7 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the maximum time-averaged emulsified oil thickness on the sea surface (0.04µm BAOAC "Sheen" thickness threshold applied). No probability threshold is applied due to limited functionality in OSCAR. This explains the slightly larger extent than shown in the surface emulsified oil probability maps

WInter Season (November - April)



Summer Season (May - October)

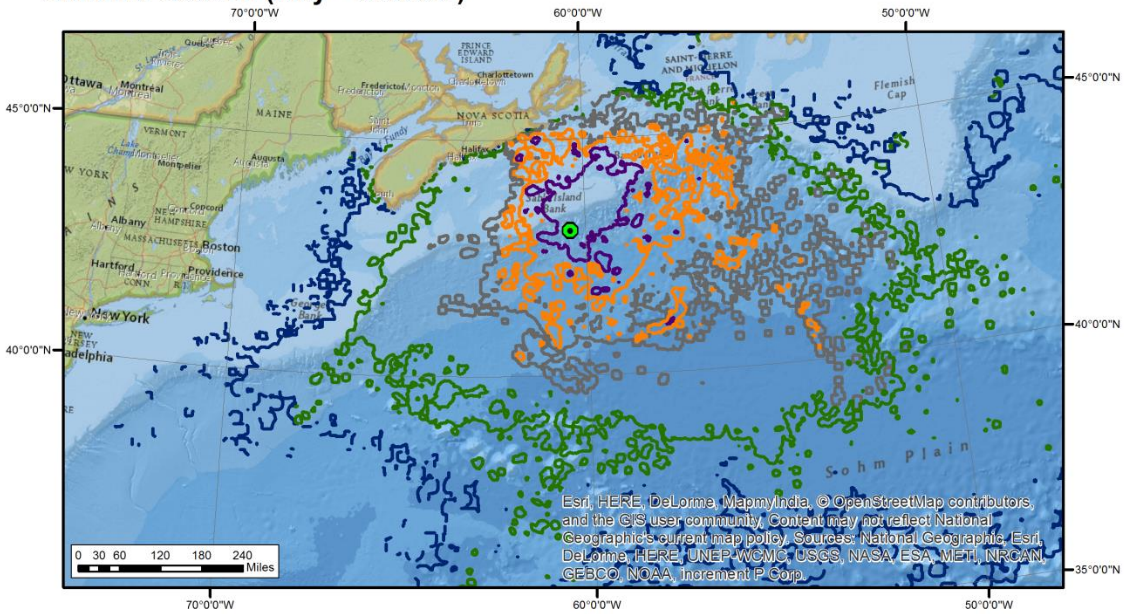


Figure 6.8 *Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the maximum time-averaged emulsified oil thickness on the sea surface (0.04µm BAOAC "Sheen" thickness threshold applied). No probability threshold is applied due to limited functionality in OSCAR. This explains the slightly larger extent than shown in the surface emulsified oil probability maps*

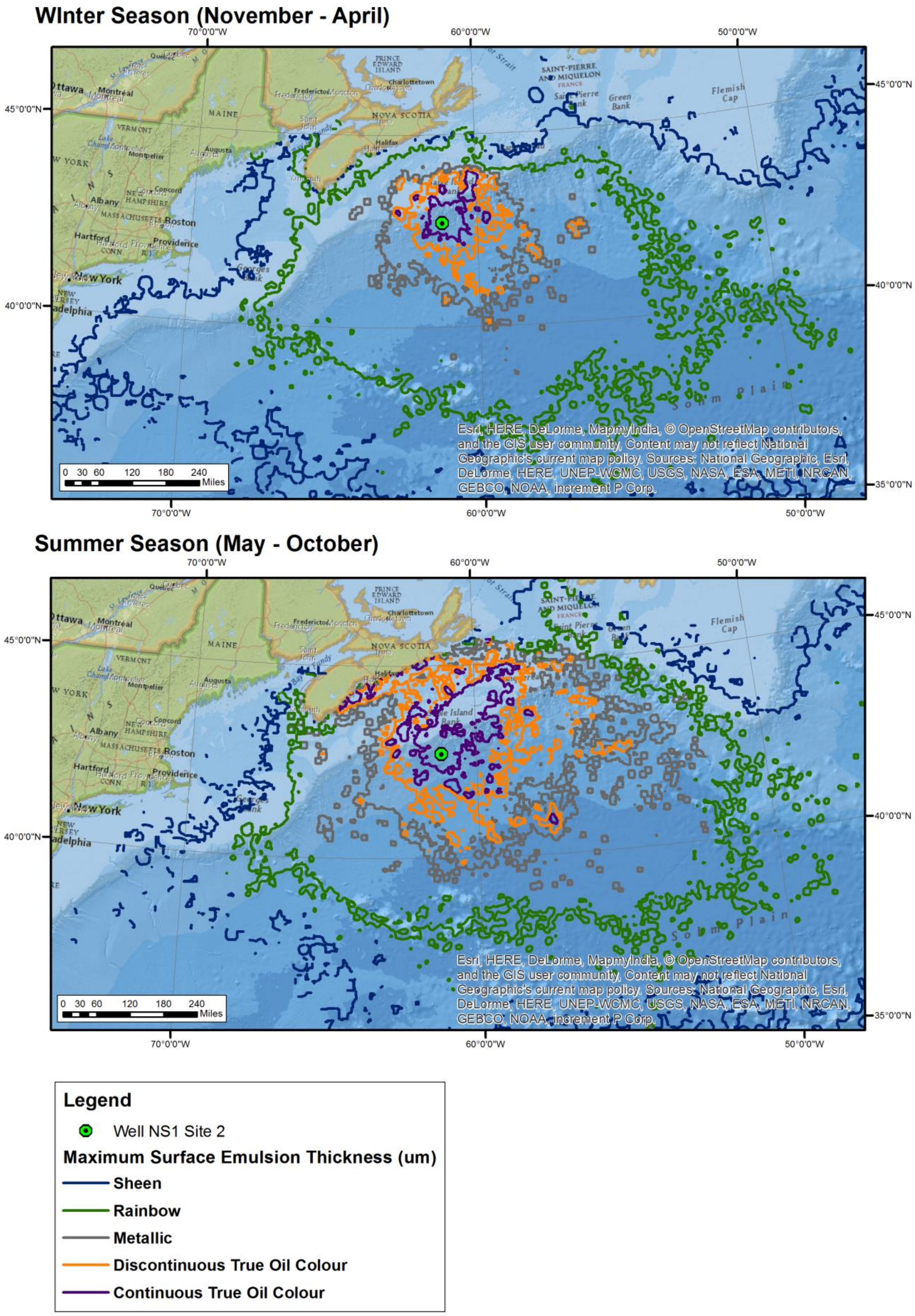


Figure 6.9 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the average of time-averaged emulsified oil thickness on the sea surface (0.04µm BAOAC "Sheen" thickness threshold applied). No probability threshold is applied due to limited functionality in OSCAR. This explains the slightly larger extent than shown in the surface emulsified oil probability maps

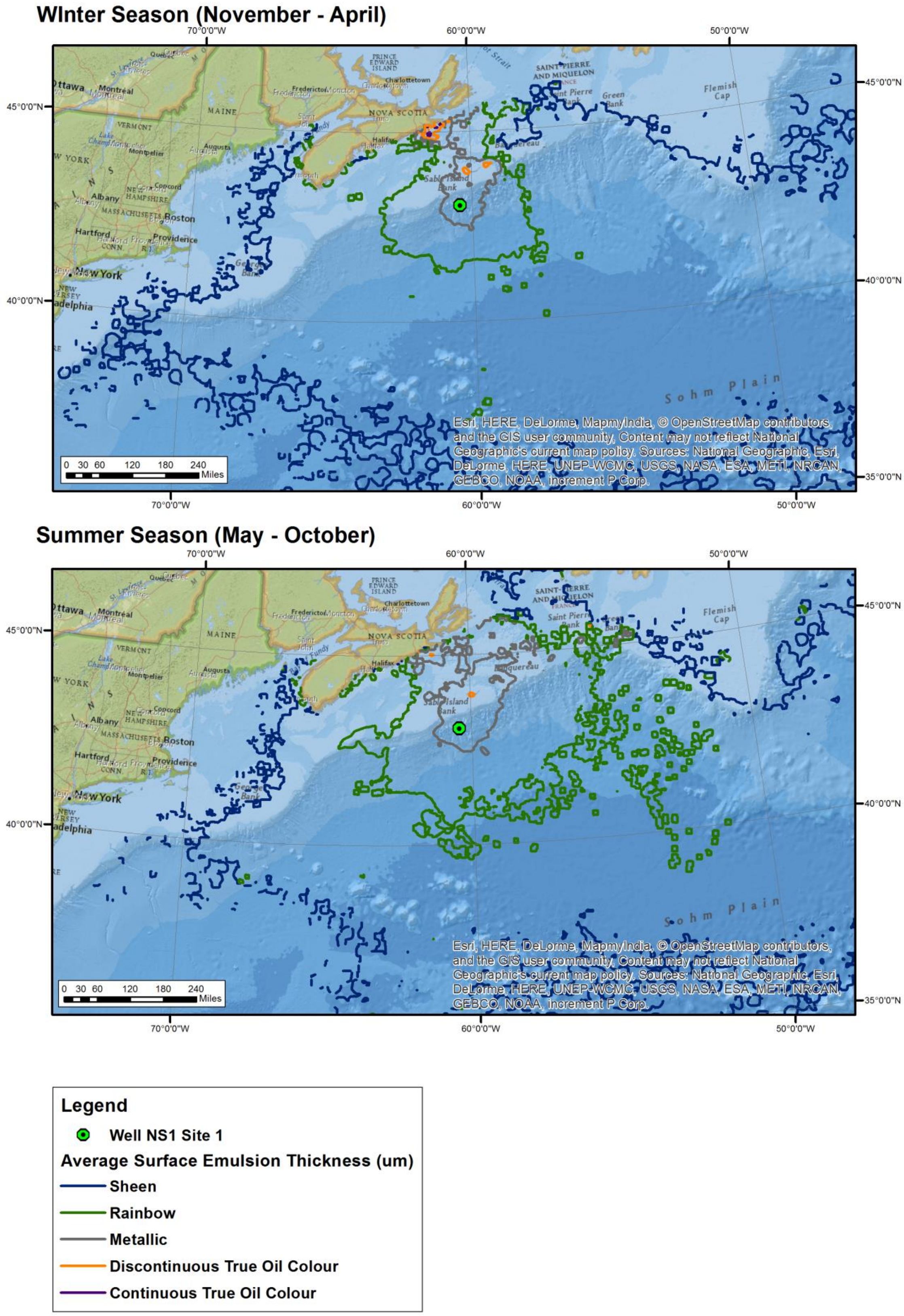
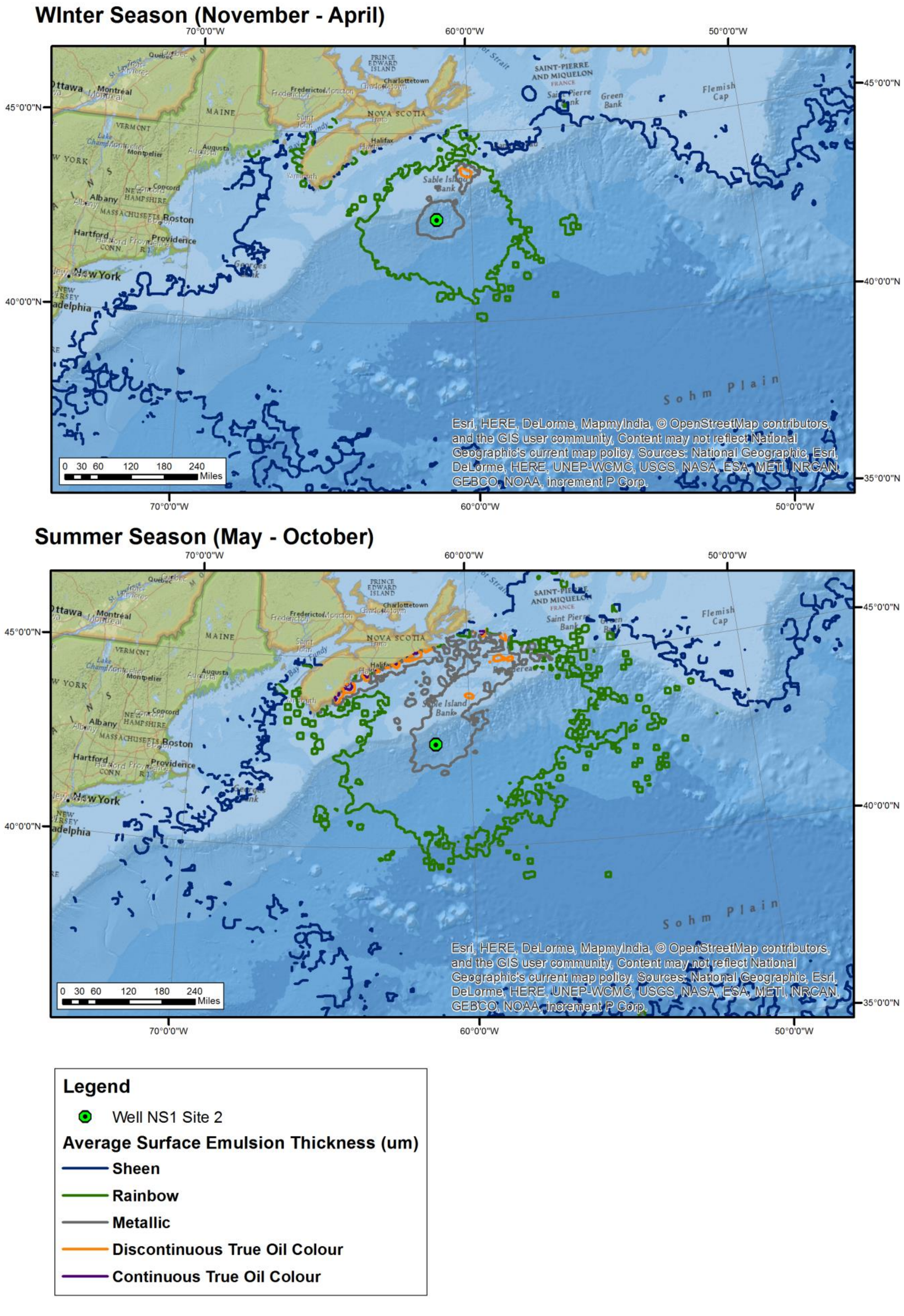


Figure 6.10 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the average of time-averaged emulsified oil thickness on the sea surface (0.04µm BAOAC "Sheen" thickness threshold applied). No probability threshold is applied due to limited functionality in OSCAR. This explains the slightly larger extent than shown in the surface emulsified oil probability maps



6.1.2 Water Column Results

Seasonal summaries from the stochastic simulations are presented in the following statistical maps based on all 210 runs completed for the summer and winter scenarios:

- Probability of Water Column Contamination (Figures 6.11 and 6.12)
  - Contour map showing the probability of oil being present in the water column at total hydrocarbon (THC) concentrations (dispersed and dissolved oil) exceeding the 58 ppb THC threshold level.
- Minimum Travel Time of Oil in the Water Column (Figures 6.13 and 6.14)
  - Contour map showing the quickest time (from all the stochastic trajectories) before the THC concentration in any water column grid cell exceeds the 58 ppb THC concentration threshold.
- Maximum Exposure Time of Oil in the Water Column (Figures 6.15 and 6.16)
  - Contour map showing the longest time (from all the stochastic trajectories) that the THC concentration in any water column grid cell exceeds the 58 ppb THC concentration threshold.
- Maximum Time-Averaged THC Concentration in the Water Column (Figures 6.17 and 6.18)
  - Contour map showing the maximum of time-averaged THC concentration values calculated for each water column grid cell at the end of each stochastic trajectory (only concentration values exceeding the 58 ppb THC threshold are included in the time-average calculations)
- Maximum Time-Averaged Dissolved Oil Concentration in the Water Column (Figures 6.19 and 6.20)
  - Contour map showing the maximum of time-averaged dissolved oil concentration values > 1 ppb calculated for each water column grid cell at the end of each stochastic trajectory (only concentration values exceeding the 58 ppb THC threshold are included in the time-average calculations)

The in-water dispersed and dissolved oil threshold exceedance of 58 ppb for total hydrocarbons (THC) is expected to remain in offshore waters with a smaller areal extent than for surface oil thicker than 0.04 µm (Figure 6.11 and 6.12). The modelling results indicate that the in-water oil exceedance will not reach the near shore waters of mainland Nova Scotia.

The results indicate that the minimum time for in-water oil concentrations >58 ppb to arrive at the maximum distance from the well is between 50 and 75 days (see Figures 6.13 and 6.14). As noted in Section 6.1.1, well intervention response strategies could be implemented within 2 to 5 days for BOP intervention and the well could be capped between 13 and 25 days thereby decreasing the spatial extent of a spill. These activities were not factored into the model in order to demonstrate the worst-case scenario of an unmitigated blowout. Exposure time to oil concentrations above 58 ppb is also contingent on spill response time.

For these unmitigated scenarios, the predicted distance from the well site where exposure to in-water concentrations of oil > 58 ppb may exceed 14 days ranges from circa 50 to 100 km, while in-water exposure time of <1 day may be expected at the outer extent of the predicted threshold exceedance area.

Although the winter (November to April) scenario predicts that no in-water oil will reach Sable Island, there is a 5% probability that in-water oil concentrations will exceed the threshold around Sable Island for the summer (May to October) scenario. The minimum arrival times for in-water oil concentrations exceeding the threshold to waters surrounding Sable Island in the summer is predicted to be between 10 and 20 days.

Applying the 58 ppb total hydrocarbon threshold for effects to fish (an in-water concentration of dissolved and entrained oil in the top 100 m), these levels are most likely to be encountered on the Scotian Slope, with 7 to 11% average probability of these levels occurring in the Haddock Box and 9 to 13% average probability of these levels reaching the Emerald, Western, and Sable Banks on the shelf (see Section 6.3 and Appendix 5).

Figure 6.11 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the probability of the total hydrocarbon concentration (dispersed and dissolved oil) in the water column exceeding the 58 ppb threshold concentration level for any grid cell in the top 100 m of water column over the simulation period based on all simulations for probabilities > 5%

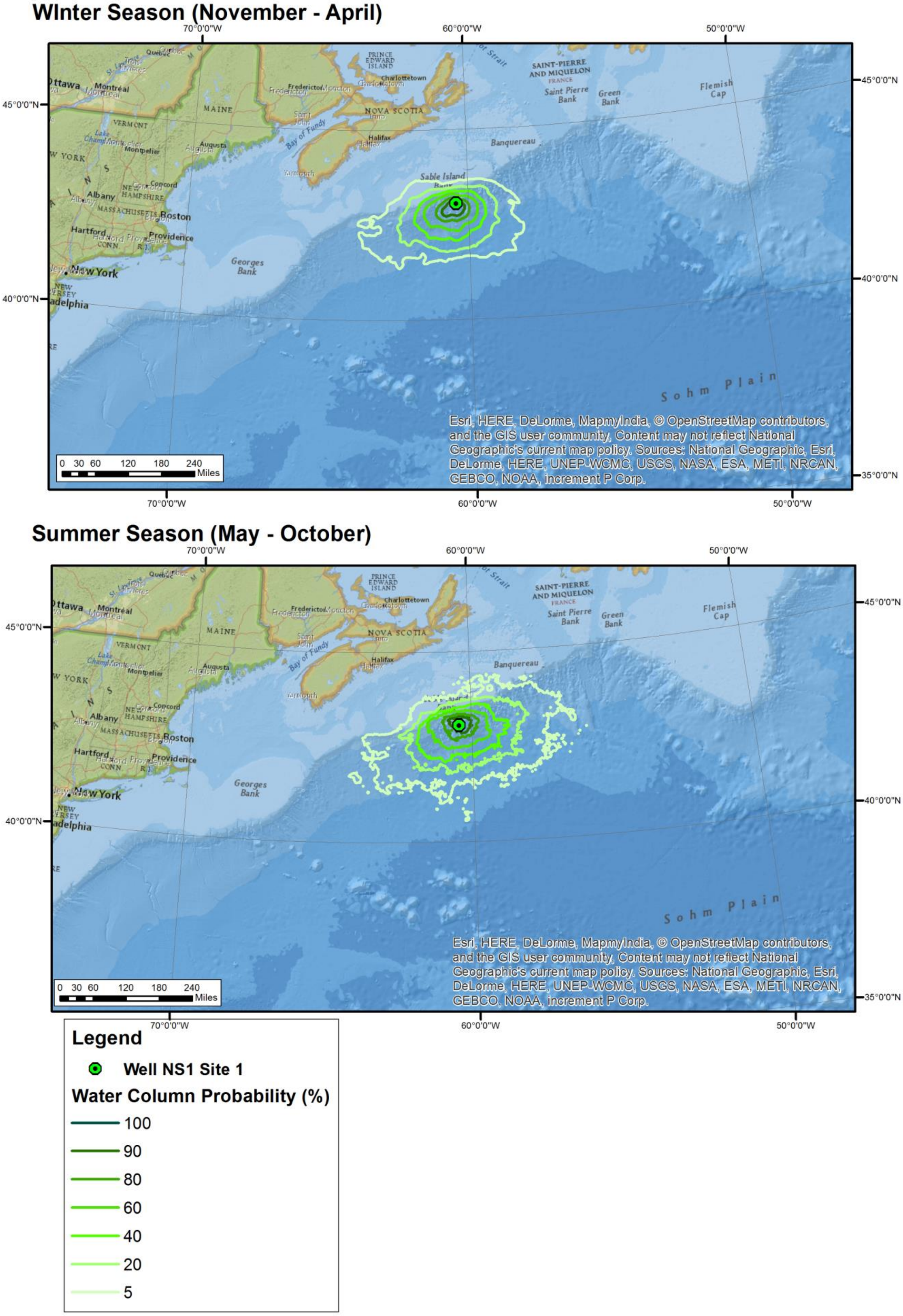


Figure 6.12 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the probability of the total hydrocarbon concentration (dispersed and dissolved oil) in the water column exceeding the 58 ppb threshold concentration level for any grid cell in the top 100 m of water column over the simulation period based on all simulations for probabilities > 5%

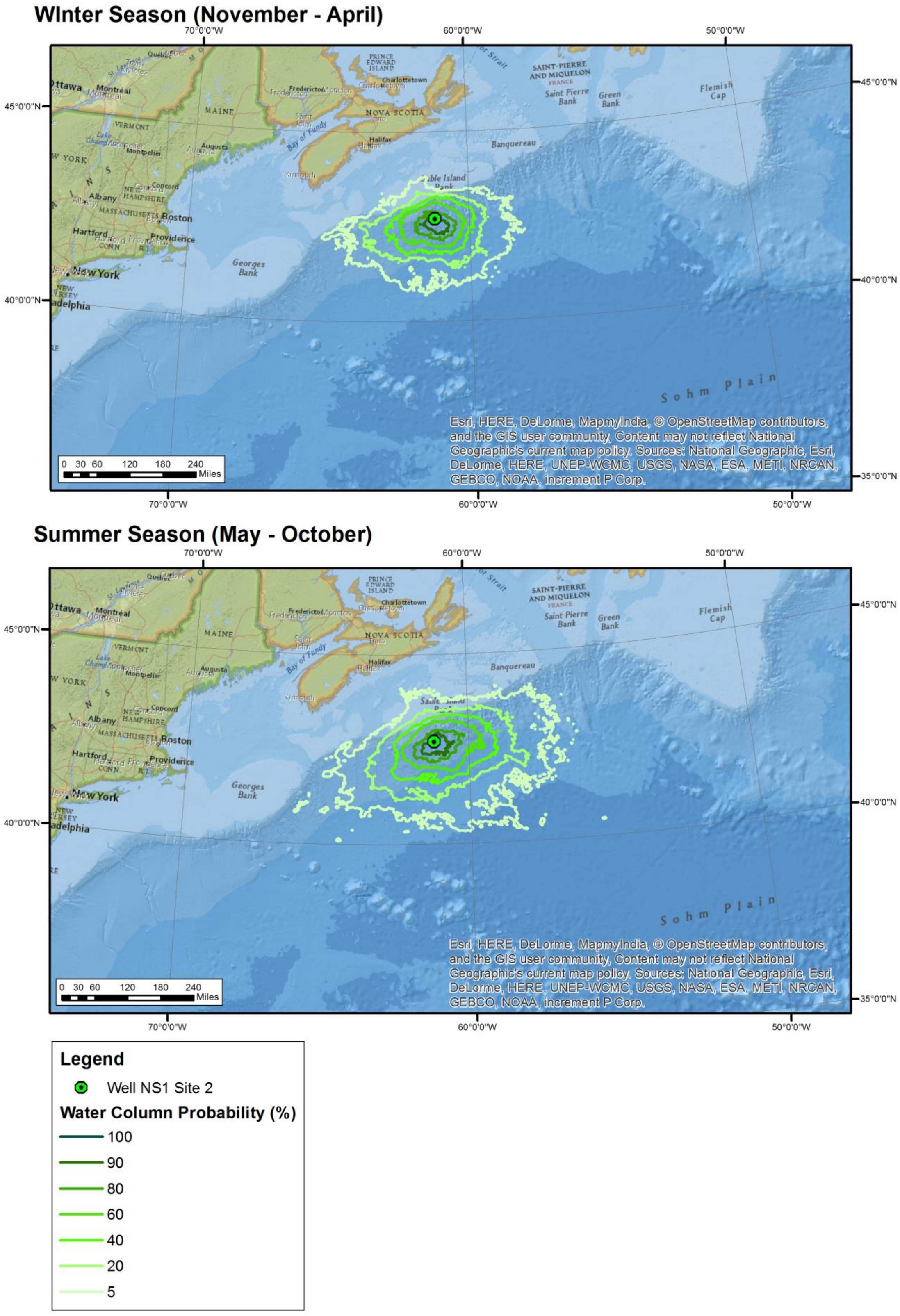


Figure 6.13 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the minimum time before the total hydrocarbon concentration (dispersed and dissolved oil) within any grid cell in the top 100 m of water column exceeds the 58 ppb THC concentration threshold (based on all stochastic trajectories, no probability limit applied)

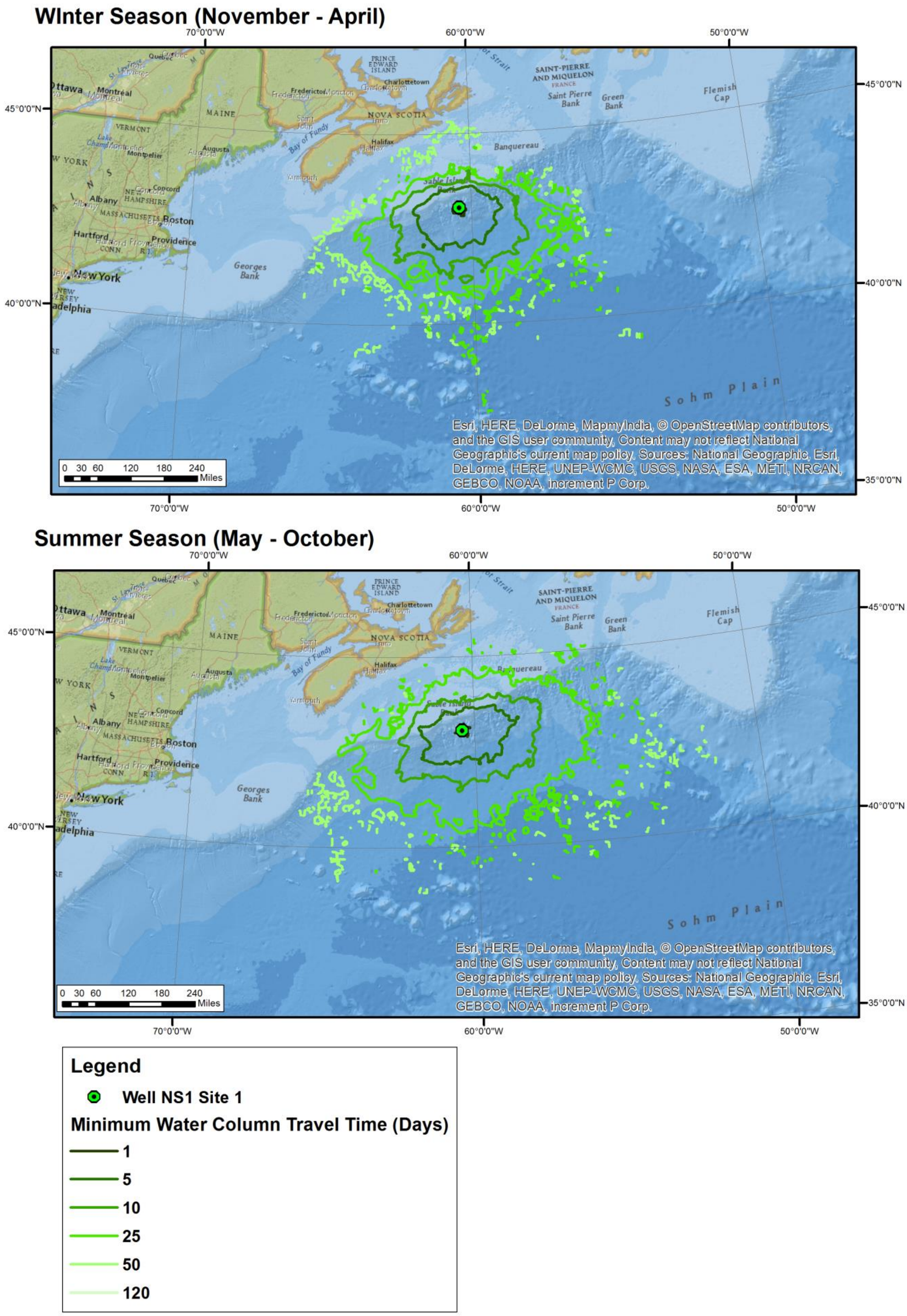


Figure 6.14 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the minimum time before the total hydrocarbon concentration (dispersed and dissolved oil) within any grid cell in the top 100m of water column exceeds the 58 ppb THC concentration threshold (based on all stochastic trajectories, no probability limit applied)

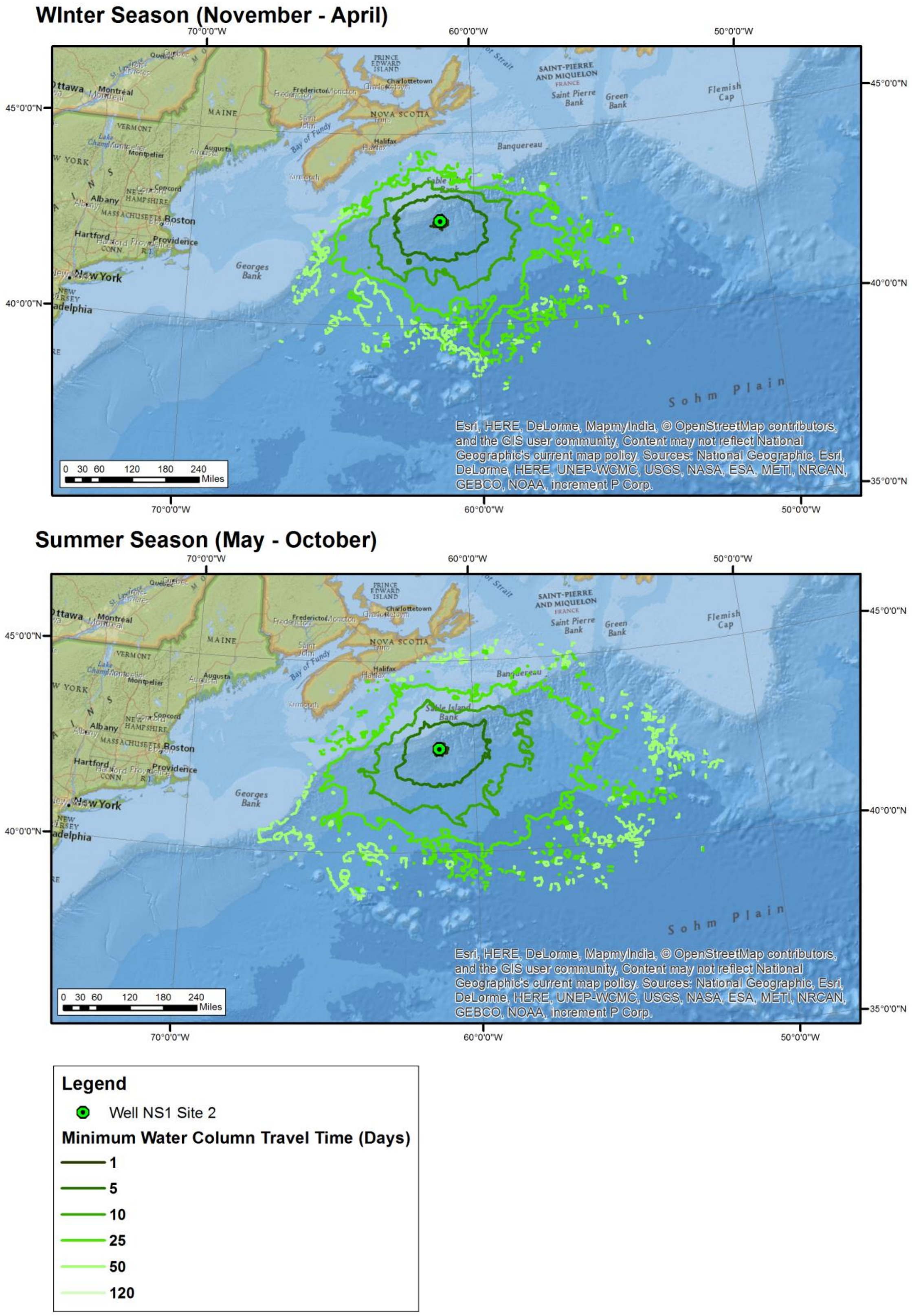


Figure 6.15 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the maximum exposure time that the total hydrocarbon concentration (dispersed and dissolved oil) within any grid cell in the top 100 m of water column exceeds the 58 ppb THC concentration threshold (based on all stochastic trajectories, no probability limit applied)

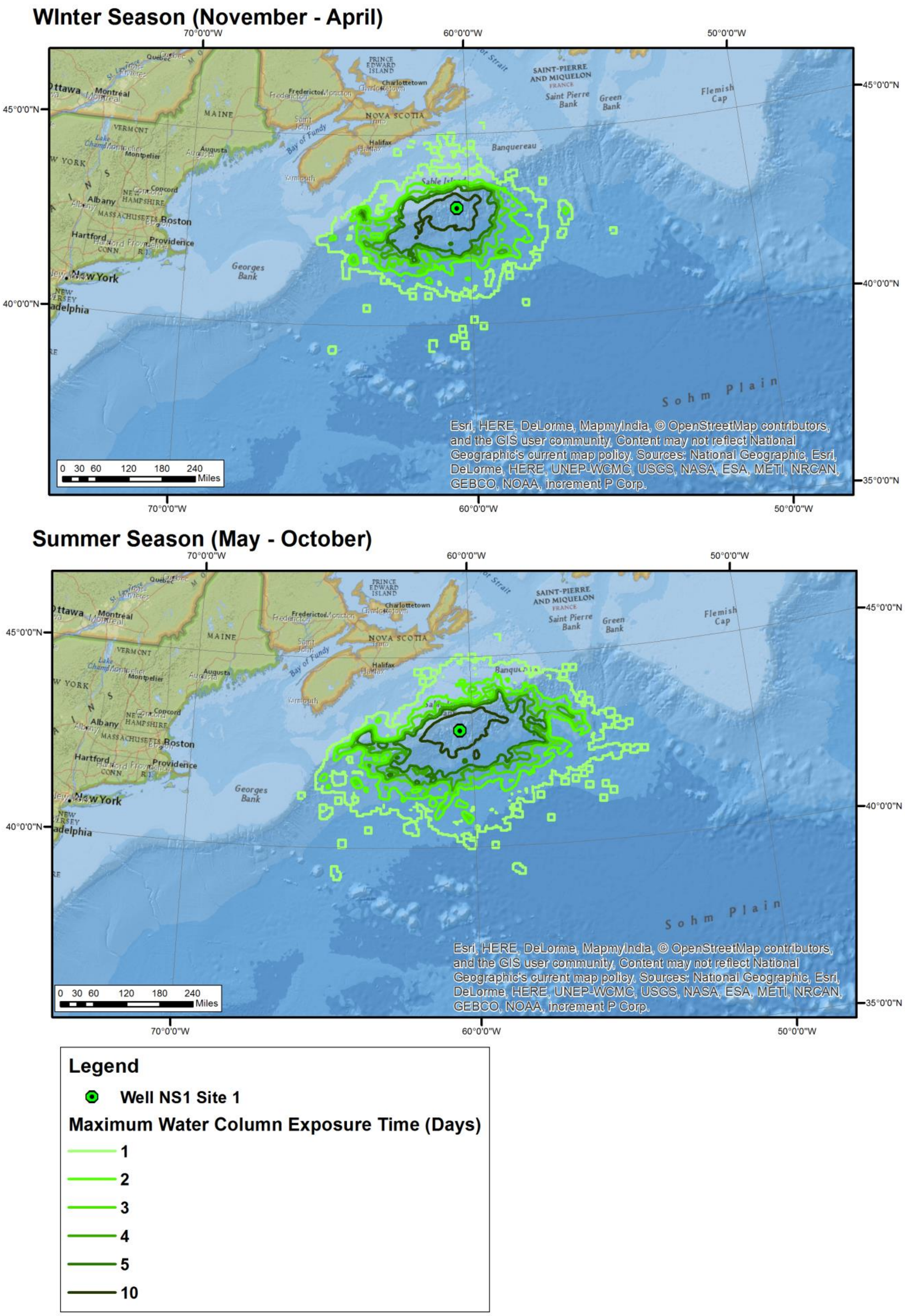


Figure 6.16 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the maximum exposure time that the total hydrocarbon concentration (dispersed and dissolved oil) within any grid cell in the top 100 m of water column exceeds the 58 ppb THC concentration threshold (based on all stochastic trajectories, no probability limit applied)

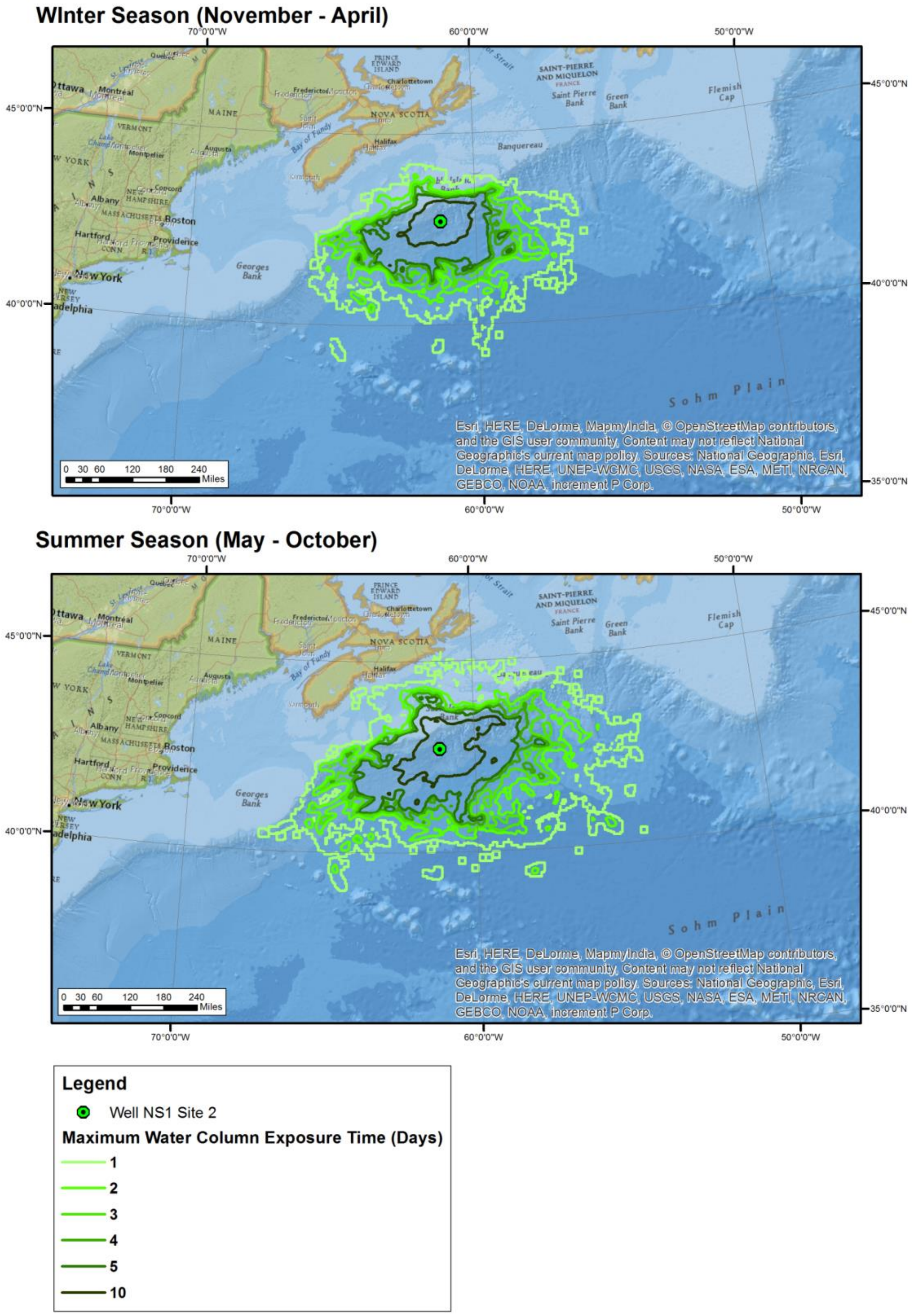


Figure 6.17 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Statistical contour maps showing the maximum time-averaged concentration of total hydrocarbons (dispersed and dissolved oil) within any grid cell in the top 100 m of water column (only concentration values exceeding the 58 ppb THC threshold are included in the time-average calculations. No probability limit applied)

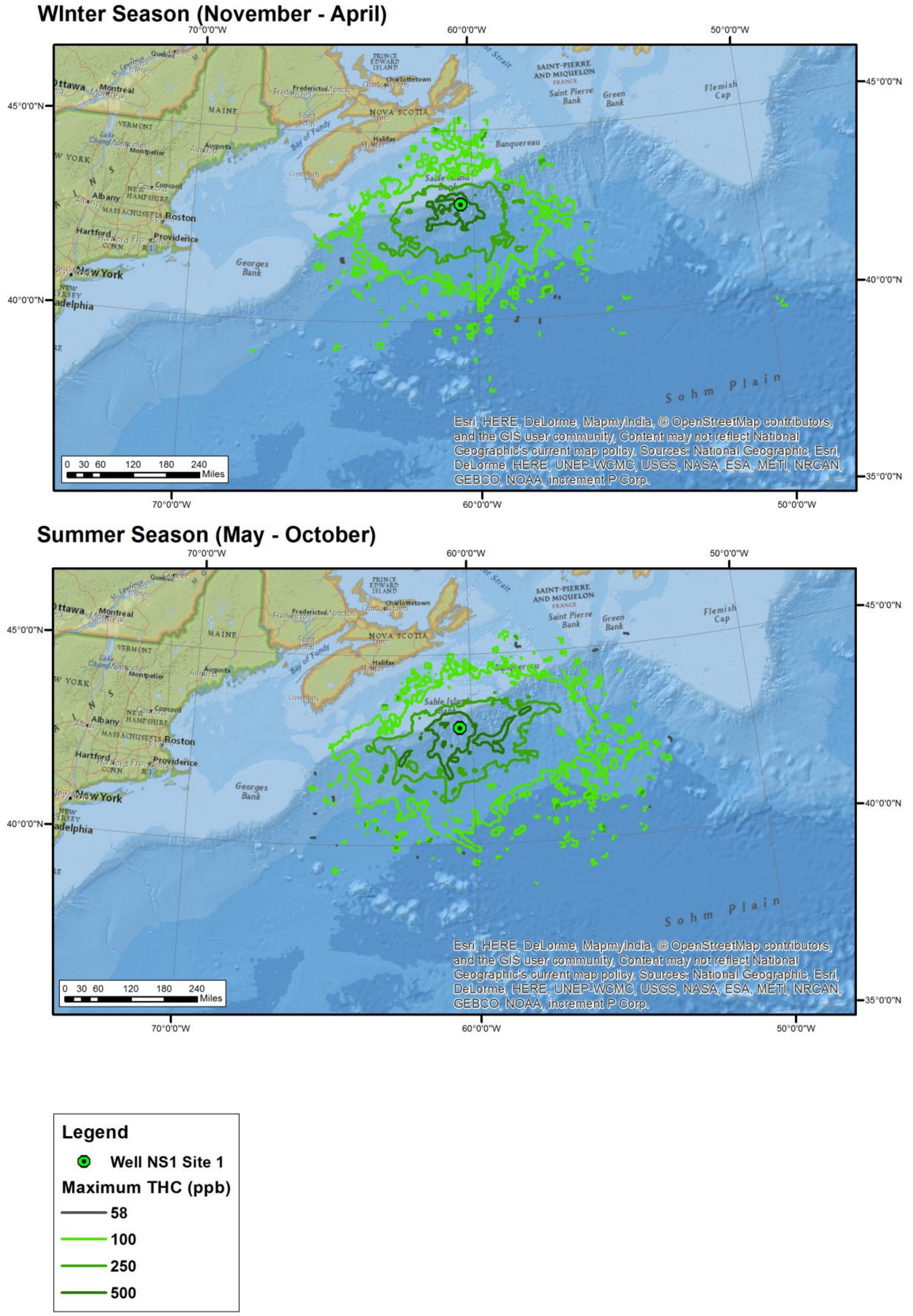


Figure 6.18 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical contour maps showing the maximum time-averaged concentration of total hydrocarbons (dispersed and dissolved oil) within any grid cell in the top 100 m of water column (only concentration values exceeding the 58 ppb THC threshold are included in the time-average calculations. No probability limit applied)

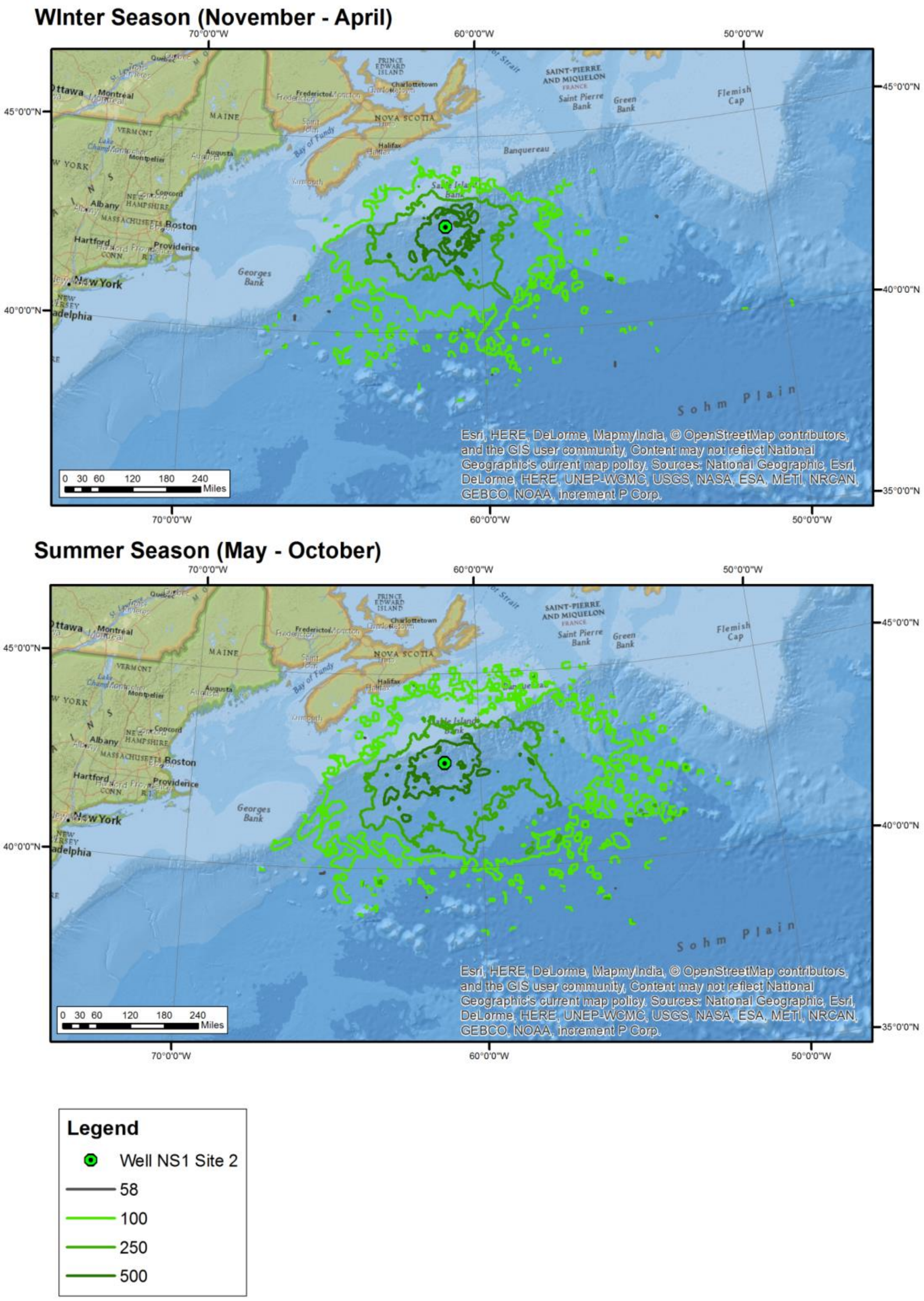
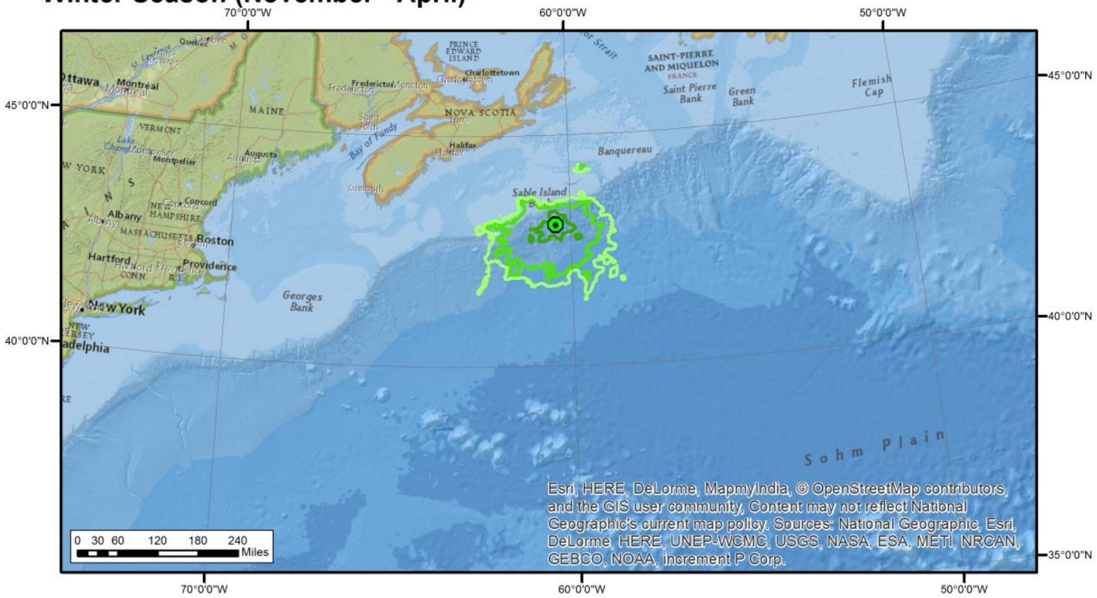
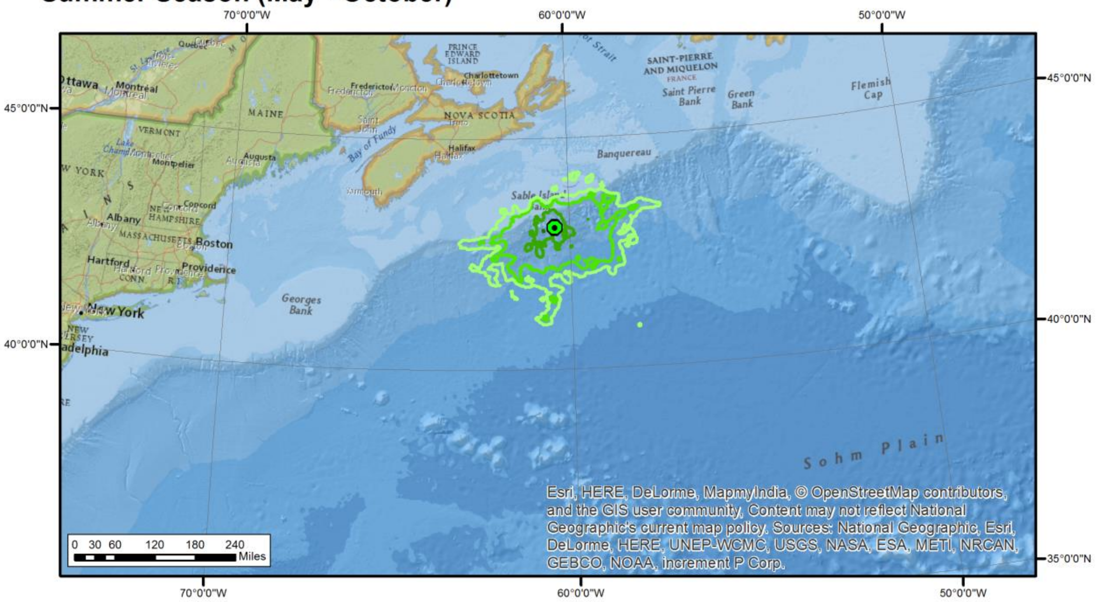


Figure 6.19 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical contour maps showing maximum time-averaged dissolved oil concentrations > 1 ppb within any grid cell in the top 100 m of water column (only concentration values exceeding the 58 ppb THC threshold are included in the time-average calculations. No probability limit applied)

WInter Season (November - April)



Summer Season (May - October)



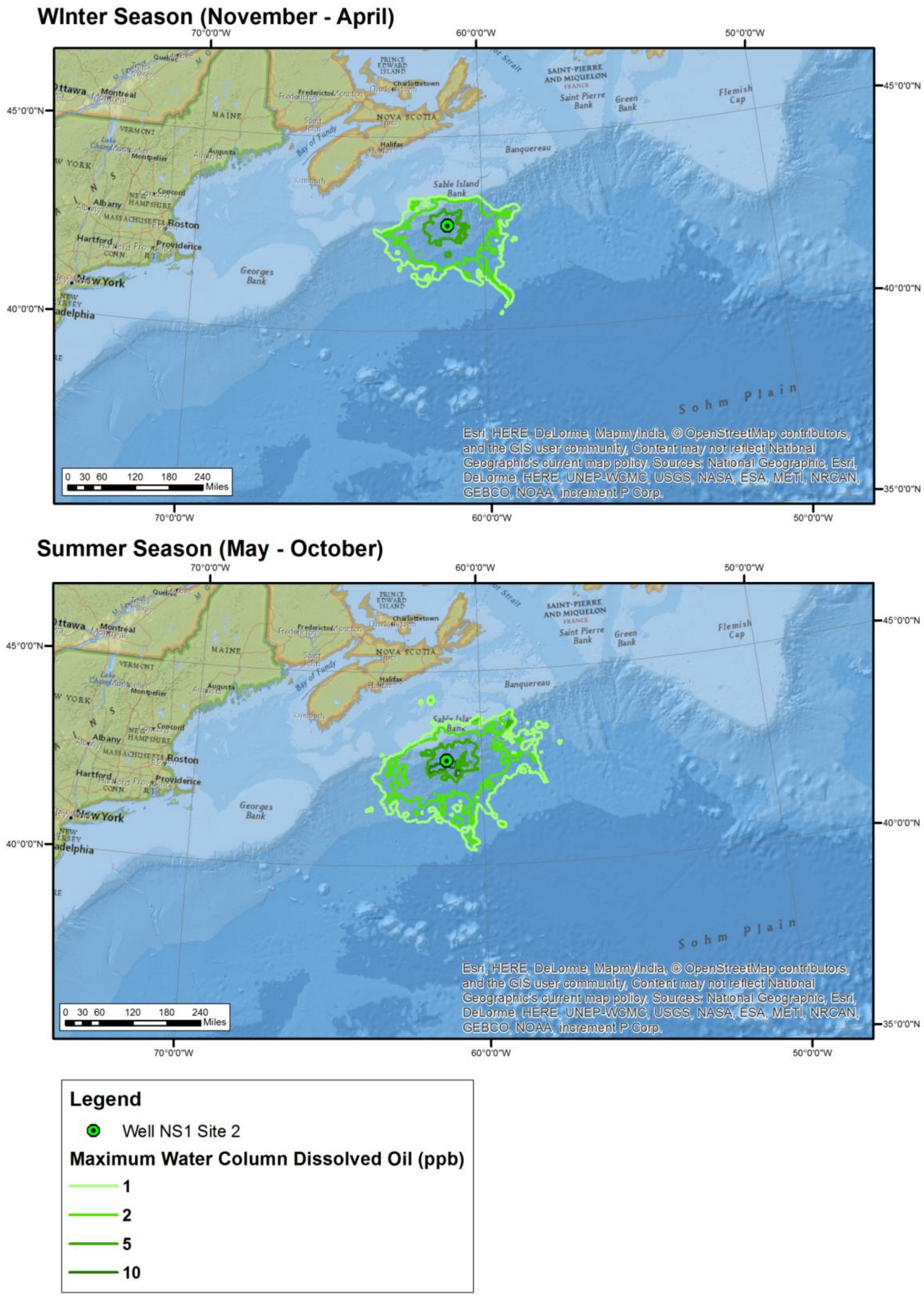
Legend

- Well NS1 Site 1

Maximum Water Column Dissolved Oil (ppb)

- 1
- 2
- 5
- 10

Figure 6.20 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical contour maps showing maximum time-averaged dissolved oil concentrations > 1 ppb within any grid cell in the top 100 m of water column (only concentration values exceeding the 58 ppb THC threshold are included in the time-average calculations. No probability limit applied)



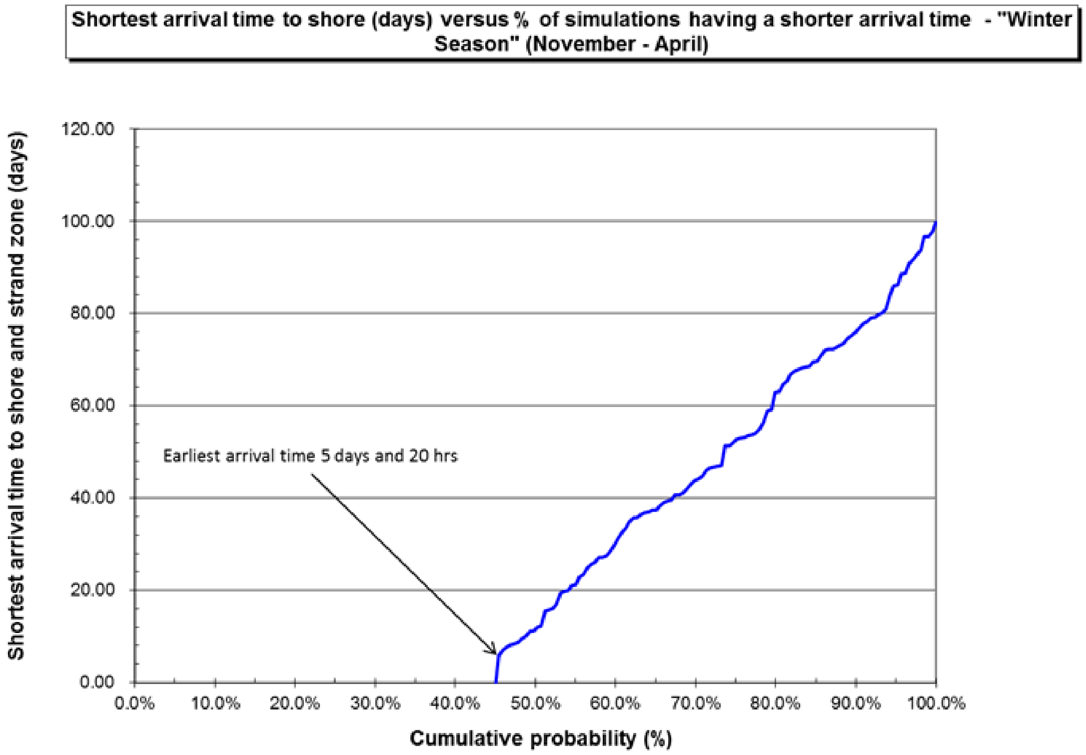
6.1.3 Shoreline Results

Figures 6.21 and 6.22 display the arrival time of oil to shore versus the corresponding percentage of simulations having a shorter arrival time for each of the weather "seasons". The earliest arrival time for shoreline oil exceeding the threshold for Site 1 occurs during the summer, with an arrival time of approximately 3.8 days to the nearest shoreline (Sable Island). In the winter season, the earliest arrival time is approximately 5.8 days to Sable Island. For Site 2, the earliest arrival time for shoreline oiling (Sable Island) above the threshold occurs during the summer approximately 6.6 days following the start of the release. During the winter, the earliest arrival time occurs after approximately 10.5 days.

Figures 6.23 and 6.24 illustrate the total mass of oil on the shoreline for the entire modelling domain as a function time after the start of the release with the corresponding percentage of simulations having less oil on the shoreline. For Site 1, the predicted maximum amounts of oil accumulating on the shoreline for the summer and winter seasons were circa 666 and 255 tonnes respectively, with peak oiling occurring between 20 and 50 days. These amounts of oil represent 0.7% and 0.2% of the total amount of oil released. For Site 2, the maximum amounts of accumulated oil on the shoreline were 666 tonnes in the summer and 220 tonnes in the winter, with peak oil occurring within a slightly longer timeframe of 35 to 100 days.

However, there was a wide range in the maximum amount of oil accumulated on the shoreline, with <1 tonne occurring in 56% of the cases during the winter season for Site 1 and 67% of the cases for Site 2. In the summer season, < 1 tonne of stranded oil occurred in 31% of the cases for Site 1 and 36% of the cases for Site 2.

Figure 6.21 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Graph showing the shortest arrival time of oil to shore with percentage of simulations having a longer arrival time.



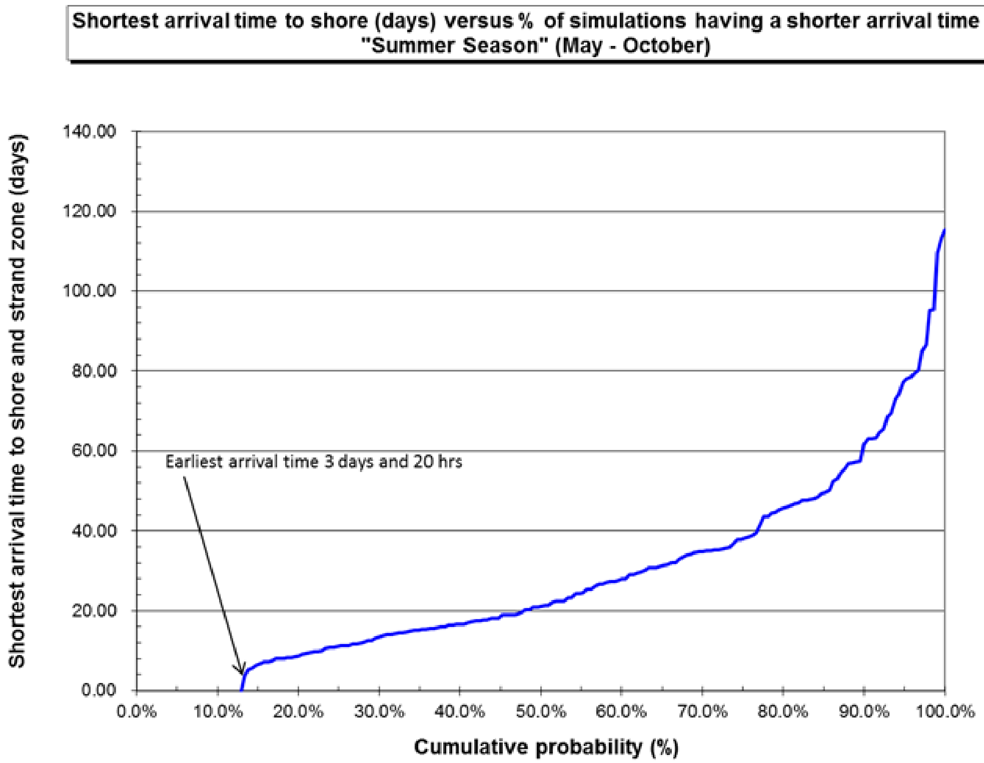
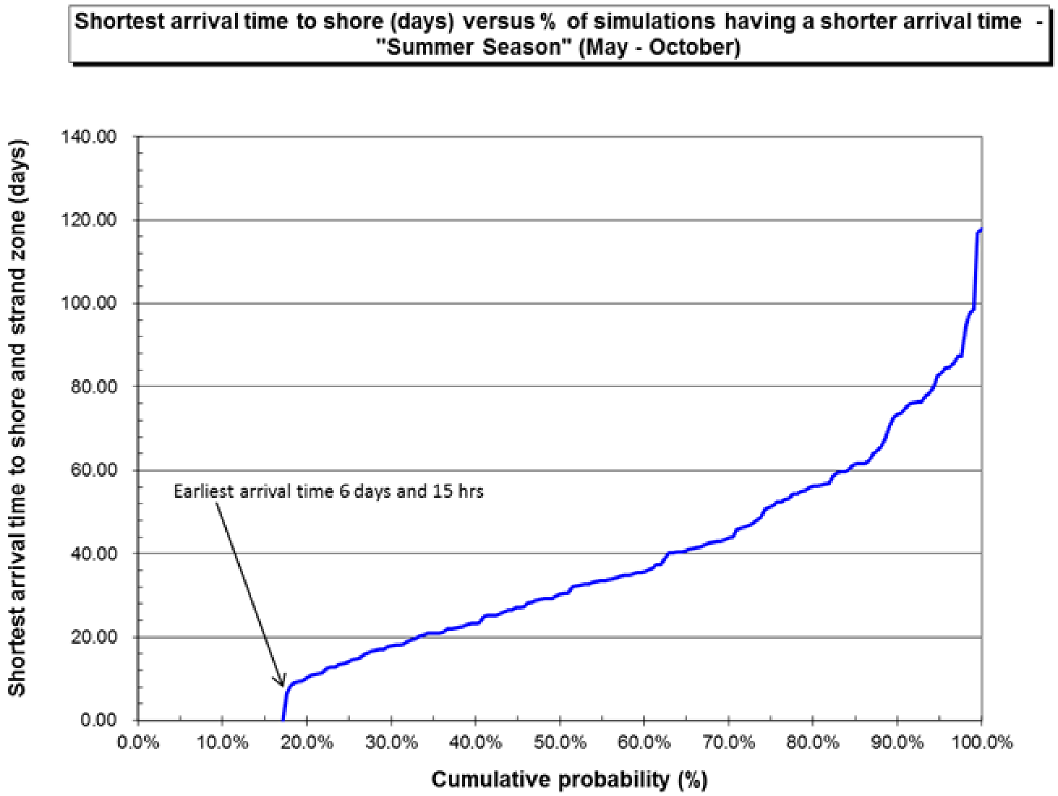


Figure 6.22 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Graph showing the shortest arrival time of oil to shore with percentage of simulations having a longer arrival time.



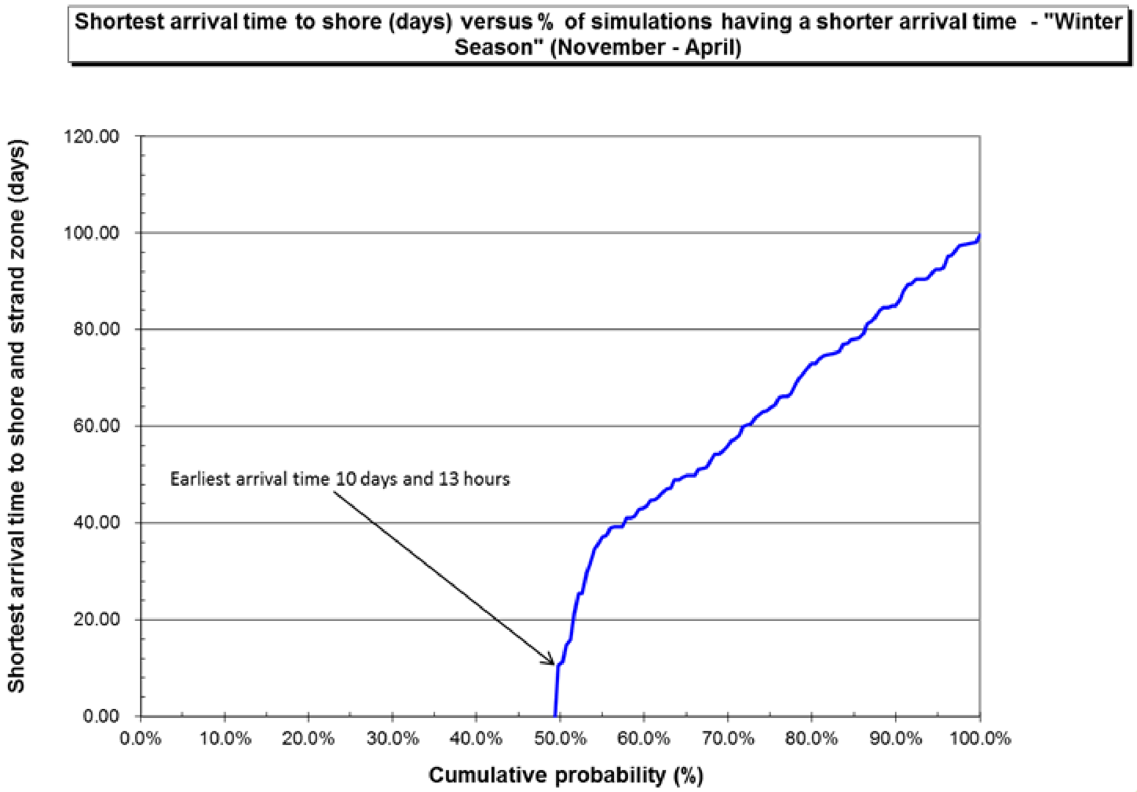
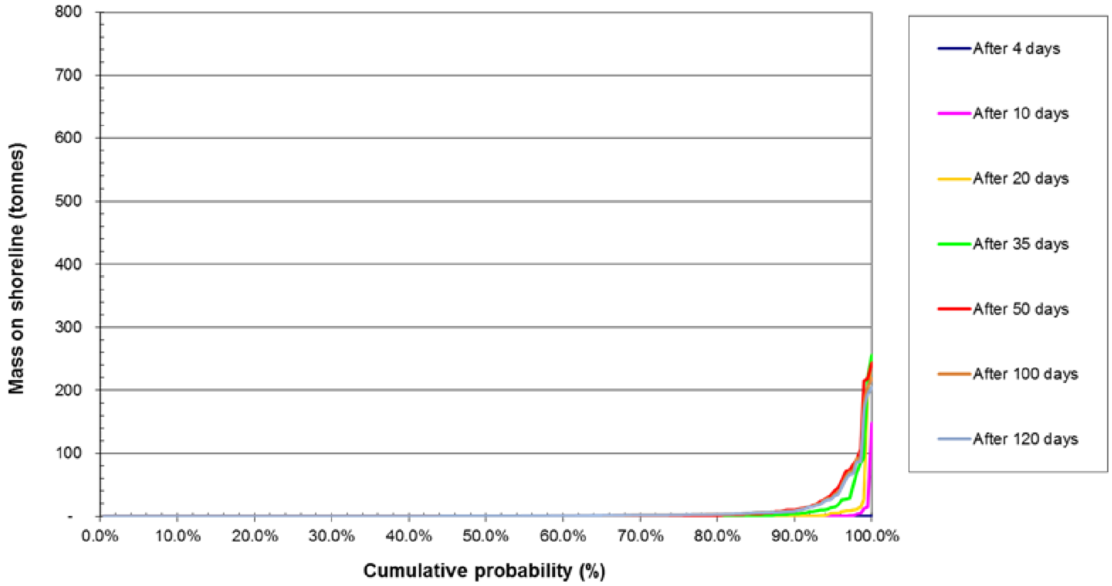


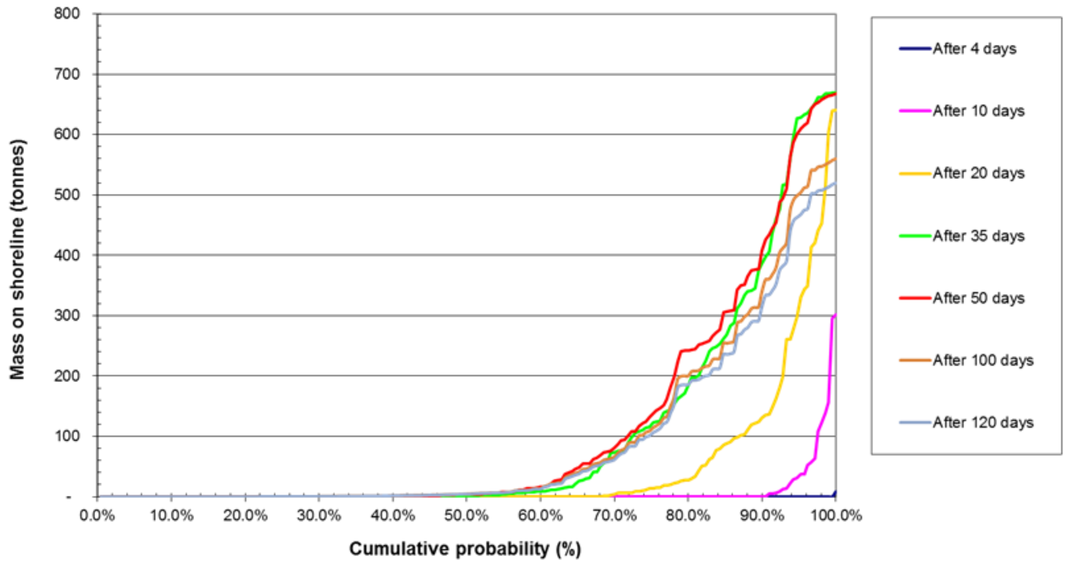
Figure 6.23 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Mass of oil on the shoreline as a function time after the start of the release with percentage of simulations having less oil on the shoreline.

Mass of oil on shoreline as a function of time after start of the release versus % of simulations having less oil on the shoreline - "Winter Season" (November - April)



	After 4 days	After 10 days	After 20 days	After 35 days	After 50 days	After 100 days	After 120 days
Average	-	1	3	5	7	7	7
d10	-	-	-	-	-	-	-
Median - d50	-	-	-	-	-	0	0
d90	-	-	-	4	10	9	8
Max - d100	-	148	252	255	244	219	205

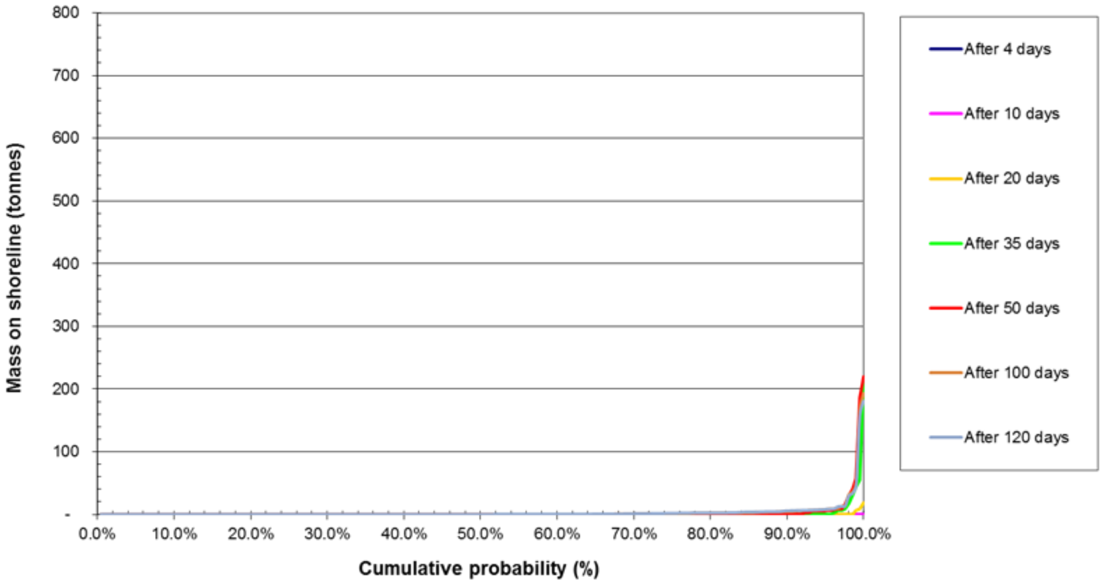
Mass of oil on shoreline as a function of time after start of the release versus % of simulations having less oil on the shoreline - "Summer Season" (May - October)



	After 4 days	After 10 days	After 20 days	After 35 days	After 50 days	After 100 days	After 120 days
Average	0	7	44	102	110	92	85
d10	-	-	-	-	-	-	-
Median - d50	-	-	-	1	3	5	4
d90	-	0	131	387	409	342	317
Max - d100	8	302	641	669	668	560	520

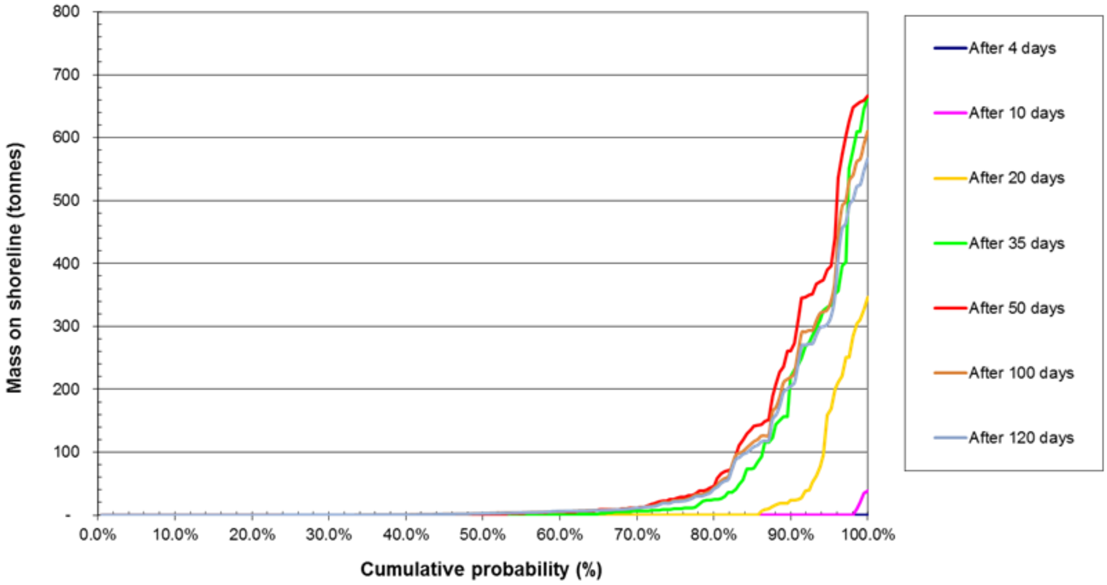
Figure 6.24 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Mass of oil on the shoreline as a function time after the start of the release with percentage of simulations having less oil on the shoreline.

Mass of oil on shoreline as a function of time after start of the release versus % of simulations having less oil on the shoreline - "Winter Season" (November - April)



	After 4 days	After 10 days	After 20 days	After 35 days	After 50 days	After 100 days	After 120 days
Average	-	-	0	2	3	3	3
d10	-	-	-	-	-	-	-
Median - d50	-	-	-	-	-	0	0
d90	-	-	-	-	0	4	6
Max - d100	-	-	18	219	220	193	181

Mass of oil on shoreline as a function of time after start of the release versus % of simulations having less oil on the shoreline - "Summer Season" (May - October)



	After 4 days	After 10 days	After 20 days	After 35 days	After 50 days	After 100 days	After 120 days
Average	-	0	17	50	66	57	53
d10	-	-	-	-	-	-	-
Median - d50	-	-	-	-	1	3	3
d90	-	-	23	221	262	220	206
Max - d100	-	39	346	665	666	610	567

Shoreline statistics from the stochastic simulations are presented in the following statistical maps based on all 210 runs completed for the summer and winter scenarios:

- Probability of Shoreline Oiling (Figures 6.25 and 6.26)
  - Maps showing the probability of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m^2).

- Minimum Arrival Time of Shoreline Oiling (Figures 6.27 and 6.28)
  - Maps showing the fastest time from the start of the release when oil appears on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m^2).

- Degree of Shoreline Oiling (Figures 6.29 and 6.30)
  - Maps showing the maximum accumulated amounts of emulsified oil on the shoreline exceeding the minimum film or sheen thickness threshold of 1 micron (1 g/m^2), categorised by degree of oiling according to the International Tank Owners Pollution Federation (ITPOF) guidelines for the recognition of oil on shorelines(19).

There are several coastline areas (including those outside of the RAA) that could potentially be exposed to shoreline oiling above the 1.0 g/m2 threshold. More detailed maps for key areas (Sable Island, Nova Scotia, Maine coastline (USA) Saint Pierre and Miquelon (France), Grand Bank / Fortune Bay (Newfoundland)) are presented in Appendix 4.

At Sable Island shoreline oiling is possible for both scenarios (Sites 1 and 2) for both seasons (summer and winter), with the summer season resulting in the most oil stranded. Site 1 also results in more shoreline oiling than Site 2, which is in deeper water and further offshore. The probability of shoreline oiling exceeding the 1 µm threshold (“stain/film” oiling) ranges from 55% up to a maximum of 66% (Site 1 summer season; see Figure A4.7 and A4.8). The earliest arrival time for shoreline oil exceeding the threshold for Site 1 occurs during the summer with an arrival time of approximately 3.8 days to the nearest shoreline (Sable Island). In the winter season, the earliest arrival time is approximately 5.8 days to Sable Island. For Site 2, the earliest arrival time for shoreline oiling (Sable Island) above the threshold occurs during the summer approximately 6.6 days following the start of the release. During the winter, the earliest arrival time occurs after approximately 10.5 days. Figures A4.9 to A4.12 depict shoreline, arrival times, and associated thickness.

Stochastic modelling indicates a low potential (0 to10%) for shoreline oiling along the Nova Scotia coastline, with most predicted contact locations being less than 1%. A higher probability for shoreline emulsion mass exceeding 1 µm (“stain/film” oiling) is predicted to occur during the summer season (May to October). It is expected that the oil would be highly weathered, as the minimal arrival time for this coastline interaction ranges from 20 to

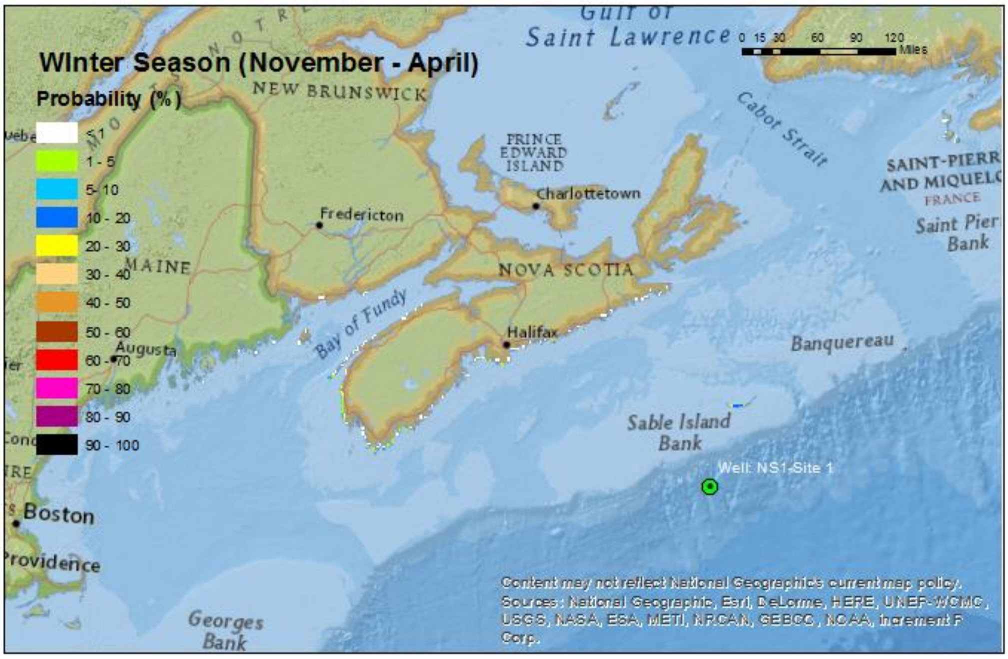
100 days. This timeframe would provide sufficient time to mobilize spill response in these areas.

Shoreline oiling may occur along portions of the Eastern Shore and Southern tip of Nova Scotia including the Yarmouth, Barrington, Shelbourne region, Brier Island and the Canso Coastal Barrens, although the likelihood of this occurring is low (less than 5% in most cases (see Figures A4.1 to A4.6). The only heavy oiling (>10 mm thickness of emulsified oil on the shoreline), that potentially occurs on the mainland is associated with the Site 2 scenario in the summer season and is predicted to take place around Riverport, Kinsburg, La Have Islands and West Dublin areas (Figure A4.6).

Some moderate to light oiling may also occur on the islands of Saint Pierre and Miquelon in the summer season from both Site 1 and Site 2 scenarios although the probability of oiling was low (<5%). Arrival times ranged from 30 to 75 days. In the winter season the probability of oiling is < 1%.

The stochastic results for the Site 2 scenario indicate that some occasional beaching events can occur along the USA coastline of Maine (from Bar Harbor to the Canadian border at Saint Andrews) during the winter season, with probabilities < 5% (Figure A.4.14) and arrival times > 75 days (Figure A4.16). These events are associated with the stranding of weathered tar balls (mostly stain/film thickness (0.1 to 0.001 mm), Figure A4.18). A few isolated tar ball stranding events also occur in the Cape Cod Bay region near Rhodes Island albeit with a very low probability of occurrence (<1%).

Figure 6.25 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the probability of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m^2)



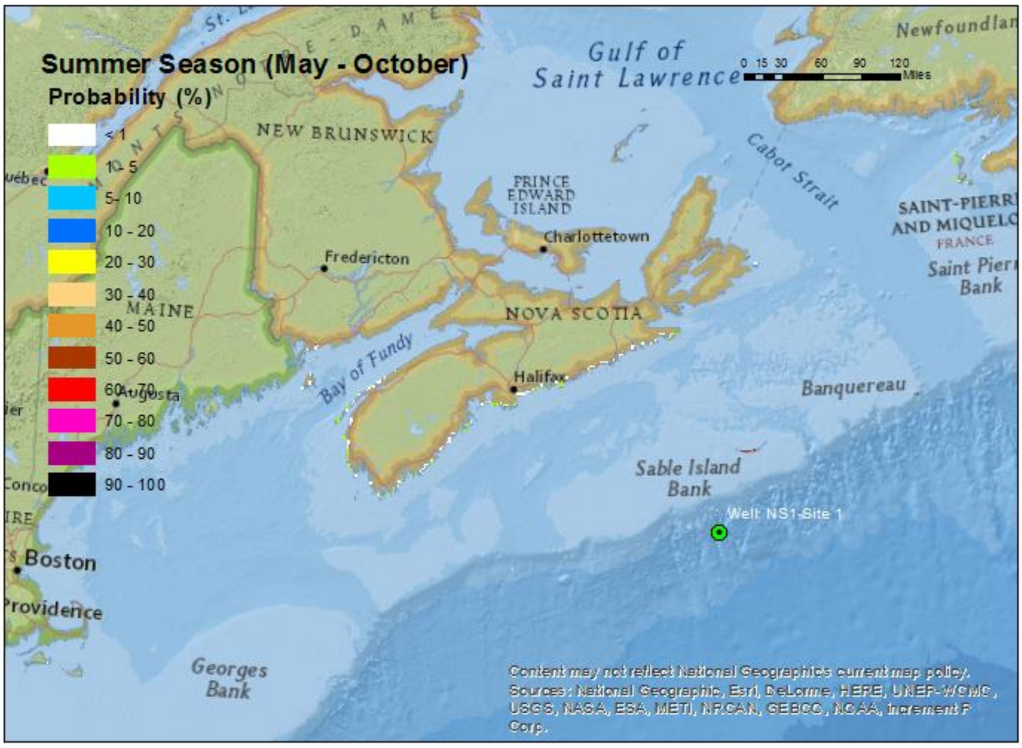


Figure 6.26 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the probability of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m^2)

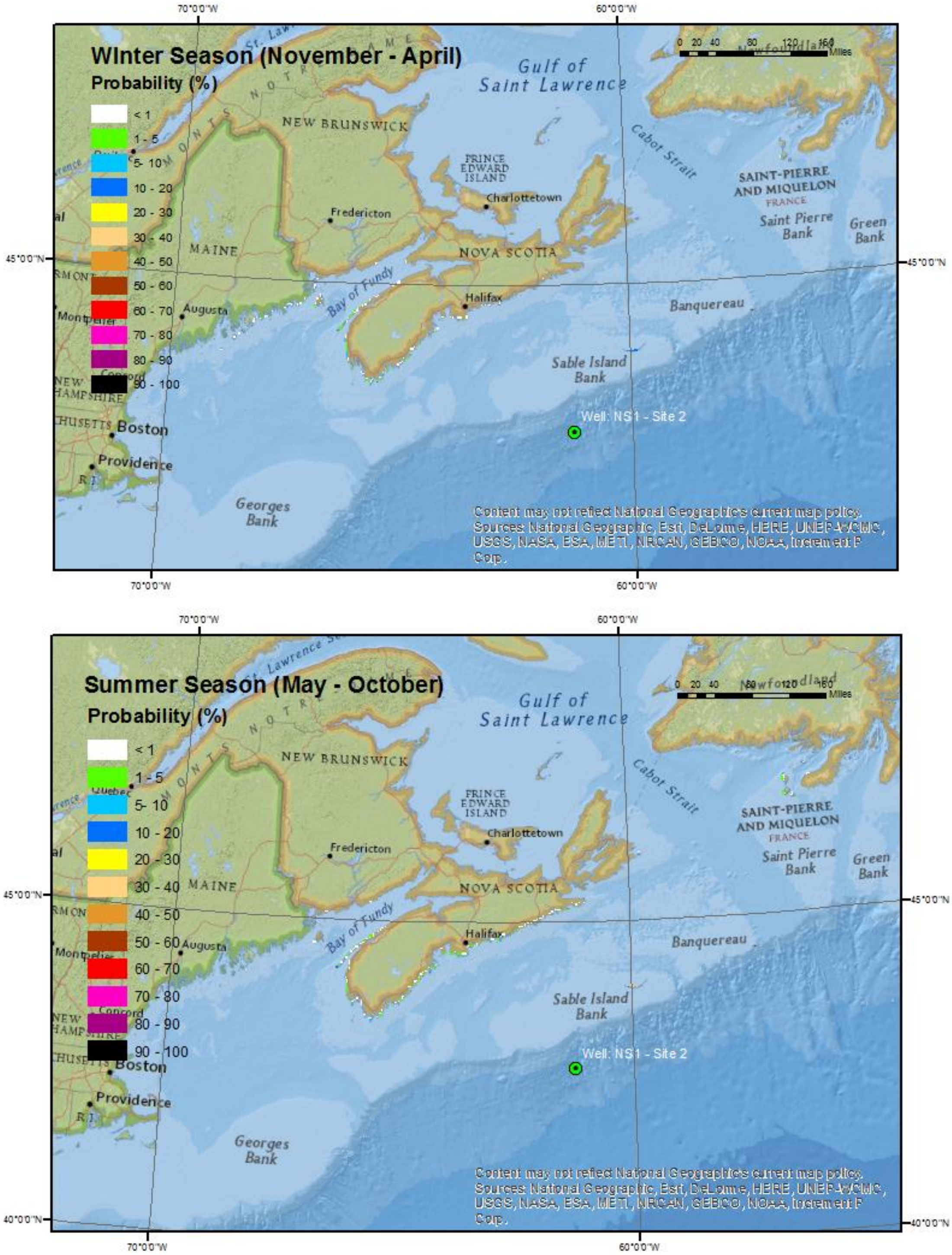


Figure 6.27 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the minimum arrival time of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)

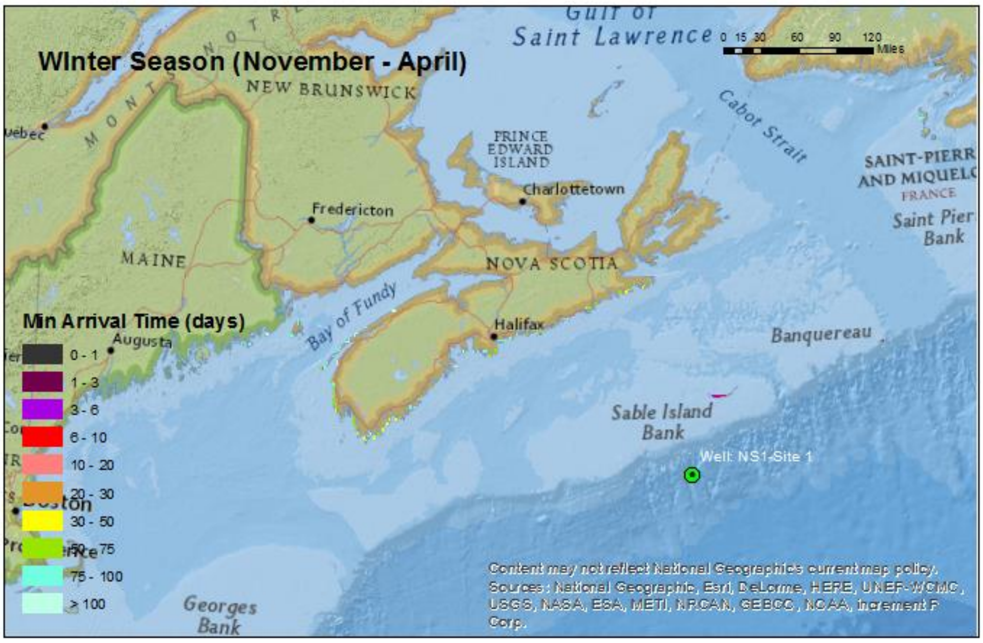


Figure 6.28 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the minimum arrival time of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)

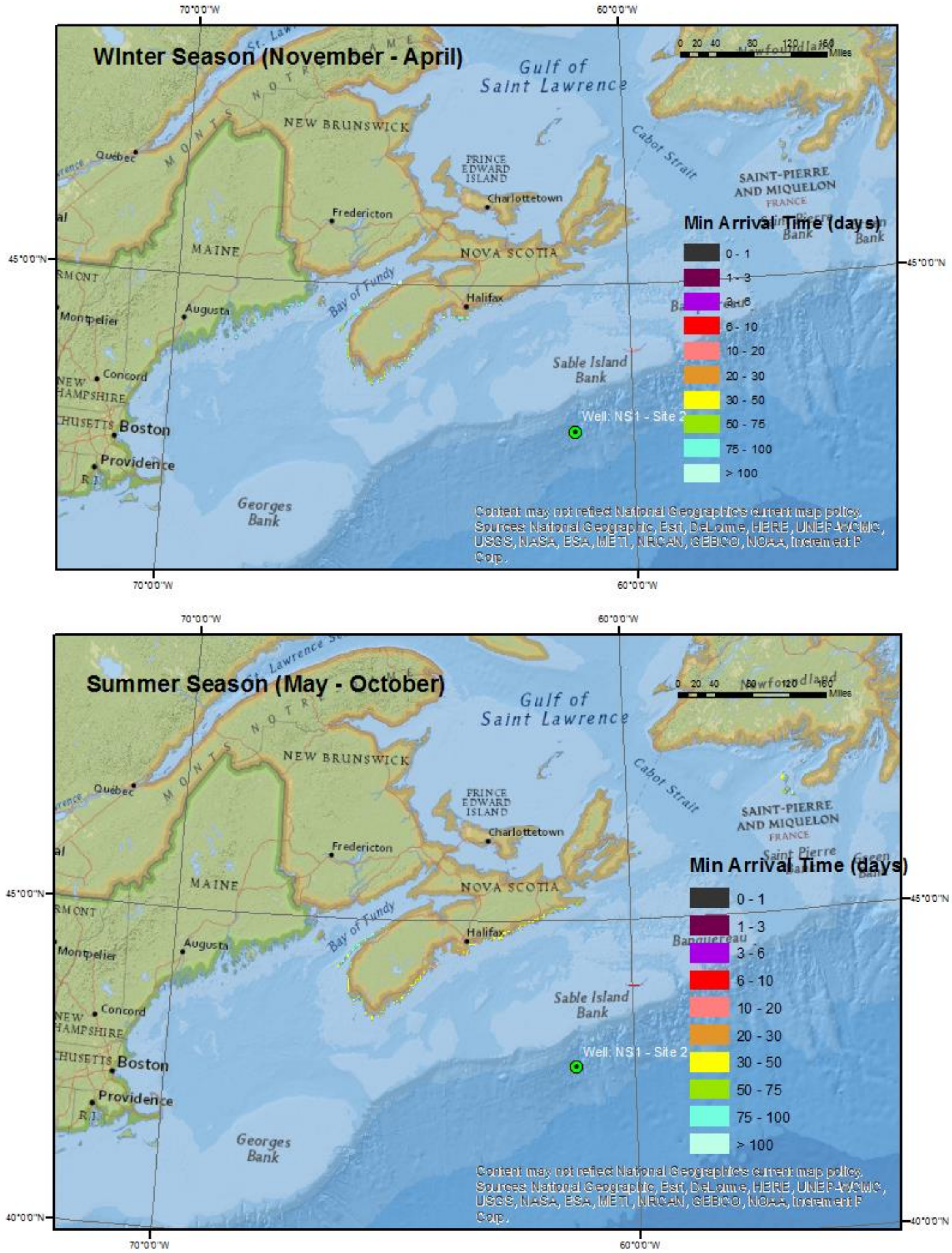
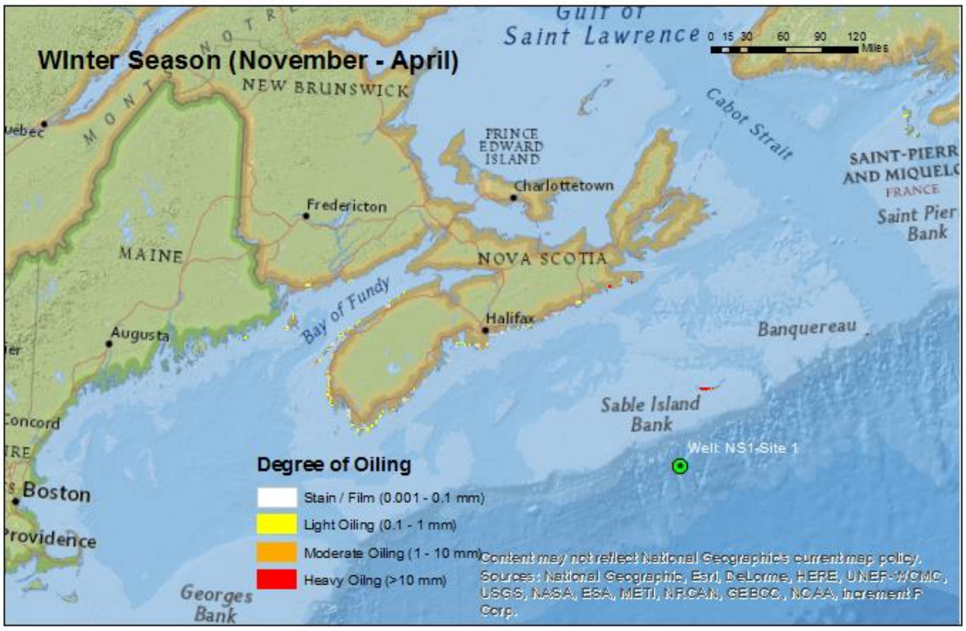


Figure 6.29 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the maximum accumulated emulsion thickness on the shoreline in accumulated amounts that exceed the minimum thickness threshold of 1 micron (1 g/m^2). (Degree of oiling categorised according to the International Tank Owners Pollution Federation (ITPOF) guidelines for the recognition of oil on shorelines [19])



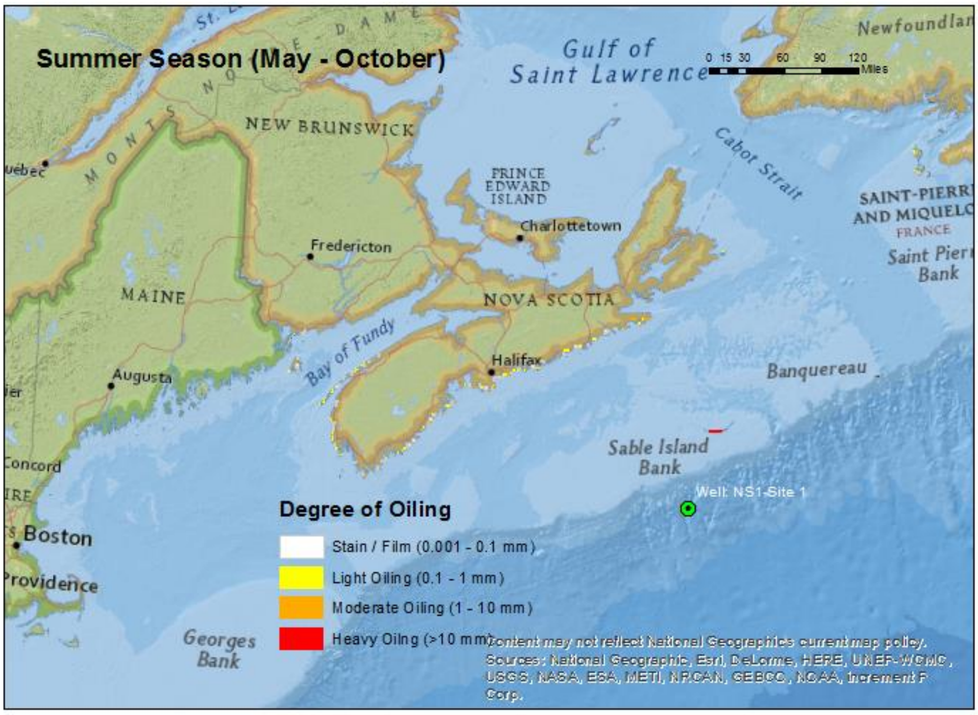
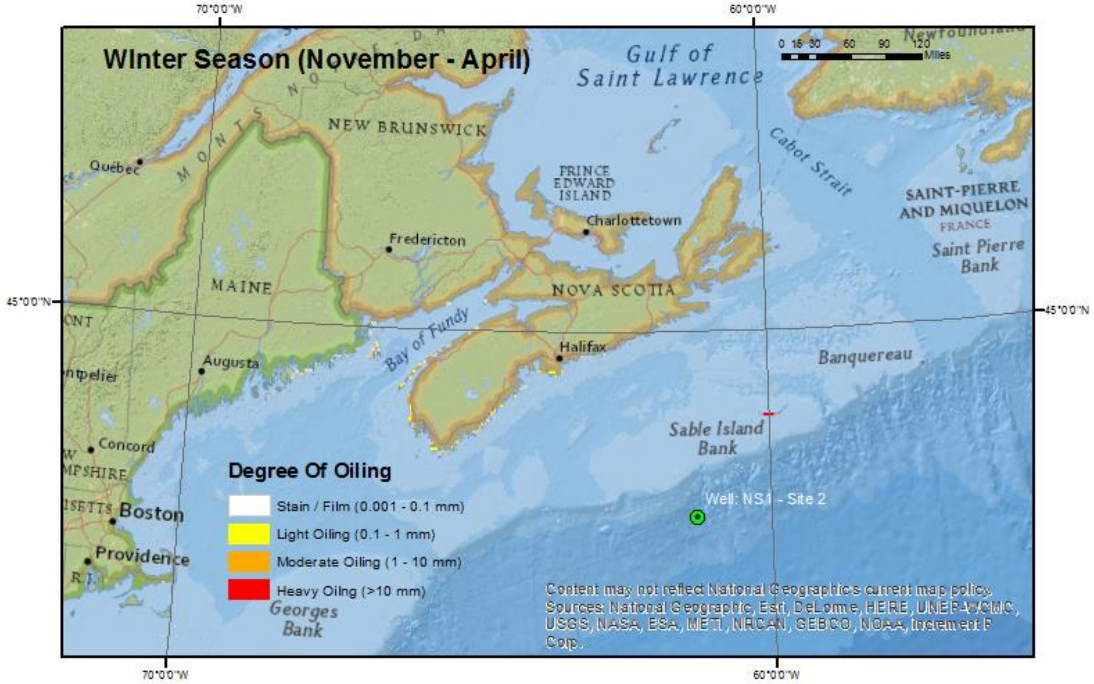
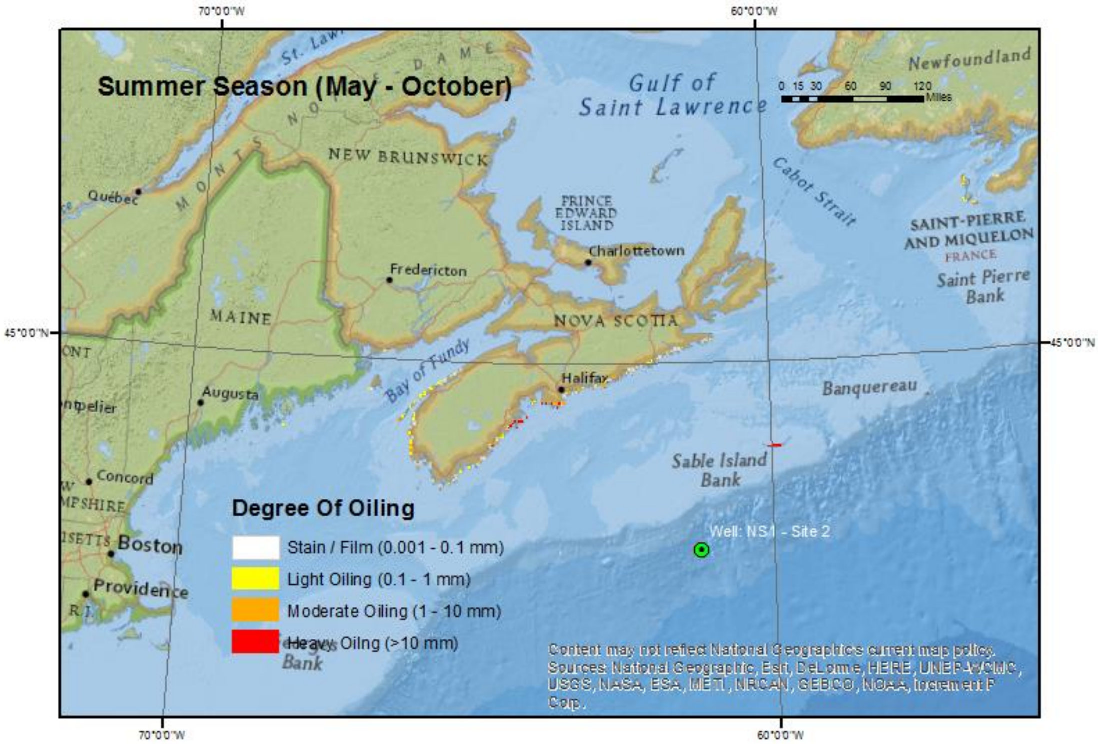


Figure 6.30 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the maximum accumulated emulsion thickness on the shoreline in accumulated amounts that exceed the minimum thickness threshold of 1 micron (1 g/m²). (Degree of oiling categorised according to the International Tank Owners Pollution Federation (ITPOF) guidelines for the recognition of oil on shorelines [(19)])





6.2 Deterministic Simulation Results

Individual or "deterministic" trajectories were identified and selected from the stochastic results that represented the maximum shoreline oiling for each well site and season. These representative worst credible case scenarios were then rerun deterministically to establish near-field and far-field fate and transport. The deterministic simulations provide insight to the individual trajectories, oil weathering behavior, the mass of oil in each environmental compartment (air, water, surface, land and sediment) and other information (area of oil slick, length of shoreline oiled etc.) related to each single spill at a given location and time which cannot be assessed using stochastic models.

The results of representative cases identified for maximum shoreline oiling, from each stochastic analysis, for both well sites and for winter and summer seasons, are provided in Table 6.1. Table 6.1 describes the specific details for each scenario including the time for oil to reach the shoreline, maximum mass of oil on the shoreline, length of coastline impacted, and the total amount of oil released.

Table 6.2 also shows the release conditions for the oil spill trajectories from the stochastic simulations that resulted in the shortest arrival times for shoreline oiling. Thresholds for surface oil thickness (0.04 µm), total hydrocarbon concentration in the water column (58 ppb) were applied to the "cumulative footprint" deterministic simulation outputs.

Figures 6.31 to 6.50 provide outputs for representative summer, 30-day unmitigated blowout scenarios depicting surface oiling, in-water oiling, and shoreline oiling for Sites 1 and 2.

Descriptions of these figures are provided below to assist with the interpretation.

- *Surface Oil Figures:* Figure 6.37 and 6.47 show the footprint of floating emulsified surface oil and the predicted maximum thicknesses (µm) which exceeds the 0.04 µm thickness threshold at each surface location over the 120-day spill simulation period.

- *Water Column Figures:* Figure 6.38 and 6.48 show the footprint of THCs (dispersed and dissolved oil in the water column and the predicted maximum concentrations of THCs which exceed the 58 ppb THC threshold at any grid cell within the upper 100 m of water column over during the 120-day spill simulation period. Figure 6.39 and 6.49 show the footprint of dissolved oil in the water column and the predicted maximum concentrations of dissolved oil which exceed a 1 ppb threshold at any grid cell within the upper 100 m of water column over during the 120-day spill simulation period.

- *Mass Balance Figures:* Figures 6.34, 6.35, 6.43 and 6.44 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 released up to that point. Components of the oil tracked over time include the proportion of oil on the sea surface, entrained into the water column, stranded on shore, evaporated into the atmosphere, and that which has been degraded through biodegradation.

- *Shoreline Impact Figures:* Figures 6.35 and 6.45 show the mass of oil (not emulsified oil) deposited onto shoreline and length of shoreline impacted.

- *Surface Oil Area Coverage Figures*: Figures 6.36 and 6.46 show the areal coverage of emulsified surface oil exceeding a 0.04 µm sheen thickness threshold and a 100 µm minimum threshold for thick oil.

Table 6.1 NS-1 subsea well blowout scenarios. Summary of the release conditions and deterministic modelling results for the oil spill trajectories selected from the stochastic scenarios that produced the maximum amount of accumulated oil on shoreline.

Deterministic simulations	**Scenario - Case 1A (Maximum oil on shoreline- Winter Season)**	**Scenario - Case 1A (Maximum oil on shoreline - Summer Season)**	**Scenario - Case 2A (Maximum oil on shoreline - Winter Season)**	**Scenario - Case 2A (Maximum oil on shoreline - Summer Season)**
	24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)	**24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)**	**35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)**	**35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)**
Season	Winter Season (November - April)	Summer Season (May - October)	Winter Season (November - April)	Summer Season (May - October)
Simulation number	31	13	161	104
Start time	04 November 2006 21:00	19 June 2006 23:00	18 April 2009 03:00	24 June 2008 03:00
Simulation duration	120 days	120 days	120 days	120 days
Release duration	30 days	30 days	30 days	30 days
Initial Release rate	24,890 bpd	24,890 bpd	35,914 bpd	35,914 bpd
Total oil release	115,377 tonnes	99,190 tonnes	142,902 tonnes	142,903 tonnes
First shore hit	5.0 days	7.0 days	31.0 days	12.0 days
Maximum mass on shoreline	239 tonnes	670 tonnes	224 tonnes	669 tonnes
Ashore time (maximum mass)	18.0 days	42.0 days	37.0 days	32.0 days
Length of coastline impacted (at maximum mass ashore)	27.8 km	27.8 km	23.8 km	27.8 km
Maximum length of coastline impacted	27.8 km	27.8 km	31.8 km	79.5 km
Ashore time (maximum length)	12.0 days	13.0 days	89.0 days	101.0 days
Impacted Area Exceeding Thresholds: ***Surface Oiling:***				
0.04 microns	283,839 km^2	315,259 km^2	495,538 km^2	507,166 km^2
10 microns	39,938 km^2	57,000 km^2	49,599 km^2	91,778 km^2
100 microns	22,486 km^3	36,046 km^3	24,167 km^3	63,203 km^3
Water Column:				
58 ppb THC	48,337 km^2	55,905 km^2	70,306 km^2	105,050 km^2
1 ppb total dissolved hydrocarbons	14,334 km^2	14,271 km^2	15,627 km^2	24,859 km^2

Table 6.2 NS-1 subsea well blowout scenarios. Summary of the release conditions of the oil spill trajectories from the stochastic simulations that resulted in the shortest arrival times for shoreline oiling

Deterministic simulations	Scenario - Case 1A (Shortest arrival time for stranded oil - Winter Season)	Scenario - Case 1A (Shortest arrival time for stranded oil - Summer Season)	Scenario - Case 2A (Shortest arrival time for stranded oil - Winter Season)	Scenario - Case 2A (Shortest arrival time for stranded oil - Summer Season)
	24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)	24,890 bpd (Initial oil release rate) / 30 days duration (capping stack)	35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)	35,914 bpd (Initial oil release rate) / 30 days duration (capping stack)
Season	Winter Season (November - April)	Summer Season (May - October)	Winter Season (November - April)	Summer Season (May - October)
Simulation number	31	116	30	197
Start time	04 November 2006 21:00	13 August 2008 08:00	31 October 2006 19:00	06 July 2010 16:00
Simulation duration	120 days	120 days	120 days	120 days
Release duration	30 days	30 days	30 days	30 days
Initial Release rate	24,890 bbls/day	24,890 bbls/day	24,890 bbls/day	24,890 bbls/day
Total oil release	115,377 tonnes	115,377 tonnes	115,377 tonnes	115,377 tonnes
First shore hit	5.82 days	3.81 days	10.52 days	6.61 days
	140 hours	91 hours	252 hours	159 hours

6.2.1 Well: NS-1 Case 1A – maximum oil on shoreline scenario (Summer Season)

Near-field plume dynamics

Figure 6.31 shows the results of a near-field deterministic simulation over the first 2 days of the NS-1 blowout event at Site 1 (worst case shoreline oiling scenario, summer season).

Vertical cross sections through the water column show the extent of the subsea plume, and rise of oil droplets and dissolved oil. The water column grid (100 m x 100 m horizontal resolution) is split into 100 vertical layers (22 m per layer) extending all the way to the sea-floor. As the oil rises to the surface within a few hours, the radial extent that the plume and oil droplets move away from the release location as relatively small compared to the lateral transport of oil once it arrives at the surface.

Due to the high turbulence at the release point, oil and gas released from the seabed rise as droplets and bubbles along with a substantial quantity of entrained water as a multiphase plume. Oil droplet size does not significantly affect the transport of the mixture of plume fluid. Hence, the phases are initially clustered together and then move as an integral mixture governed by plume buoyancy forces. The Terminal Level for Plume Dynamics (TLPD), is the level where the plume dynamics is not important any more. Dissolution of gas and the lighter oil components may occur as the plume rises (a lateral extrusion of dissolved hydrocarbon components away from the plume below the TLDP is clearly visible after 2 days in Figure 6.31).

Above the TLPD the oil droplet size distribution become important, as smaller droplets move more slowly towards the surface when compared to larger droplets. Cross currents move droplets laterally, thus the droplets can spread in all directions. The 3-D plume model OSCAR simulation results suggest that the TLPD occurs at about 1,955 m below sea-level and is reached within 10 minutes of oil being released at the seabed.

The snapshots profiles in Figure 6.32 show that the central core of the plume (comprising dispersed and dissolved oil) does not extend more than 15 km radially away from the release location.

The oil droplet size model in OSCAR predicts a d95 droplet size of 8.8 mm and d50 (median) droplet size of 4.1 mm for the Site 1 release. The model predicts it will take the largest oil droplets (8.8 mm) another 5 hours to rise to the surface, with 50% having arrived after 10 hours (see Figure 6.32).

Figure 6.31 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 19th June 2006 23:00 GMT). Snapshot maps showing the total hydrocarbon concentration (THC) of dispersed oil droplets and dissolved oil in the water column vs time after start of release.

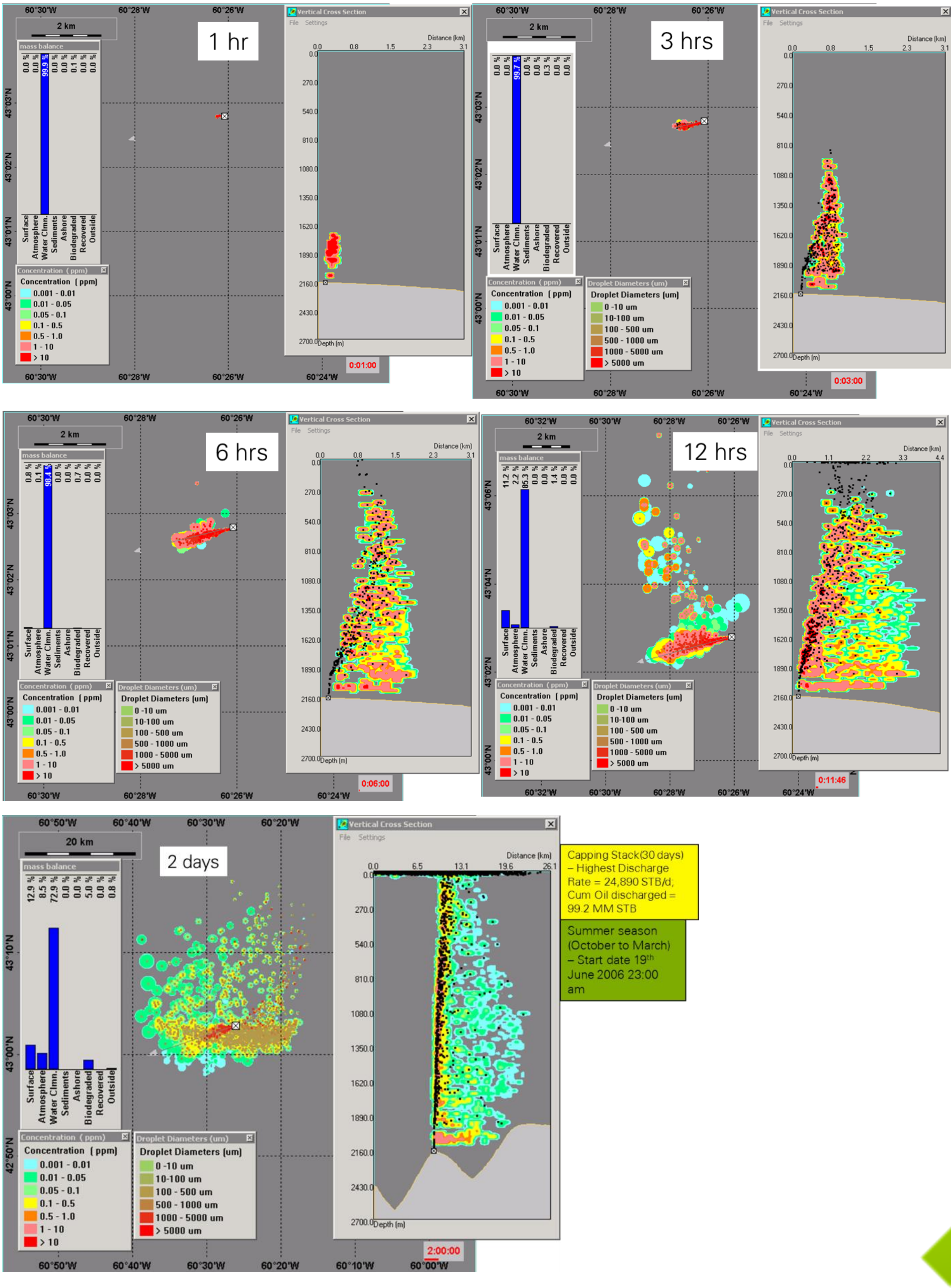
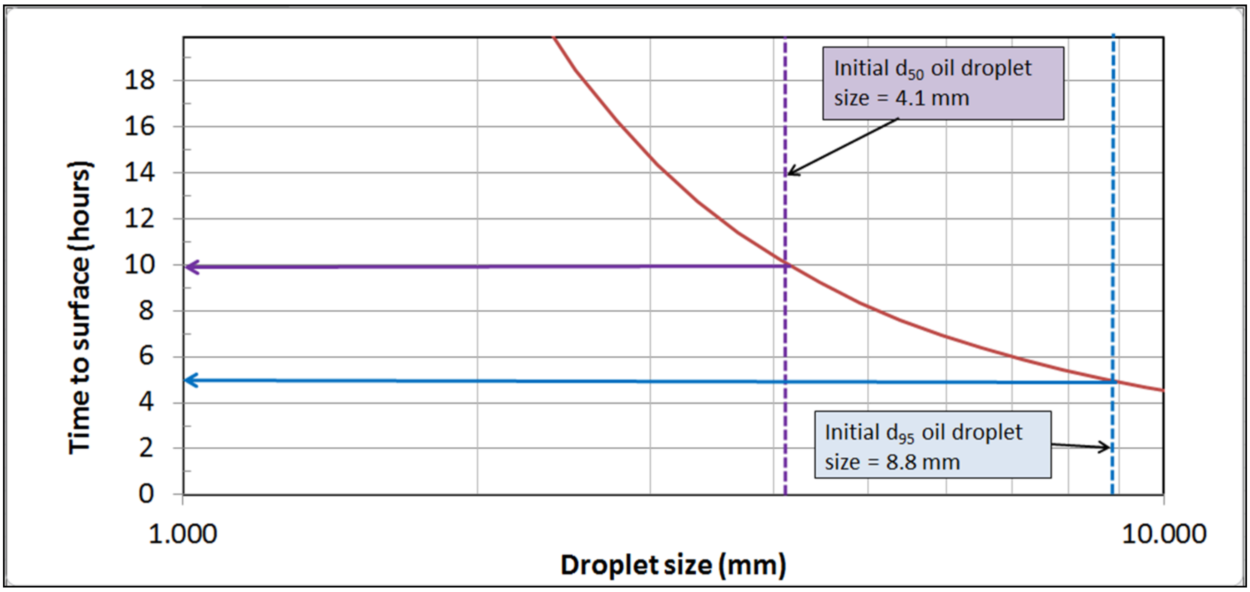


Figure 6.32 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 19th June 2006 23:00 GMT). Graph showing the predicted droplet rise-time to surface from the plume trapping height (1,955 m below sea-level) vs droplet size



Oil mass balance

Figures 6.33 and 6.33 show the mass balance time development and distribution of oil for the Site 1 worst case, maximum shoreline oiling, summer scenario. The simulation chosen started on 19th June 2006 at 23:00 GMT and resulted in a maximum oil mass on the shore of 670 tonnes, with the first oil beaching after 7 days.

The model results predicted that the water content of the oil emulsion arriving on the shoreline would be 78%, so the stranded oil tonnages need to be increased by a factor of 4.55 to derive the tonnage of oil emulsion beached on the shoreline.

At the end of the “worst” shoreline oiling simulation for the summer season, 37,340 tonnes of oil would be biodegraded ("decayed") and 29,480 tonnes evaporated (Figure 6.33). This accounts for 38% and 30% of the total oil released respectively. The maximum amount of oil in the water column ("dispersed") is reported as 38,010 tonnes after 34 days, the maximum amount of oil on the surface is 16,180 tonnes after 32 days and the maximum amount of weathered oil that sinks and becomes incorporated into the sediment is 16,630 tonnes after 106 days. After 120 days, 0.03 % of the release is reported on the surface and 16 % in the water column; with that remaining in the water column dispersed to negligible concentrations (< 10 ppb THC dispersed oil).

The modeling results for Site 1 (Figure 6.37 – 6.39) predict that the majority of oil would remain offshore. In the event that surface oil was to enter the near shore area of Nova Scotia, it is predicted to have a thickness of between 0.04 and 0.3 µm. Exceedances of the in-water oil threshold is predicted to also be limited to offshore waters; however, the area impacted is smaller than that of surface oiling. Shoreline oiling exceeding the threshold level is expected to be limited to the coastline of Sable Island. Unmitigated oiling on Sable Island is predicted to be heavy with a thickness of > 10 mm. The maximum length of shoreline impacted would occur after 7 days with 27.8 km of coastline being affected (Figure 6.35 and 6.40). The maximum mass of oil on the shoreline occurs later (after 42 days) and is associated with 670 tonnes of oil accumulated on the shoreline.

Figure 6.33 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Maximum oil ashore simulation (Summer Season, start date 19th June 2006 23:00 GMT). Graph showing time development of oil mass balance.

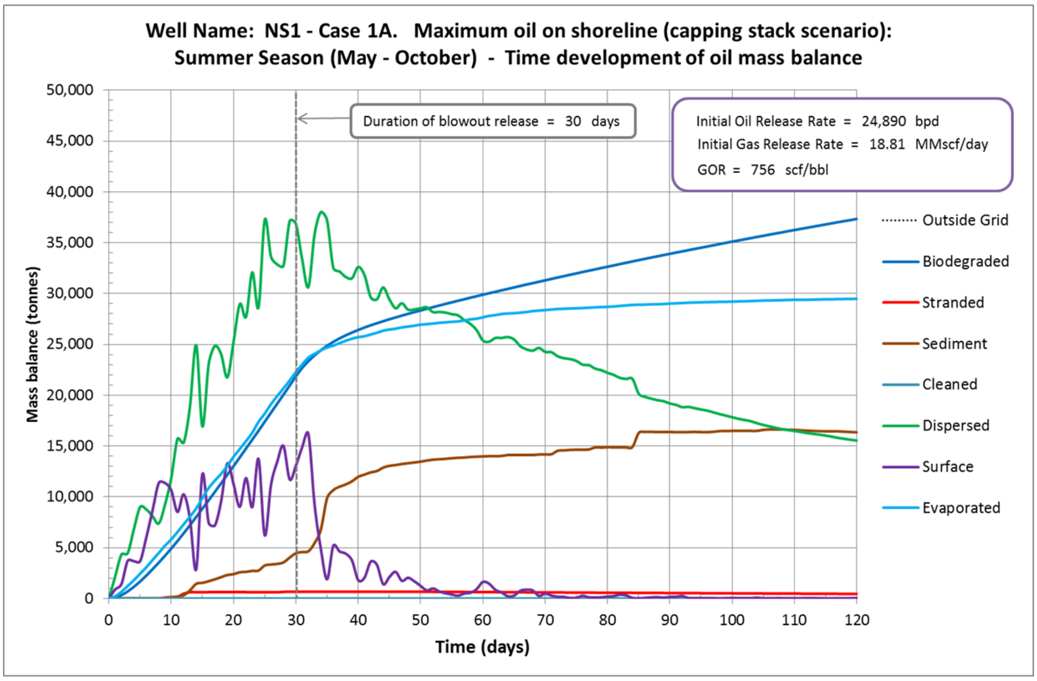


Figure 6.34 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Maximum oil ashore simulation (Summer Season, start date 19th June 2006 23:00 GMT). Graph showing mass balance distribution of oil over the duration of the simulation.

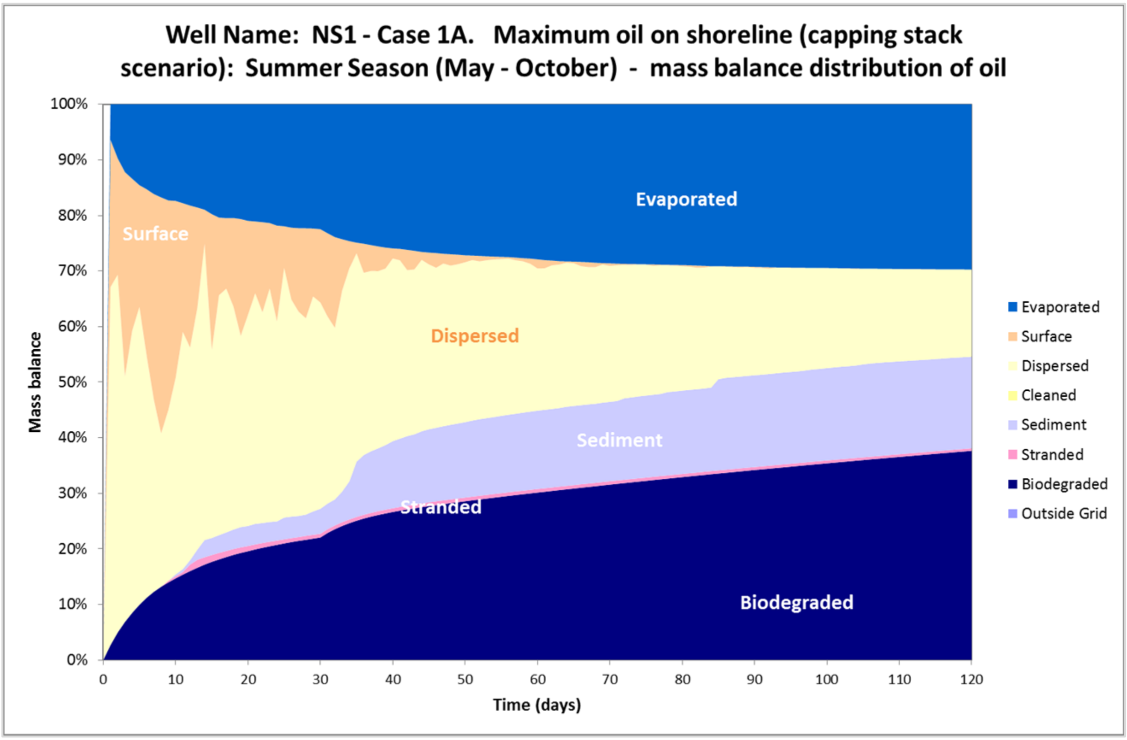


Figure 6.35 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 19th June 2006 23:00 GMT). Graph showing mass of oil stranded on the shoreline and length of shoreline oiled.

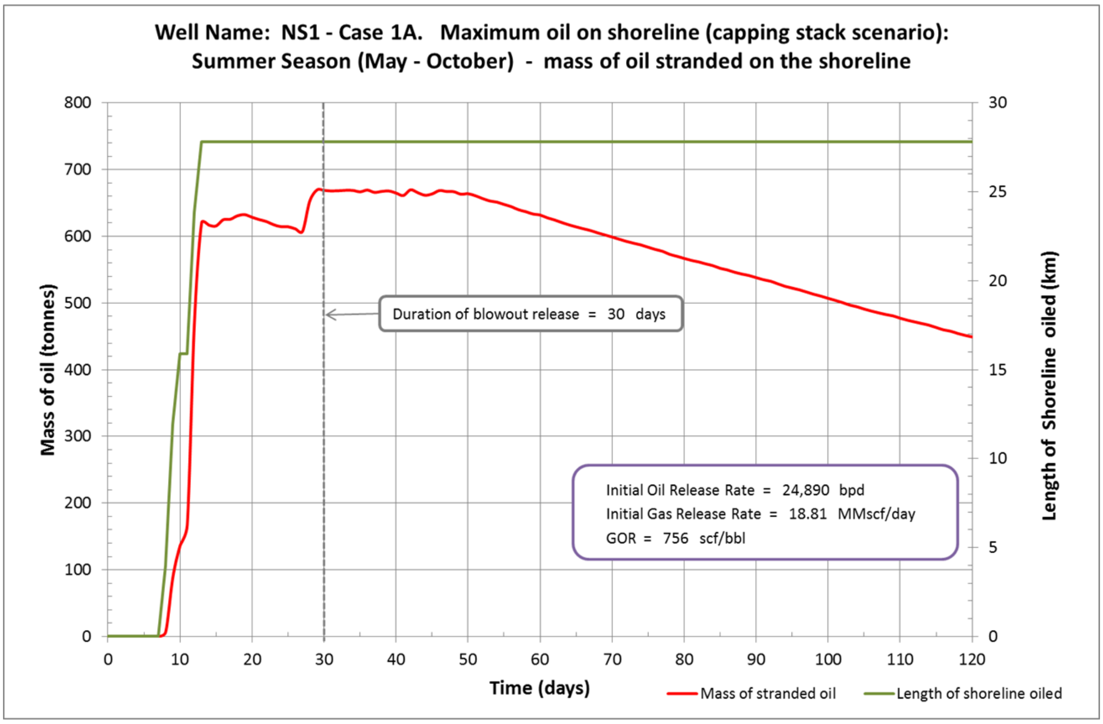


Figure 6.36 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Maximum oil ashore simulation (Summer Season, start date 19th June 2006 23:00 GMT). Graph showing area coverage of surface oil

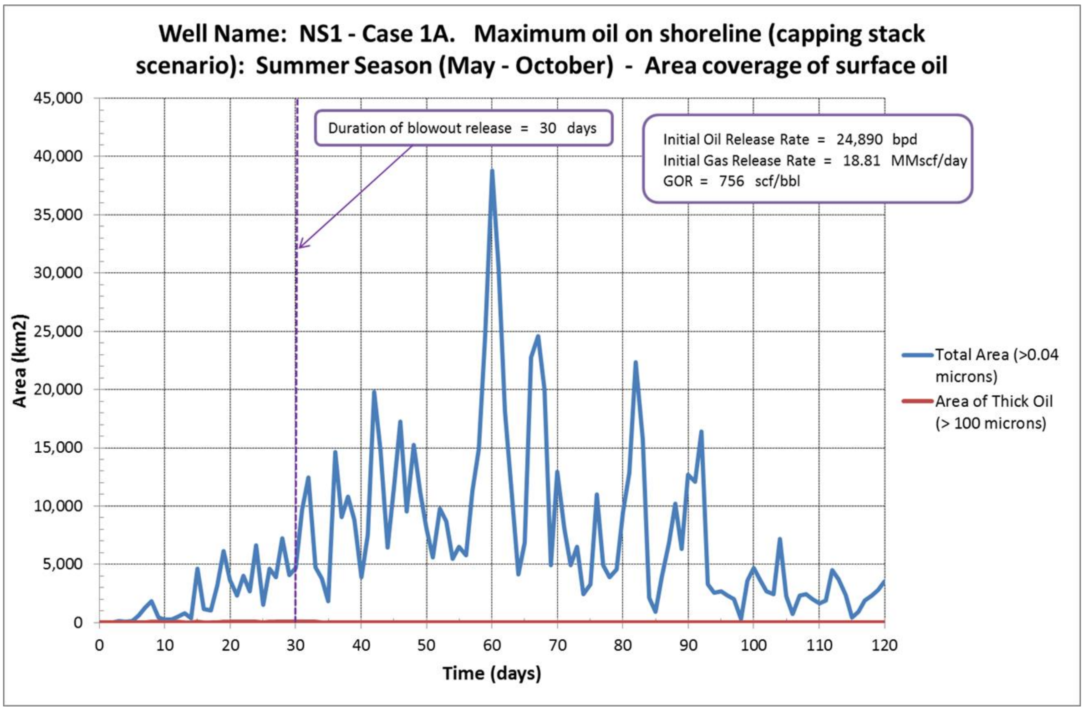


Figure 6.37 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 19th June 2006 23:00 GMT). Contour map showing the maximum surface oil thickness at each location over the simulation period (0.04µm BAOAC "Sheen" thickness threshold applied)

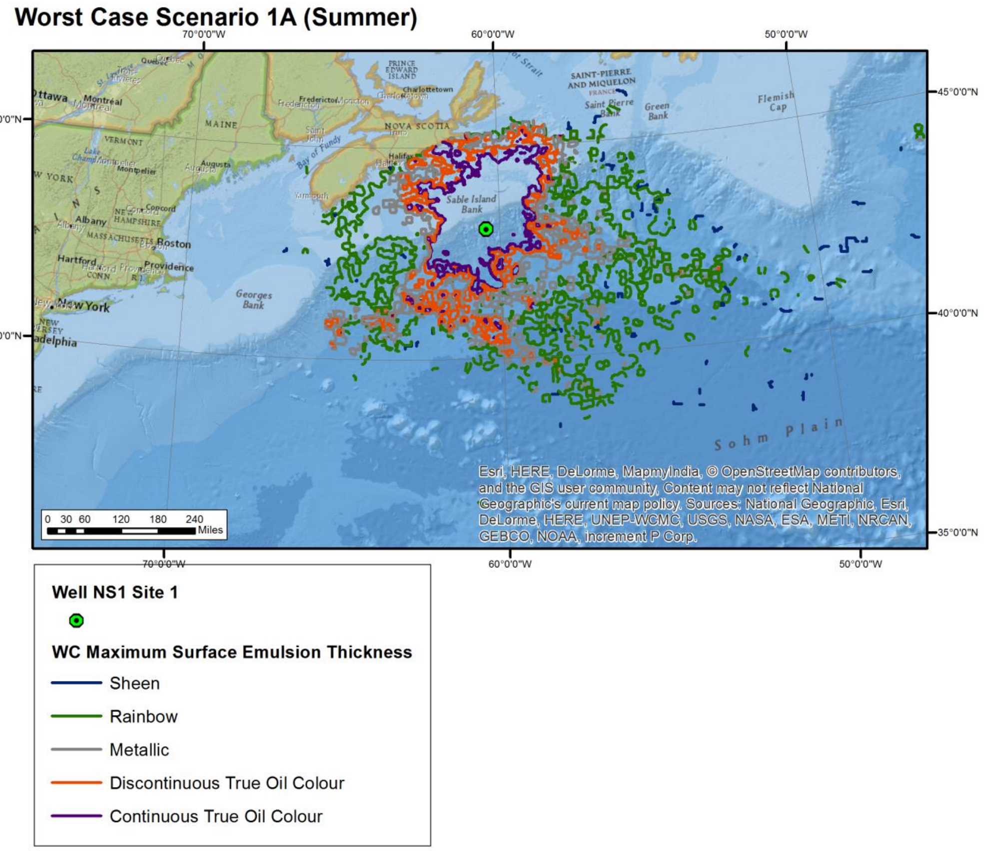


Figure 6.38 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 19th June 2006 23:00 GMT). Contour map showing the maximum concentration of total hydrocarbons (dispersed and dissolved) within any grid cell in the top 100 m of water column over the entire simulation (58 ppb THC threshold applied).

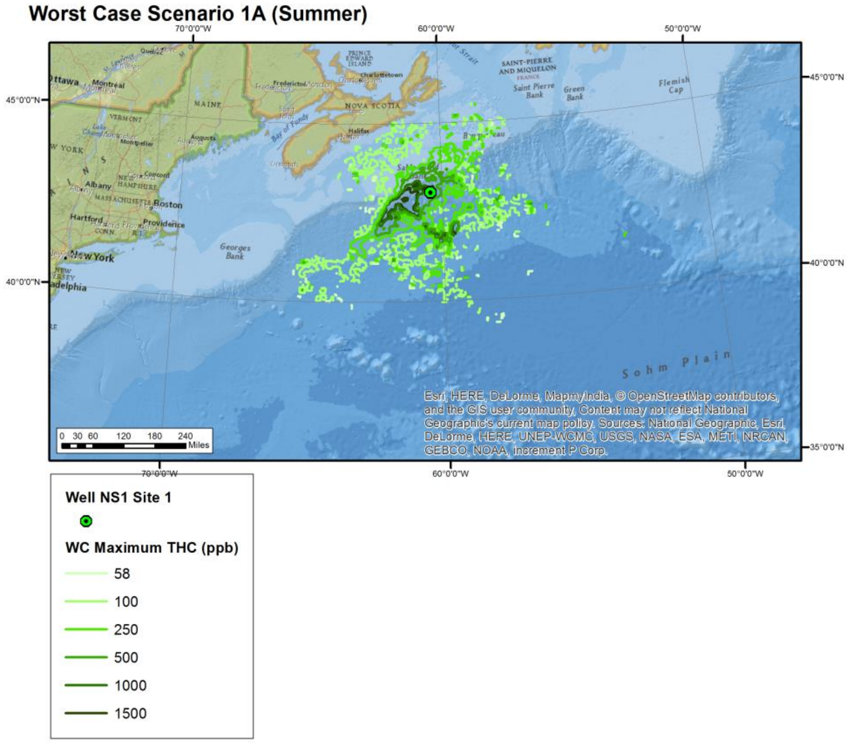


Figure 6.39 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 19th June 2006 23:00 GMT). Contour map showing the maximum concentration of dissolved oil within any grid cell in the top 100 m of water column over the entire simulation (1 ppb threshold applied).

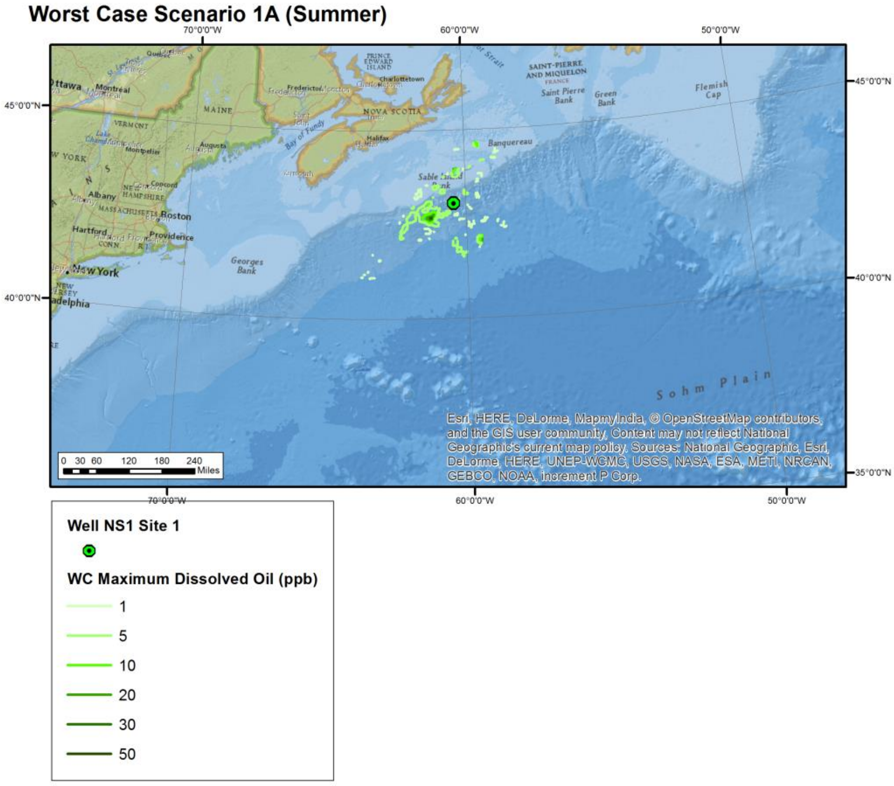
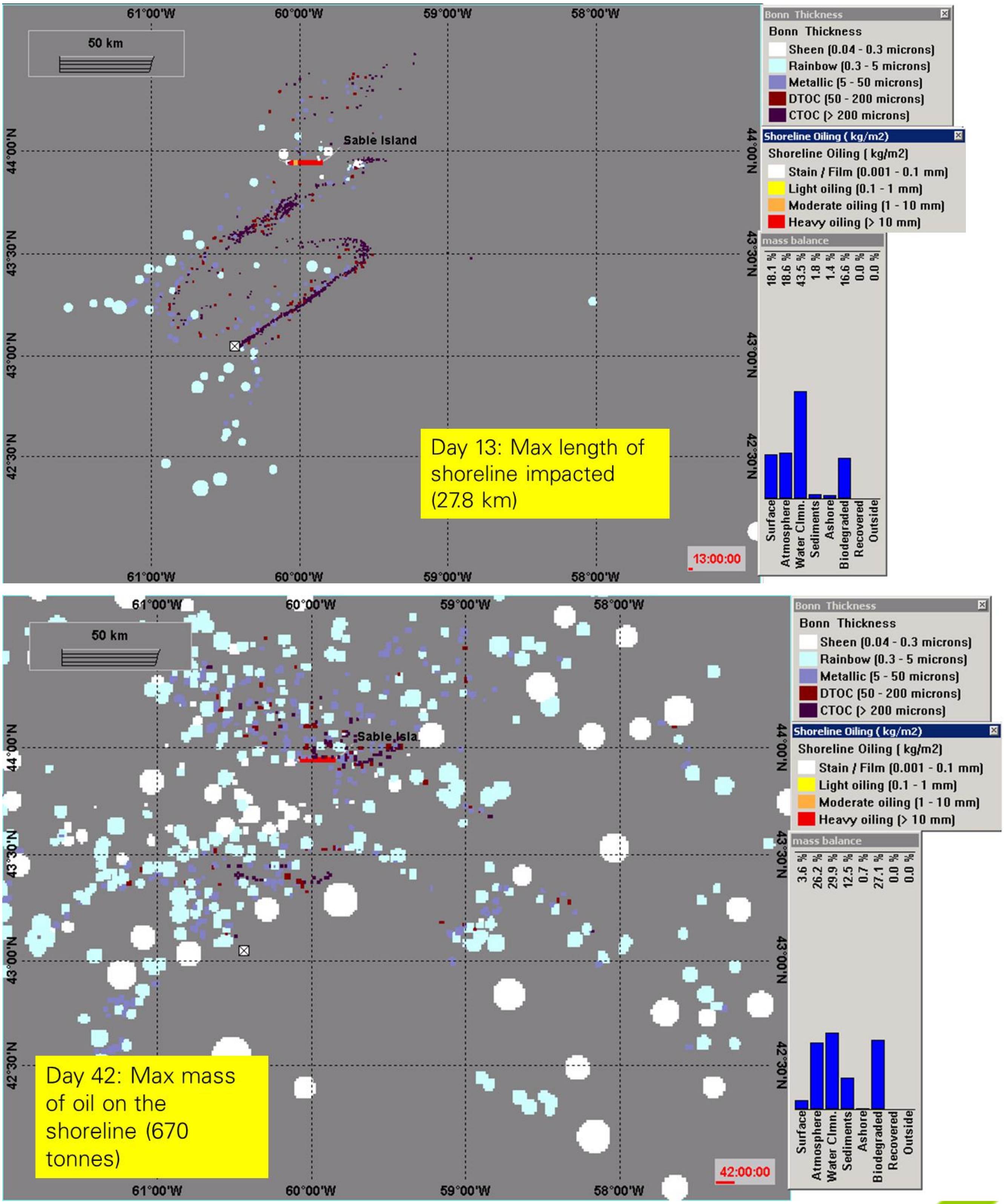


Figure 6.40 Case 1A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 19th June 2006 23:00 GMT). Snapshot maps showing extent of the surface slick and shoreline oiling 13 and 42 days after the start of the release



6.2.2 Well: NS-1 Case 2A – maximum oil on shoreline scenario (Summer Season)

Near-field plume dynamics

Figure 6.41 shows the results of a near-field deterministic simulation over the first 2 days of the NS-1 blowout event at Site 2 (worst case shoreline oiling scenario, summer season).

Vertical cross sections through the water column show the extent of the subsea plume, and rise of oil droplets and dissolved oil. The water column grid (100 m x 100 m horizontal resolution) is split into 100 vertical layers (27 m per layer) extending all the way to the sea-floor.

The results were broadly similar to those for Site 1, although the central core of the dispersed oil plume was more constrained, suggesting that cross currents velocities were smaller than those experienced during the Site 1 simulation. The snapshots profiles in Figure 6.32 show that the central core of the plume (comprising dispersed and dissolved oil) does not extend more than 5 km radially away from the release location until the upper 300 m of the water column, where cross currents increase the radial extent of the dispersed oil to around 10 km.

Two lateral extrusions of dissolved hydrocarbon components away from the plume occur at water depths of circa 2,250 m and 2,400 m after 2 days (Figure 6.41).

The oil droplet size model in OSCAR predicts the same droplet size distribution as that for the Site 1 release (d95 d= 8.8 mm and d50 (median) = 4.1 mm). Although the higher release rate at Site 2 would infer a smaller droplet size, this is offset by the release occurring at deeper water depths where increased compression of gas in the release will reduce its contribution to droplet breakup.

The OSCAR simulation results suggest that the TLPD occurs at about 2,370 m below sea-level and is reached within 10 minutes of oil being released at the seabed. The model predicts it will take the largest oil droplets (8.8 mm) another 6 hours to rise to the surface, with 50% having arrived after 12 hours (see Figure 6.42).

Figure 6.41 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Snapshot maps showing the total hydrocarbon concentration (THC) of dispersed oil droplets and dissolved oil in the water column vs time after start of release.

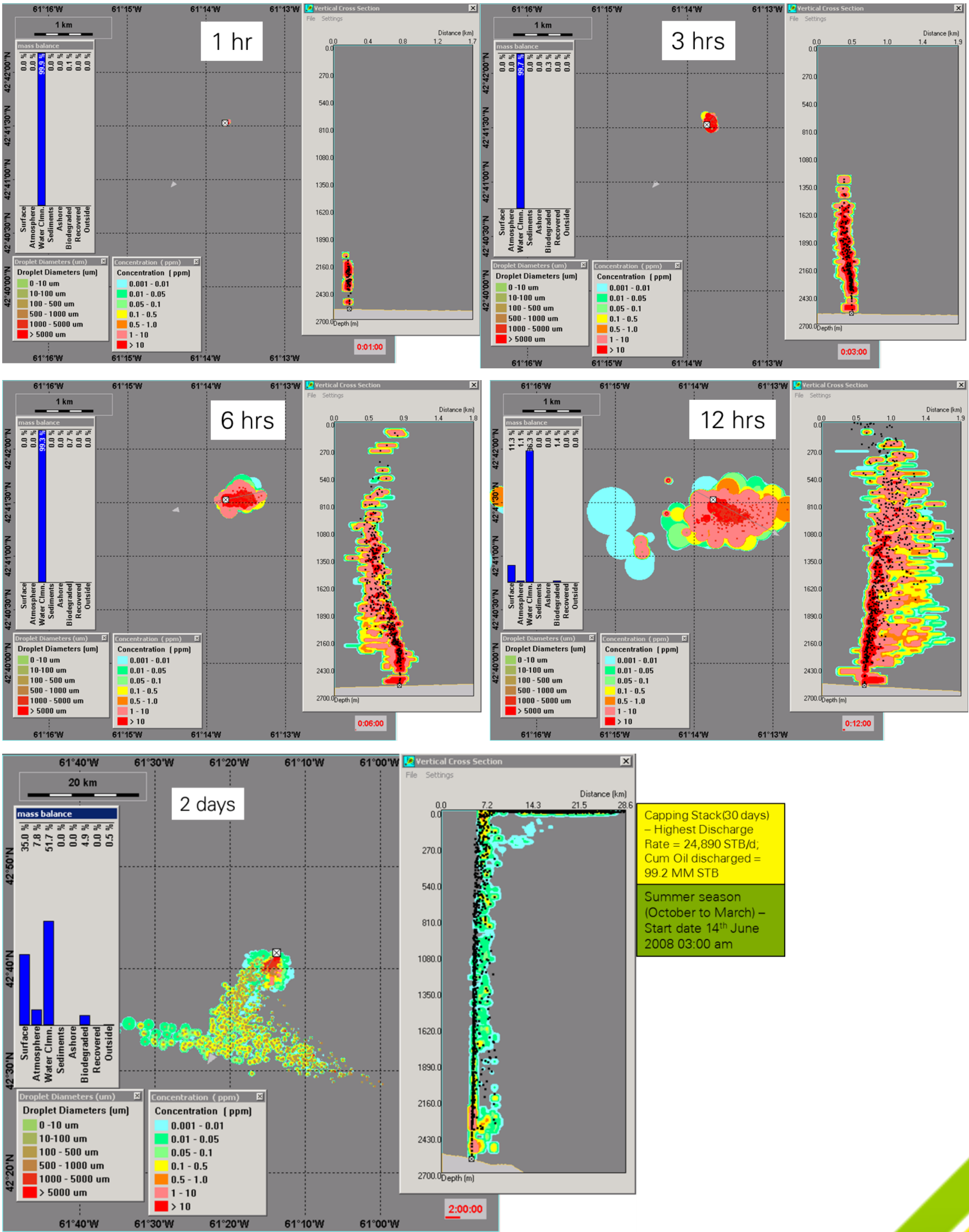
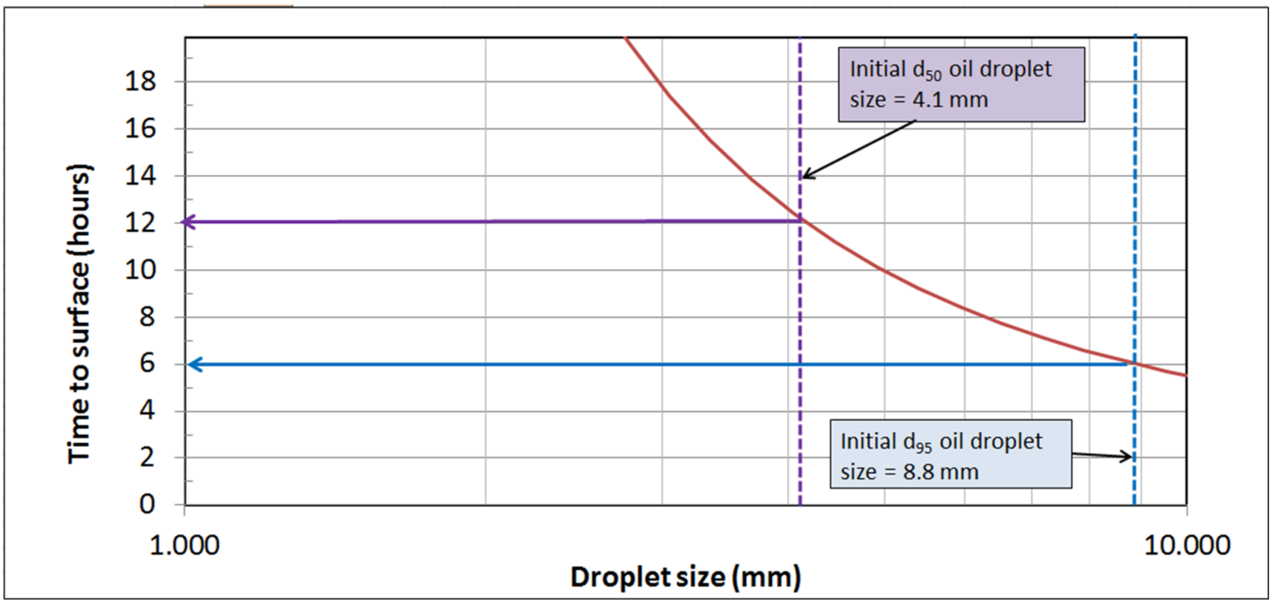


Figure 6.42 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Graph showing the predicted droplet rise-time to surface from the plume trapping height (2,370 m below sea-level) vs droplet size



Oil mass balance

Figures 6.43 and 6.44 show the mass balance time development and distribution of oil for the Site 2 worst case, maximum shoreline oiling, summer scenario. The simulation chosen started on 24th June 2008 at 03:00 GMT and resulted in a maximum oil mass on the shore of 669 tonnes, with the first oil beaching after 12 days.

The model results predicted that the water content of the oil emulsion arriving on the shoreline would be 78%, so the stranded oil tonnages need to be increased by a factor of 4.55 to derive the tonnage of oil emulsion beached on the shoreline.

At the end of the "worst" shoreline oiling simulation for the summer season, 53,680 tonnes of oil would be biodegraded ("decayed") and 43,830 tonnes evaporated (Figure 6.43). This accounts for 38% and 31% of the total oil released respectively. The maximum amount of oil in the water column ("dispersed") is reported as 56,980 tonnes after 30 days, the maximum amount of oil on the surface is 33,570 tonnes after 25 days and the maximum amount of weathered oil that sinks and becomes incorporated into the sediment is 17,310 tonnes after 120 days. After 120 days, 0.01% of the release is reported on the surface and 19% in the water column; with that remaining in the water column dispersed to negligible concentrations (< 10 ppb THC dispersed oil).

The results for Site 2 (Figure 6.47 – 6.49) illustrate that surface oiling exceeding the threshold will occur in the near shore waters of Nova Scotia, with surface thicknesses ranging from 0.04 µm to 200 µm. The in-water oil threshold follows the same trend with in-water oil concentrations ranging from 58 ppb to 1,000 ppb in the near shore waters around Nova Scotia. The maximum length of shoreline impacted would occur after 101 days with 80 km of coastline affected including the coastlines of both Sable Island and mainland Nova Scotia (Figure 6.45 and 6.50). The maximum mass of oil on the shoreline occurs earlier (after 32 days) with 669 tonnes of oil accumulated on the shoreline.

Figure 6.43 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Maximum oil ashore simulation (Summer Season, start date 24th June 2008 03:00 GMT). Chart showing time development of oil mass balance.

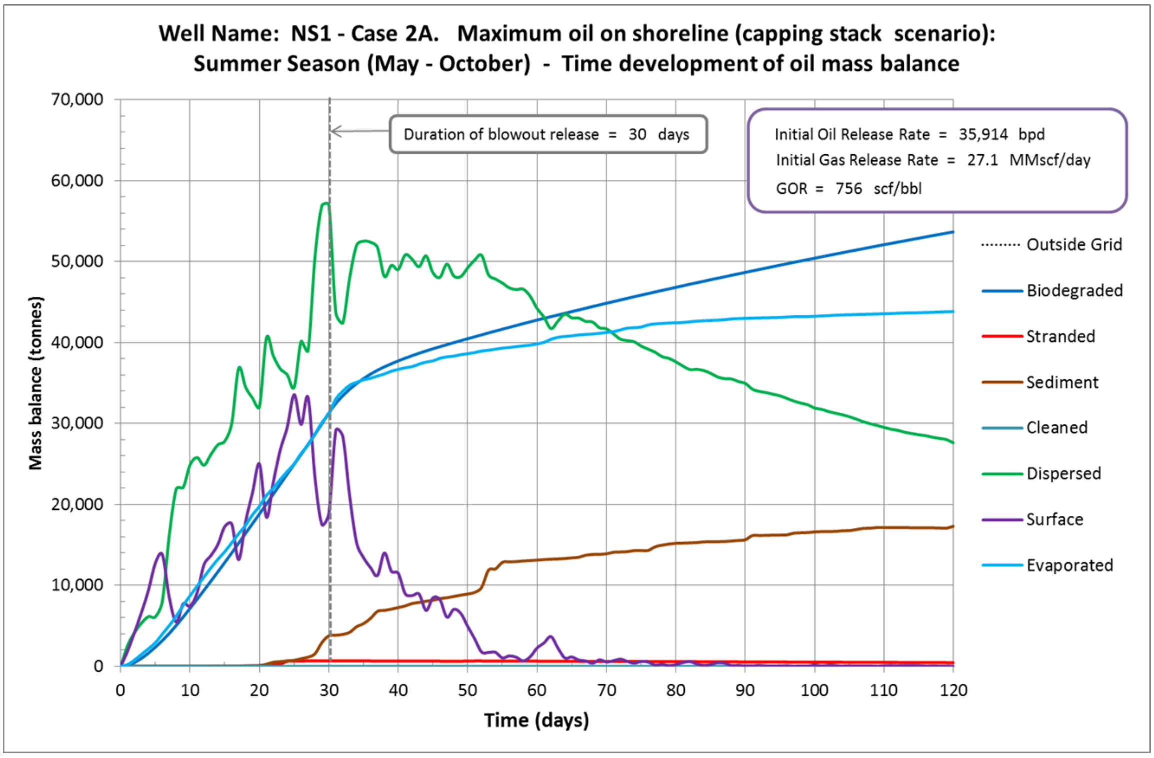
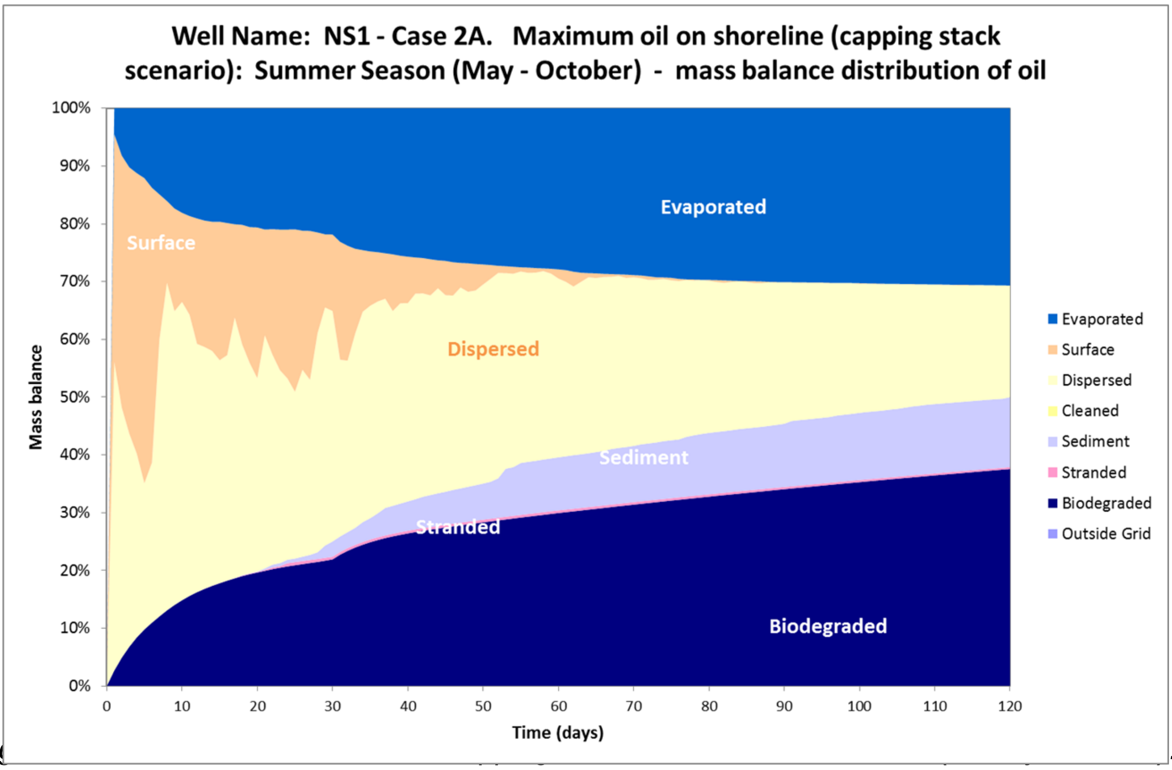


Figure 6.44 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Maximum oil ashore simulation (Summer Season, start date 24th June 2008 03:00 GMT). Graph showing mass balance distribution of oil over the duration of the simulation.



Fi .
Maximum oil ashore simulation (Summer Season, start date 24th June 2008 03:00 GMT). Graph showing mass of oil stranded on the shoreline and length of shoreline oiled.

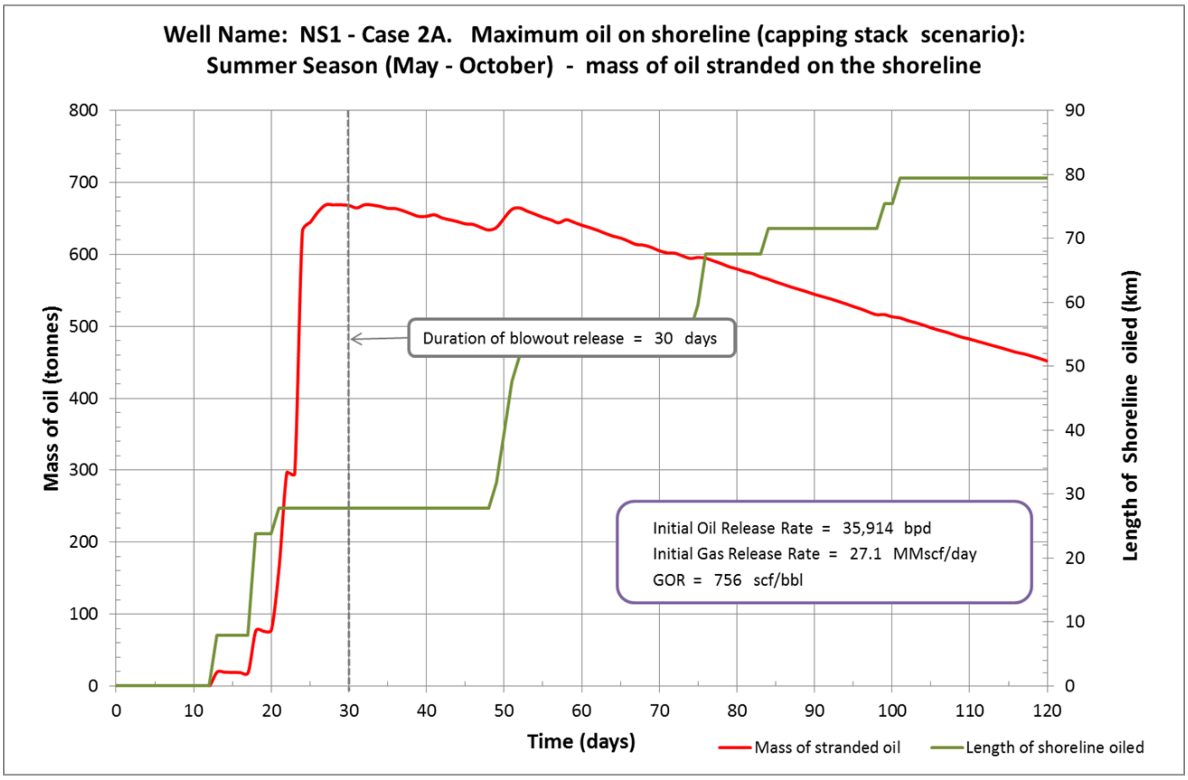


Figure 6.46 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 24th June 2008 03:00 GMT). Graph showing area coverage of surface oil.

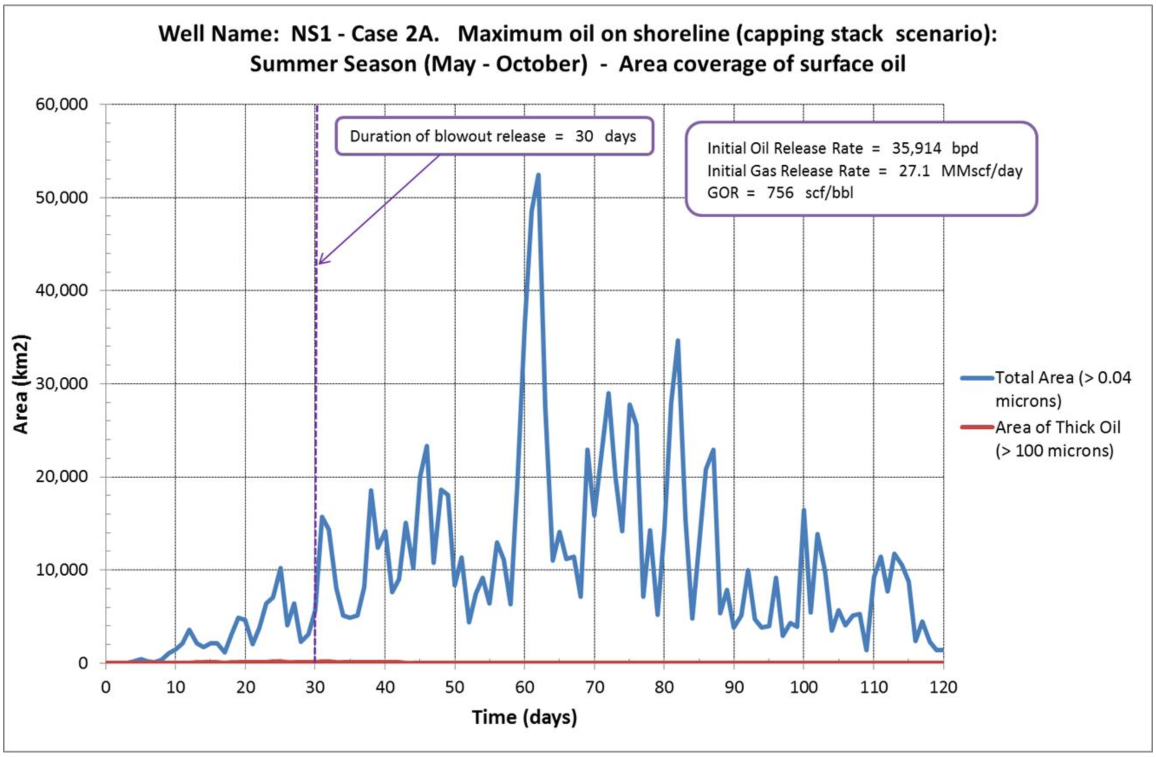


Figure 6.47 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 24th June 2008 03:00 GMT). Contour map showing the maximum surface oil thickness at each location over the simulation period (0.04µm BAOAC "Sheen" thickness threshold applied)

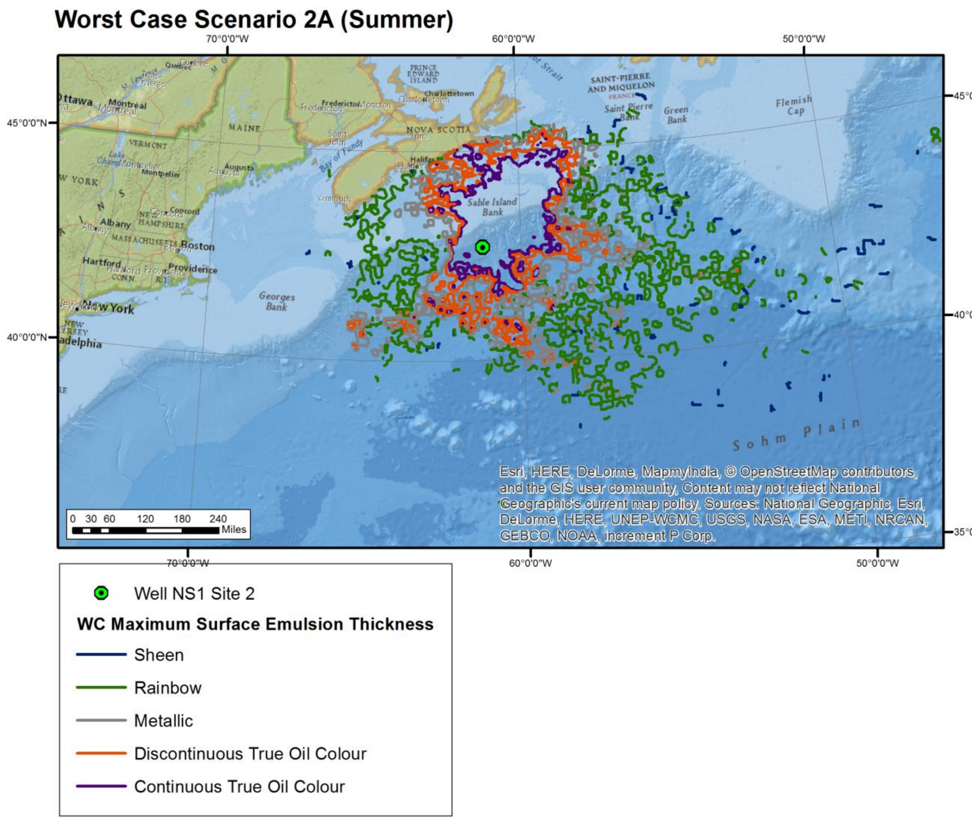


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Figure 6.48 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 24th June 2008 03:00 GMT). Contour map showing the maximum concentration of total hydrocarbons (dispersed and dissolved) within any grid cell in the top 100 m of water column over the entire simulation (58 ppb THC threshold applied).

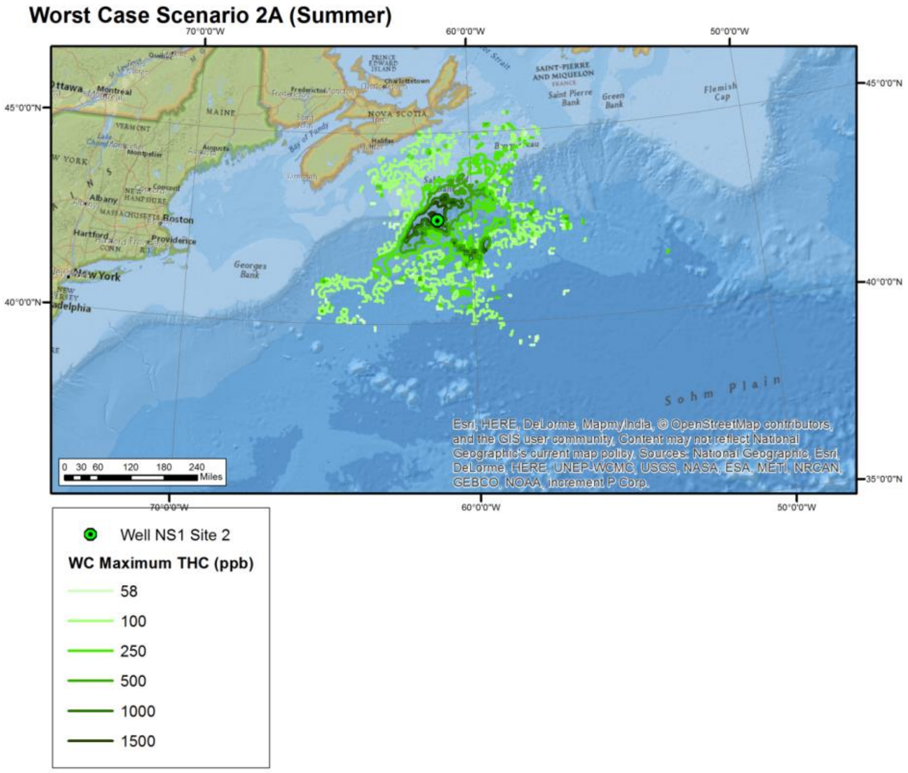


Figure 6.49 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 24th June 2008 03:00 GMT). Contour map showing the maximum concentration of dissolved oil within any grid cell in the top 100 m of water column over the entire simulation (1 ppb threshold applied).

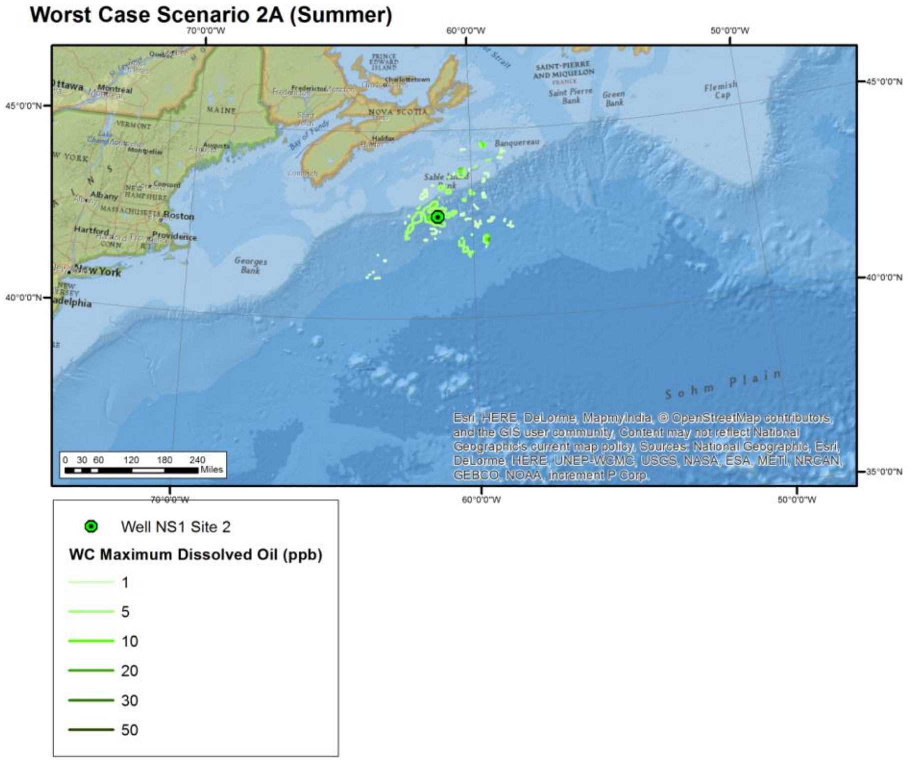
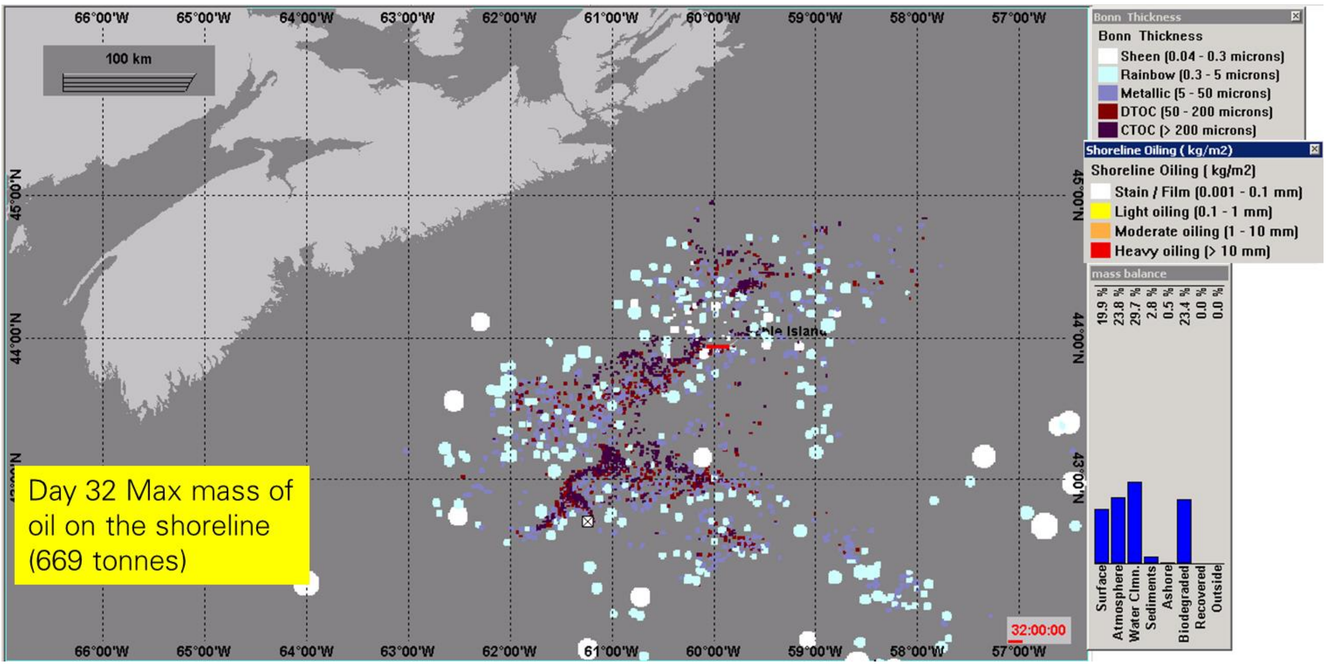
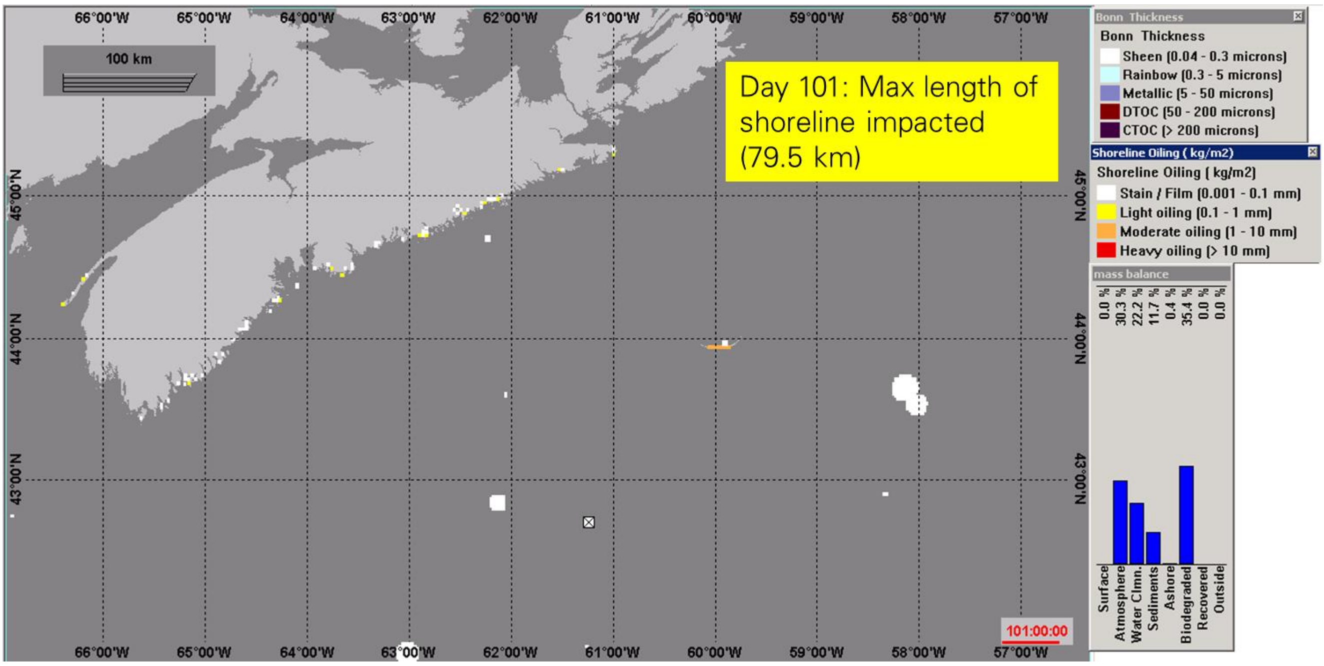


Figure 6.50 Case 2A: Well NS-1 capping stack containment scenario (30 day duration). Maximum oil ashore simulation (Summer Season, start date 24th June 2008 03:00 GMT). Snapshot maps showing extent of the surface slick and shoreline oiling 32 and 101 days after the start of the release





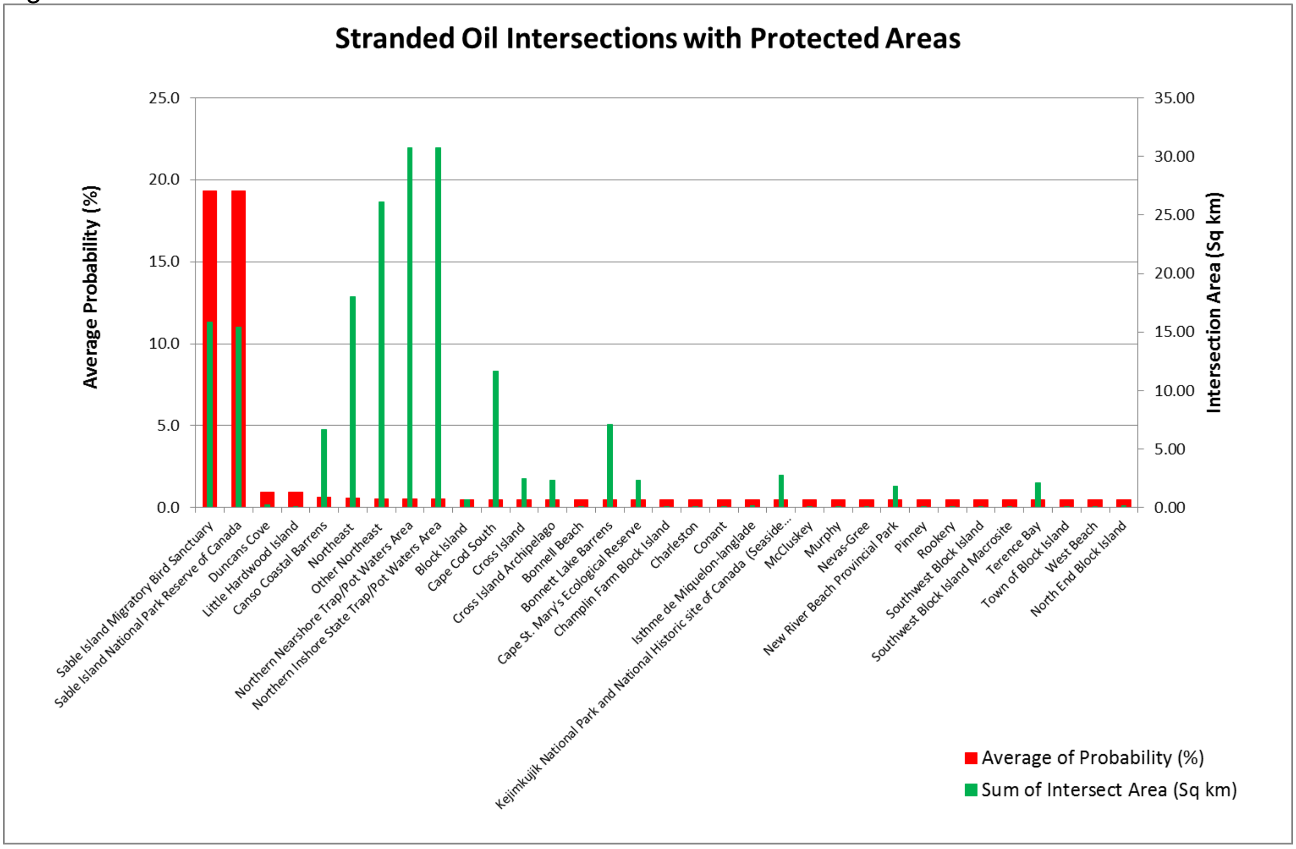
6.3 Oil Spill Intersections with Protected Area, Ecologically and Biologically Sensitive Areas and World Maritime Boundaries

The following diagrams provide a ranking of the PAs, EBSAs and WMBs most likely to be impacted by either stranded oil, oil on the sea surface, or oil in the upper water column.

6.3.1 Well: NS-1 Case 1A – (Winter Season)

Stranded oil

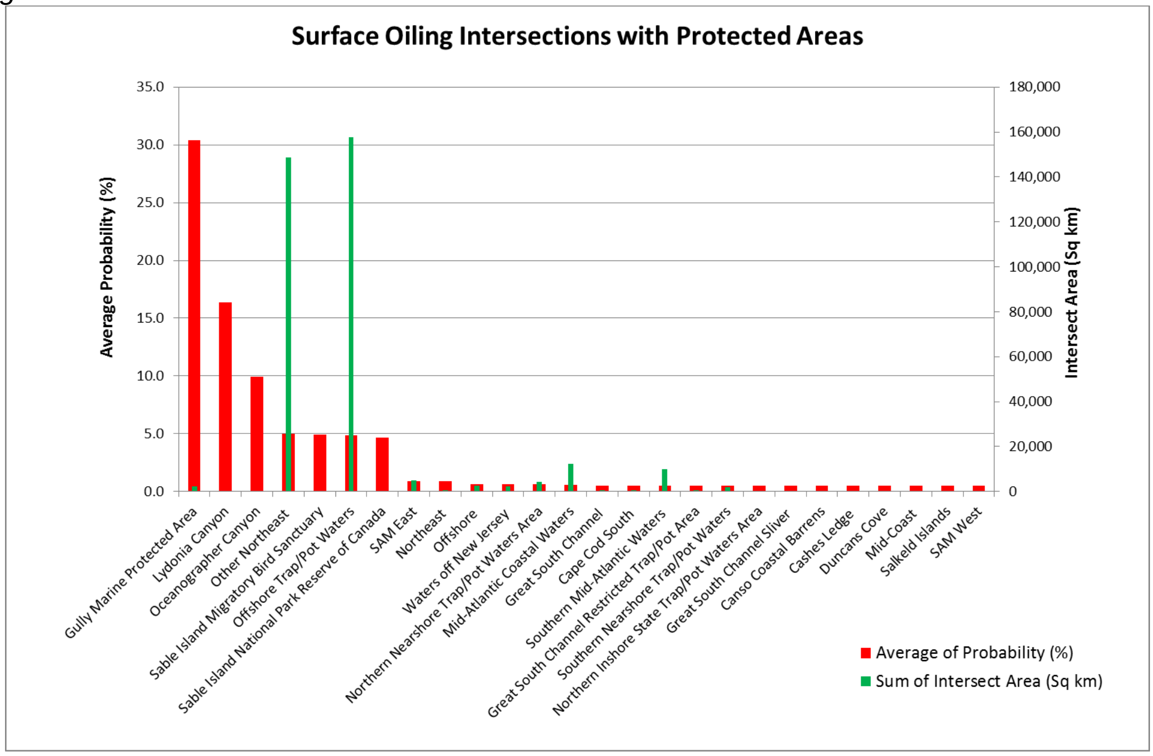
Figure 6.51



* *Probability of shoreline emulsion mass exceeding the 0.0019 tonnes/km (or 0.001 litres / m^2 = 1 micron), minimum threshold for "Stain / Film" oiling.*

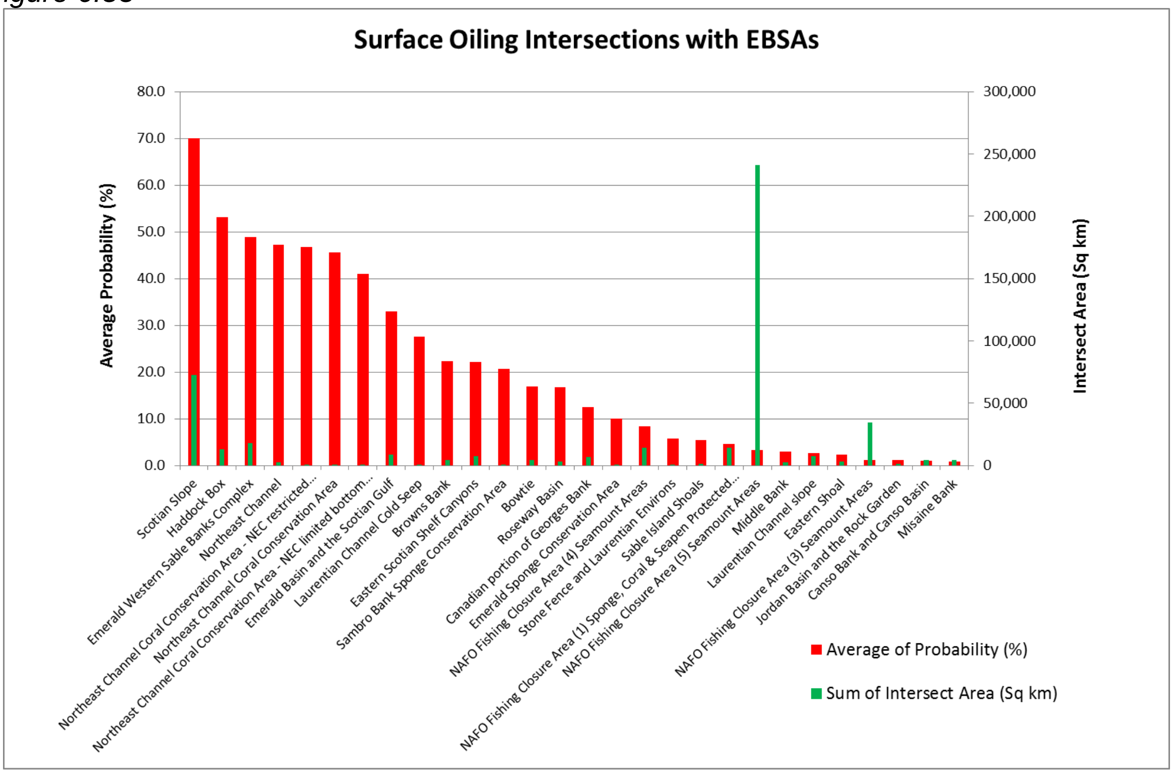
Surface oil

Figure 6.52



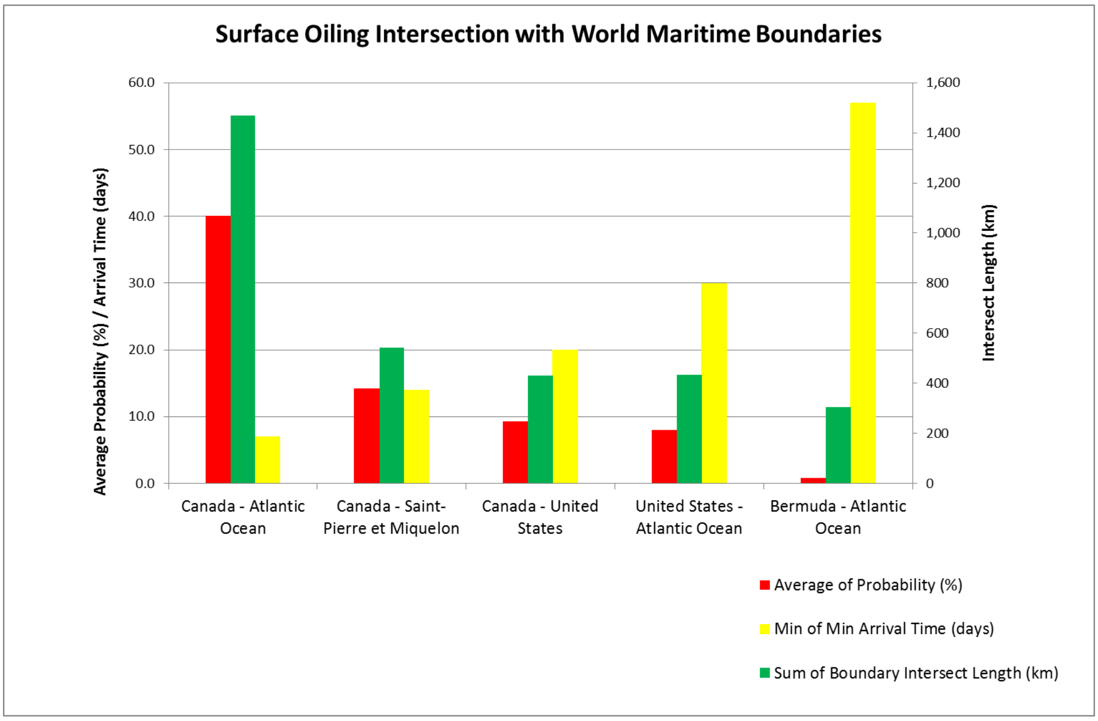
* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold*

Figure 6.53



* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold*

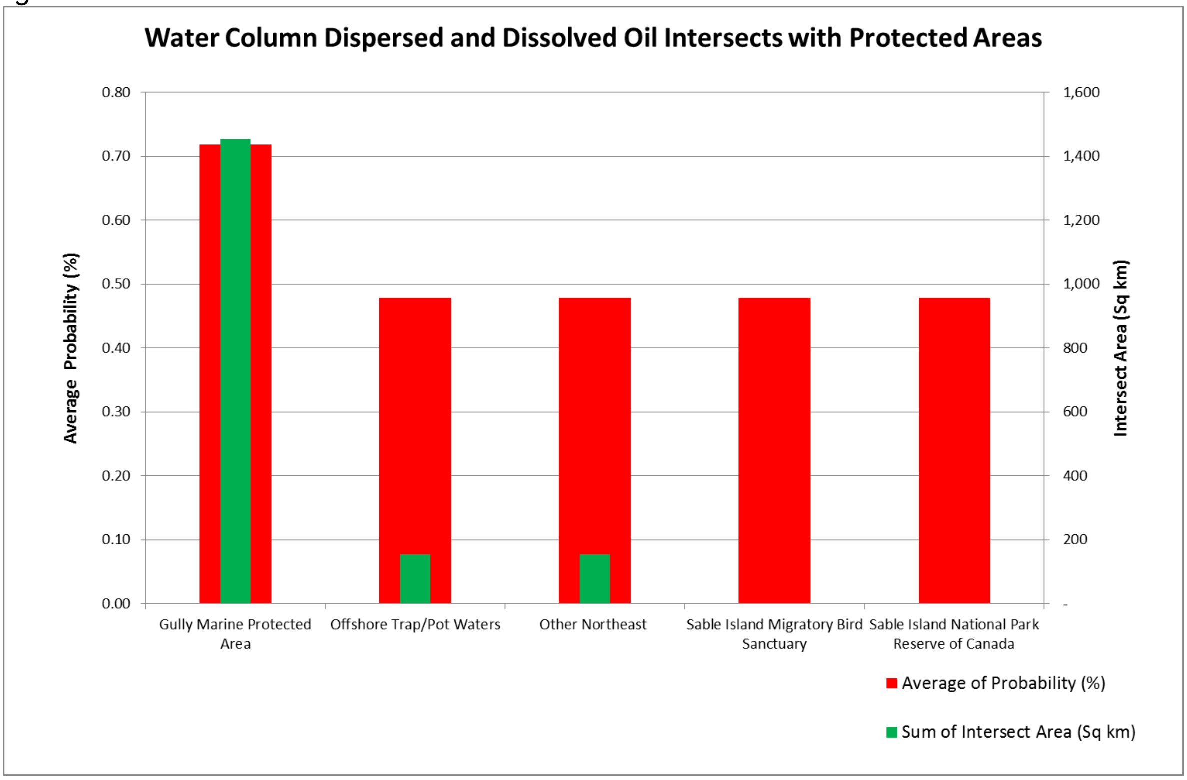
Figure 6.54



* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 μm (BAOAC "Sheen") thickness threshold*

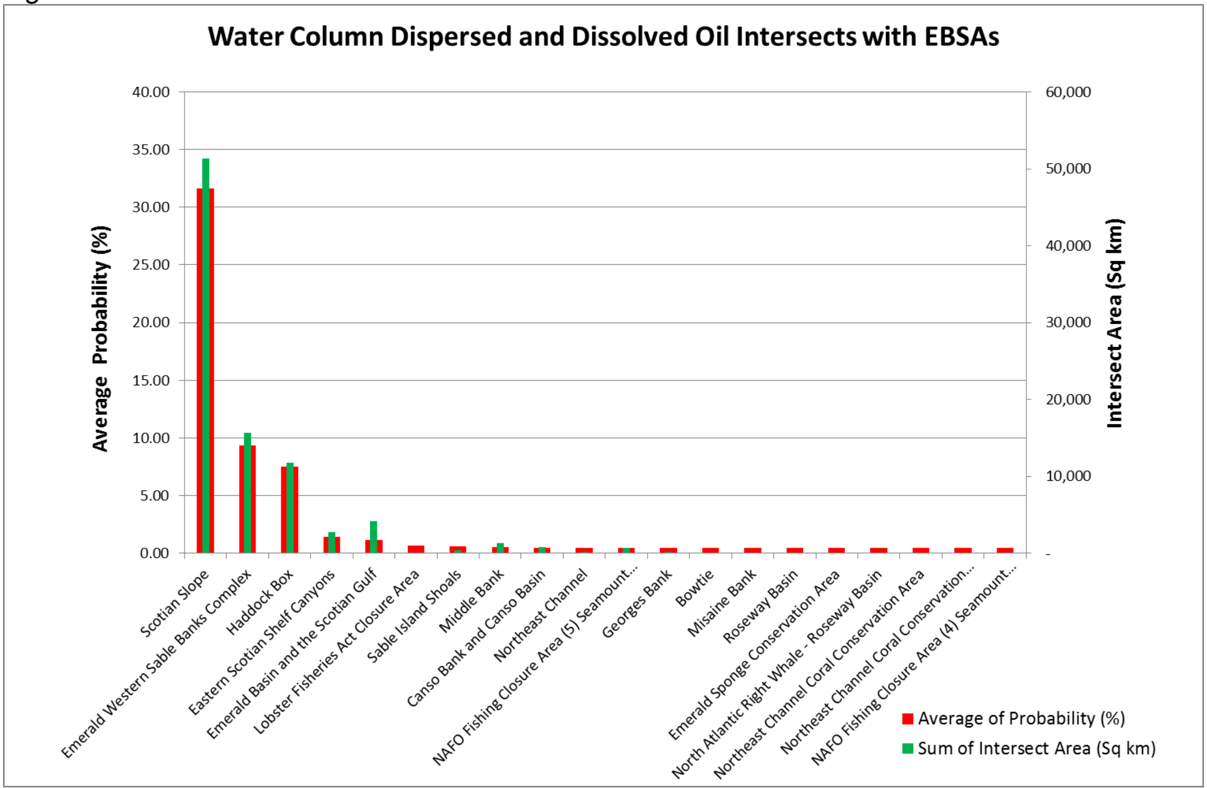
Oil in the Upper water column (<100 m water depth)

Figure 6.55



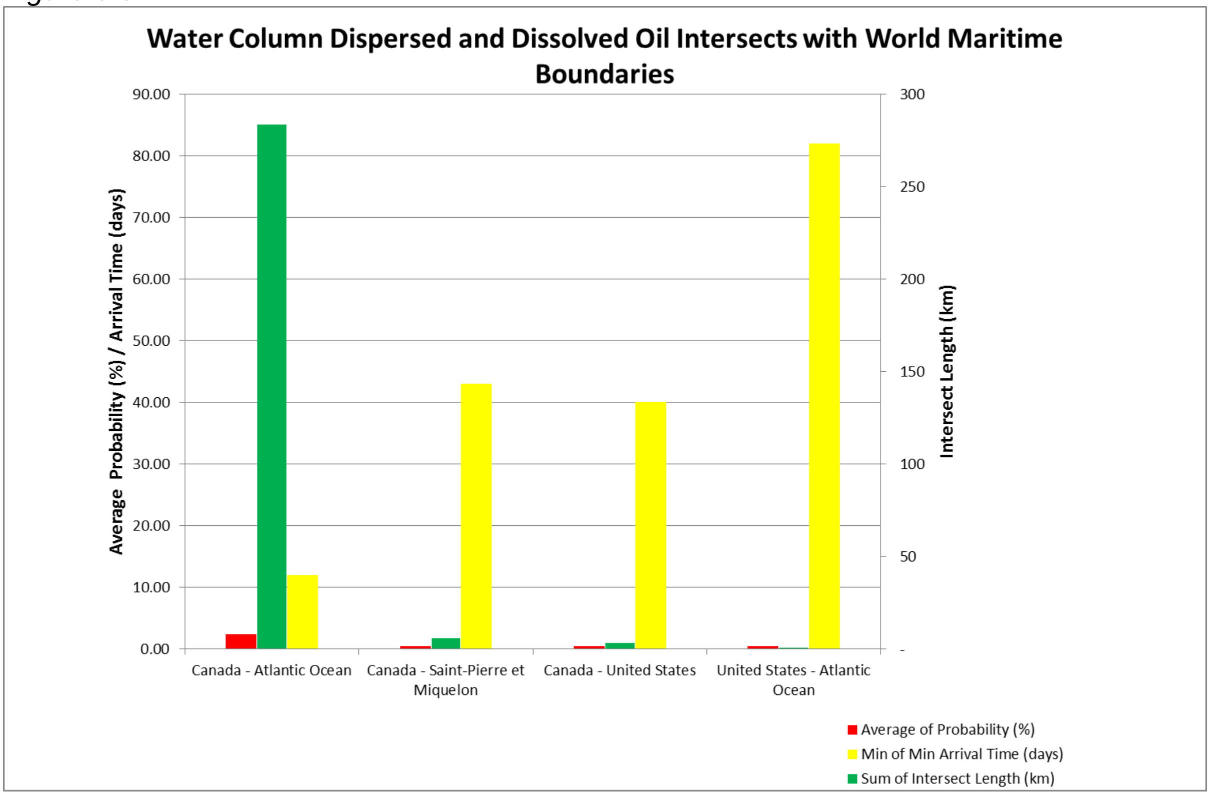
* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

Figure 6.56



* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

Figure 6.57

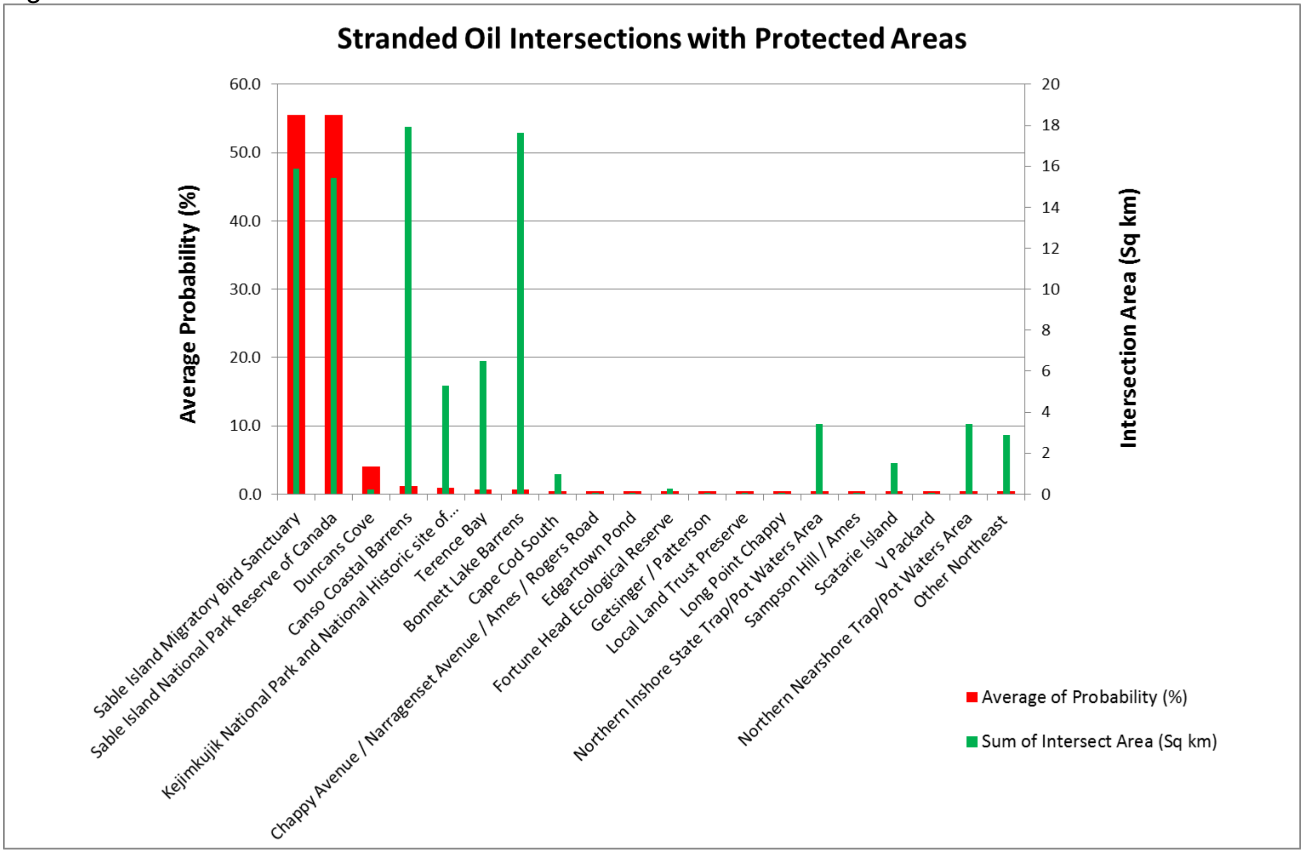


* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

6.3.2 Well: NS-1 Case 1A – (Summer Season)

Stranded oil

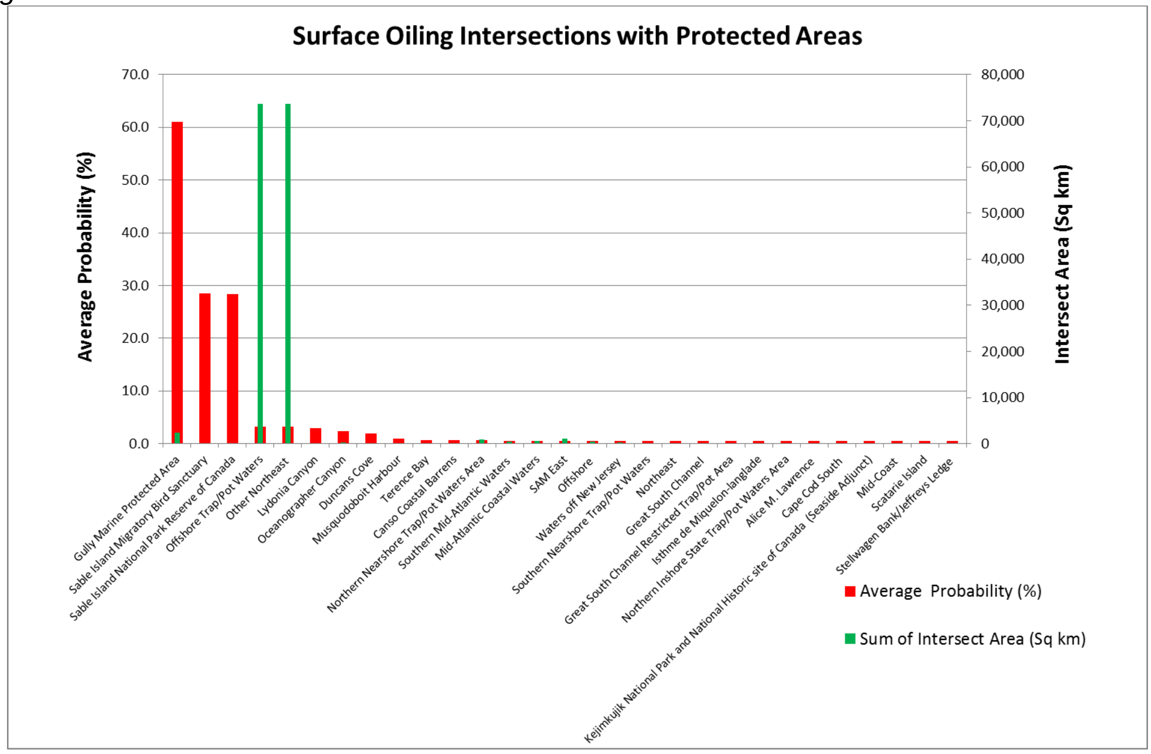
Figure 6.58



* *Probability of shoreline emulsion mass exceeding the 0.0019 tonnes/km (or 0.001 litres / m2 = 1 micron), minimum threshold for "Stain / Film" oiling.*

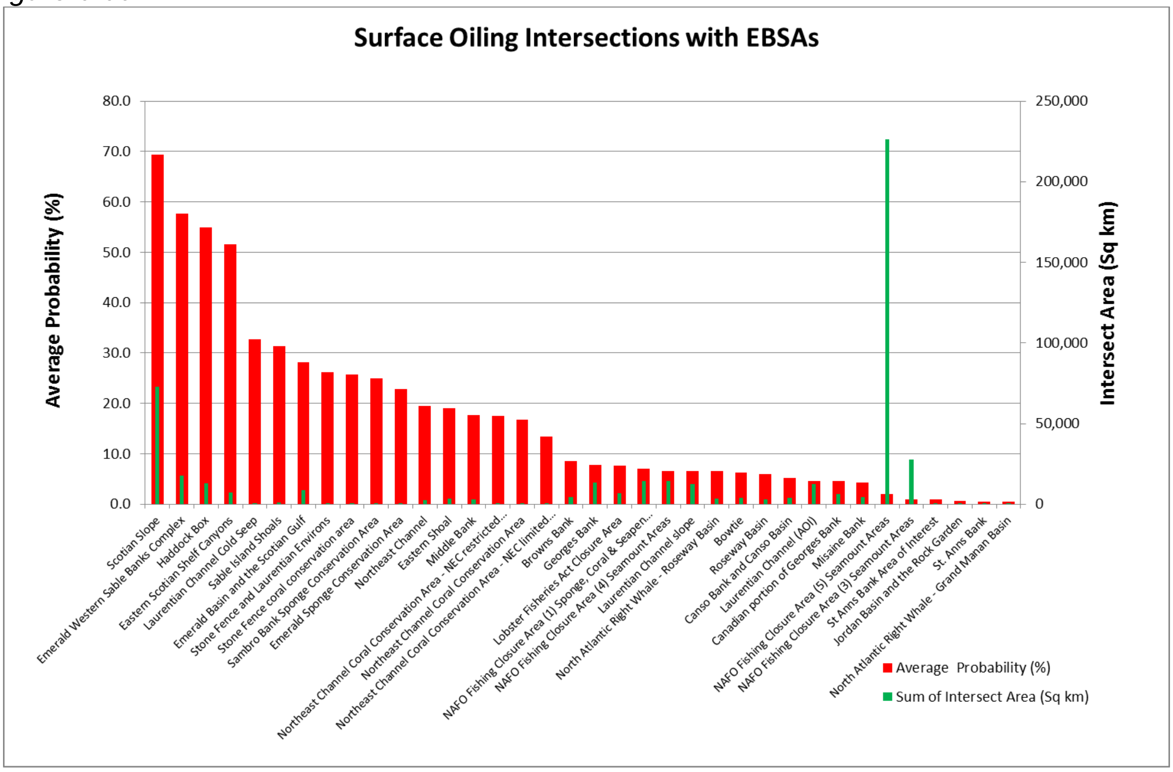
Surface oil

Figure 6.59



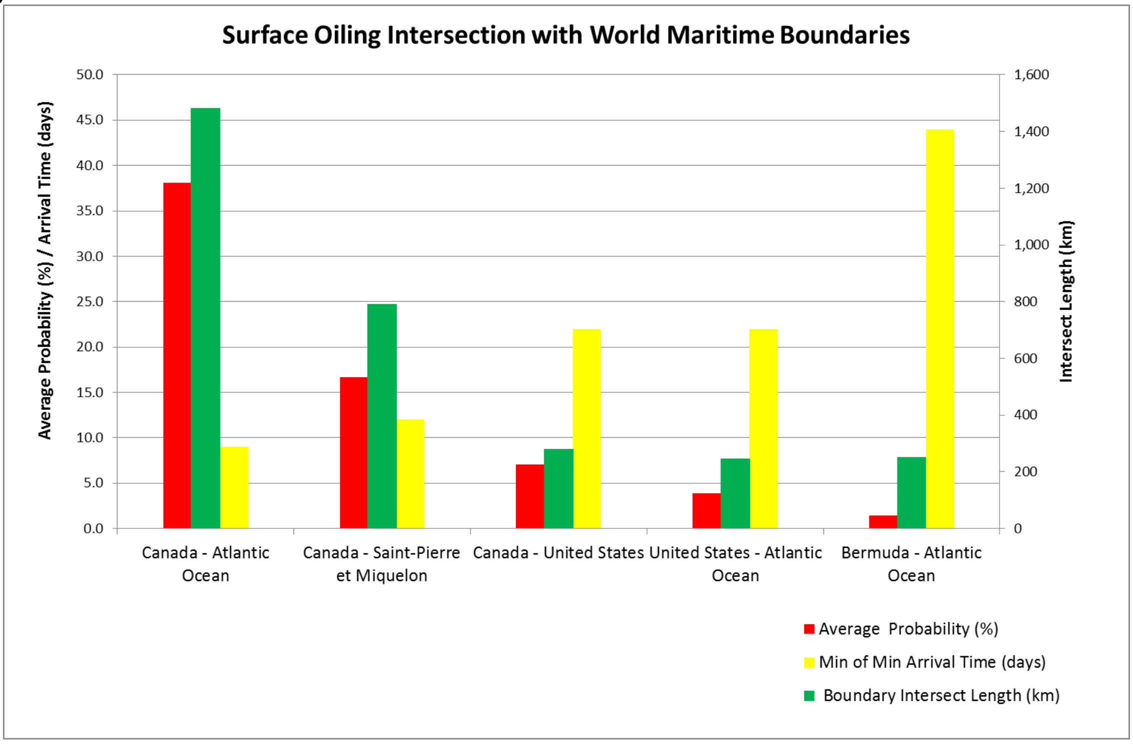
* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold*

Figure 6.60



* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold*

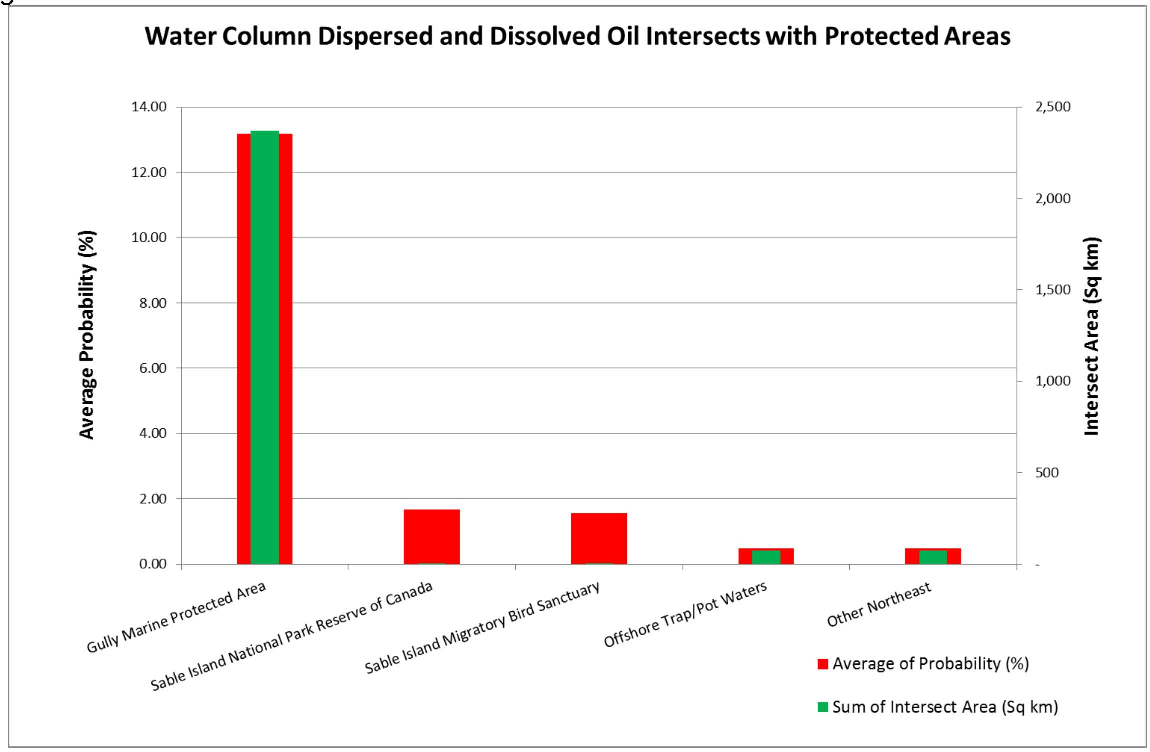
Figure 6.61



* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold*

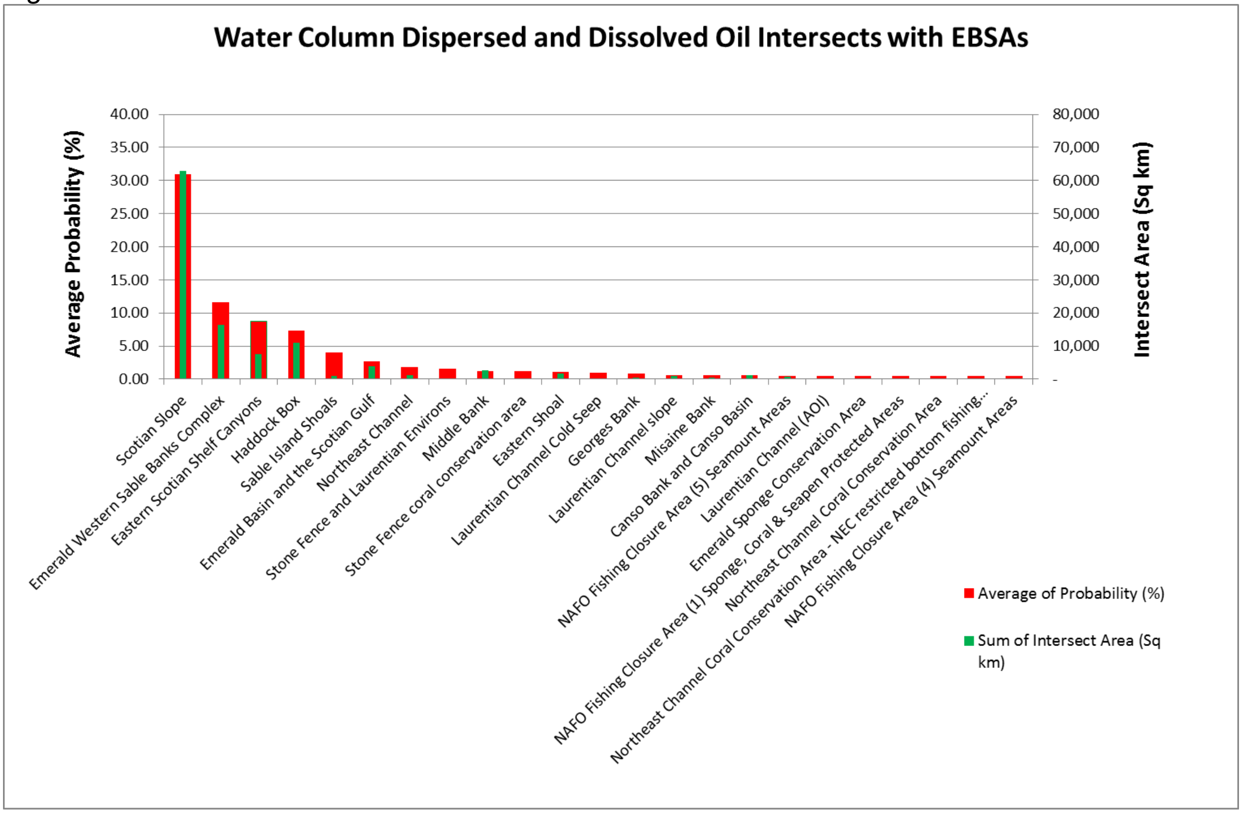
Oil in the Upper water column (<100 m water depth)

Figure 6.62



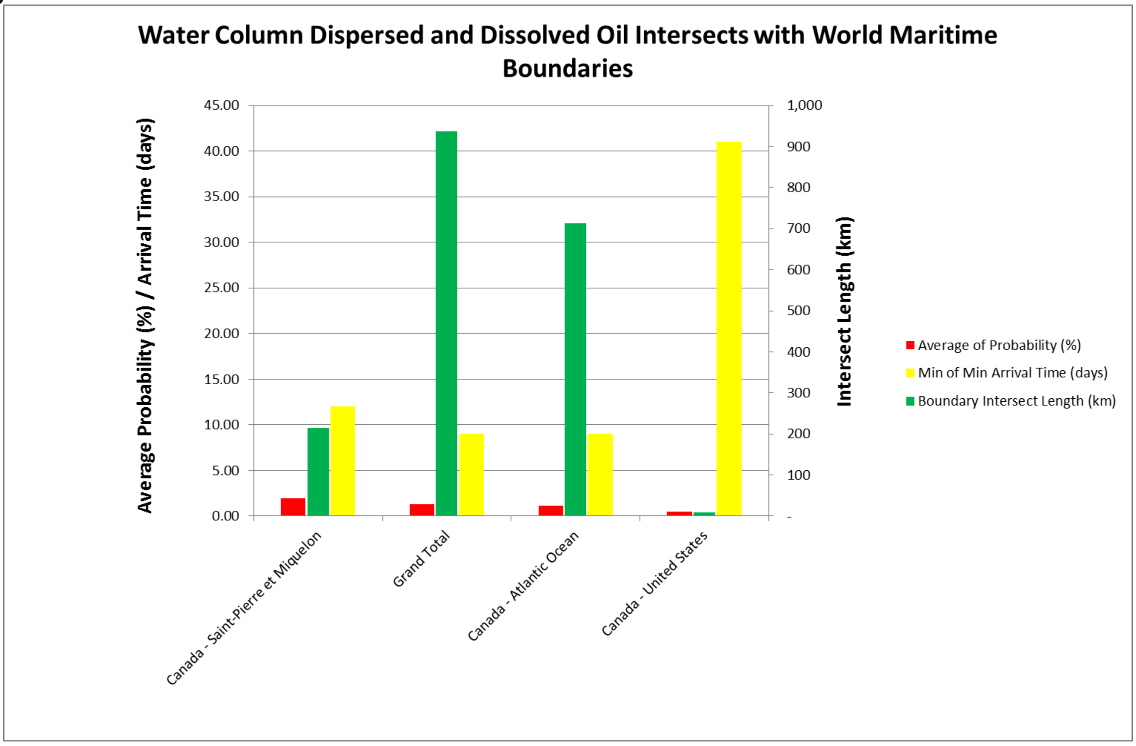
* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

Figure 6.63



* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

Figure 6.64

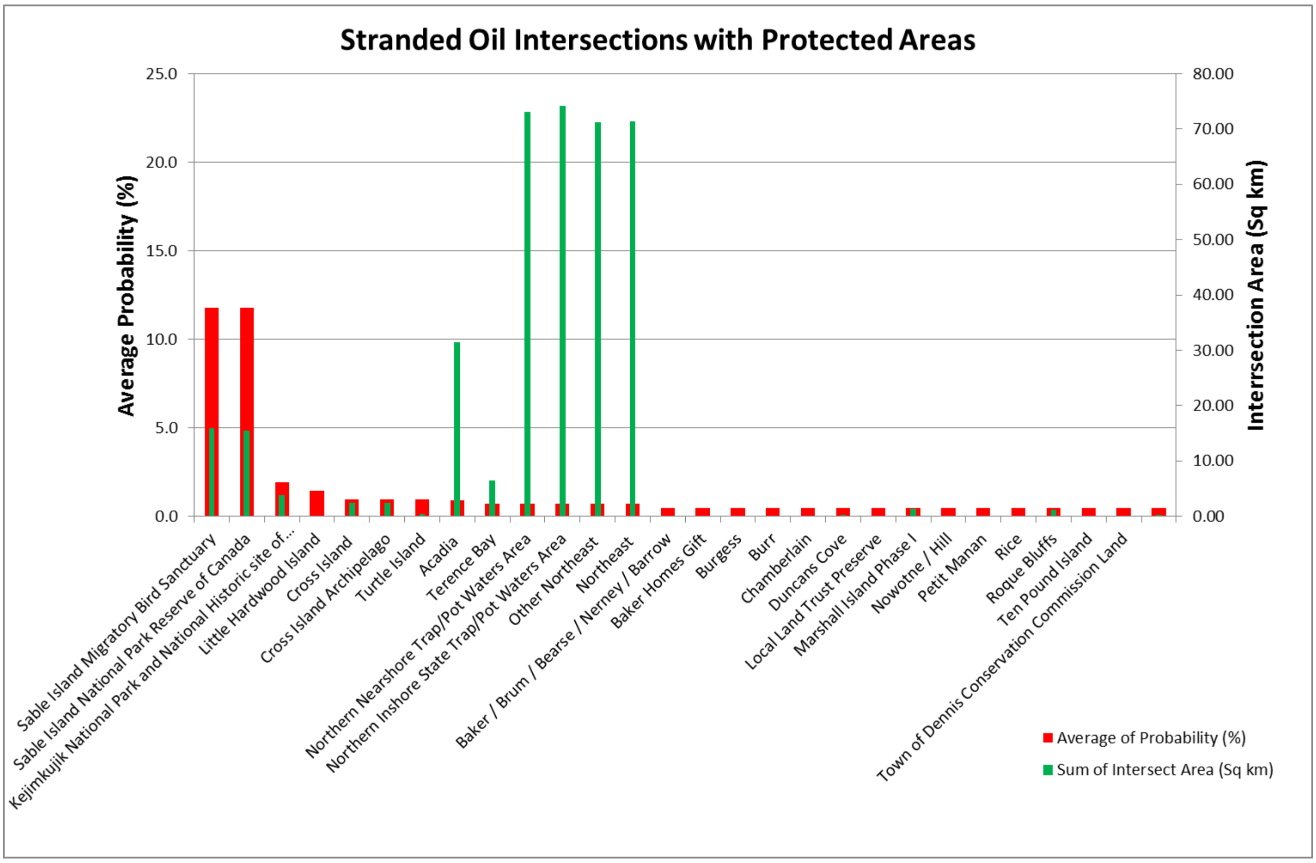


* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

6.3.3 Well: NS-1 Case 2A – (Winter Season)

Stranded oil

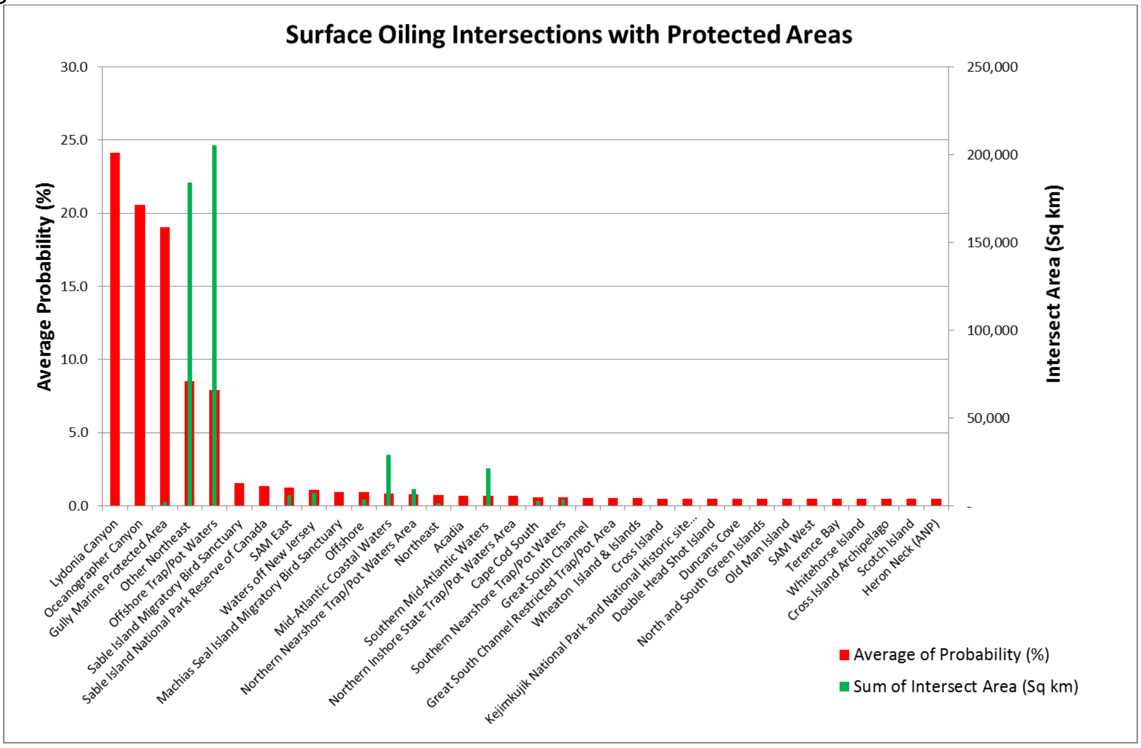
Figure 6.65



* *Probability of shoreline emulsion mass exceeding the 0.0019 tonnes/km (or 0.001 litres / m^2 = 1 micron), minimum threshold for "Stain / Film" oiling.*

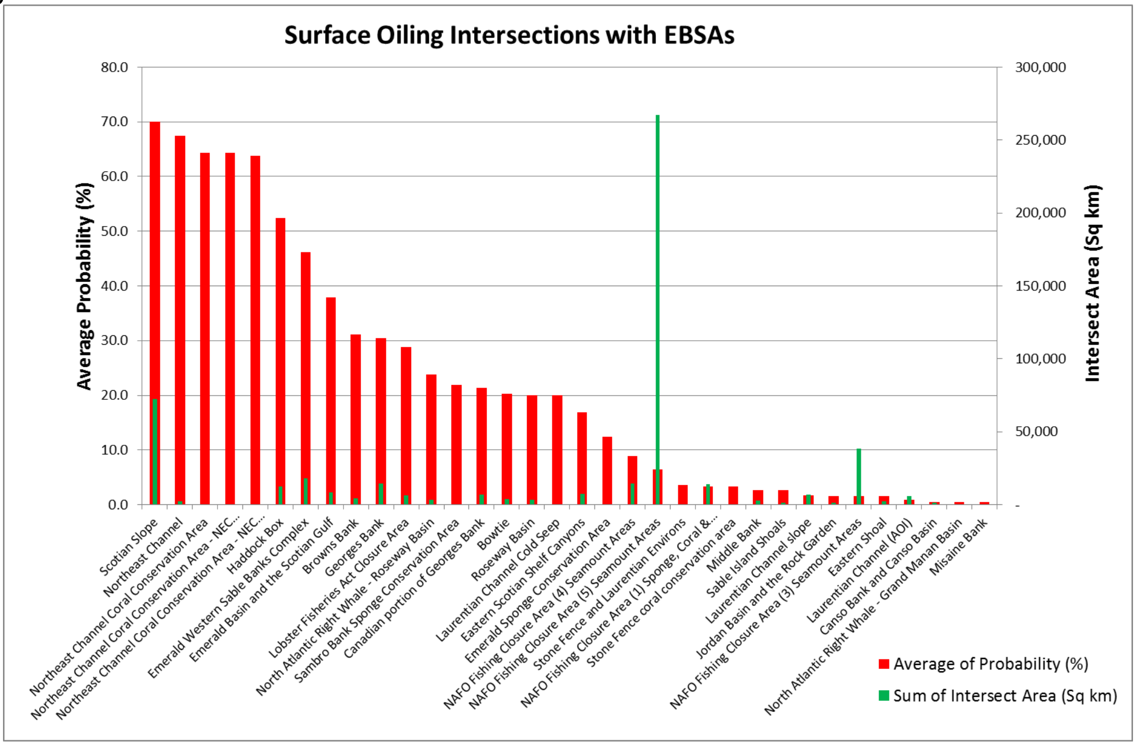
Surface oil

Figure 6.66



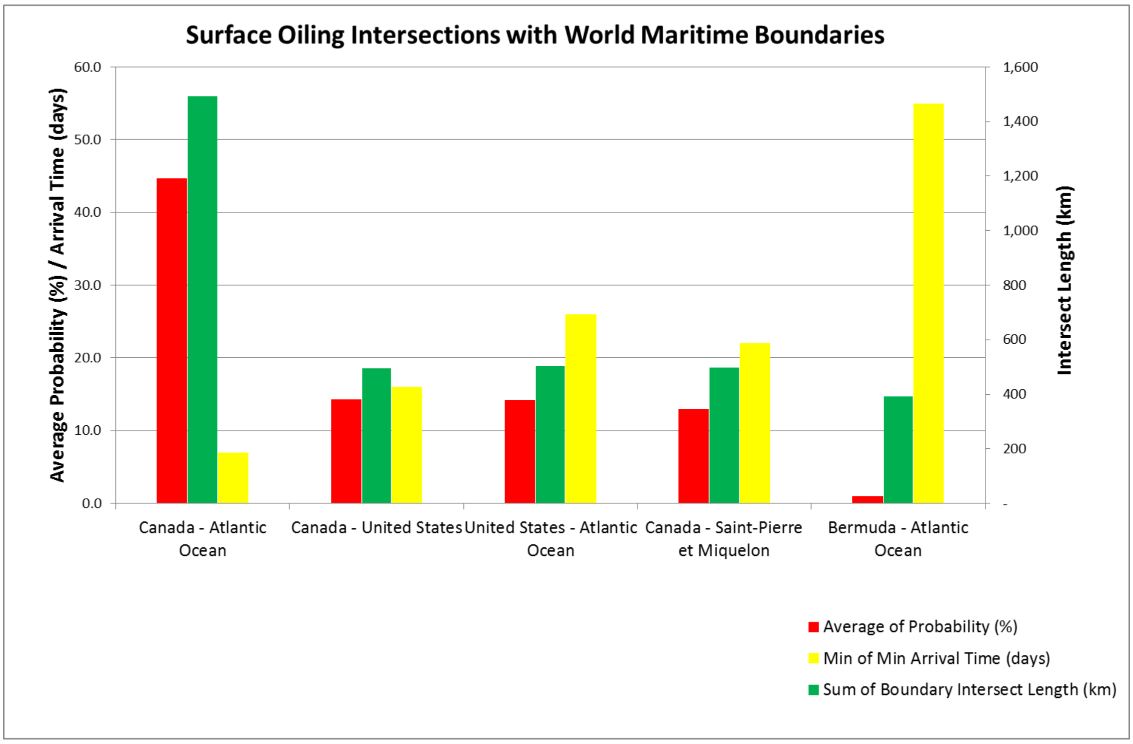
* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold*

Figure 6.67



* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold*

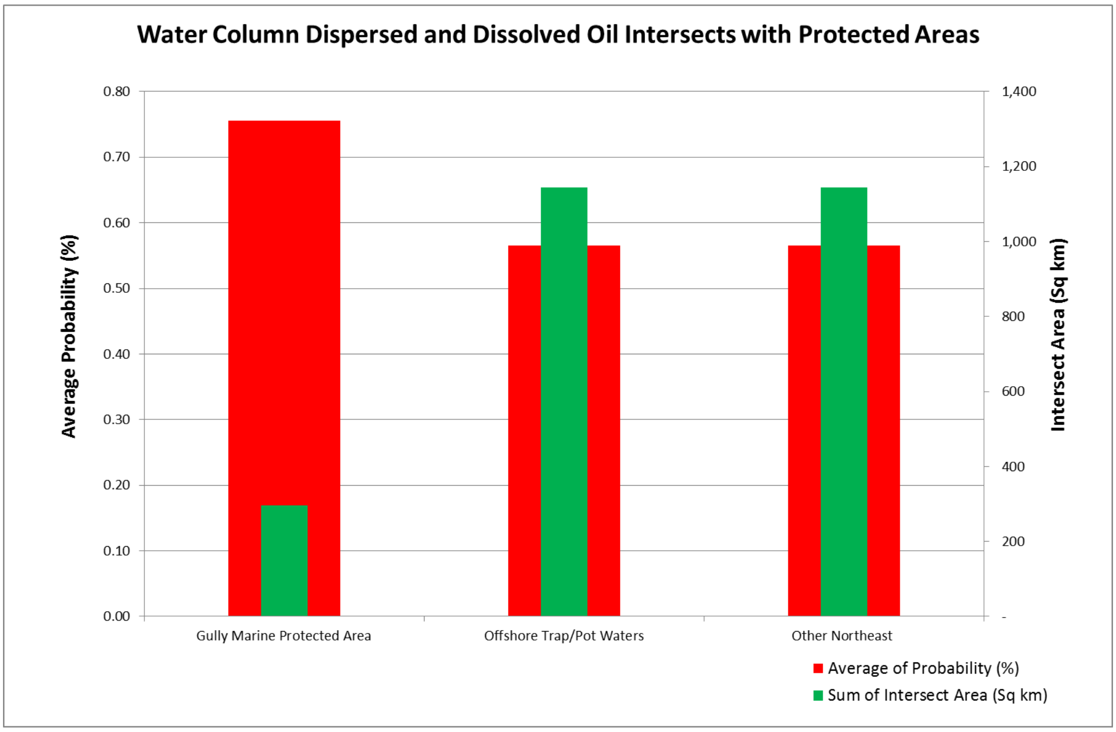
Figure 6.68



* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold*

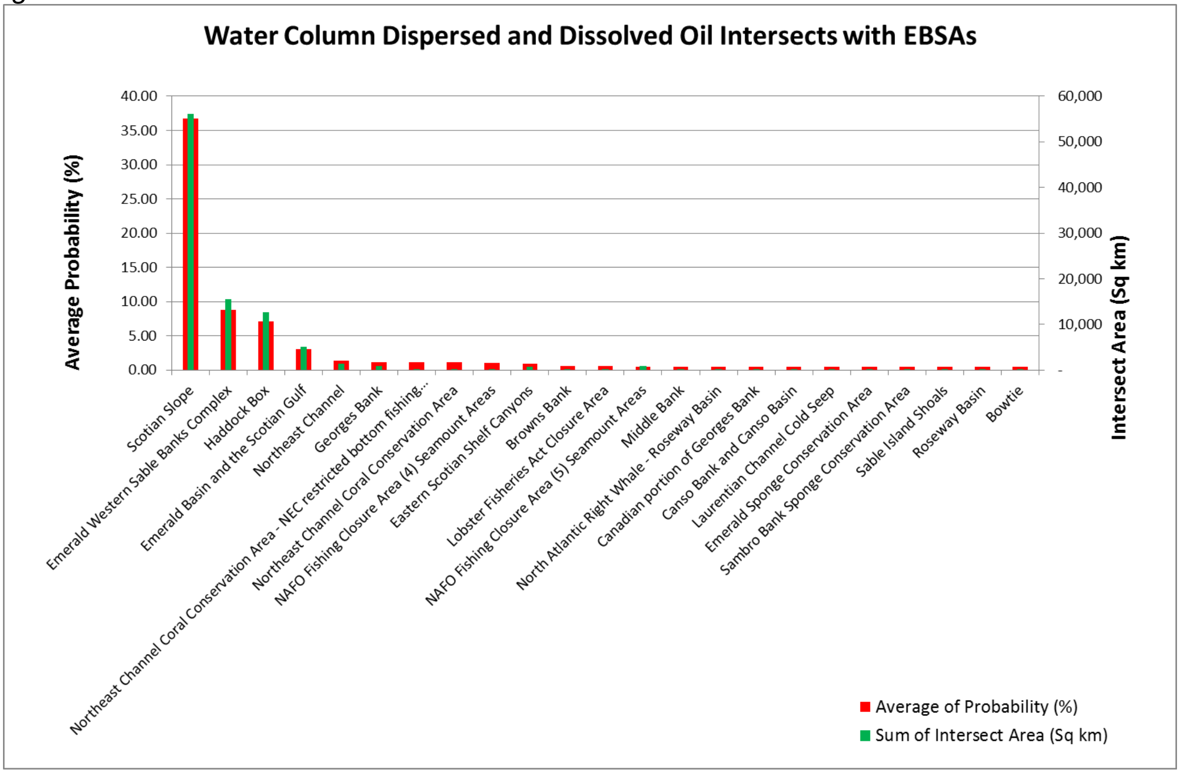
Oil in the Upper water column (<100 m water depth)

Figure 6.69



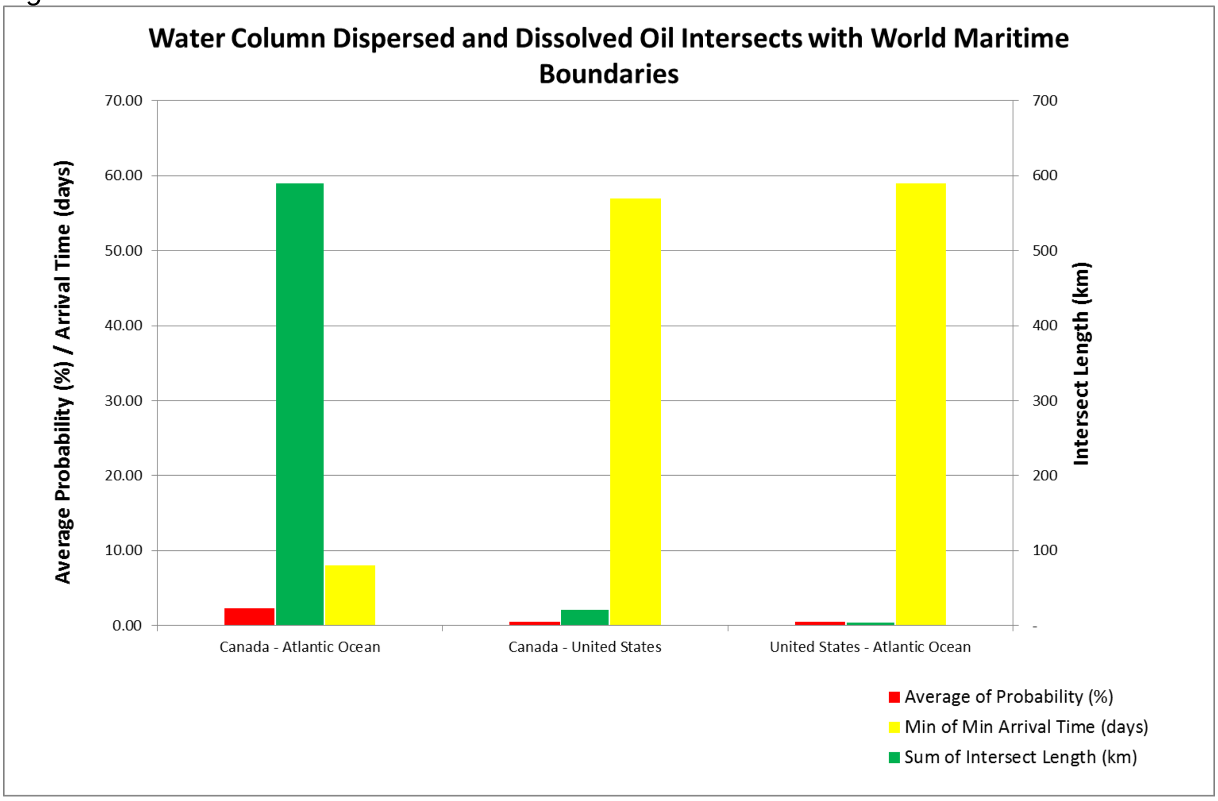
* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

Figure 6.70



* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

Figure 6.71

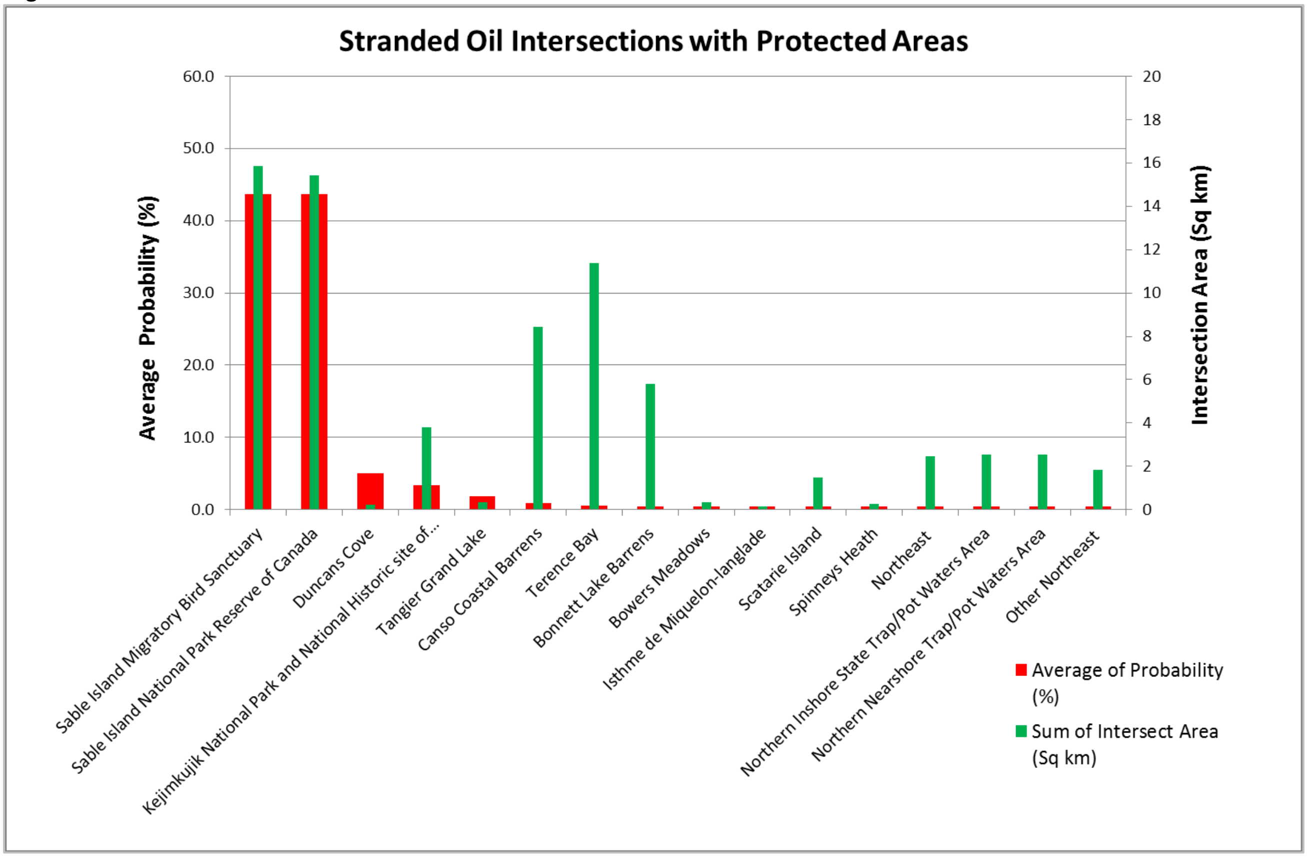


* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

6.3.4 Well: NS-1 Case 2A – (Summer Season)

Stranded oil

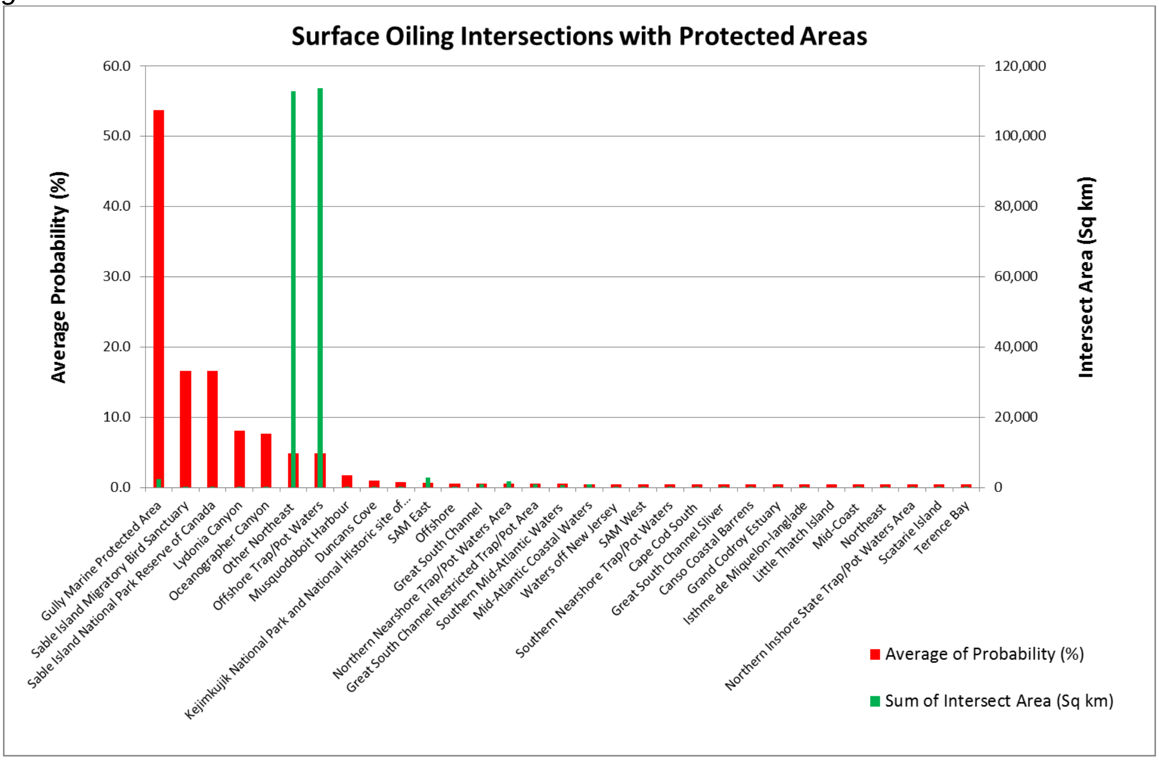
Figure 6.72



* *Probability of shoreline emulsion mass exceeding the 0.0019 tonnes/km (or 0.001 litres / m2 = 1 micron), minimum threshold for "Stain / Film" oiling.*

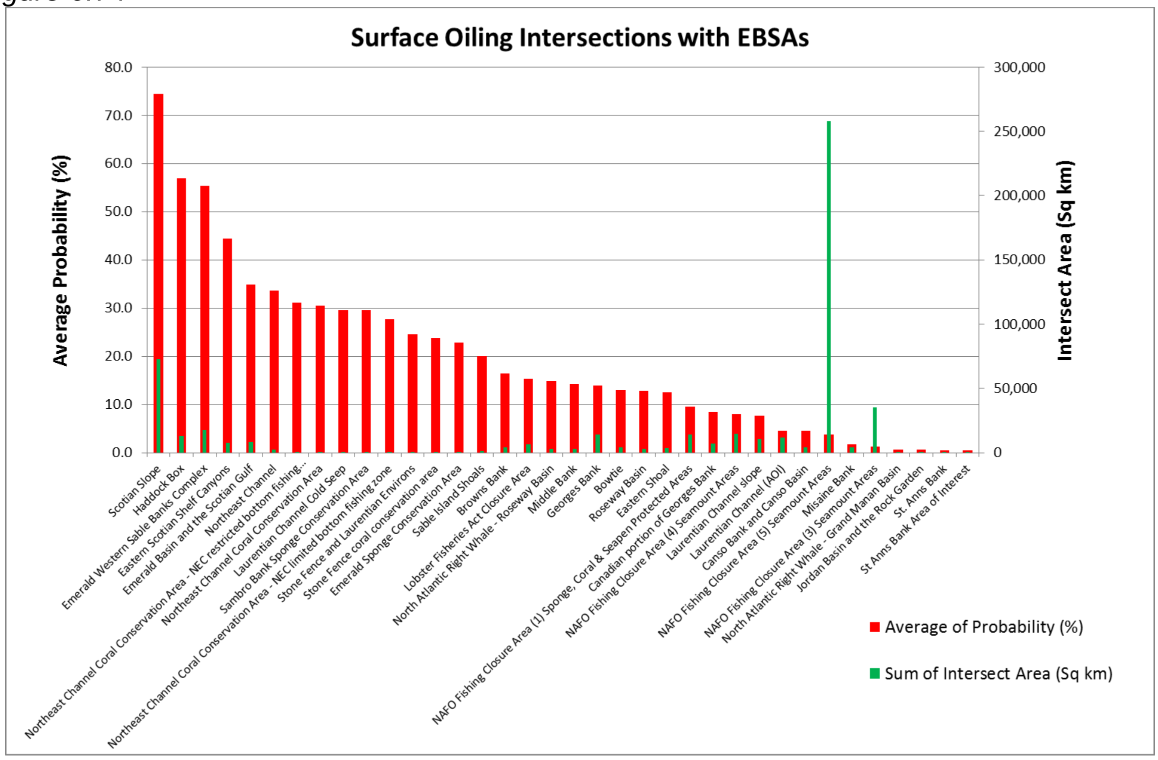
Surface oil

Figure 6.73



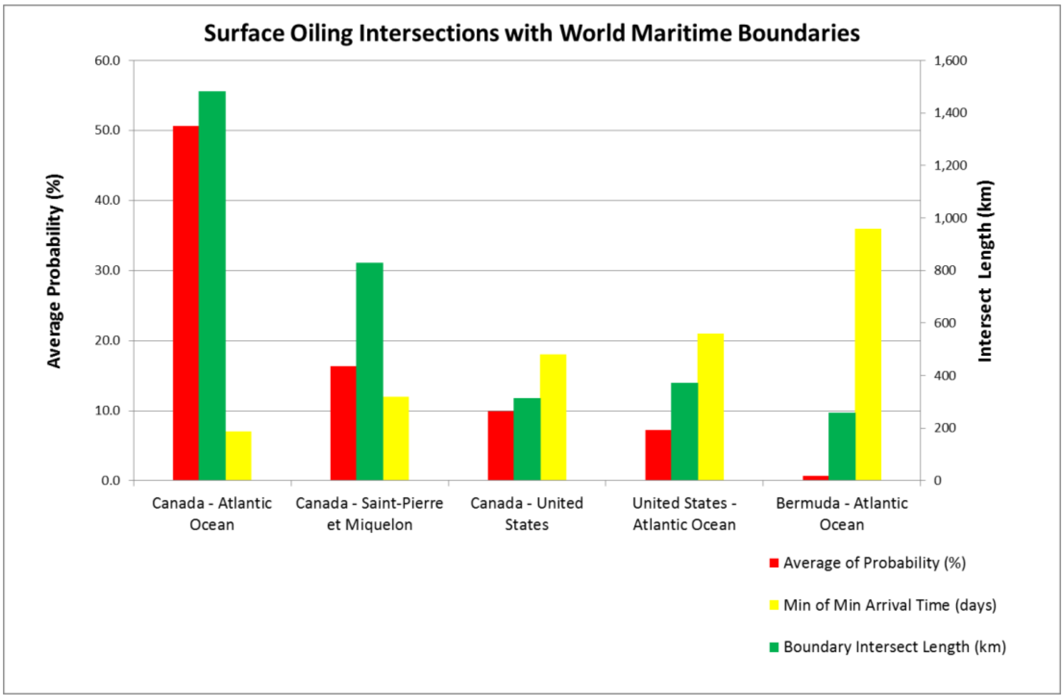
* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold*

Figure 6.74



* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold*

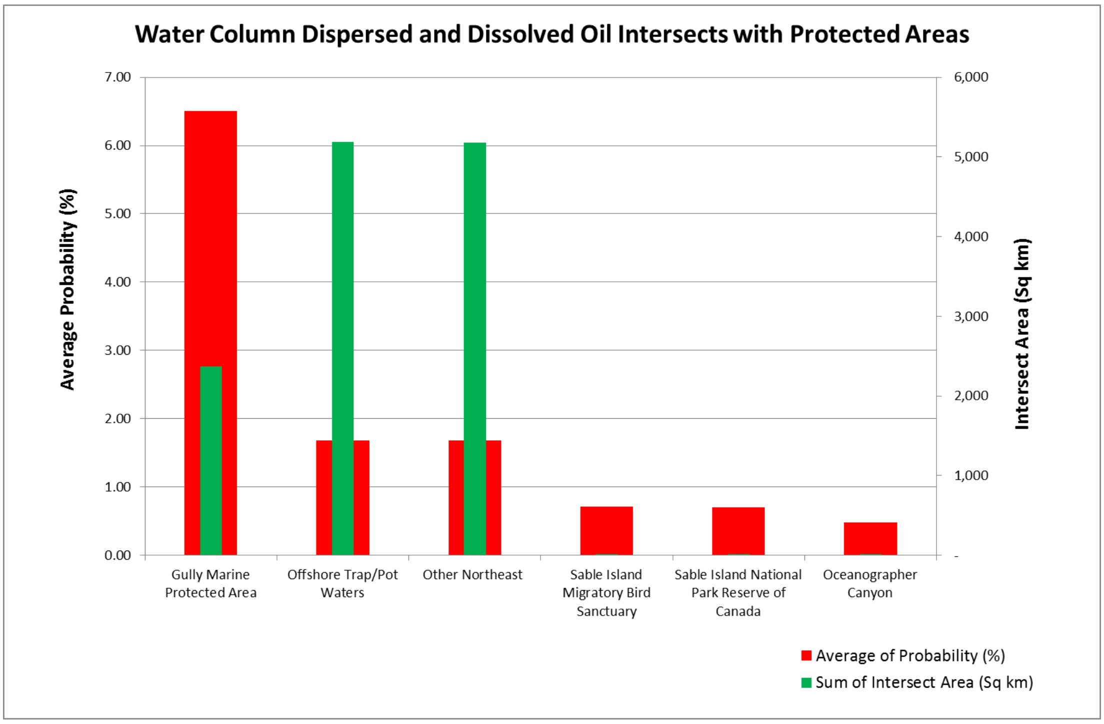
Figure 6.75



* *Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold*

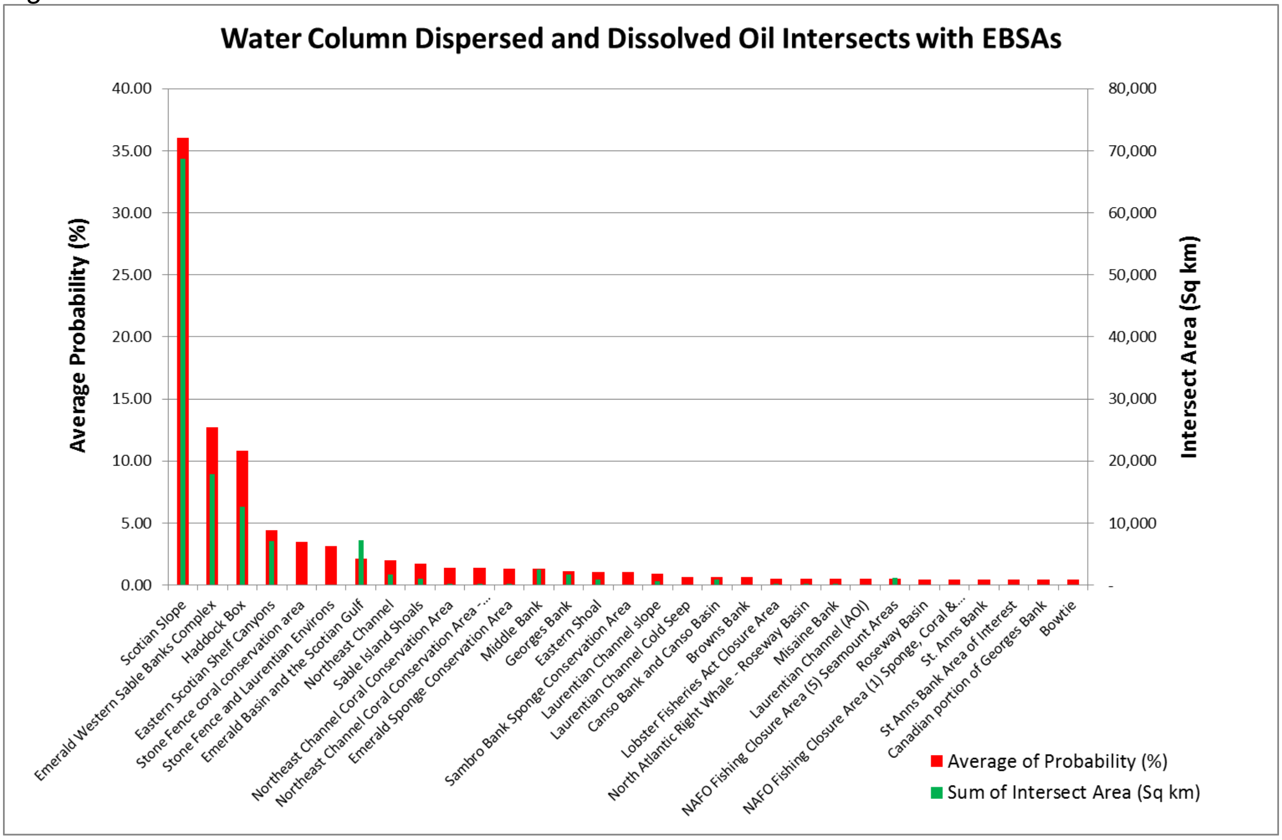
Oil in the Upper water column (<100 m water depth)

Figure 6.76



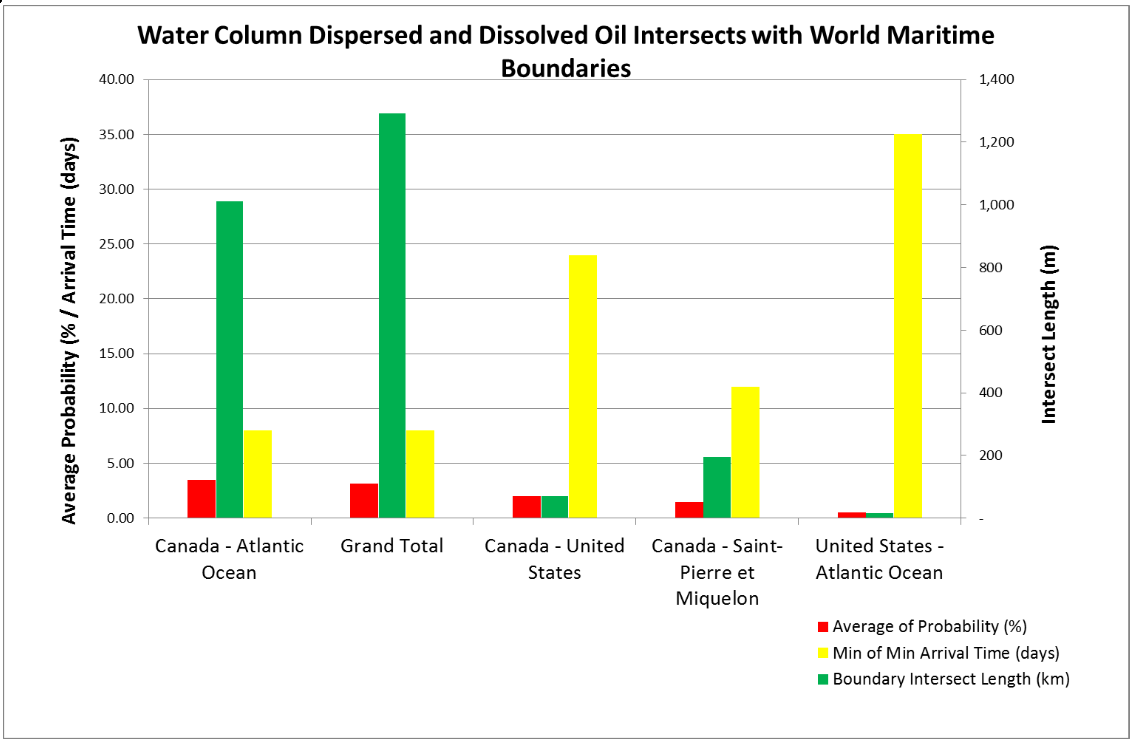
* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

Figure 6.77



* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

Figure 6.78



* *Probability of the maximum time-averaged total oil concentration in the water column (dispersed and dissolved oil) exceeding the 58 ppb threshold.*

7 Accidental hydrocarbon (diesel) discharge modelling results

To simulate an accidental discharge from Project vessels, two batch spills of diesel were modelled as a surface release using stochastic and deterministic methods. Modelling for the batch release of diesel was undertaken for unmitigated incidents involving a hose failure (a 10 bbl surface release over 1 hour) and a tank failure (a 100 bbl surface batch release over 6 hours). Simulations were run over 30 day and 50 day periods for the 10 bbl and 100 bbl spills respectively, for both summer (May to October) and winter (November to April) seasons. Site 1 was chosen as the location for the releases as it is the nearest location to Sable Island. The model settings and assumptions used in simulations were described earlier in Section 4.4.2 (Table 4.8). Stochastic simulations involved 225 individual modelling runs for the 10 bbl and 100 bbl scenarios.

7.1 Stochastic results

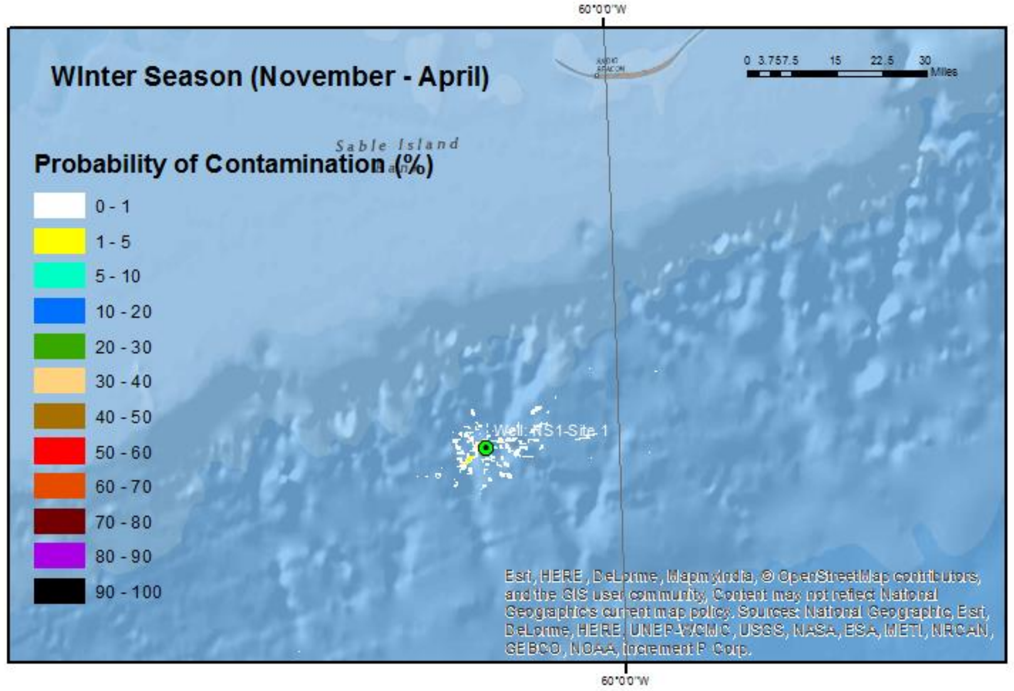
Figures 7.1 and 7.2 depict the probability of sea surface emulsified oil thickness exceeding the 0.04 µm sheen thickness threshold. The results show that the location of threshold exceedances for surface effects are expected to occur over a greater area if a spill occurs during the summer than for winter. For a 100 bbl spill, the locations for oiling in excess of 0.04 µm could extend approximately 100 km to the west and southeast and 30 km in all other directions, with a small portion of weathered diesel continuing beyond these distances.

The maximum time-averaged emulsified oil thickness on the sea surface exceeding the 0.04 µm threshold for both spill scenarios are shown in Figures 7.5 and 7.6.and ranged from 0.04 µm to 50 µm.

In-water dispersed and dissolved oil threshold exceedance of 58 ppb for total hydrocarbons (THC) was not exceeded in any of the simulations and no oil from the batch spills reached the coastline of Sable Island or Nova Scotia.

7.1.1 Sea Surface Results

Figure 7.1 10 bbl surface release of diesel. Statistical maps showing the probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold.



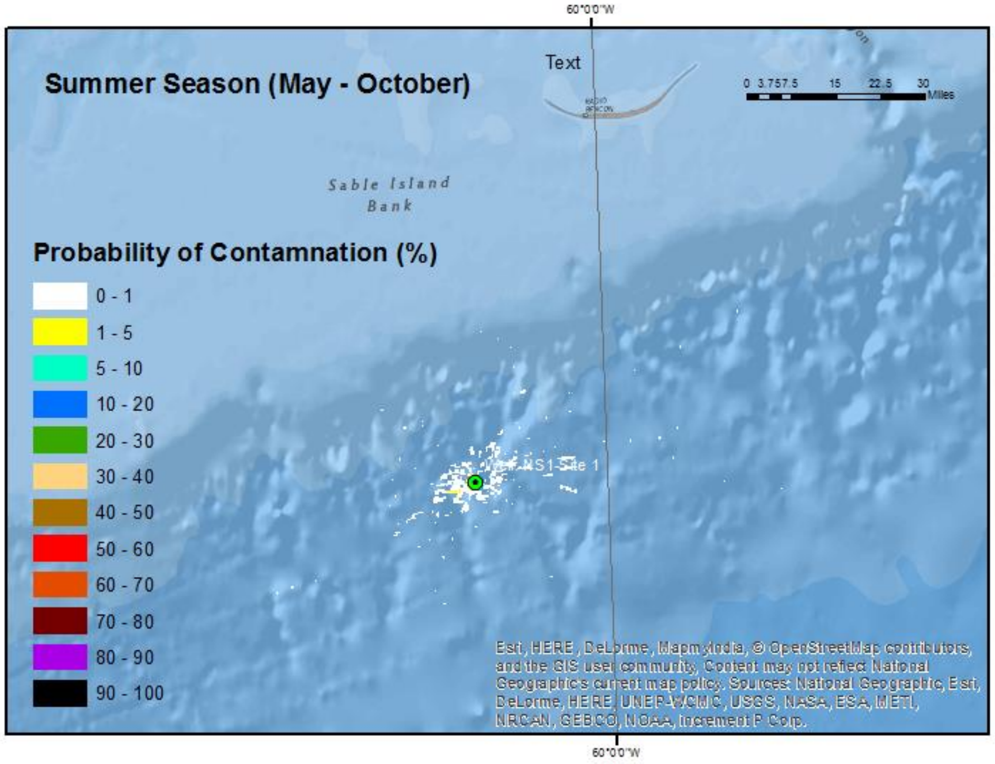
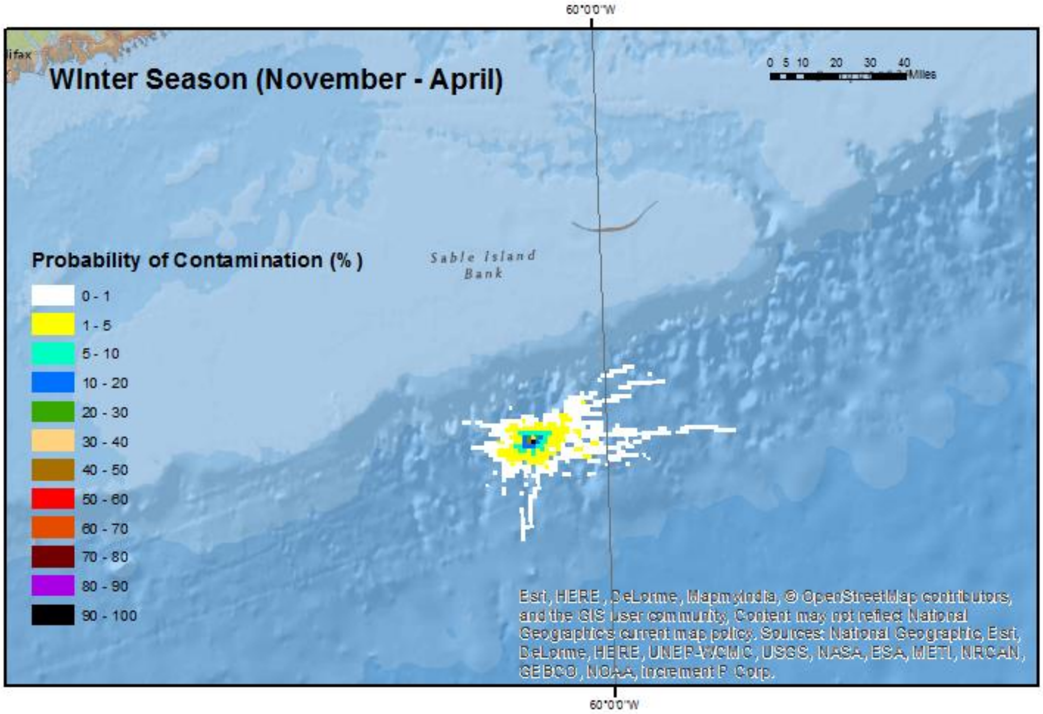


Figure 7.2 100 bbl surface release of diesel. Statistical maps showing the probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold.



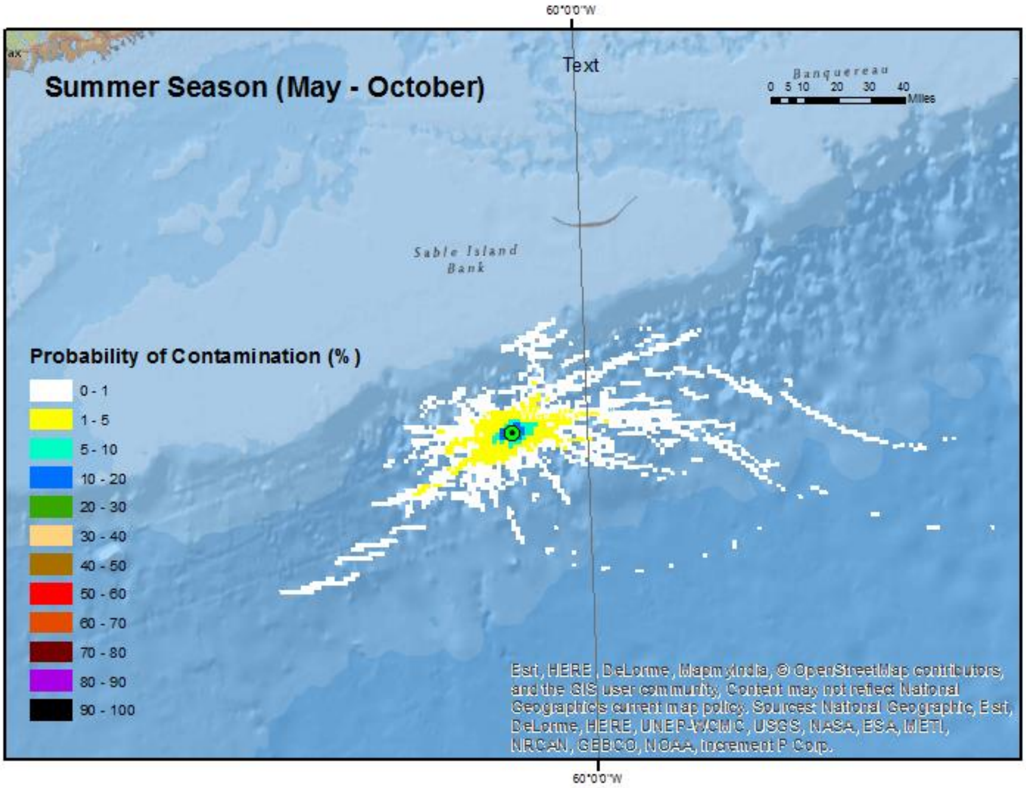
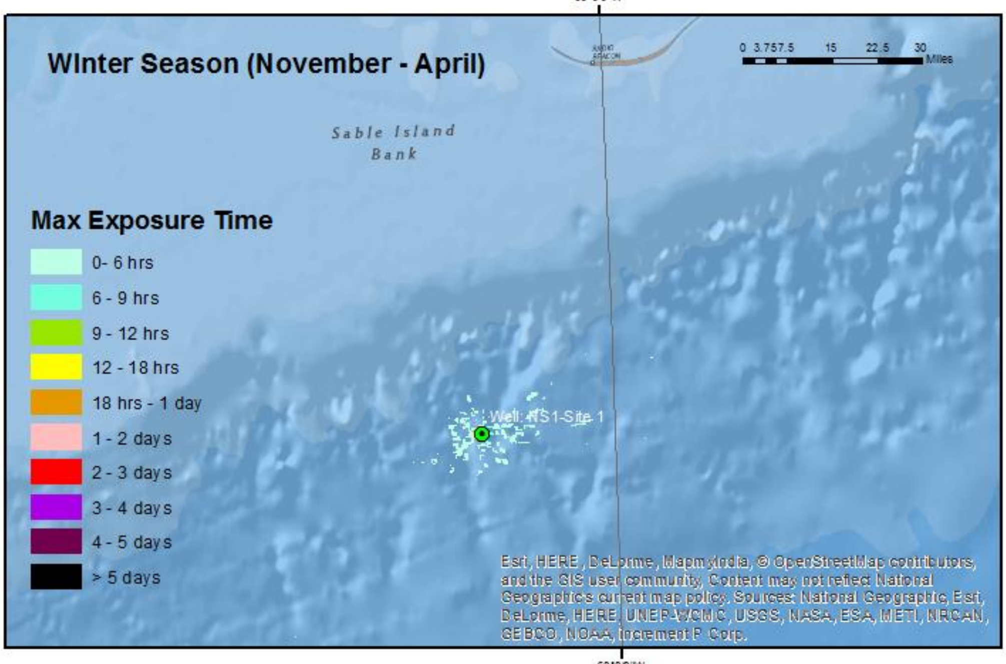


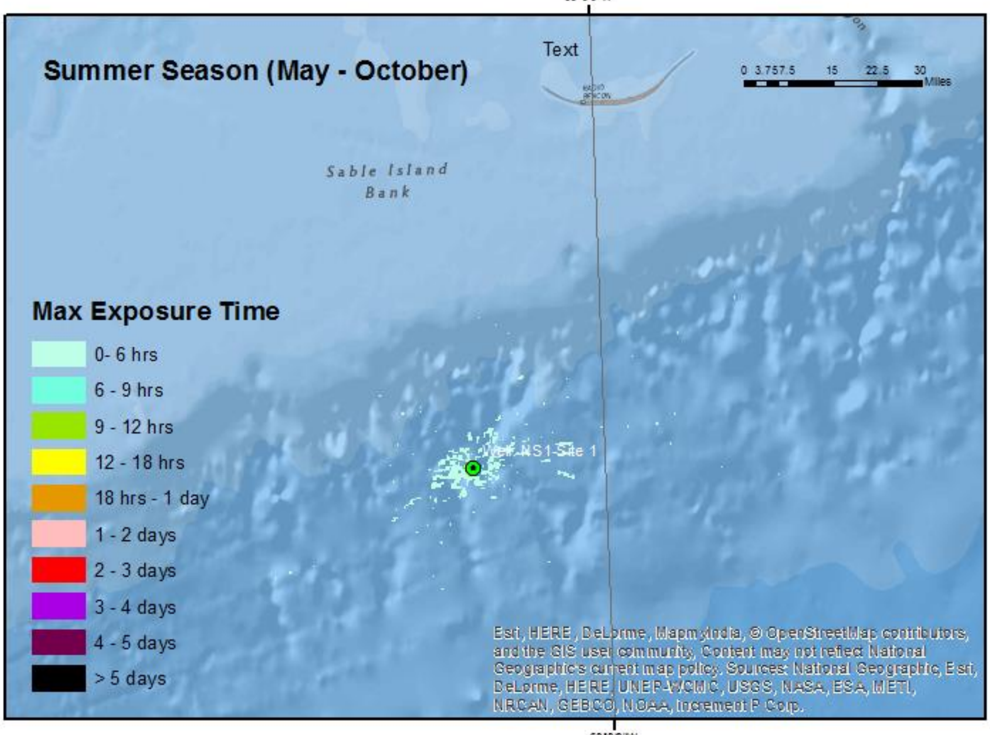
Figure 7.3 10 bbl surface release of diesel. Statistical maps showing the maximum exposure time for emulsified oil thicknesses on the sea surface which exceed the 0.04μm (BAOAC "Sheen") thickness threshold.

60°0'0"W



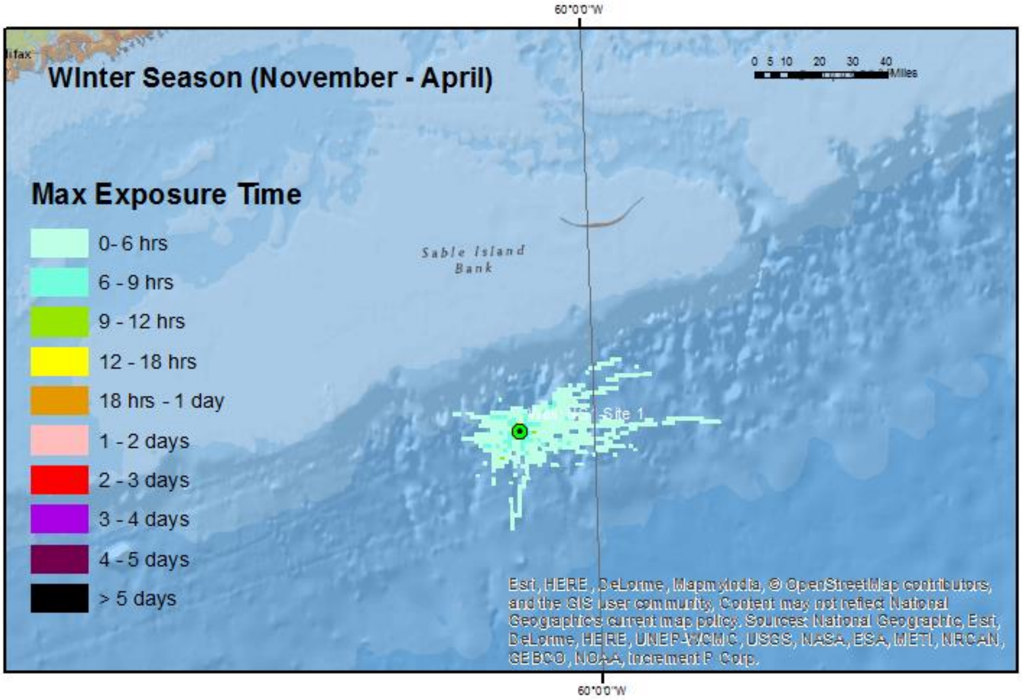
60°0'0"W

60°0'0"W



60°0'0"W

Figure 7.4 *100 bbl surface release of diesel. Statistical maps showing the maximum exposure time for emulsified oil thicknesses on the sea surface which exceed the 0.04µm (BAOAC "Sheen") thickness threshold.*



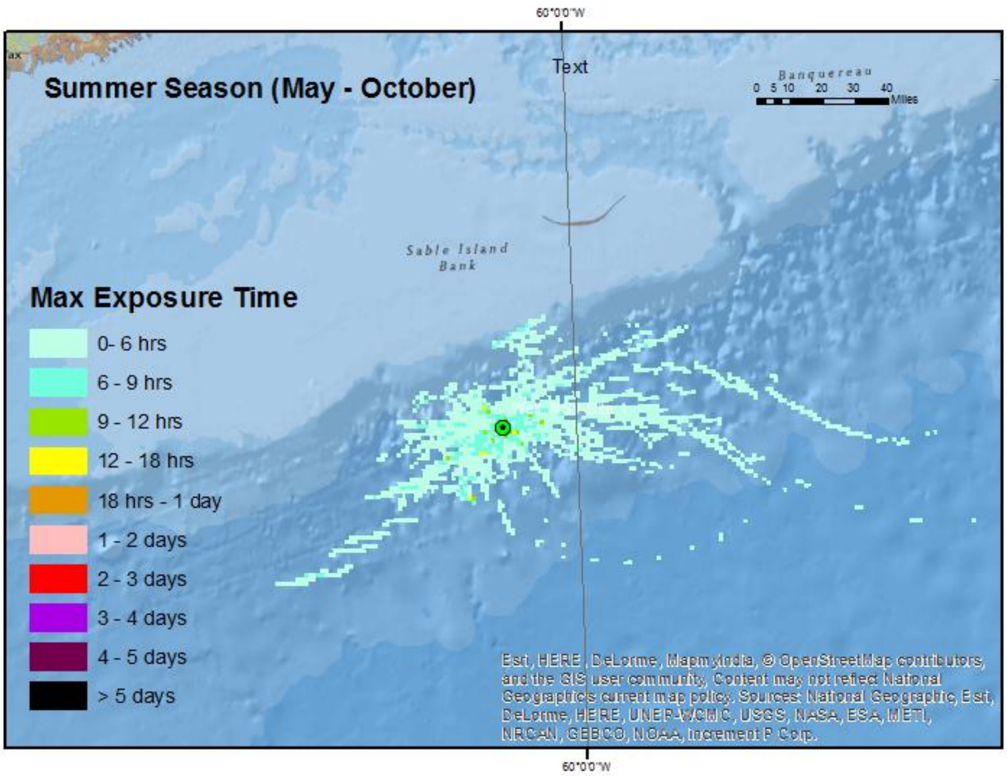
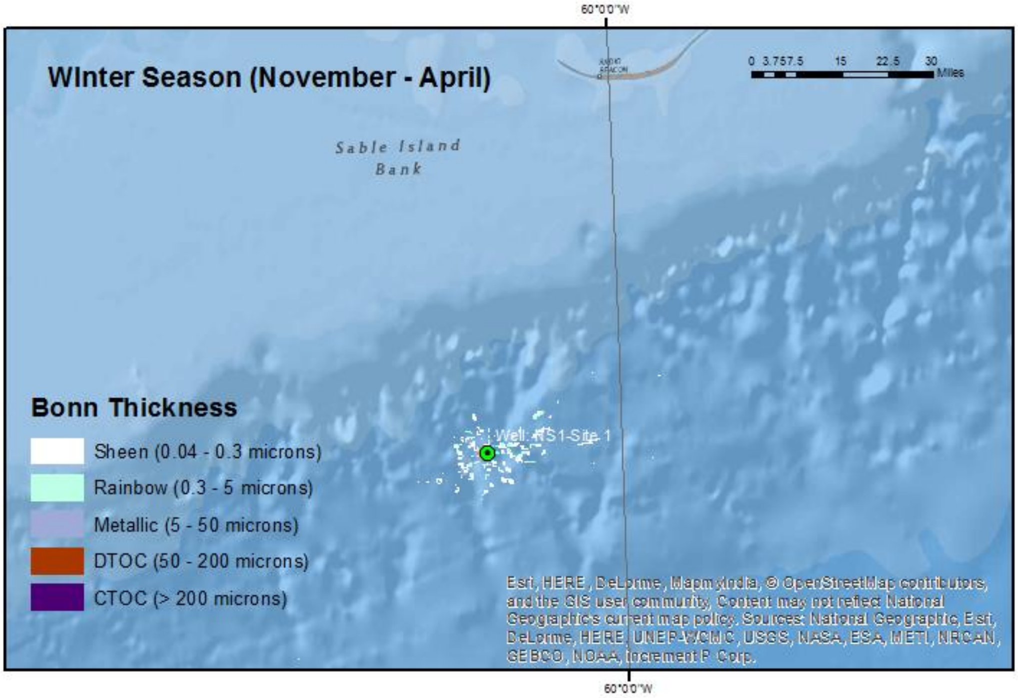


Figure 7.5 10 bbl surface release of diesel. Statistical maps showing the maximum time-averaged emulsified oil thickness on the sea surface (0.04µm BAOAC "Sheen" thickness threshold applied).



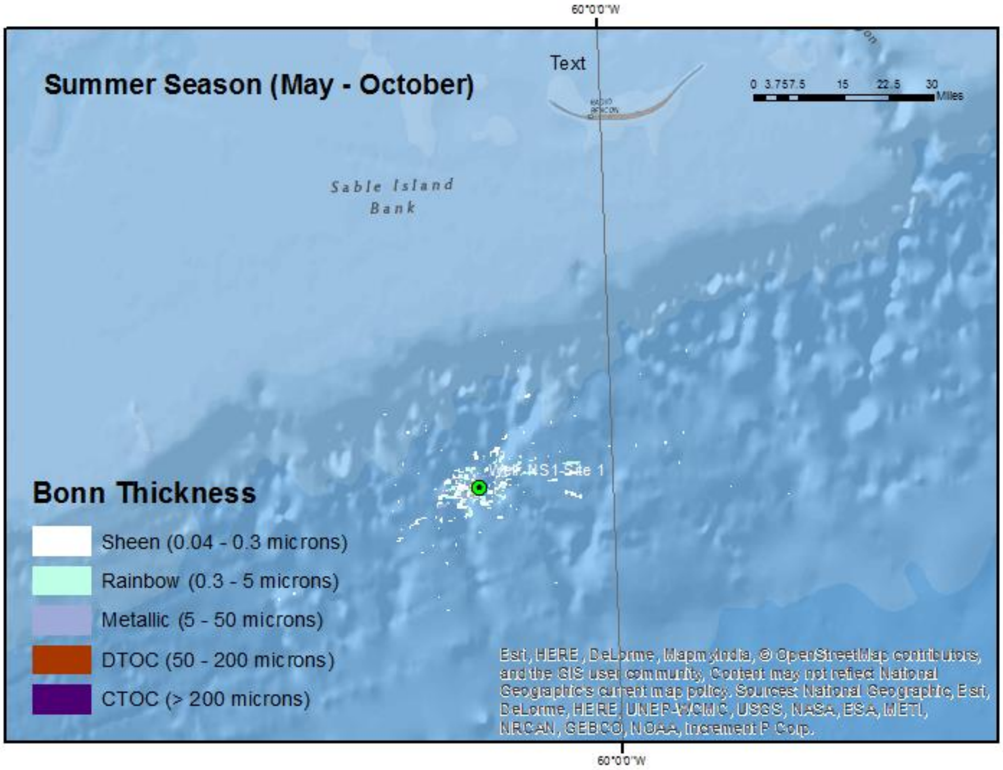
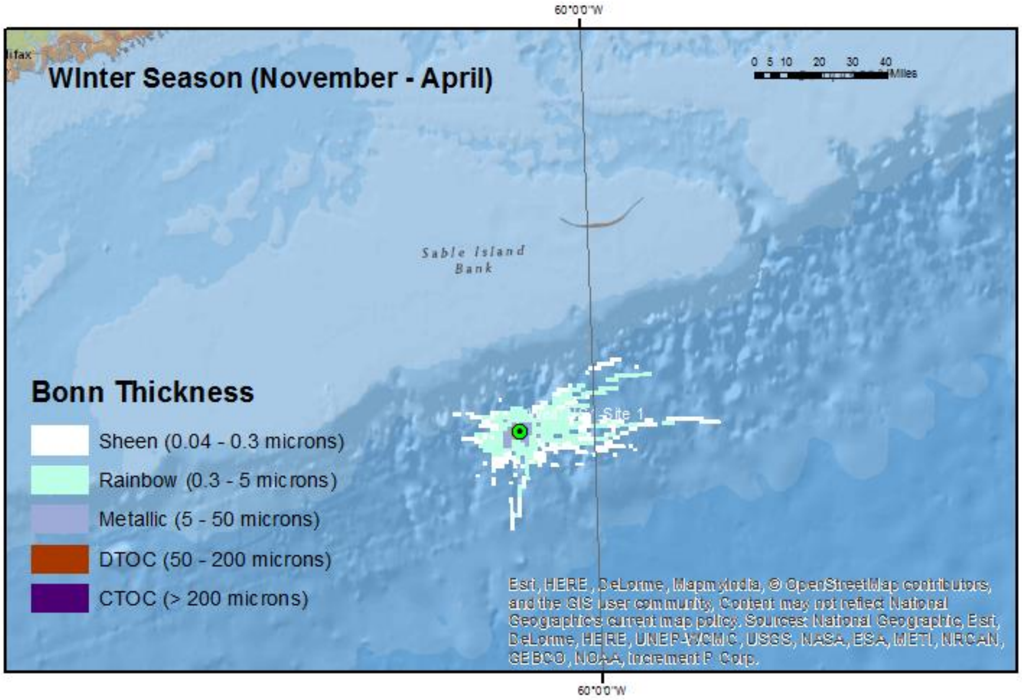
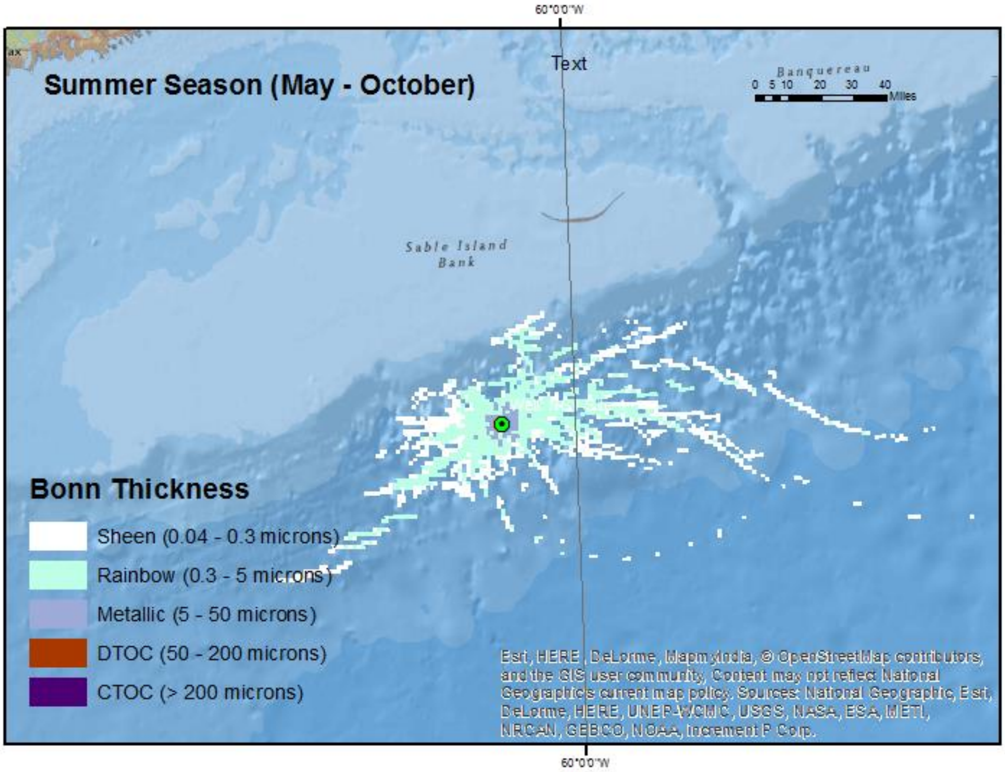


Figure 7.6 100 bbl surface release of diesel. Statistical maps showing the maximum time-averaged emulsified oil thickness on the sea surface (0.04µm BAOAC "Sheen" thickness threshold applied).





7.2 Deterministic results

Deterministic runs were carried out during the summer season to maximum surface oiling as water column and shoreline effect thresholds were not exceeded during stochastic modelling. The mass balance distribution shown in Figure 7.13 is representative of both scenarios and indicates that surface oil would rapidly evaporate and disperse into the water column following a release. In the 100 bbl batch spill scenario, approximately 65% of the spill evaporates from the surface within 3 days following the release, with remaining proportions dispersing or biodegrading within the same period.

The surface oil area coverage graph shown in Figure 7.7 for the 10 bbl spill indicates an initial transient surface oil coverage of 0.82 km^2. Moreover, only one grid cell containing oil (sheen thickness) was observed in the cumulative surface oil coverage map (Figure 7.9).

In comparison the maximum surface oil coverage (exceeding the 0.04 oil thicknesses threshold) is circa 4.4 km^2 for the 100 bbl spill. The majority of the surface oil thickness is predicted to fall within the thickness range of 0.04 to 5 µm.

For the 10 bbl and 100 bbl deterministic scenarios, areas of 23 km^2 and 336 km^2, respectively, experienced maximum total in-water concentrations of dissolved oil in excess of 1 ppb (Figures 7.11 and 7.12), with all the total in-water dissolved oil concentrations falling within the range 1 to 10 ppb (0.001 to 0.01 ppm).

Figure 7.7 10 bbl surface release of diesel. (Summer Season, start date 3rd June 2009 05:00 GMT). Graph showing area coverage of surface oil

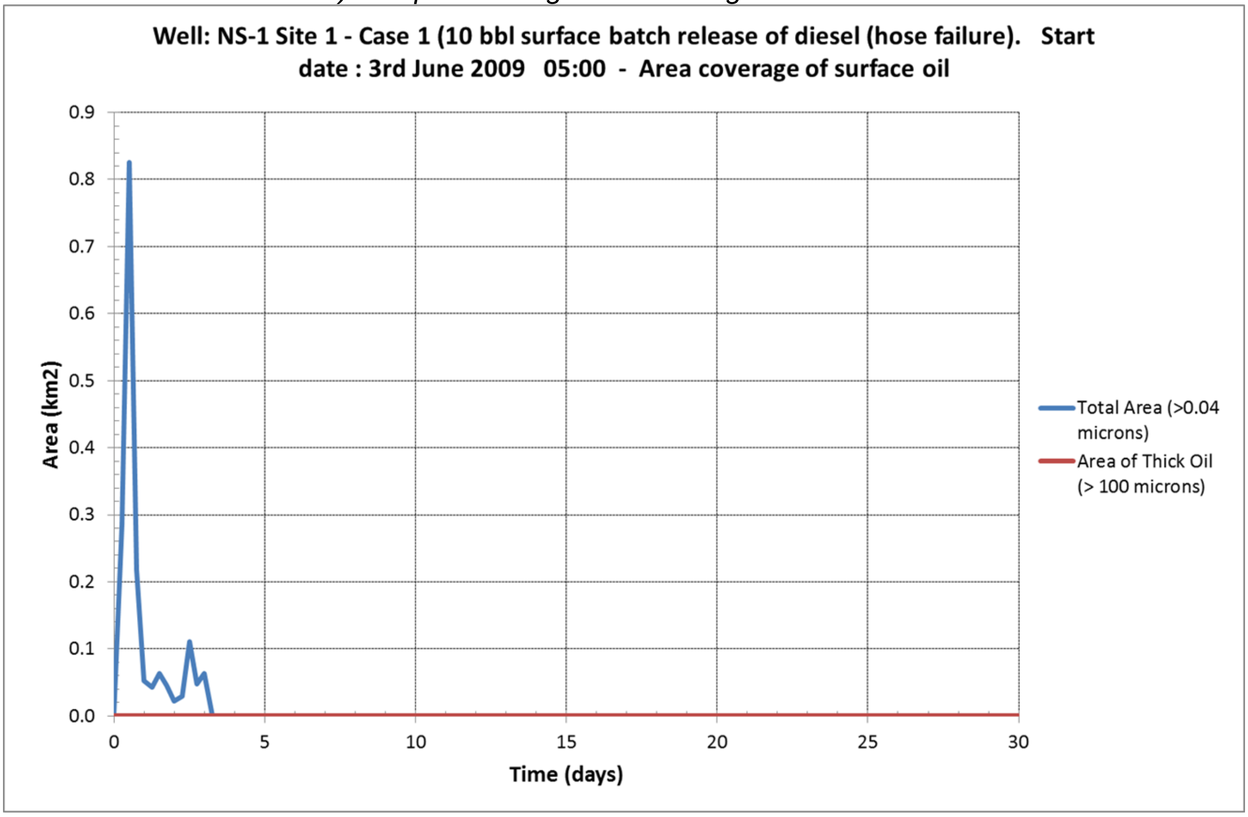


Figure 7.8 100 bbl surface release of diesel. (Summer Season, start date 3rd June 2009 05:00 GMT). Graph showing area coverage of surface oil

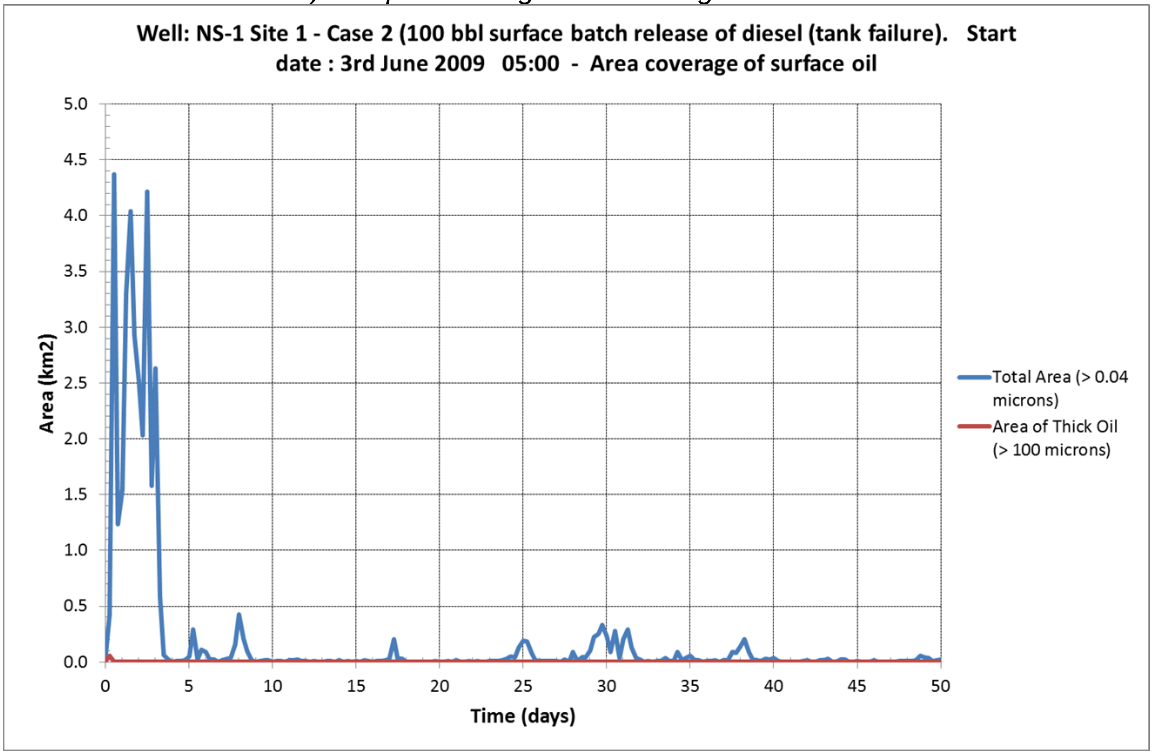


Figure 7.9 *10 bbl surface release of diesel. (Summer Season, start date 3rd June 2009 05:00 GMT). Map showing the maximum surface oil thickness at each location over the simulation period (0.04μm BAOAC "Sheen" thickness threshold applied)*

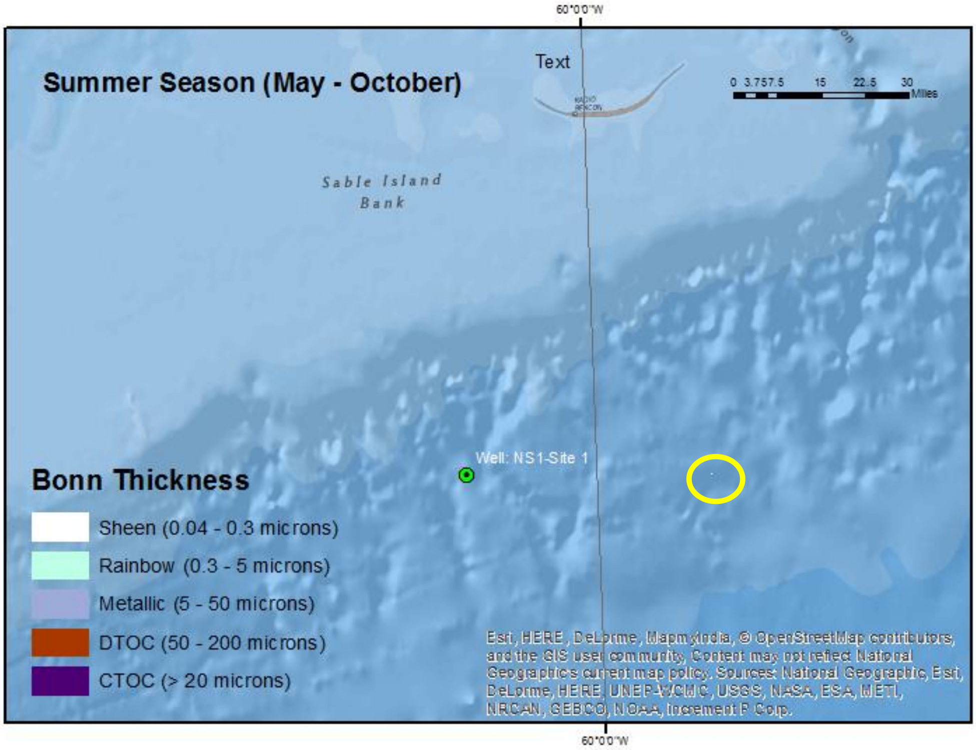


Figure 7.10 *100 bbl surface release of diesel. (Summer Season, start date 3rd June 2009 05:00 GMT). Map showing the maximum surface oil thickness at each location over the simulation period (0.04μm BAOAC "Sheen" thickness threshold applied)*

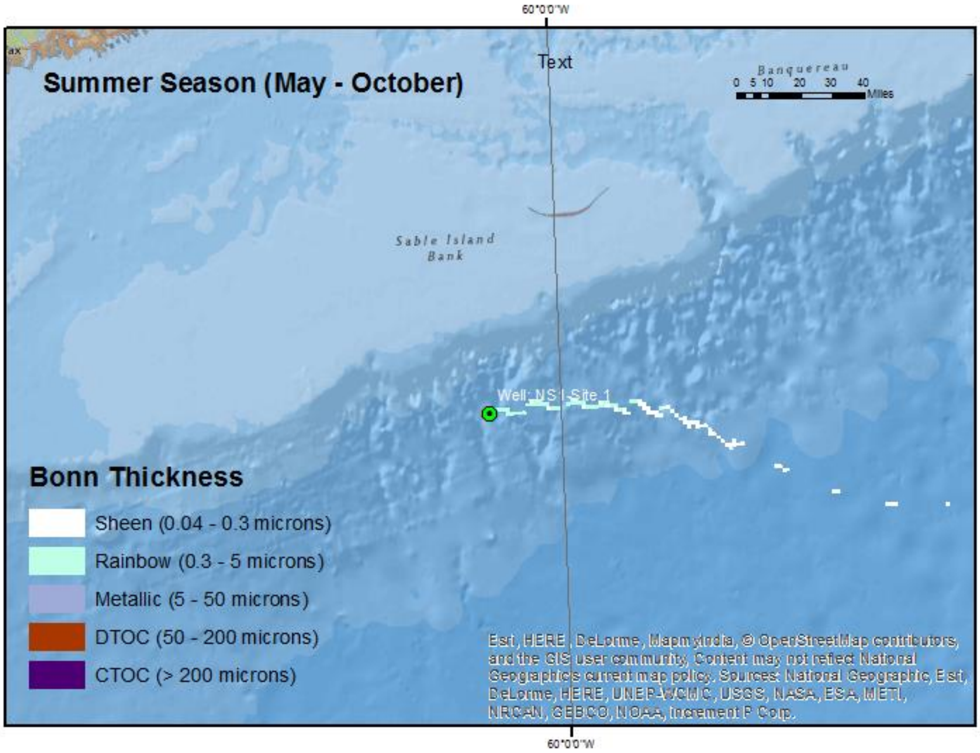


Figure 7.11 *10 bbl surface release of diesel. (Summer Season, start date 3rd June 2009 05:00 GMT). Map showing the maximum concentration of dissolved oil in the water column. No concentration threshold applied.*

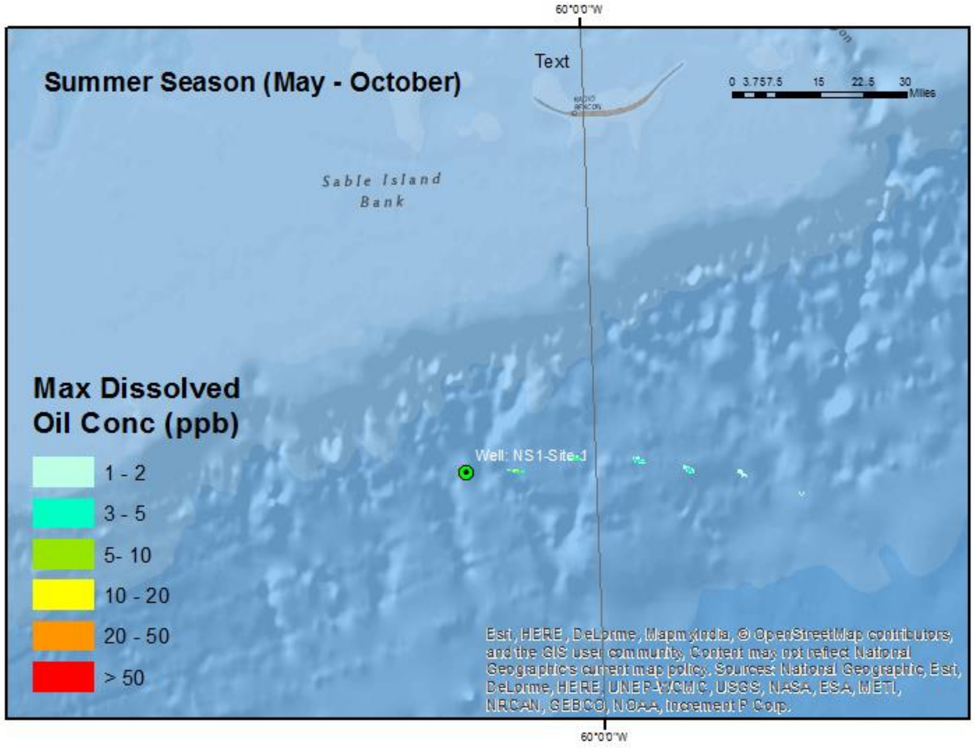


Figure 7.12 *100 bbl surface release of diesel. (Summer Season, start date 3rd June 2009 05:00 GMT). Map showing the maximum concentration of dissolved oil in the water column. No concentration threshold applied.*

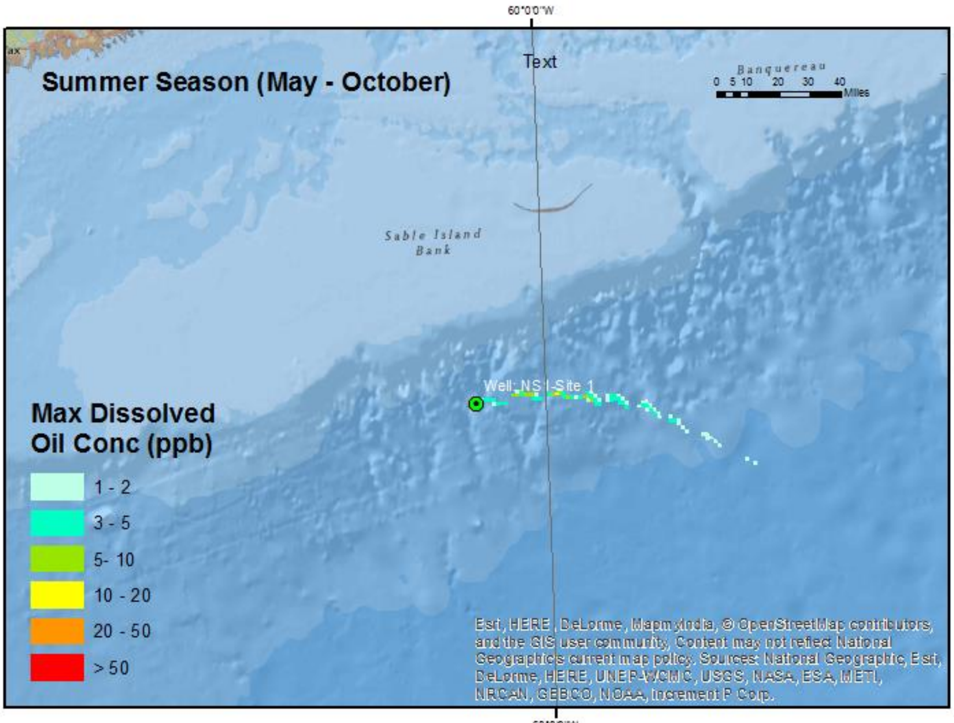
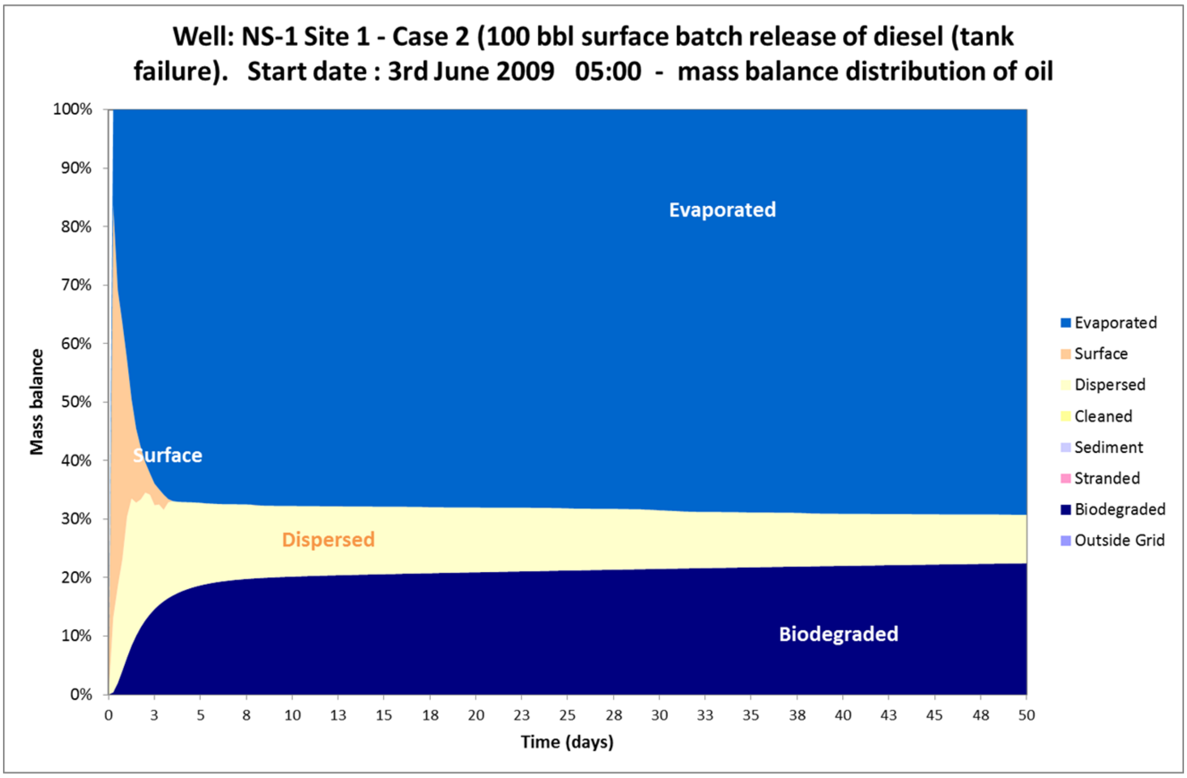


Figure 7.13 100 bbl surface release of diesel. (Summer Season, start date 3rd June 2009 05:00 GMT). Graph showing mass balance distribution of oil over the duration of the simulation



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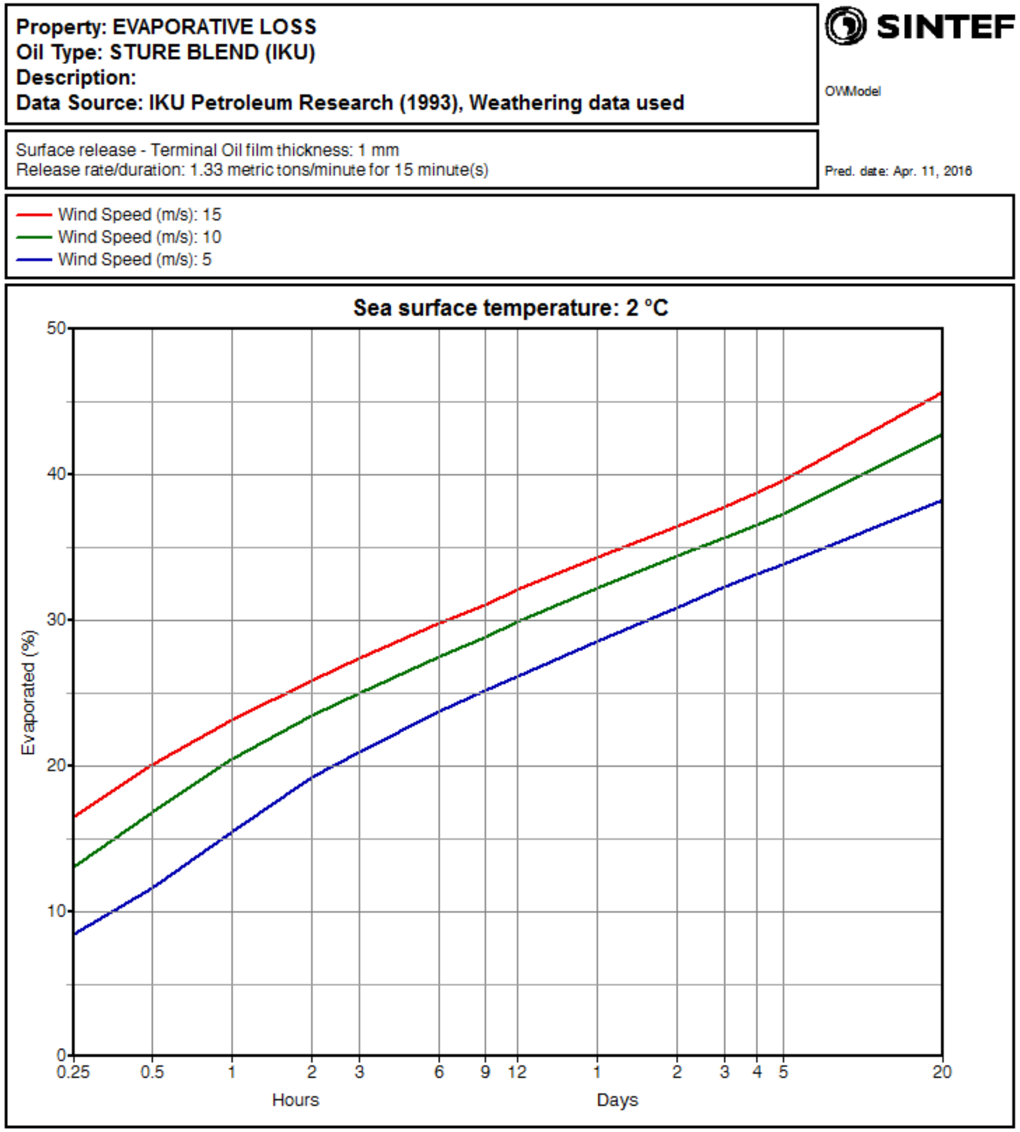
Appendix 1 Predictions of the surface oil weathering behaviour of Sture Blend (IKU)

The oil characterisation data and weathering properties of the analogue oils used in the OSCAR modelling were also used in simulations carried out using the SINTEF Oil Weathering Model (OWM). Model runs were performed to predict how each oil might weather on the sea surface in terms of its evaporative loss, water uptake and emulsion viscosity under different wind speed and sea temperature conditions. The relationship between wind speed and significant wave heights used in the prediction charts obtained from the SINTEF OWM are shown in Table A1.1. The surface sea temperatures chosen (2 - 13 ^{o}C), represent the annual temperature fluctuations in the assessment area

Table A1.1 Relationship between wind speed and significant wave heights used in the SINTEF OWM

Wind speed (m/s) (knots)	Beaufort wind	Wind type	Wave height (m)
2 – 4	2	Light breeze	0.1 - 0.3
5 – 10	3	Gentle to moderate breeze	0.5 - 0.8
10 – 20	5	Fresh breeze	1.5 - 2.5
15 – 30	6 - 7	Strong breeze	3 - 4



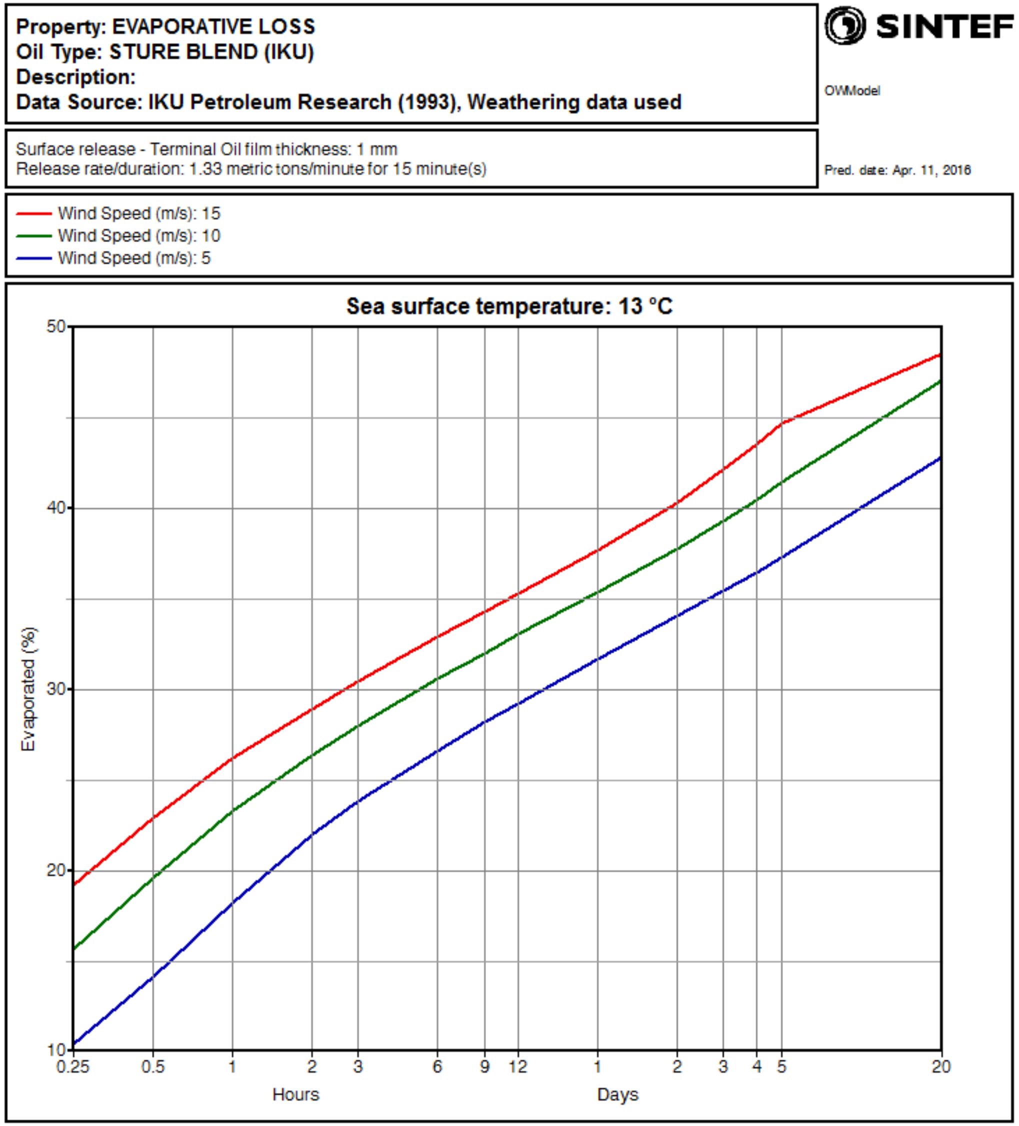


Table A1.1 Predicted evaporative loss of Sture Blend (IKU) oil predicted at sea temperatures of 2 °C and 13 °C

Property: WATER CONTENT
Oil Type: STURE BLEND (IKU)
Description:
Data Source: IKU Petroleum Research (1993), Weathering data used

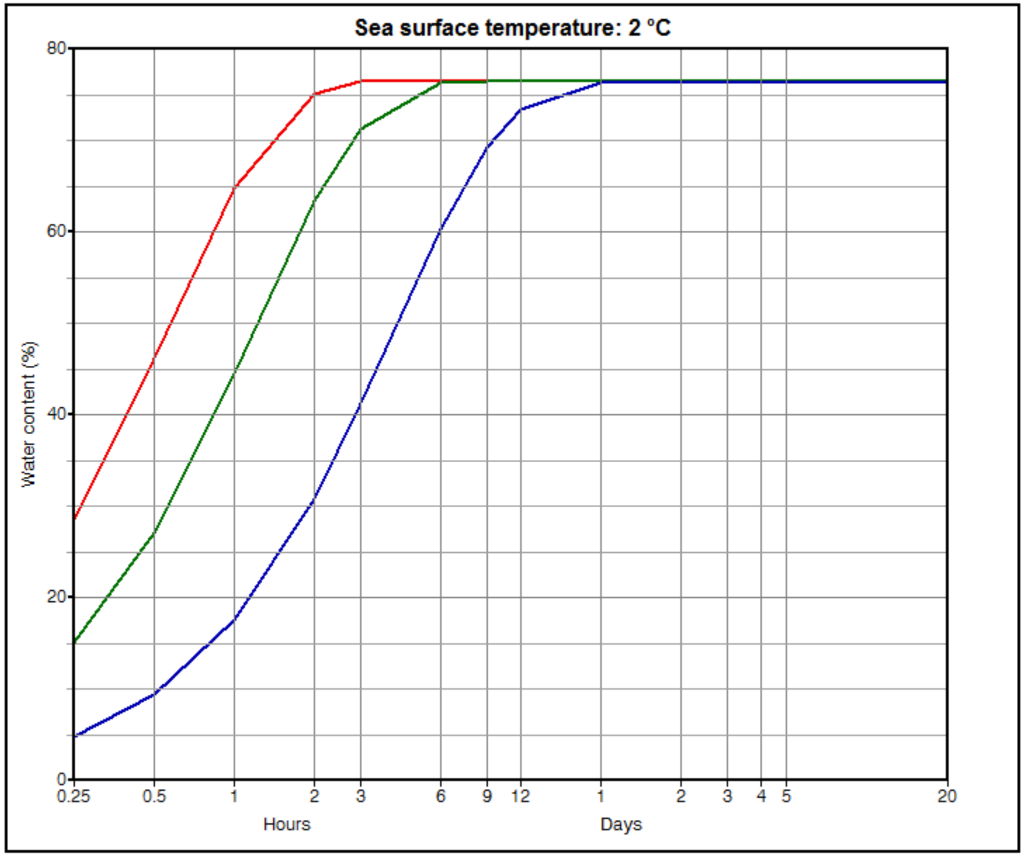
SINTEF

OWModel

Surface release - Terminal Oil film thickness: 1 mm
Release rate/duration: 1.33 metric tons/minute for 15 minute(s)

Pred. date: Apr. 11, 2016

Wind Speed (m/s): 15
Wind Speed (m/s): 10
Wind Speed (m/s): 5



Property: WATER CONTENT
Oil Type: STURE BLEND (IKU)
Description:
Data Source: IKU Petroleum Research (1993), Weathering data used

SINTEF

OWModel

Surface release - Terminal Oil film thickness: 1 mm
Release rate/duration: 1.33 metric tons/minute for 15 minute(s)

Pred. date: Apr. 11, 2016

Wind Speed (m/s): 15
Wind Speed (m/s): 10
Wind Speed (m/s): 5

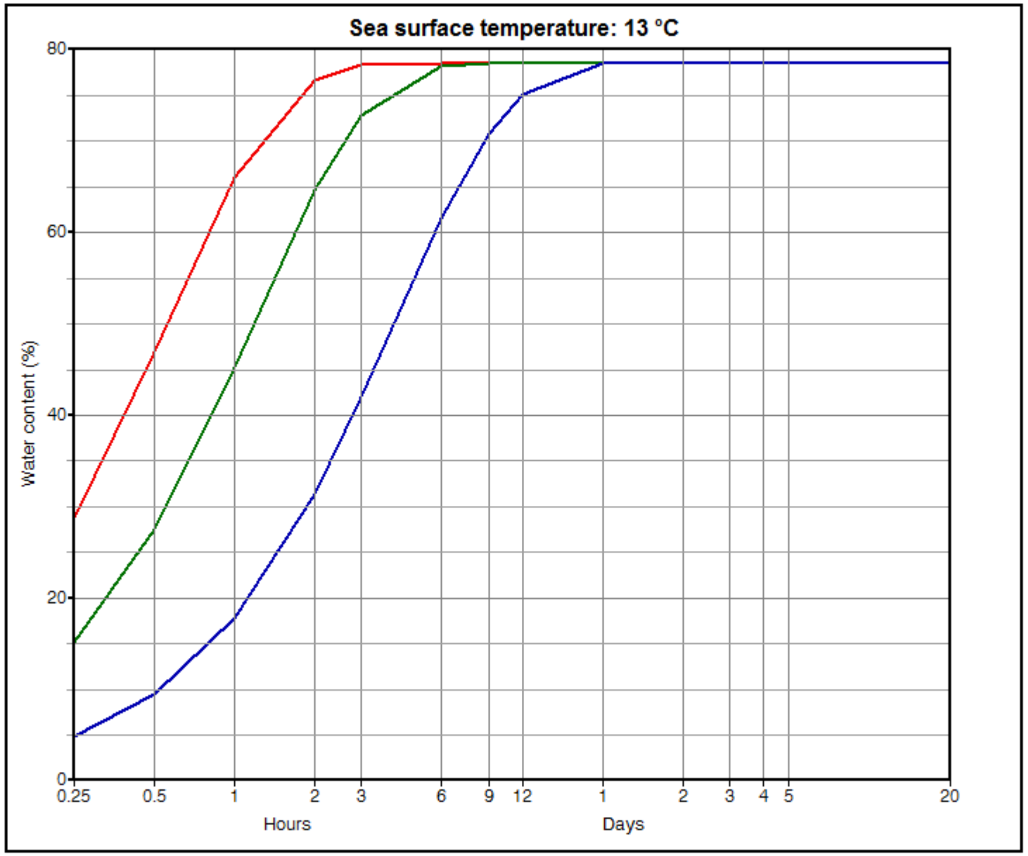
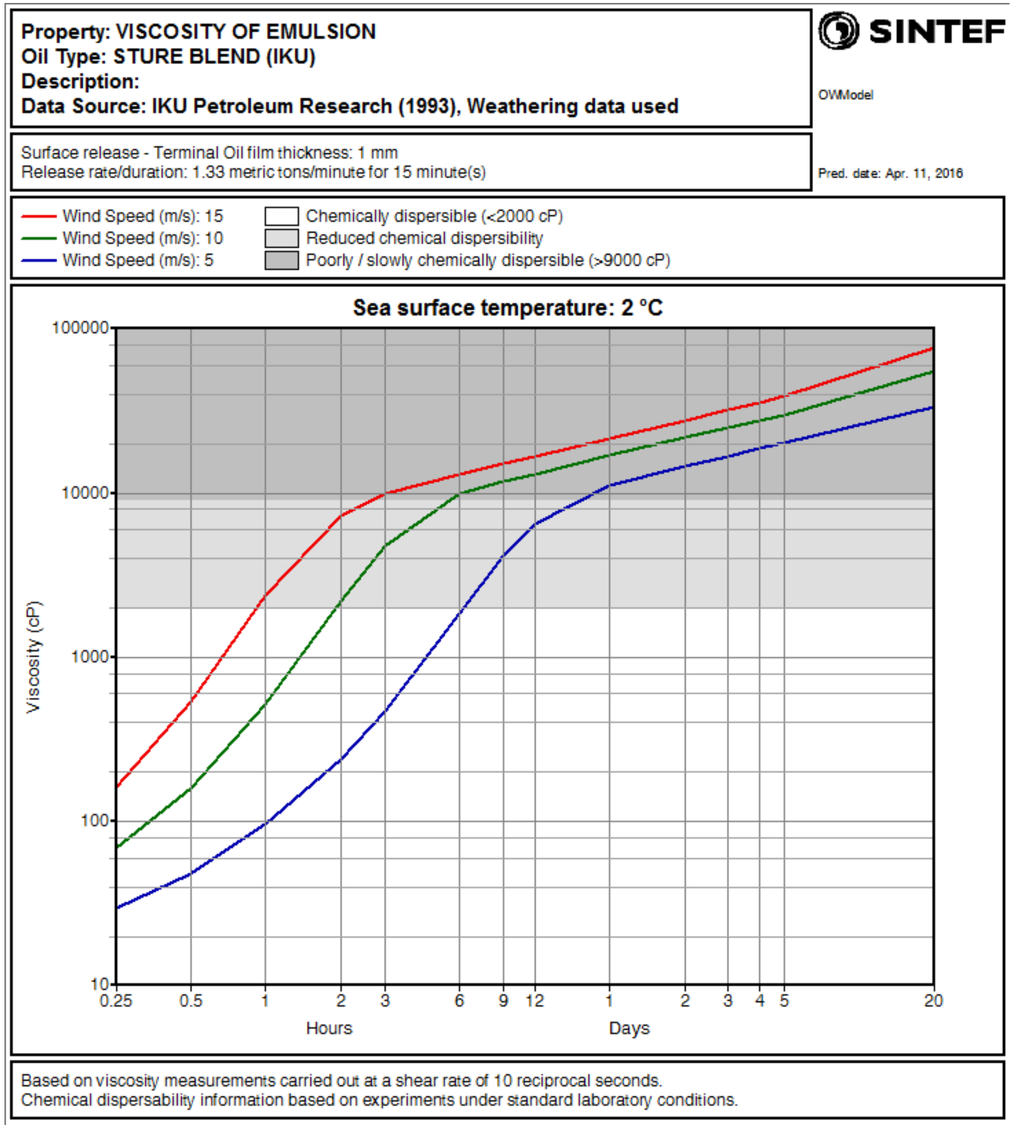


Table A1.2 Predicted water content of Sture Blend (IKU) oil predicted at sea temperatures of 2 °C and 13 °C



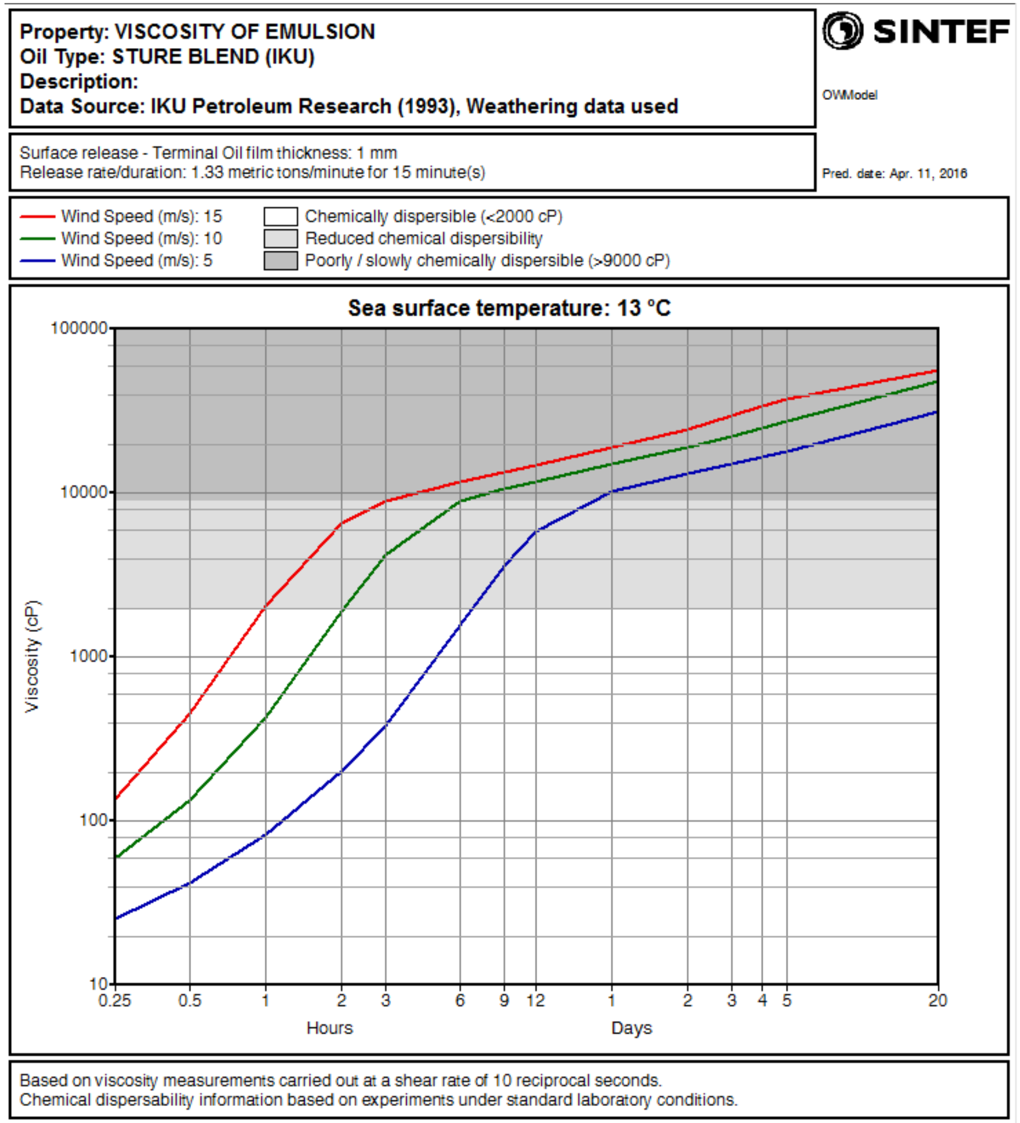


Table A1.3 Predicted viscosity of Sture Blend (IKU) oil predicted at sea temperatures of 2 °C and 13 °C

Appendix 2 Hindcast wind and hydrodynamic data for the NS-1 well locations

At each of the modelled sites 6 hourly surface HYCOM currents and NCEP (CFSR) winds were obtained by interpolating the values from the nearest model grid points. Summary statistics for both sites are presented below.

Currents

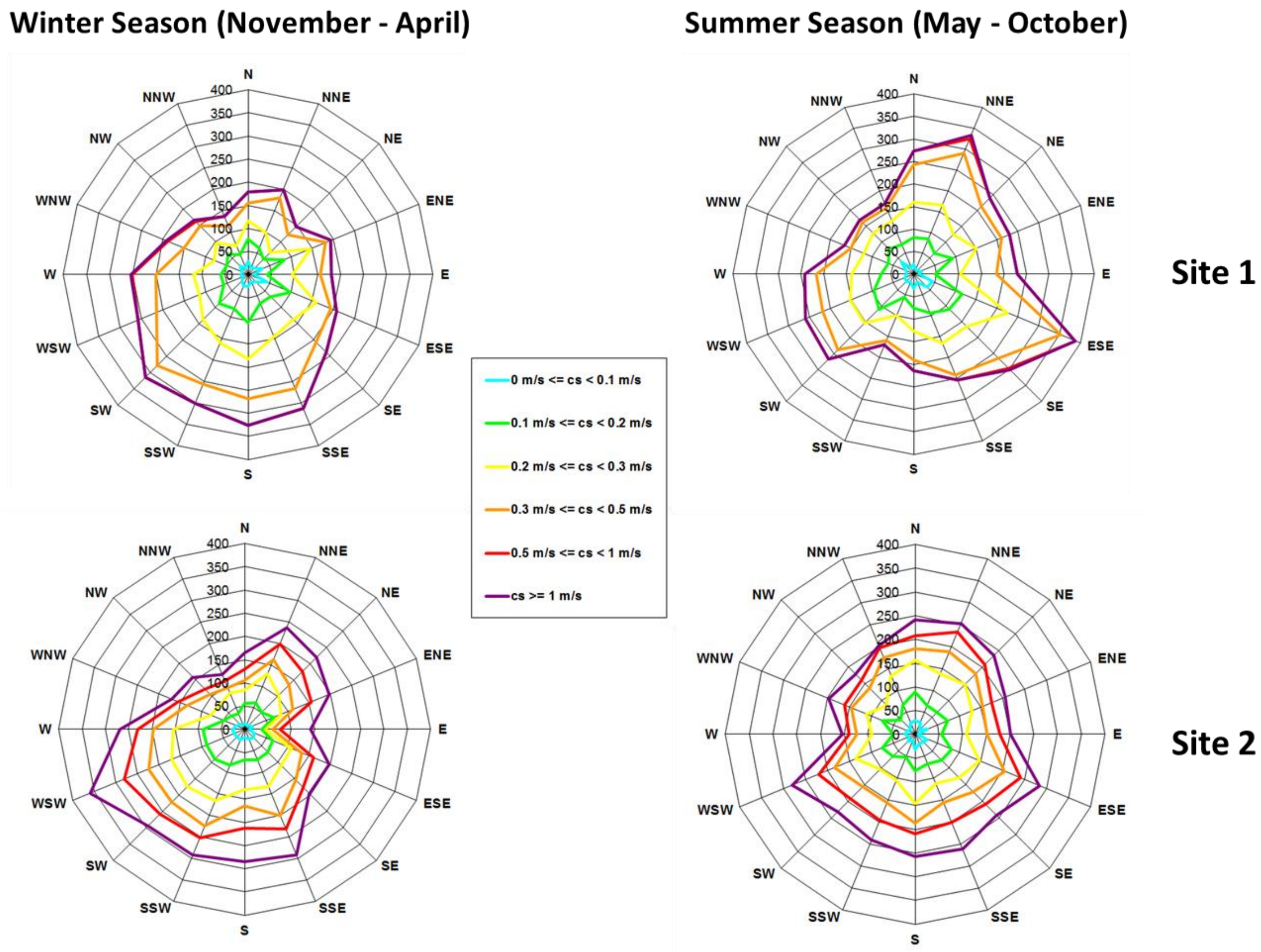


Figure A2.1 Seasonal current roses for Sites 1 and 2 derived from HYCOM model currents between 2006 - 2010. Current speeds in m/s (direction of currents is going towards).

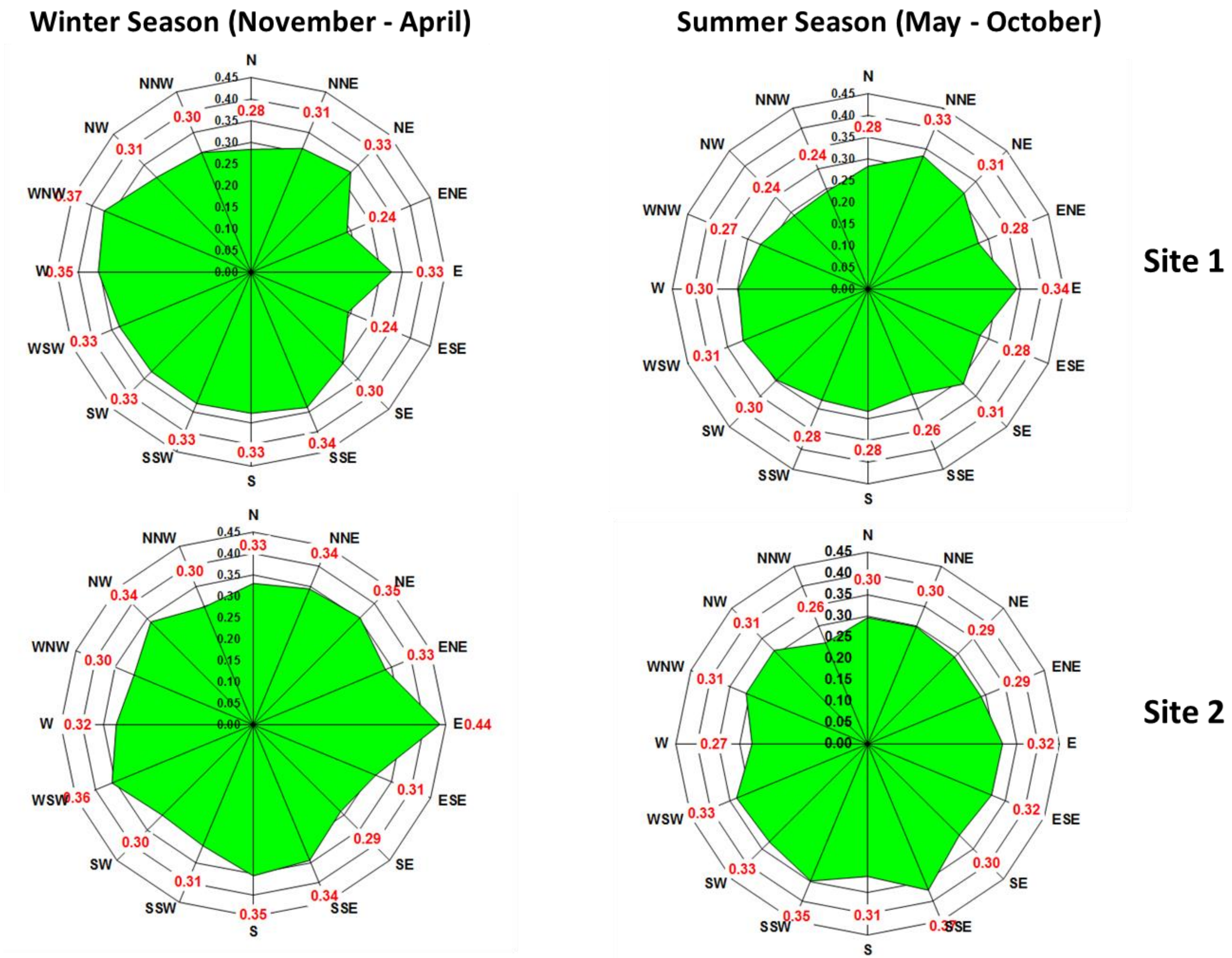


Figure A2.2 Average current speeds for Sites 1 and 2 derived from HYCOM model currents between 2006 – 2010. Current speeds in m/s (direction of currents is going towards).

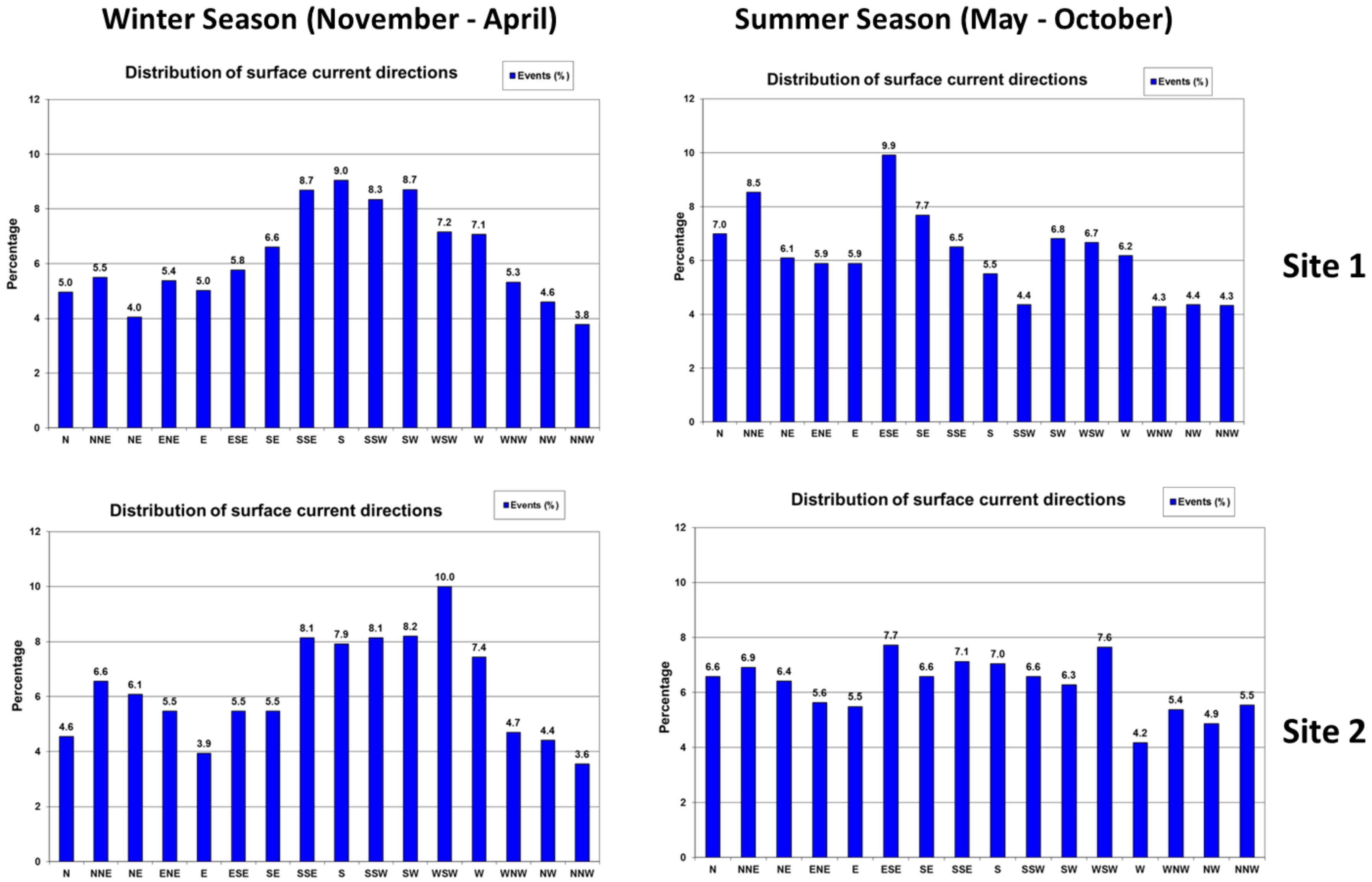


Figure A2.3 Distribution of current speeds for Sites 1 and 2 derived from HYCOM model currents between 2006 – 2010. Current speeds in m/s (direction of currents is going towards).

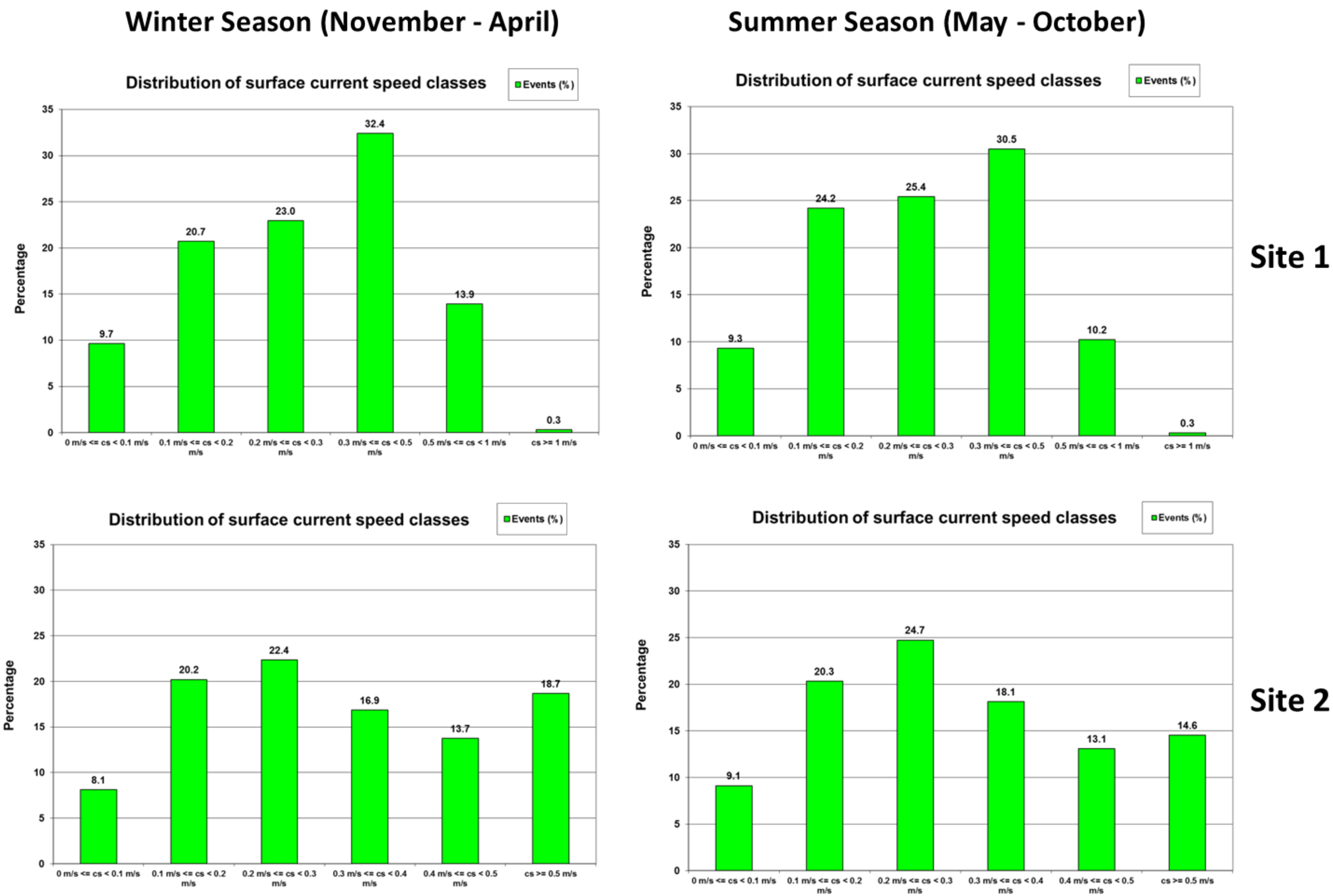
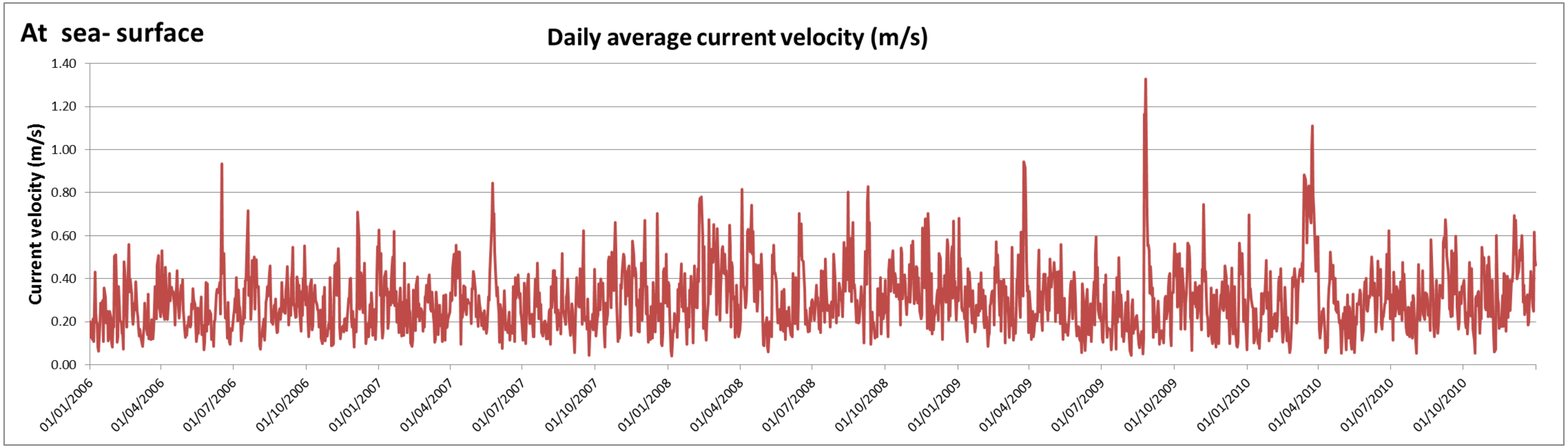


Figure A2.4 *Distribution of current class speeds for Sites 1 and 2 derived from HYCOM model currents between 2006 – 2010. Current speeds in m/s (direction of currents is going towards).*



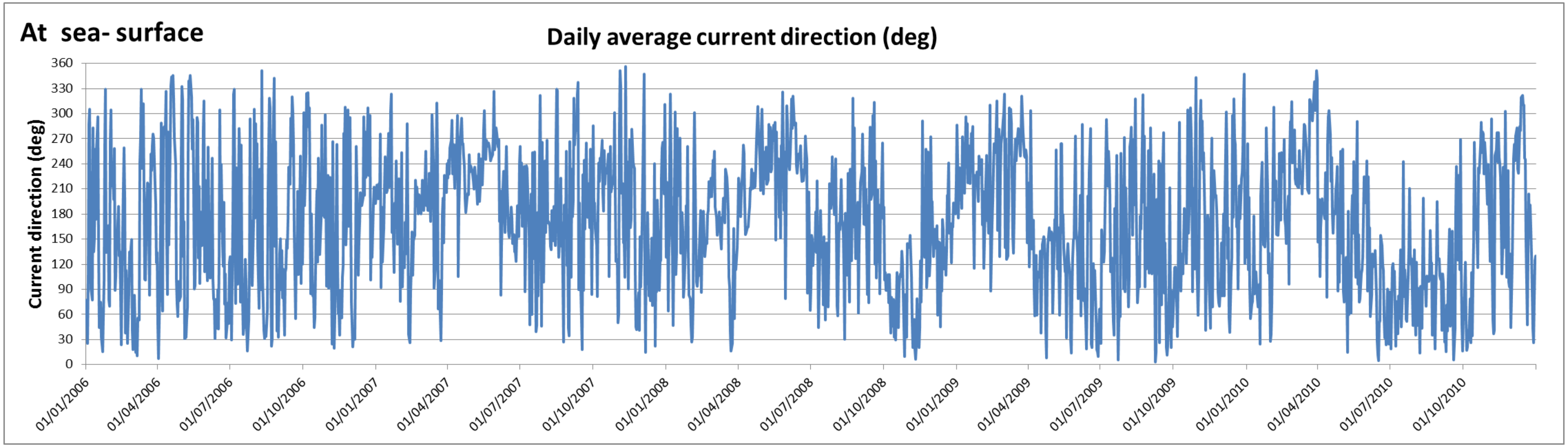
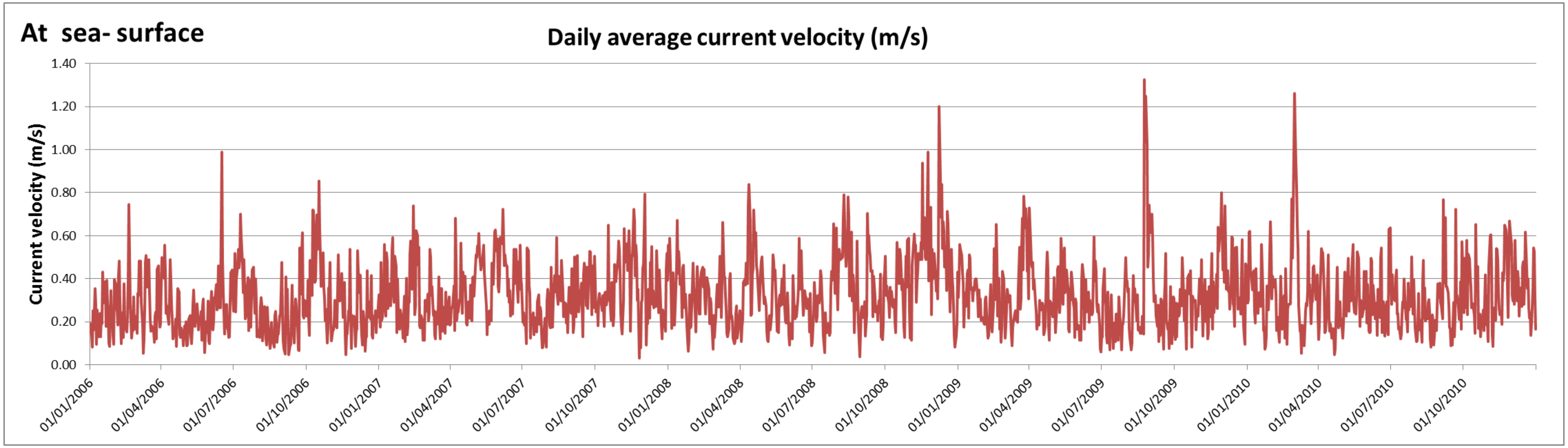


Figure A2.5 Time series of HYCOM model currents for Site 1 derived from HYCOM model currents between 2006 – 2010. Current speeds in m/s (direction of currents is going towards).



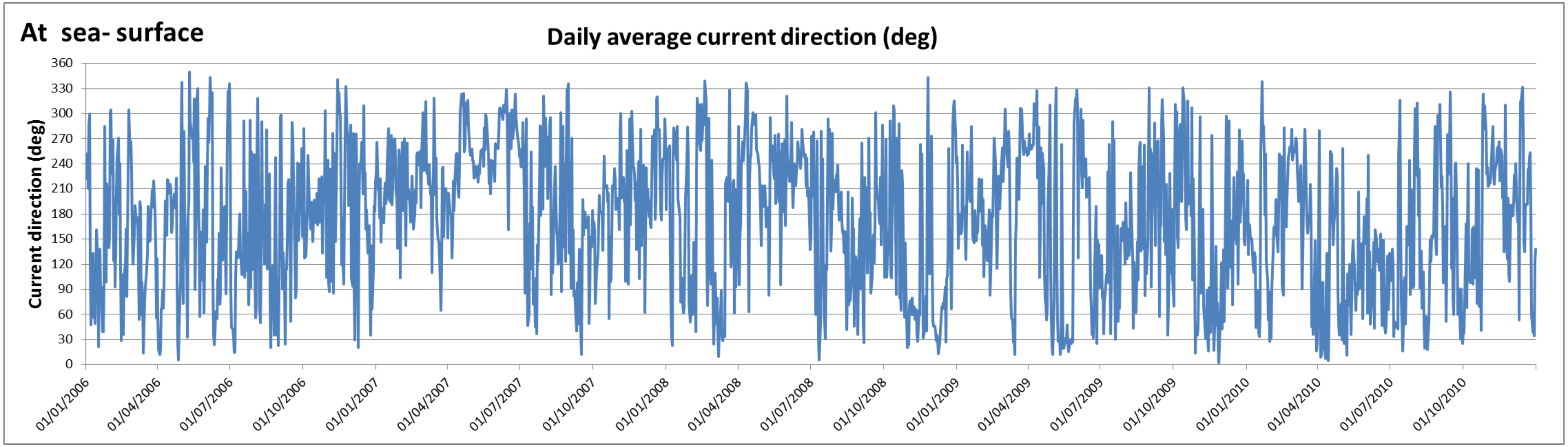
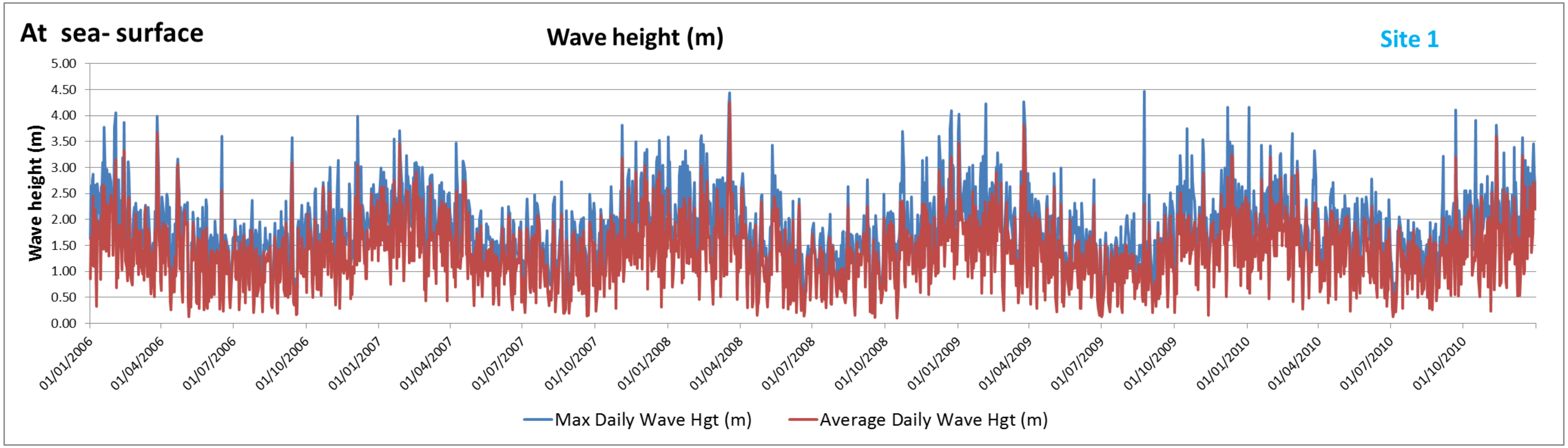


Figure A2.6 Time series of HYCOM model currents for Site 2 derived from HYCOM model currents between 2006 – 2010. Current speeds in m/s (direction of currents is going towards).



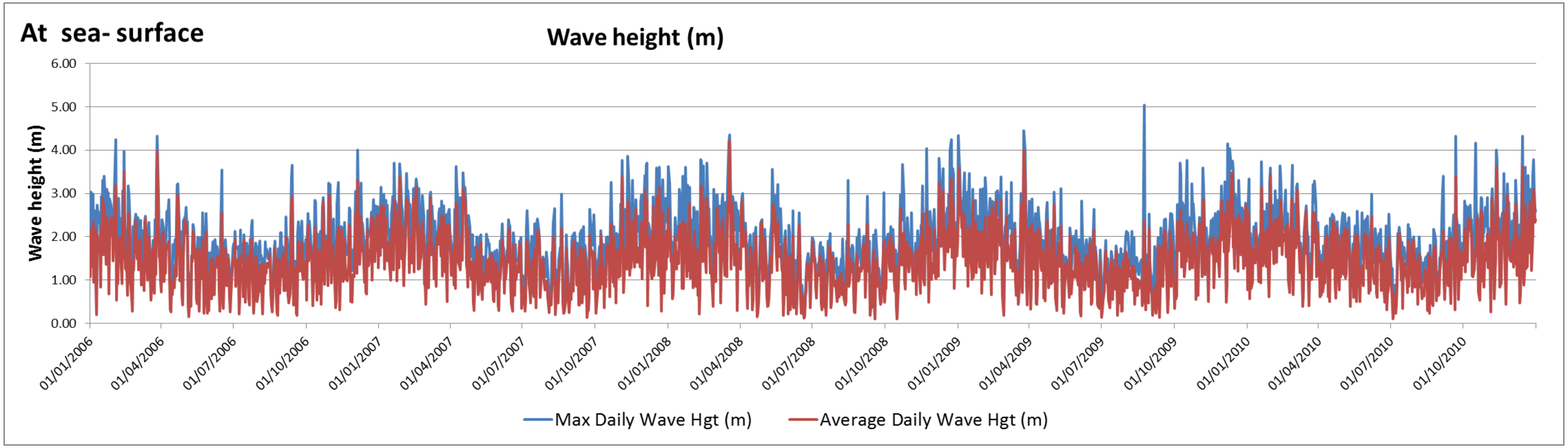


Figure A2.7 Time series of maximum and daily average wave heights for Sites 1 and 2 between 2006 – 2010 calculated internally by OSCAR from wind speed, water depth and fetch.

Winds

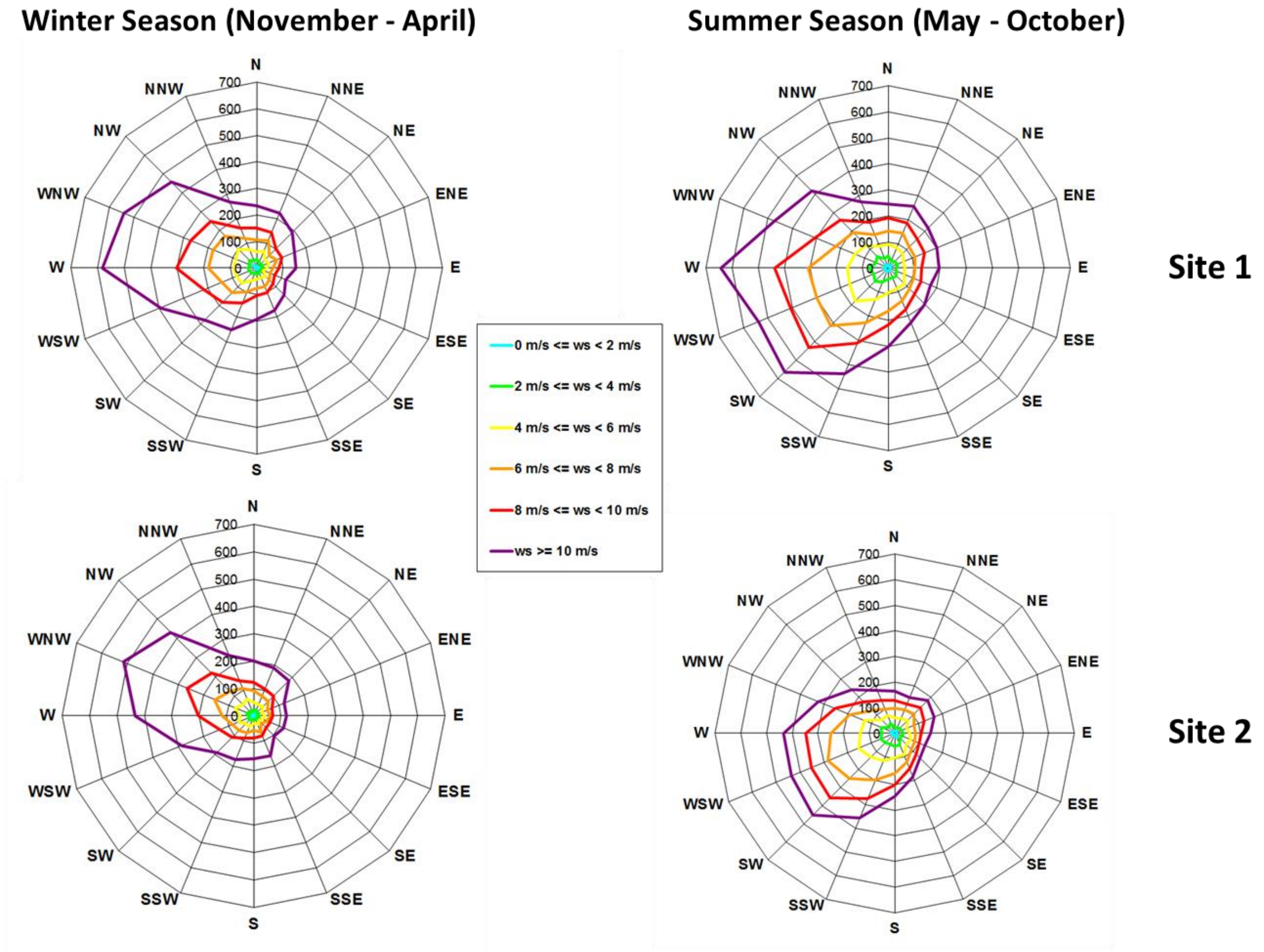


Figure A2.8 Seasonal wind roses for Sites 1 and 2 derived from NCAR/NCEP CFSR winds between 2006 – 2010. Wind speeds in m/s, using meteorological convention (direction wind is coming from).

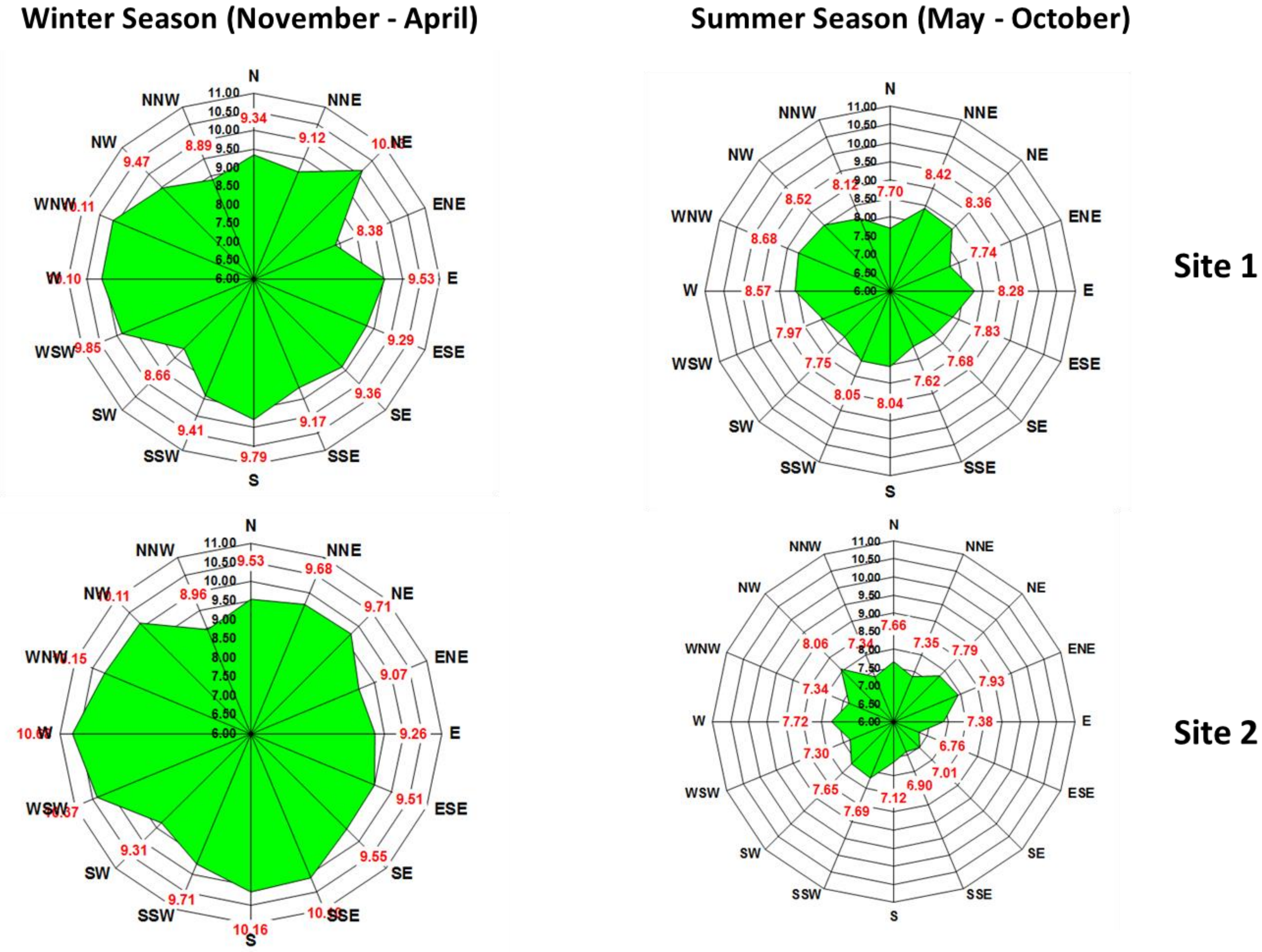


Figure A2.9 Average wind speeds for Sites 1 and 2 derived from NCAR/NCEP CFSR winds between 2006 – 2010. Wind speeds in m/s, using meteorological convention (direction wind is coming from).

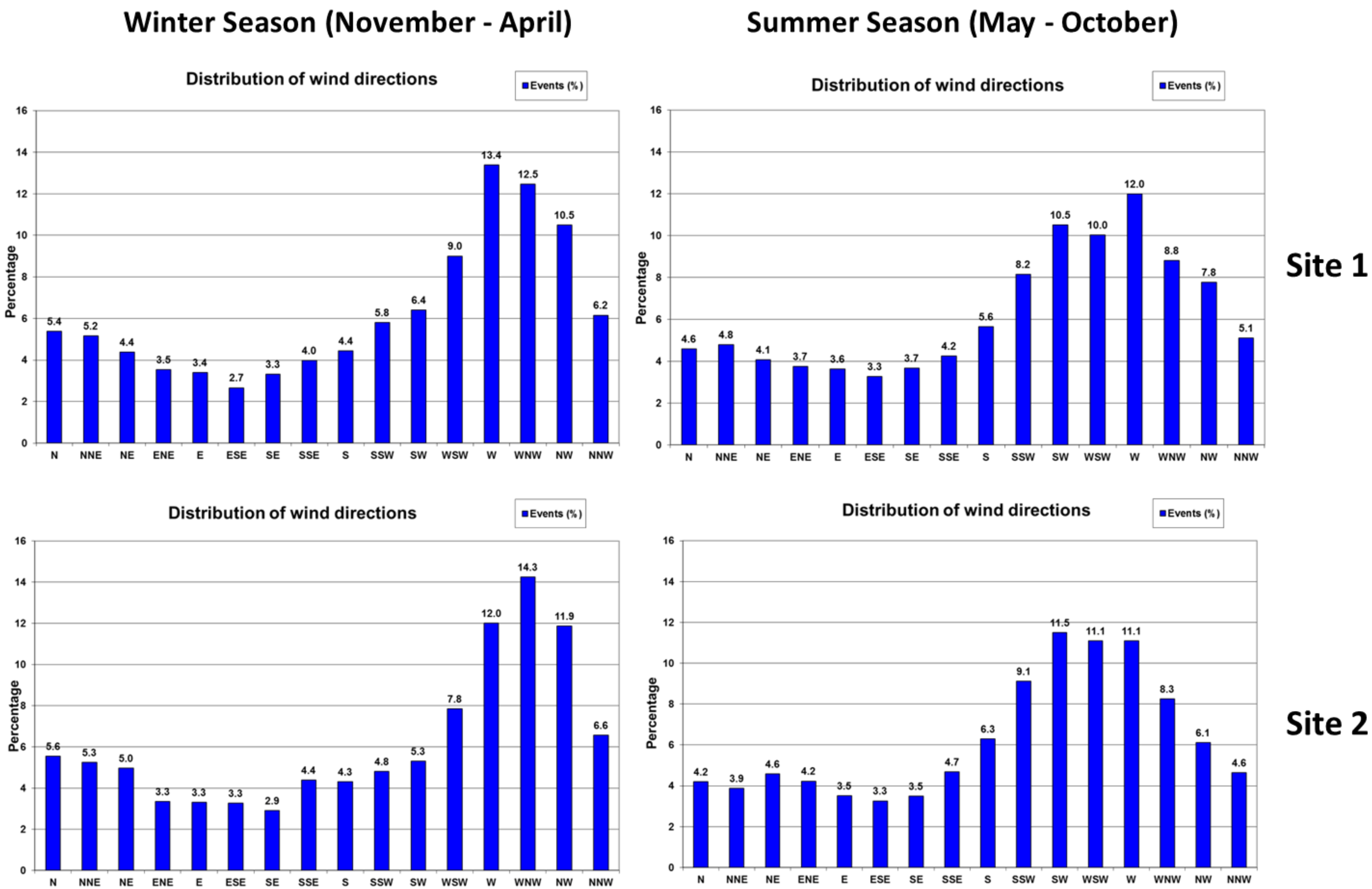


Figure A2.10 Distribution of wind speeds for Sites 1 and 2 derived from NCAR/NCEP CFSR winds between 2006 – 2010. Wind speeds in m/s, using meteorological convention (direction wind is coming from).

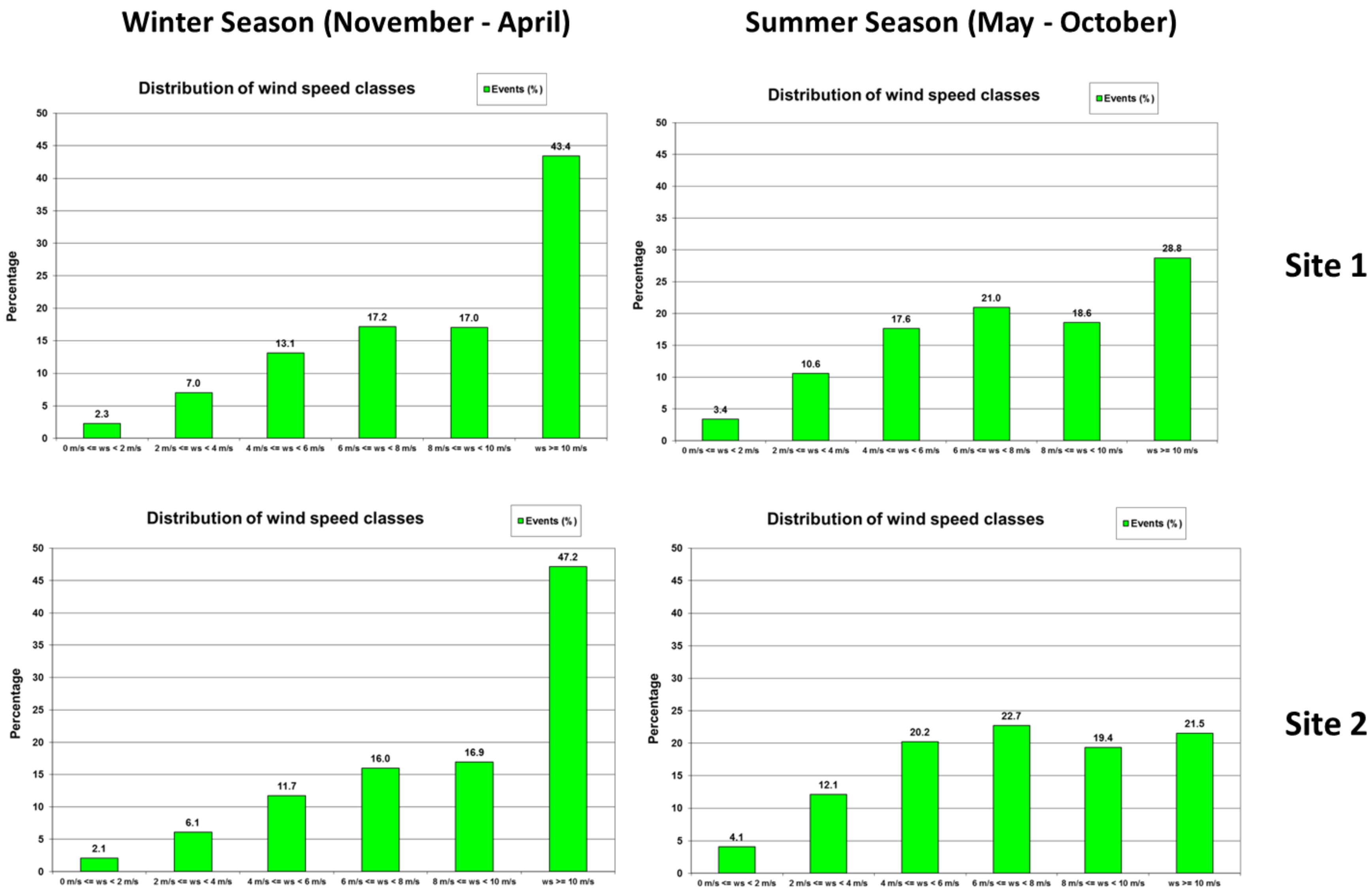
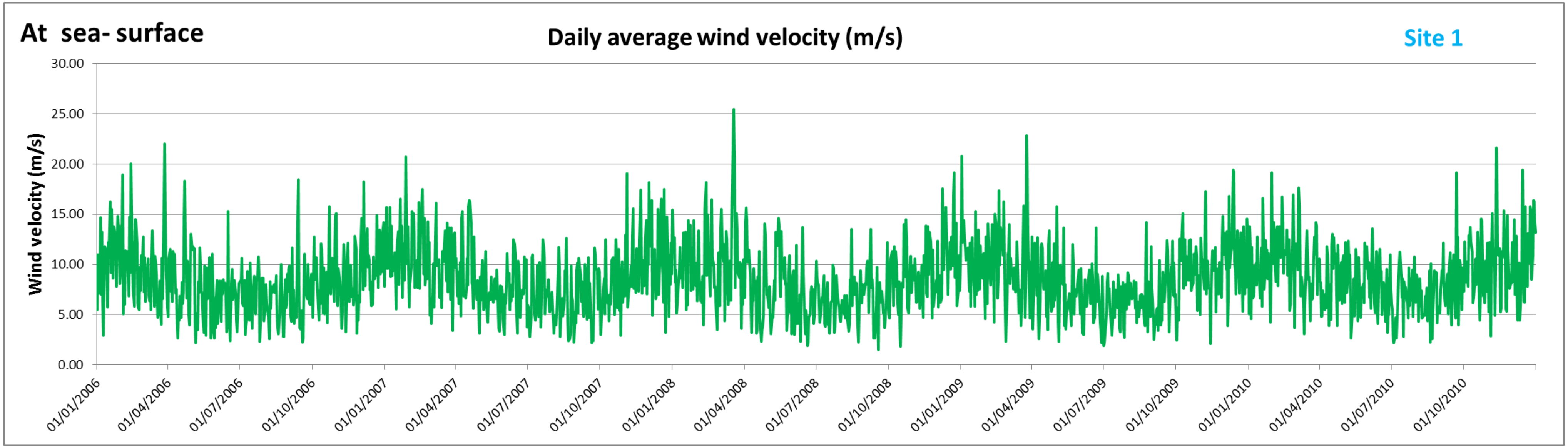


Figure A2.11 Distribution of wind class speeds for Sites 1 and 2 derived from NCAR/NCEP CFSR winds between 2006 – 2010. Wind speeds in m/s, using meteorological convention (direction wind is coming from).



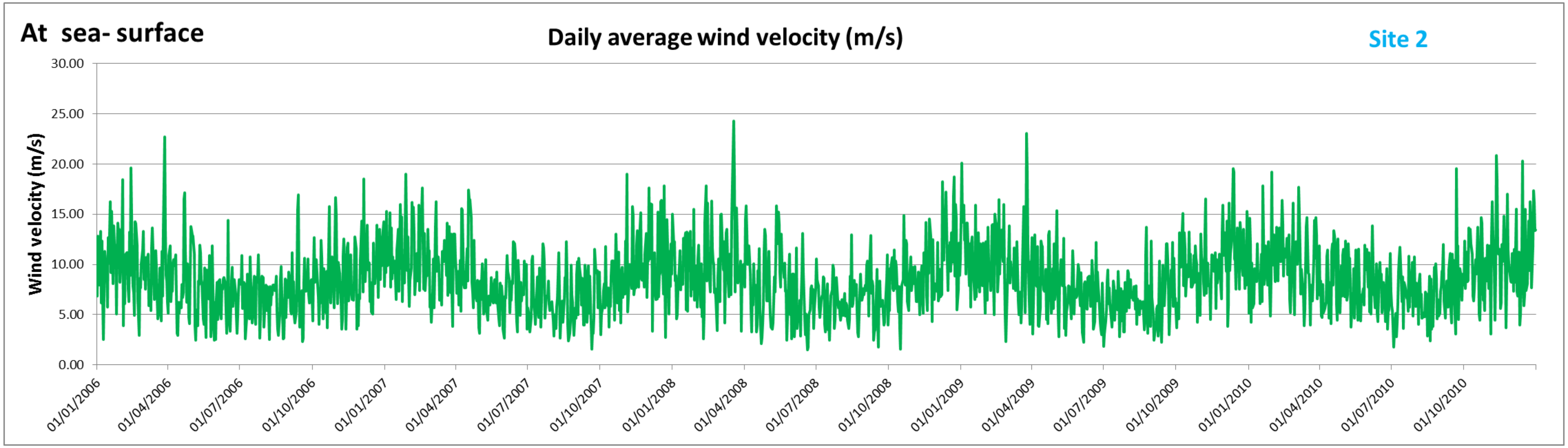


Figure A2.12 Time series of daily average wind speeds for Sites 1 and 2 derived from NCAR/NCEP CFSR model winds between 2006 – 2010.

Appendix 3 Hydrographic profiles

The HYCOM model was used to extract average monthly temperature and salinity vs. depth profiles over the period 2006 to 2010) for the NS-1 well locations. The data was then used to produce hydrographical profiles for each "seasonal" time period employed in the stochastic simulations. There was no significant difference in the profiles for each site. The profiles are presented below:

Figure A3.1

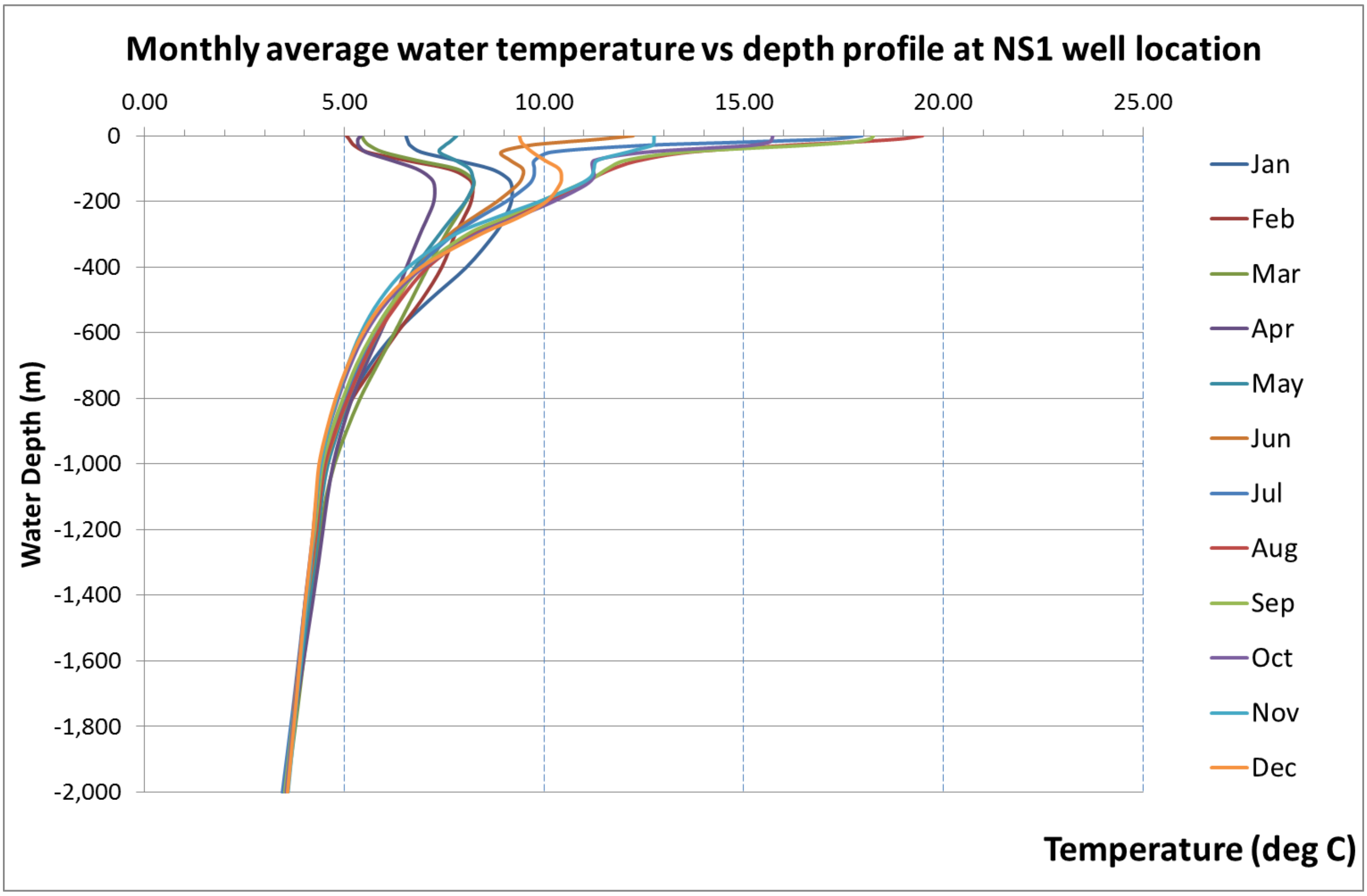


Figure A3.2

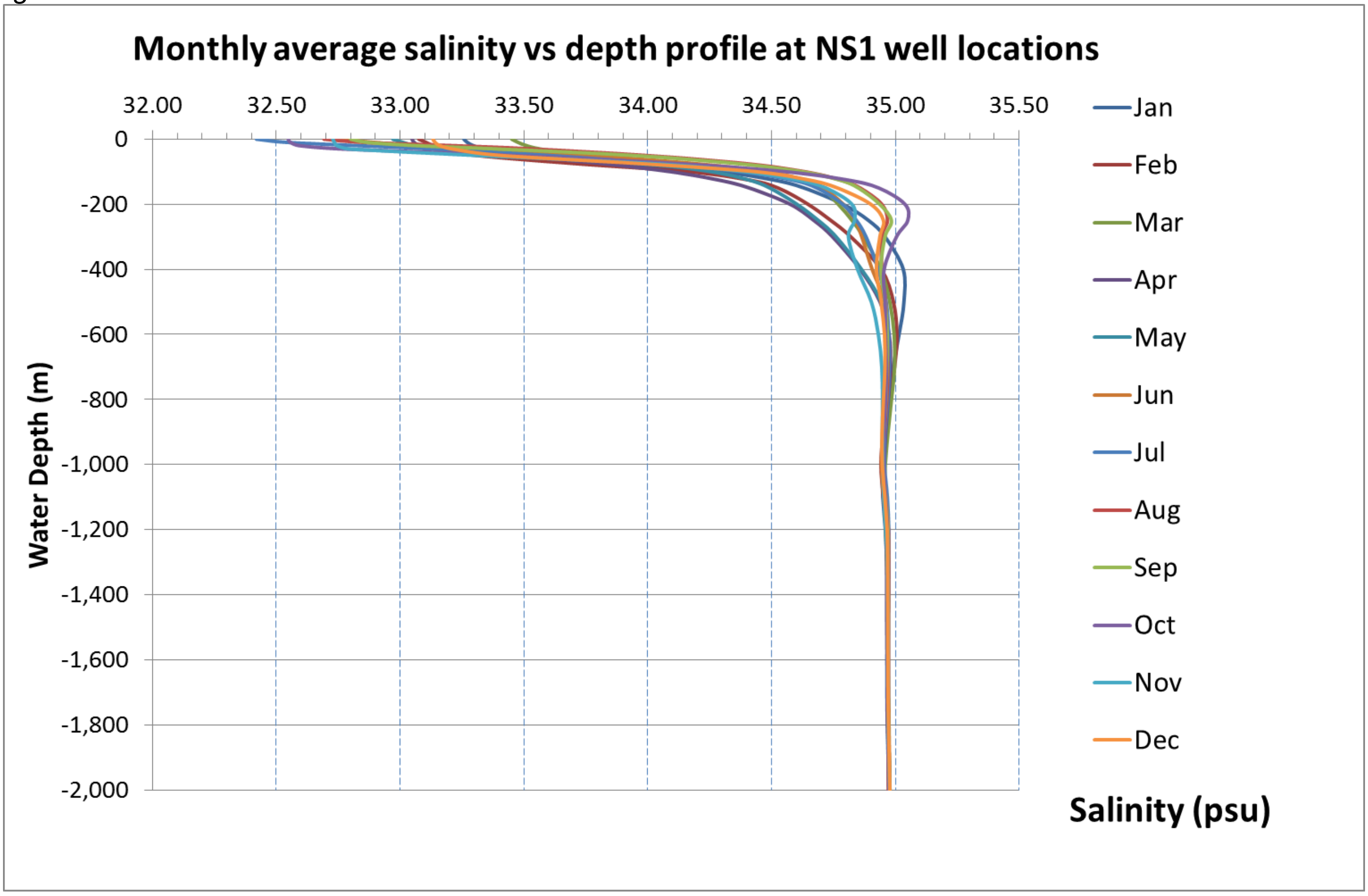


Figure A3.3

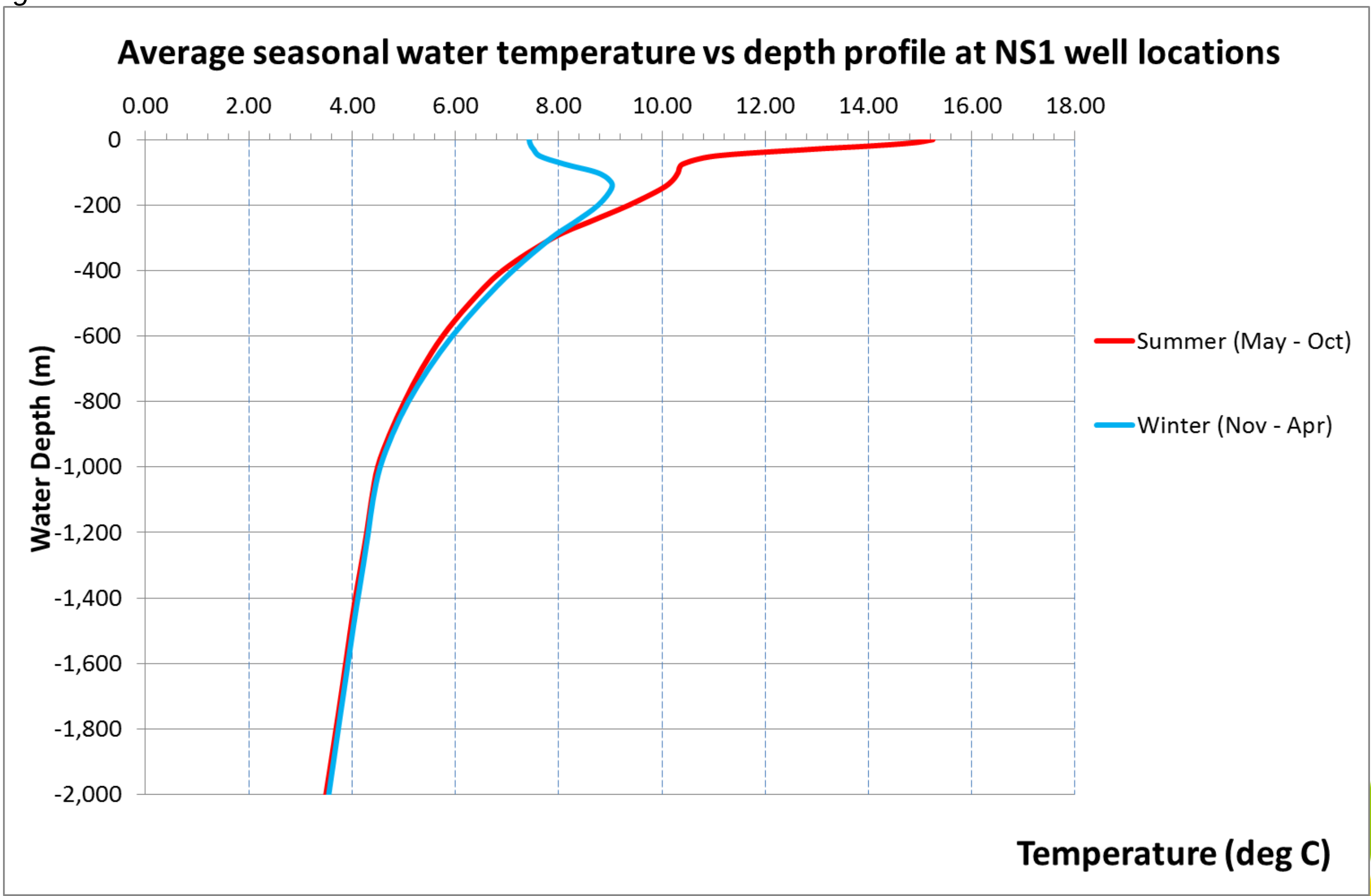
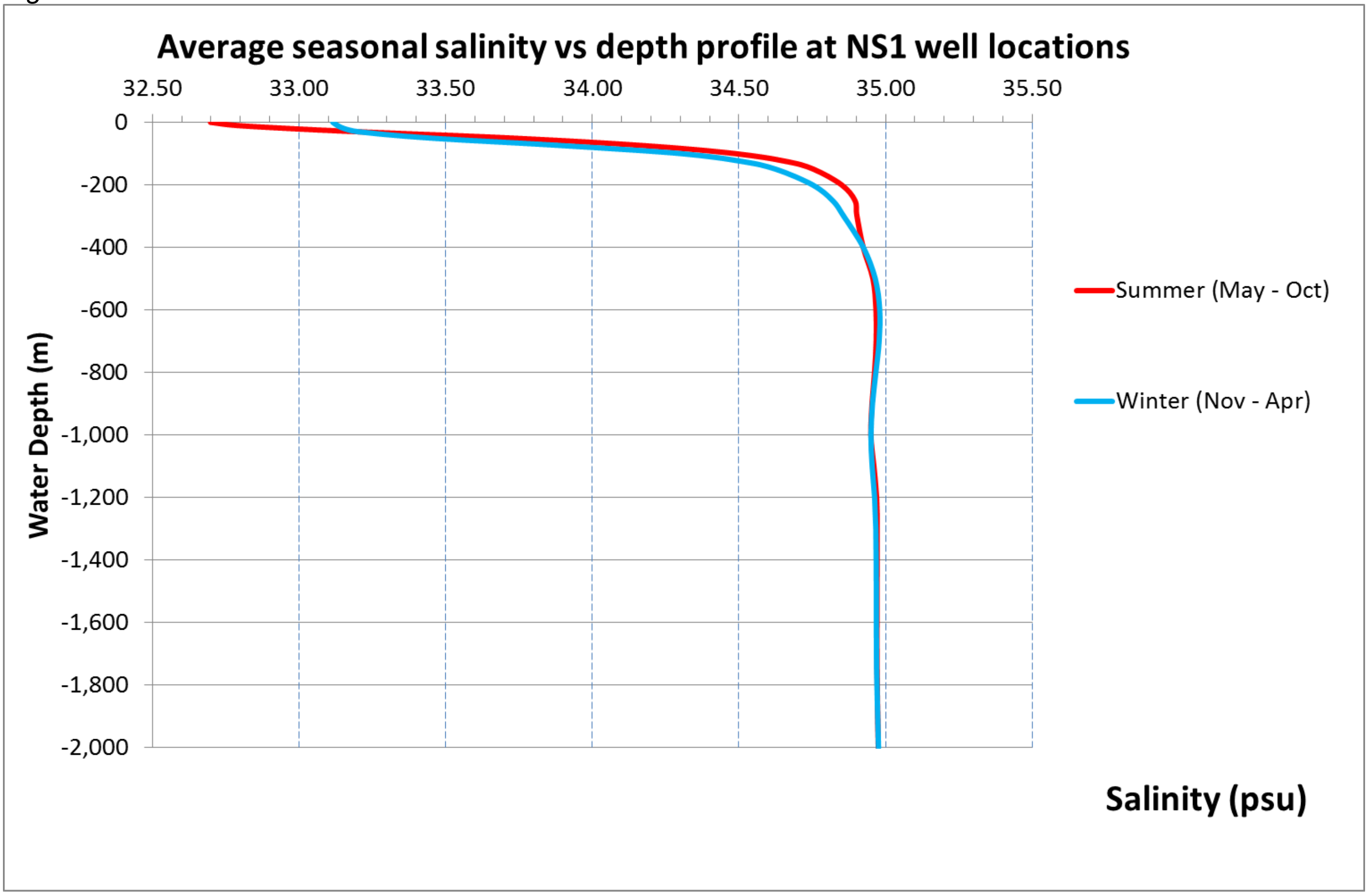


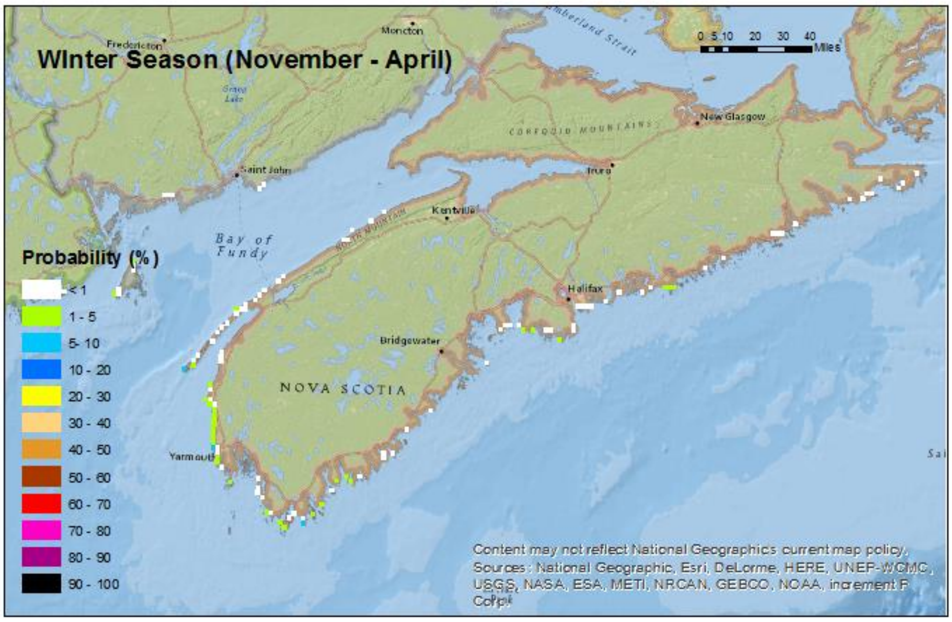
Figure A3.4


Average seasonal salinity vs depth profile at NS1 well locations
32.50
33.00
33.50
34.00
34.50
35.00
35.50
0
-200
-400
-600
-800
-1,000
-1,200
-1,400
-1,600
-1,800
-2,000
Water Depth (m)
Summer (May - Oct)
Winter (Nov - Apr)
Salinity (psu)

Appendix 4 Stochastic modelling results for the NS-1 subsea well blowout scenarios showing shorelines potentially affected by stranded oiling events

Nova Scotia Coastline

Figure A4.1 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the probability of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)



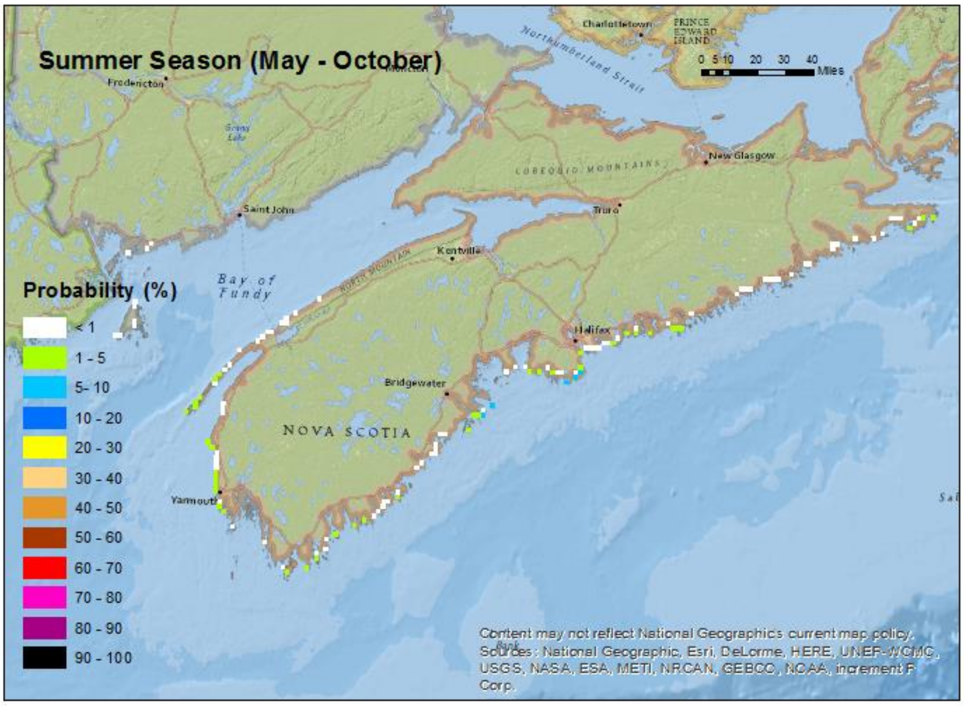
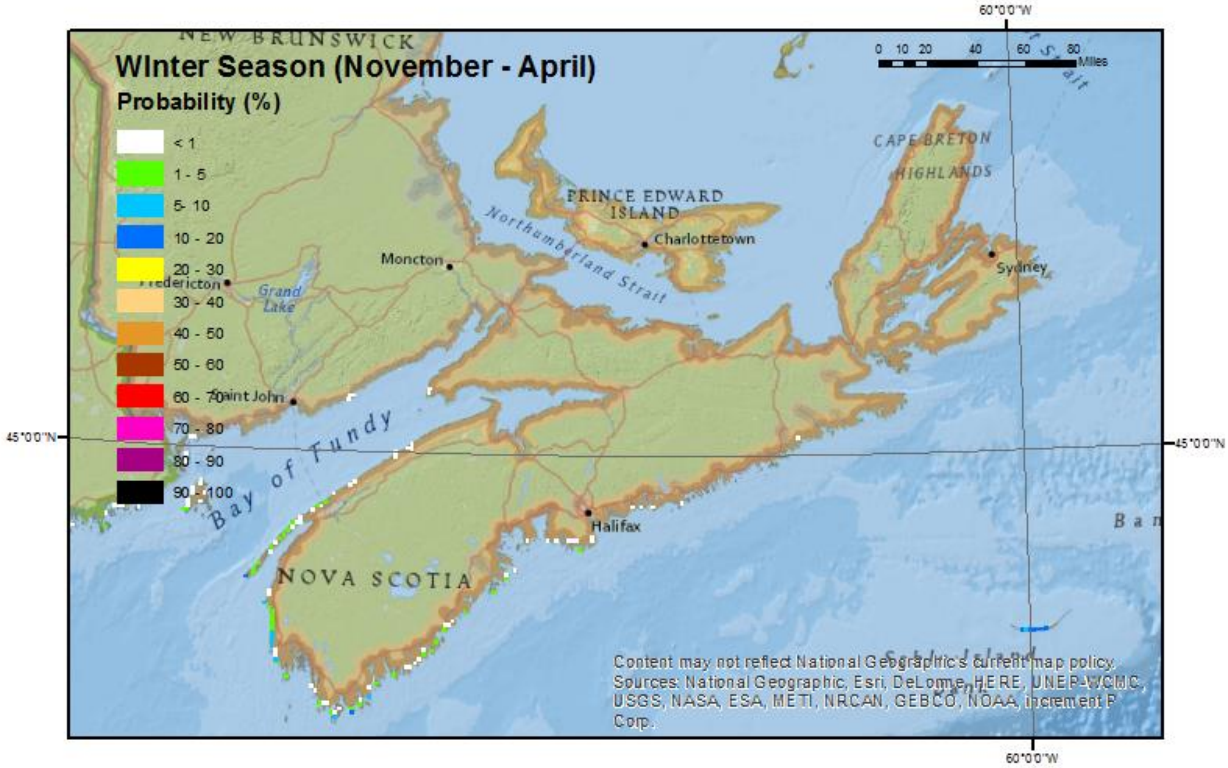


Figure A4.2 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the probability of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)



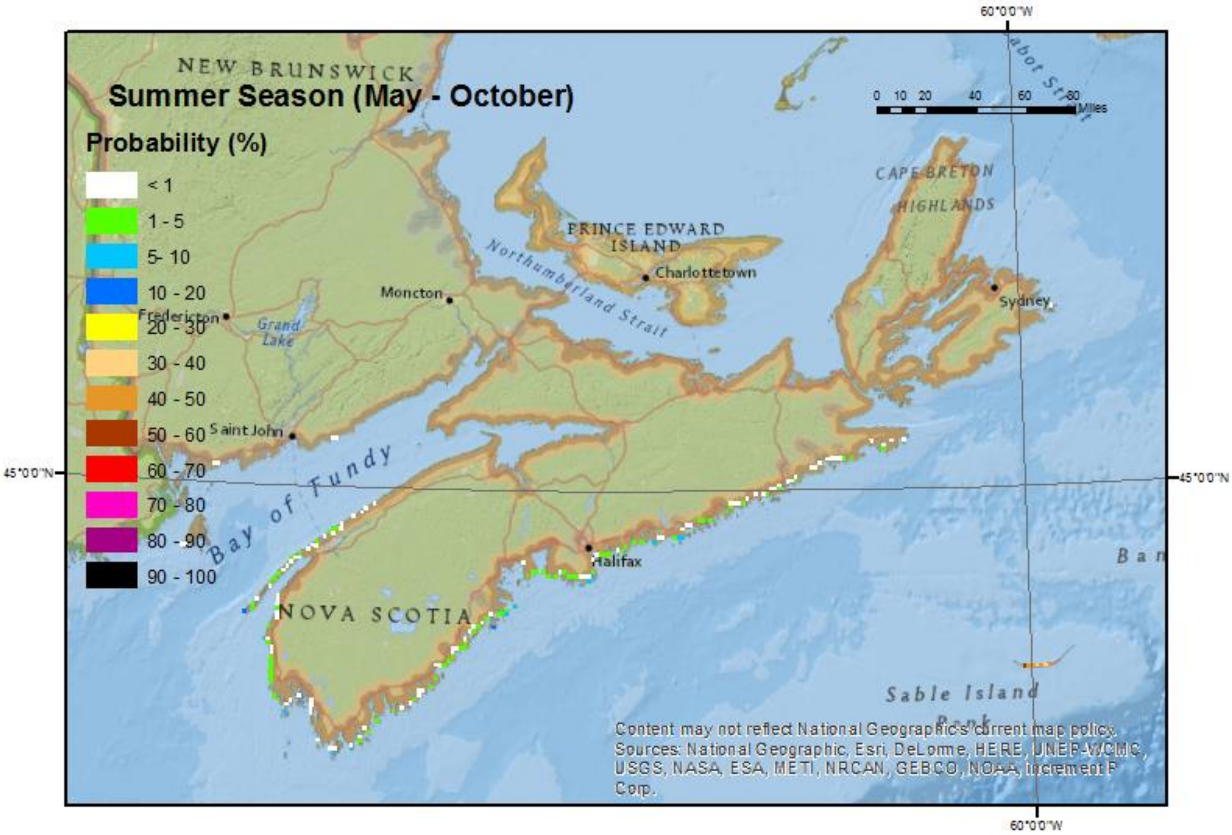
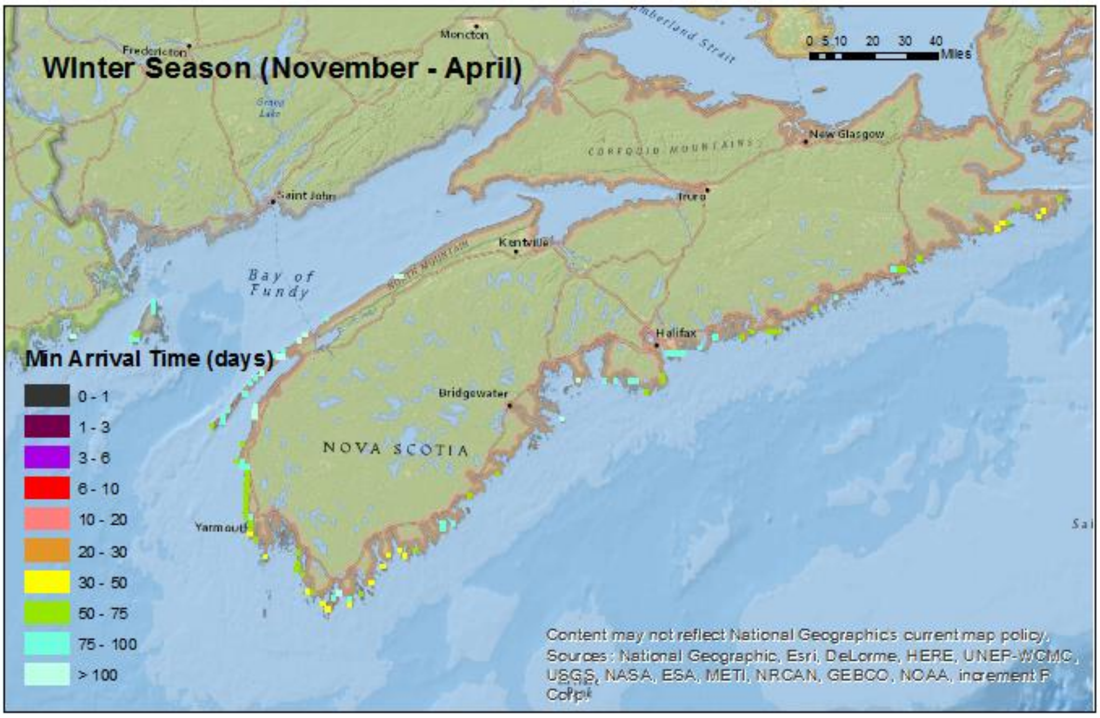


Figure A4.3 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the minimum arrival time of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)



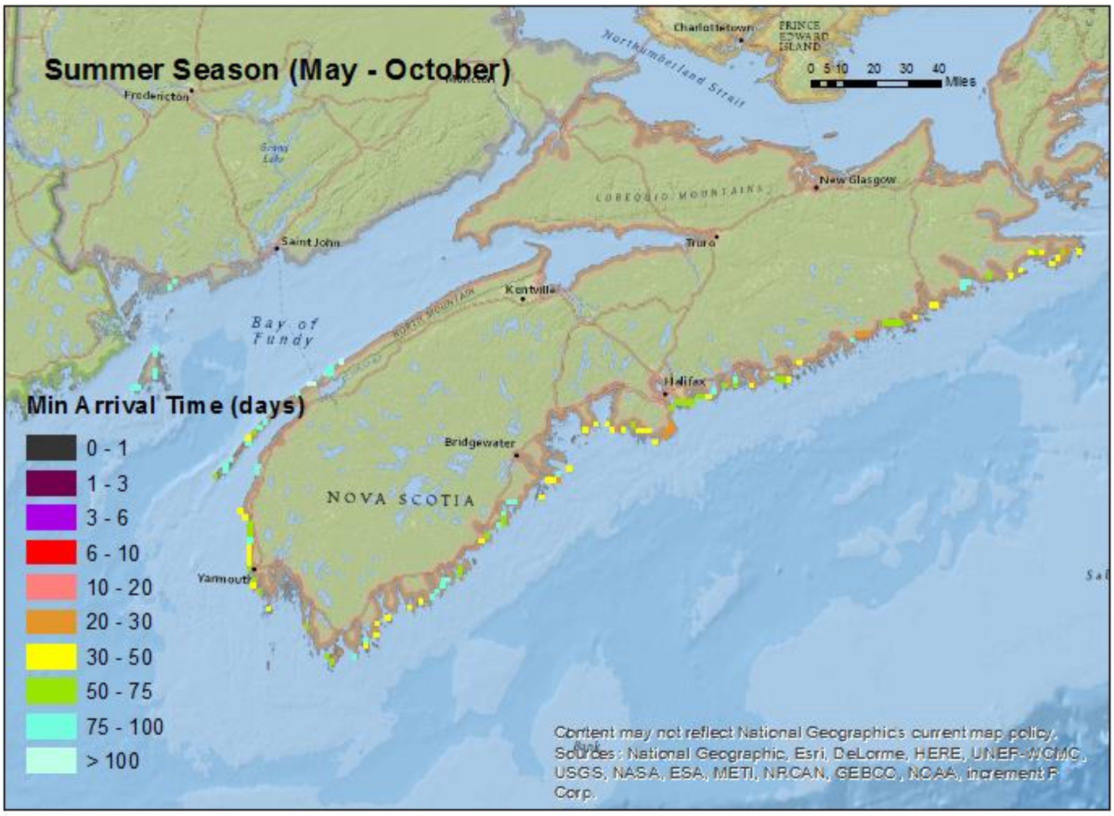


Figure A4.4 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the minimum arrival time of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)

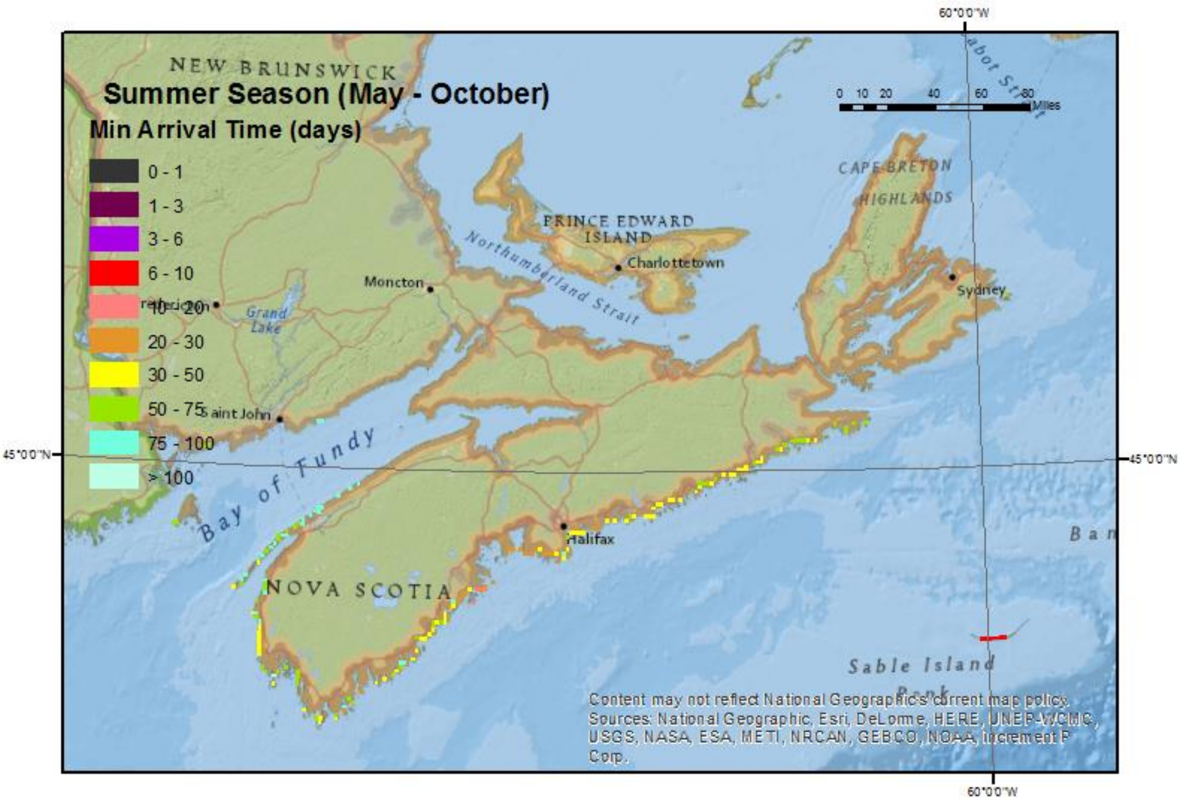
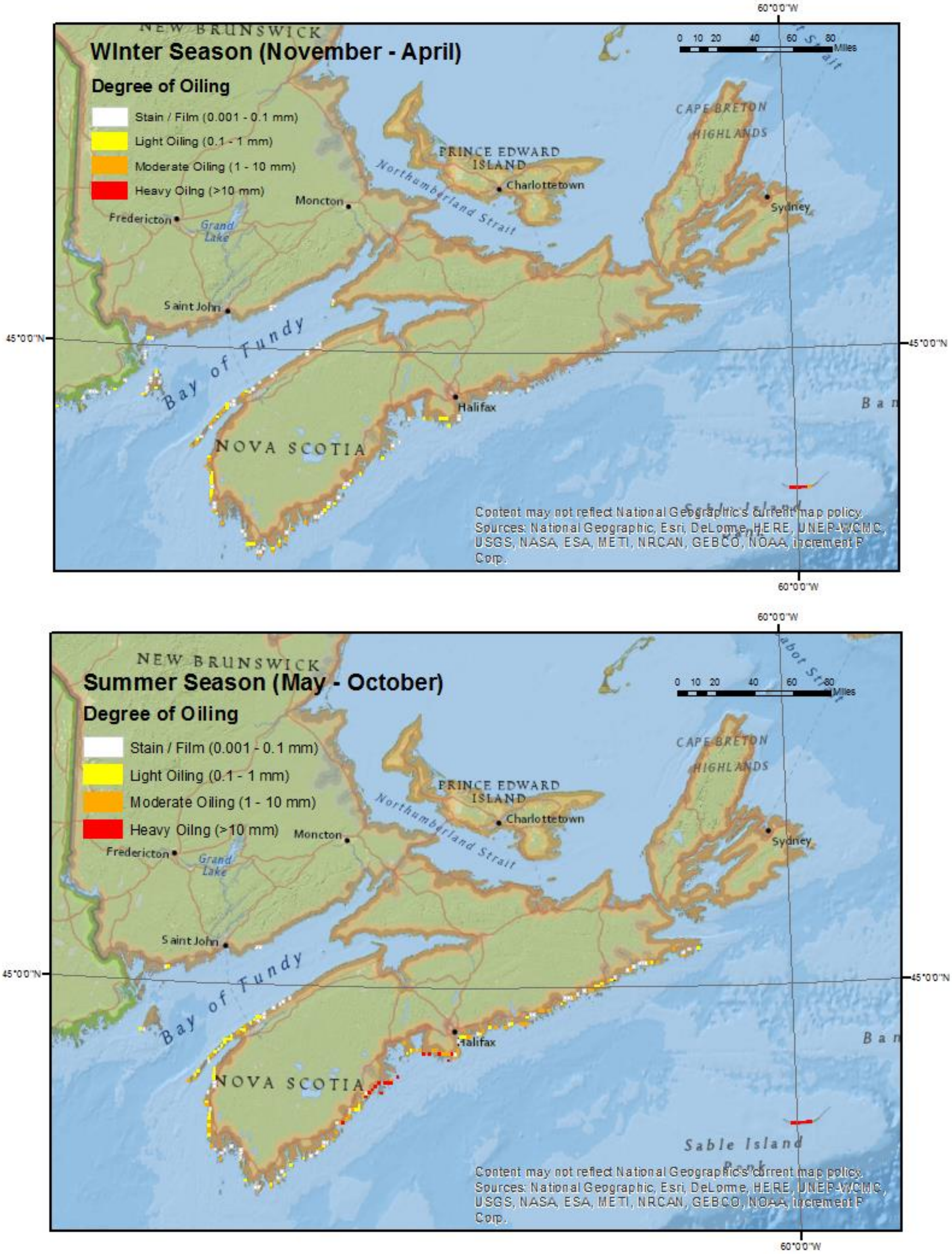


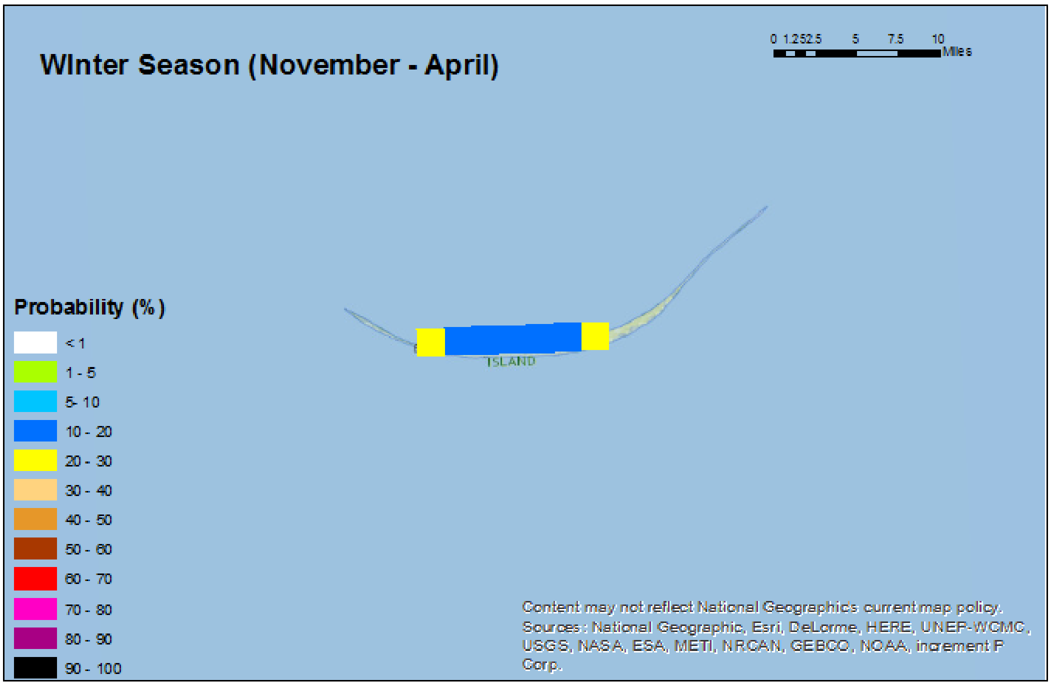
Figure A4.5 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the maximum accumulated emulsion thickness on the shoreline in accumulated amounts that exceed the minimum thickness threshold of 1 micron (1 g/m^2). (Degree of oiling categorised according to the International Tank Owners Pollution Federation (ITPOF) guidelines for the recognition of oil on shorelines [(19)])

Figure A4.6 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the maximum accumulated emulsion thickness on the shoreline in accumulated amounts that exceed the minimum thickness threshold of 1 micron (1 g/m^2). (Degree of oiling categorised according to the International Tank Owners Pollution Federation (ITPOF) guidelines for the recognition of oil on shorelines [19])



Sable Island

Figure A4.7 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the probability of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m^2)



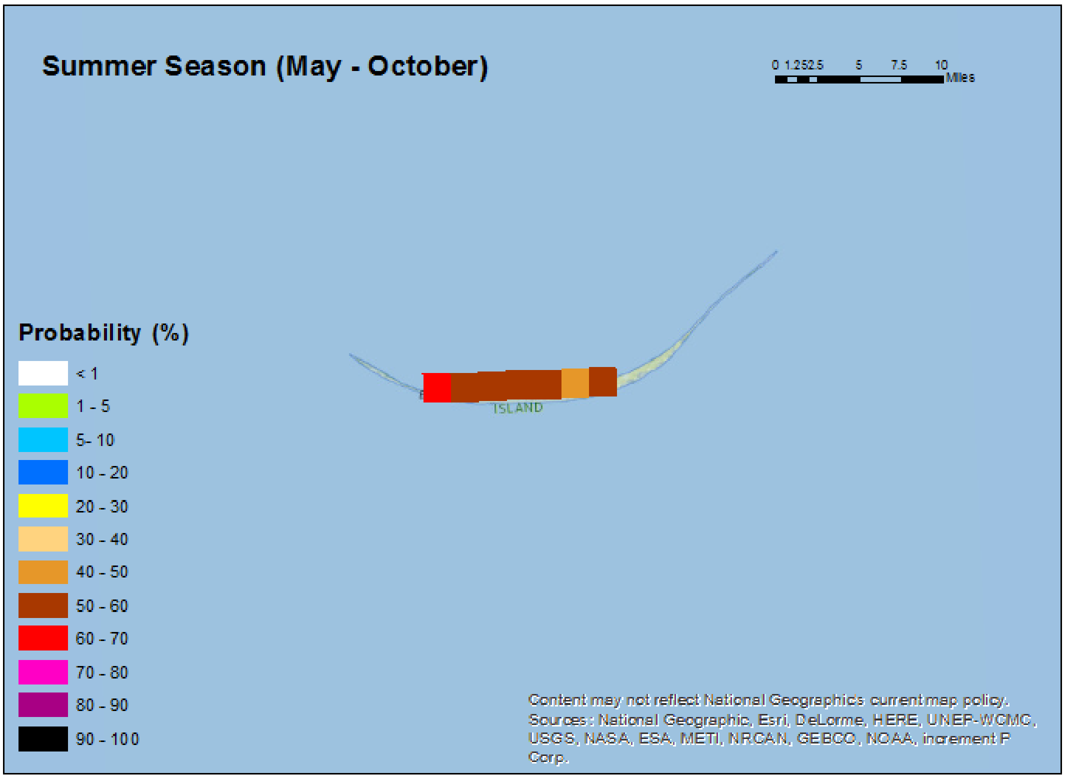
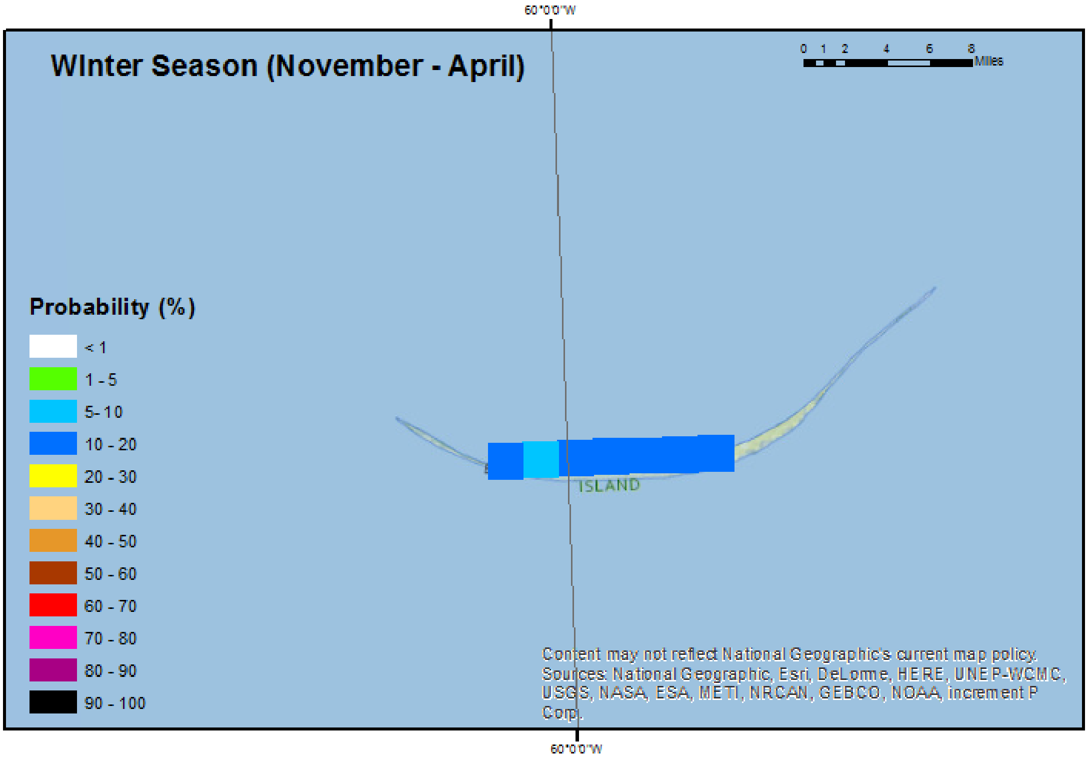


Figure A4.8 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the probability of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)



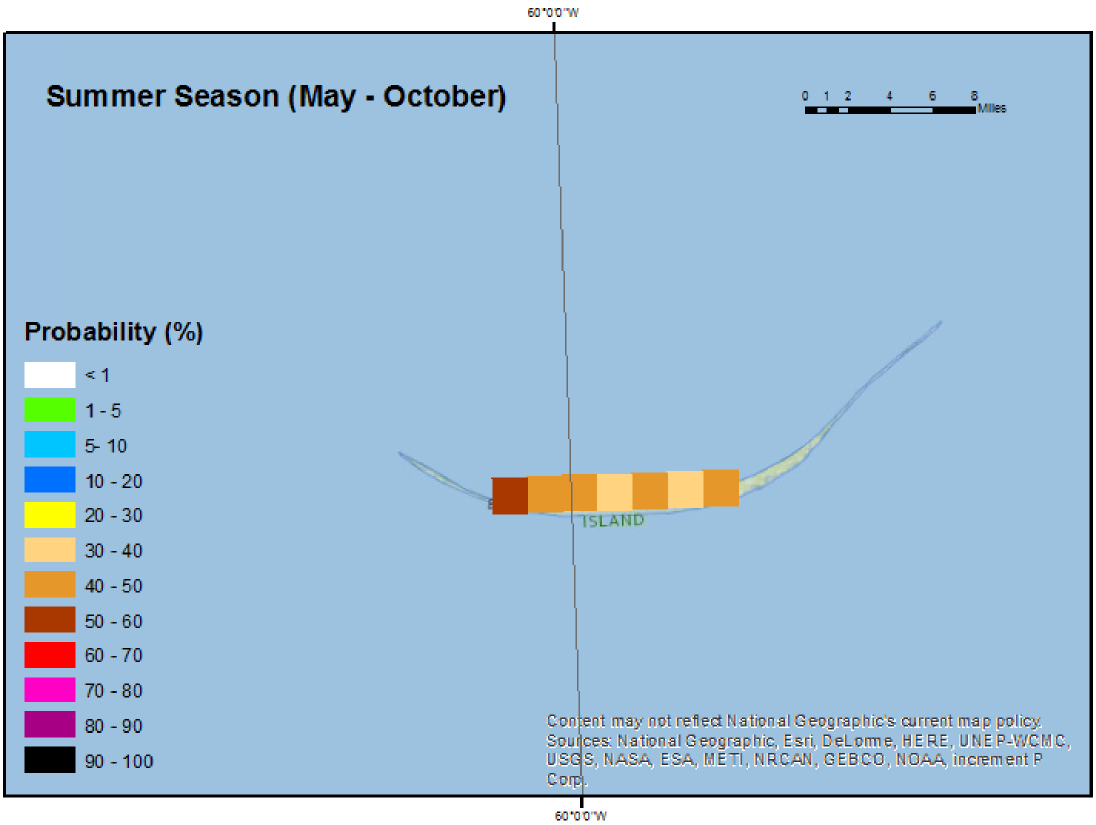
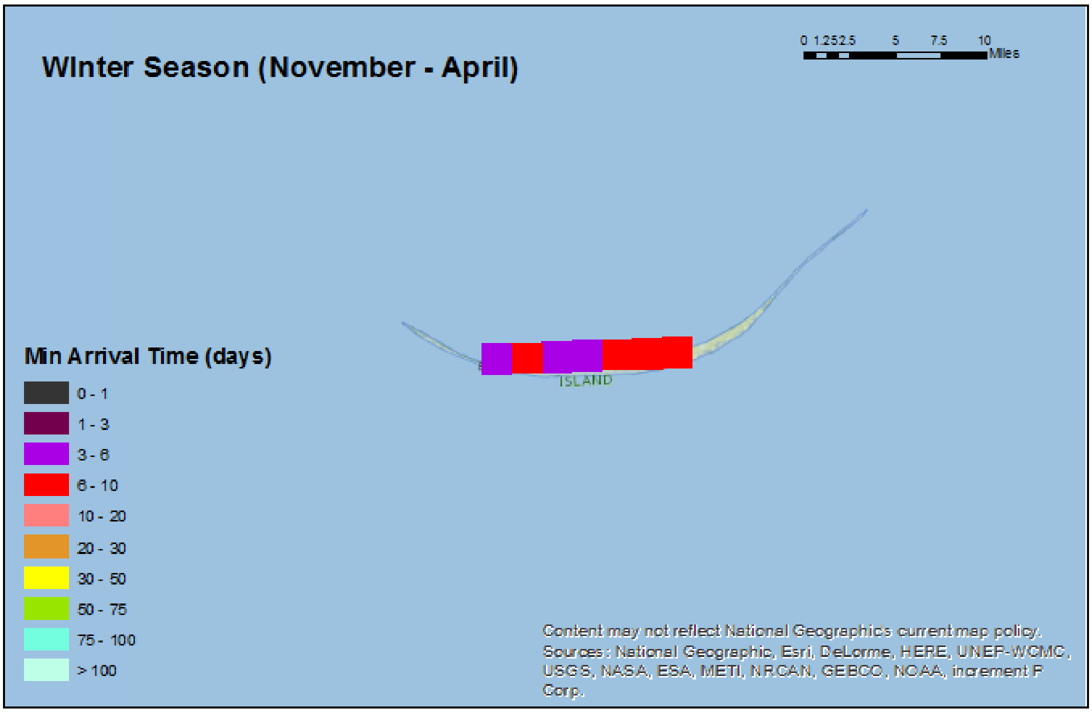


Figure A4.9 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the minimum arrival time of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)



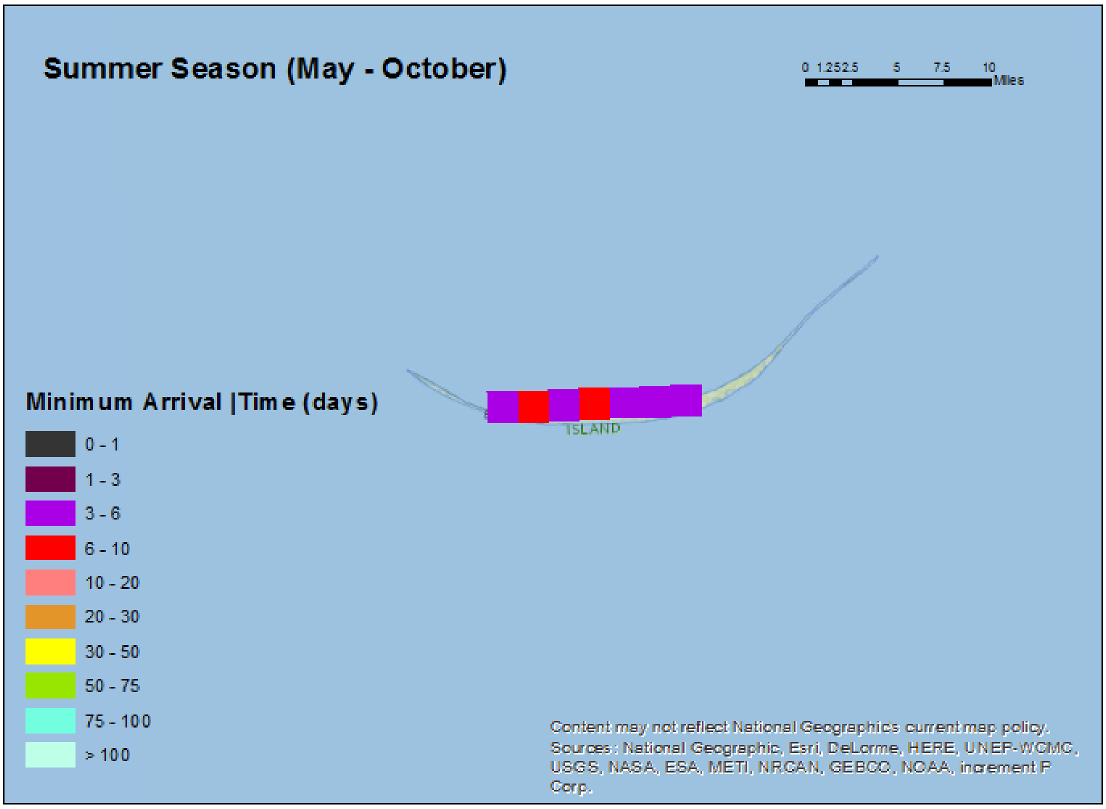
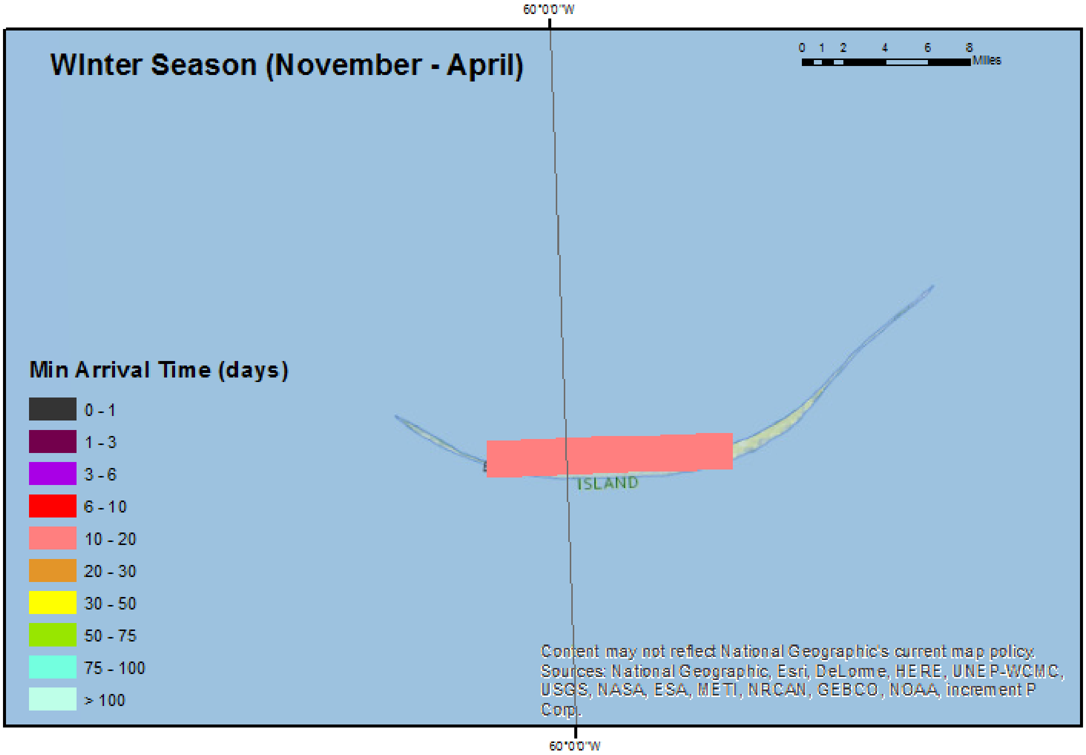


Figure A4.10 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the minimum arrival time of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m^2)



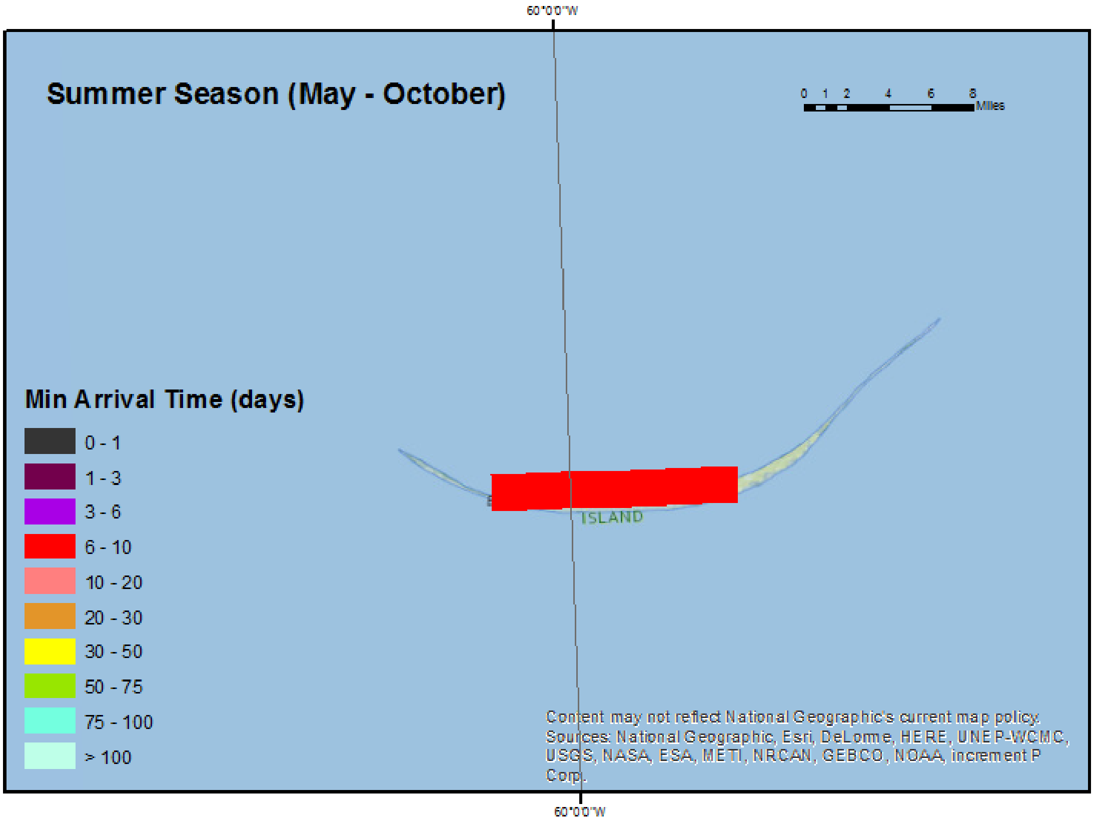
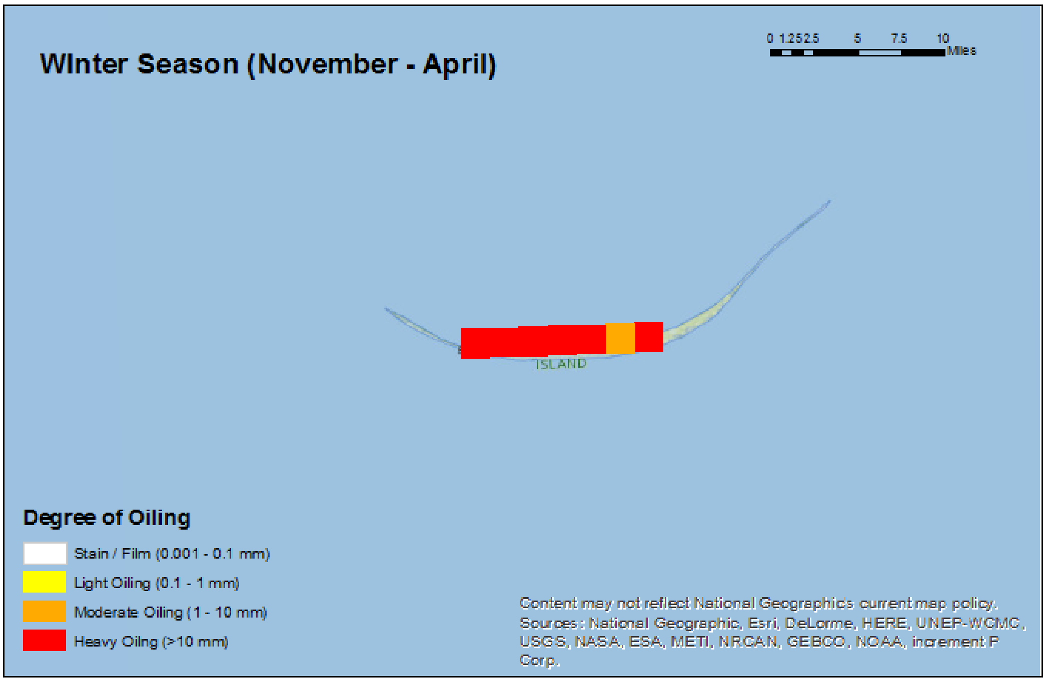


Figure A4.11 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the maximum accumulated emulsion thickness on the shoreline in accumulated amounts that exceed the minimum thickness threshold of 1 micron (1 g/m²). (Degree of oiling categorised according to the International Tank Owners Pollution Federation (ITPOF) guidelines for the recognition of oil on shorelines [(19)])



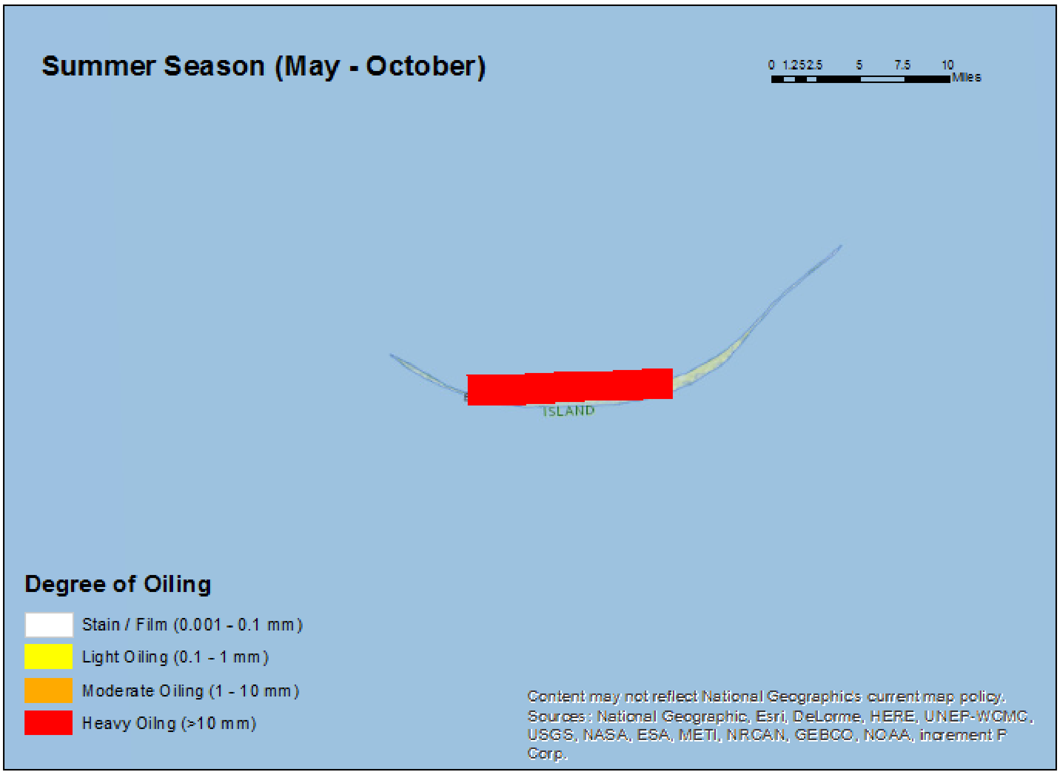
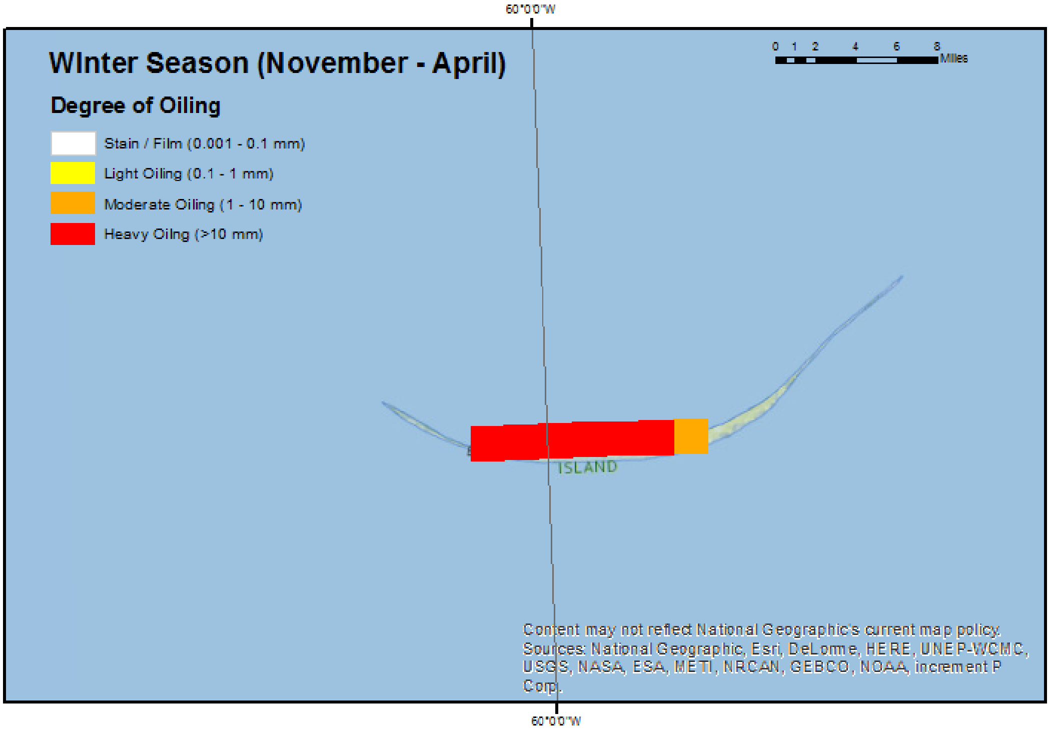
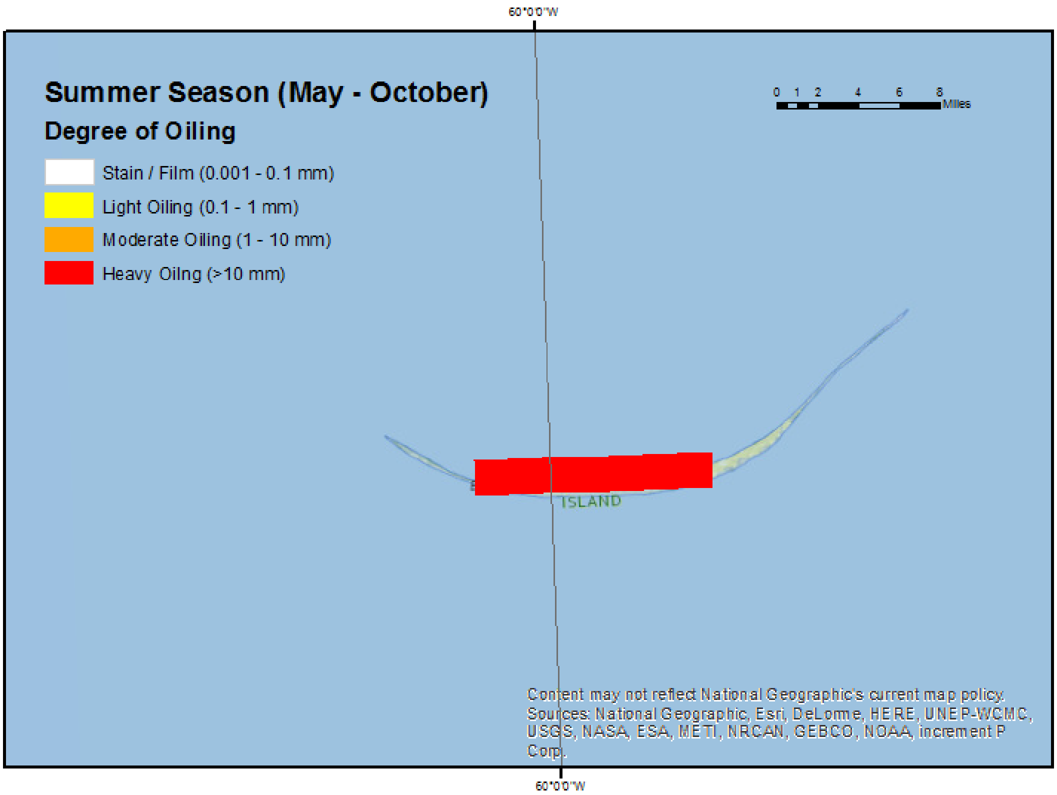


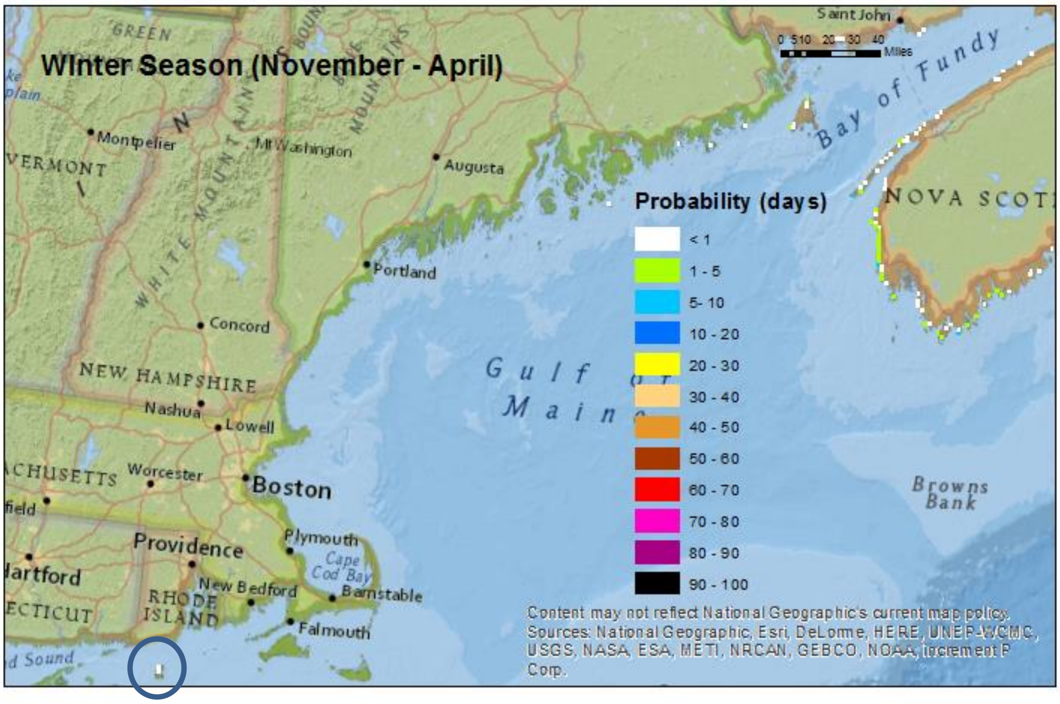
Figure A4.12 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the maximum accumulated emulsion thickness on the shoreline in accumulated amounts that exceed the minimum thickness threshold of 1 micron (1 g/m^2). (Degree of oiling categorised according to the International Tank Owners Pollution Federation (ITPOF) guidelines for the recognition of oil on shorelines [(19)])





USA Coastline

Figure A4.13 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the probability of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)



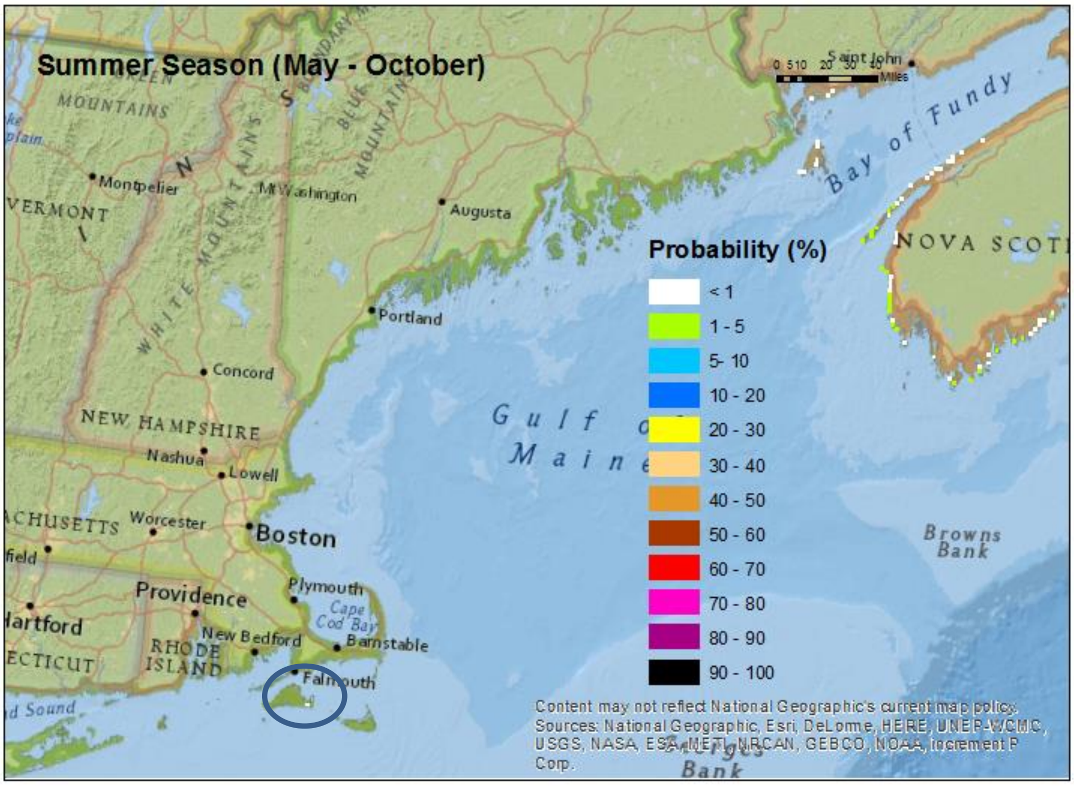
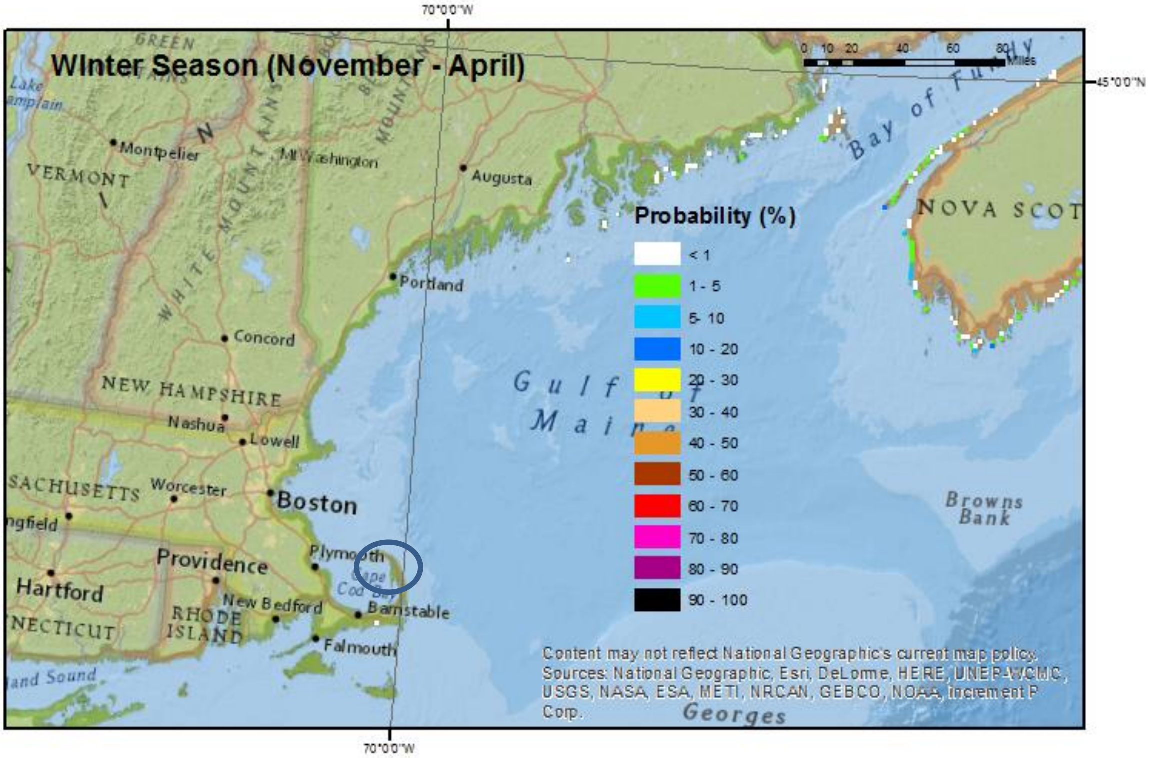


Figure A4.14 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the probability of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)



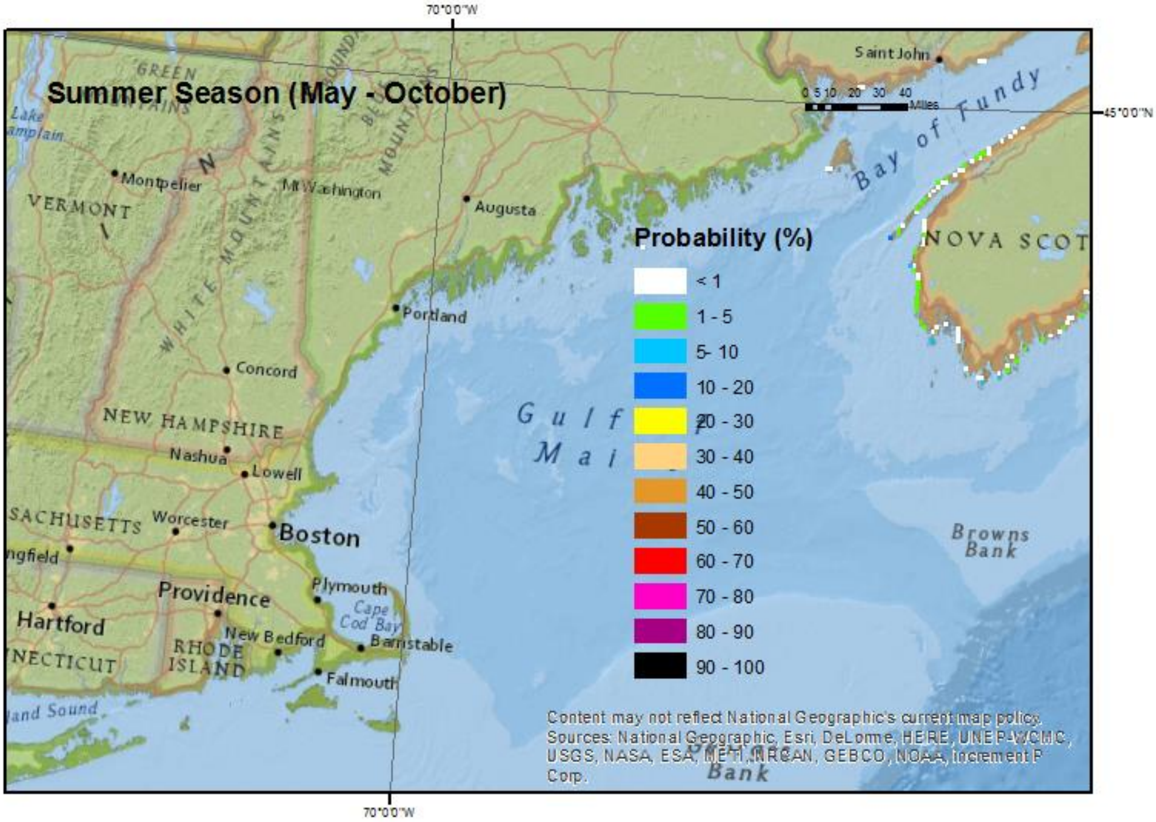
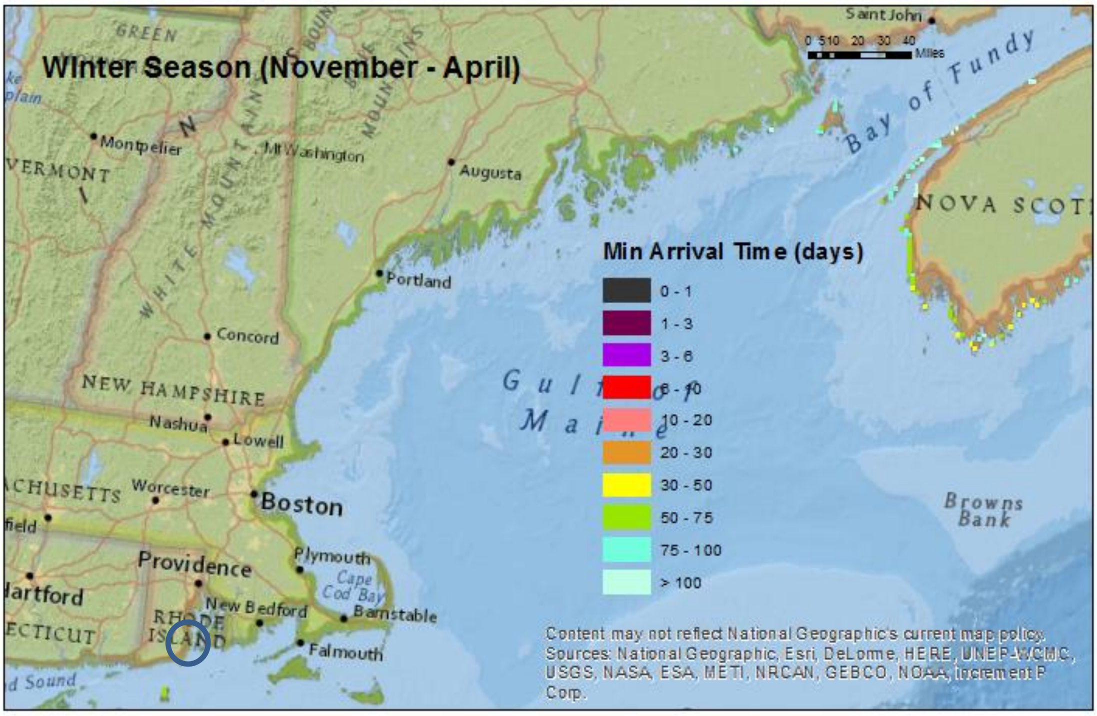


Figure A4.15 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the minimum arrival time of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m^2)



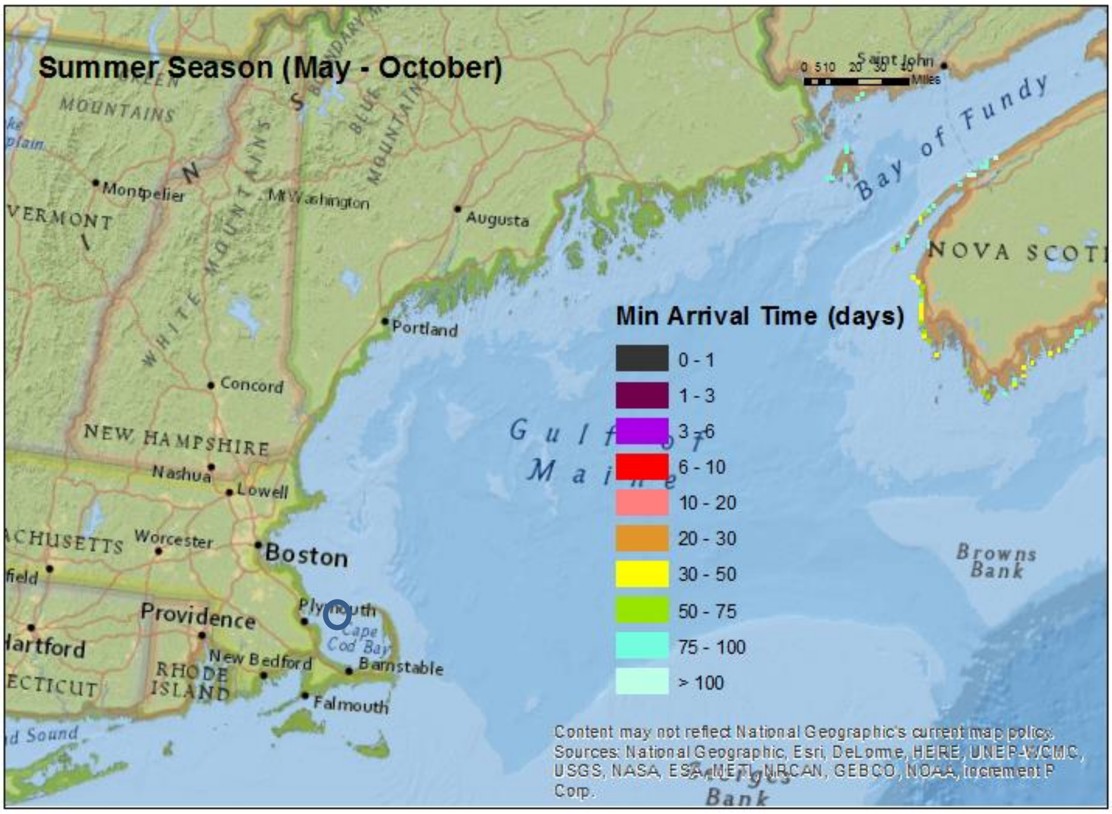
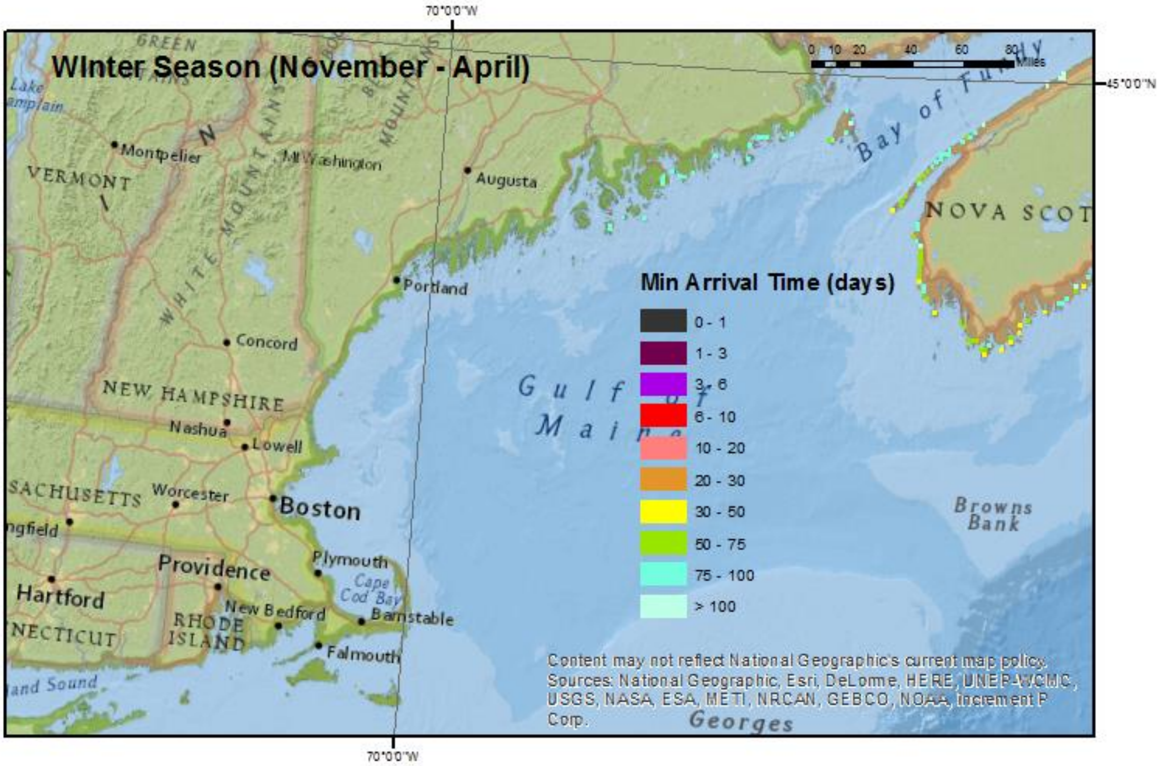


Figure A4.16 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the minimum arrival time of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m^2)



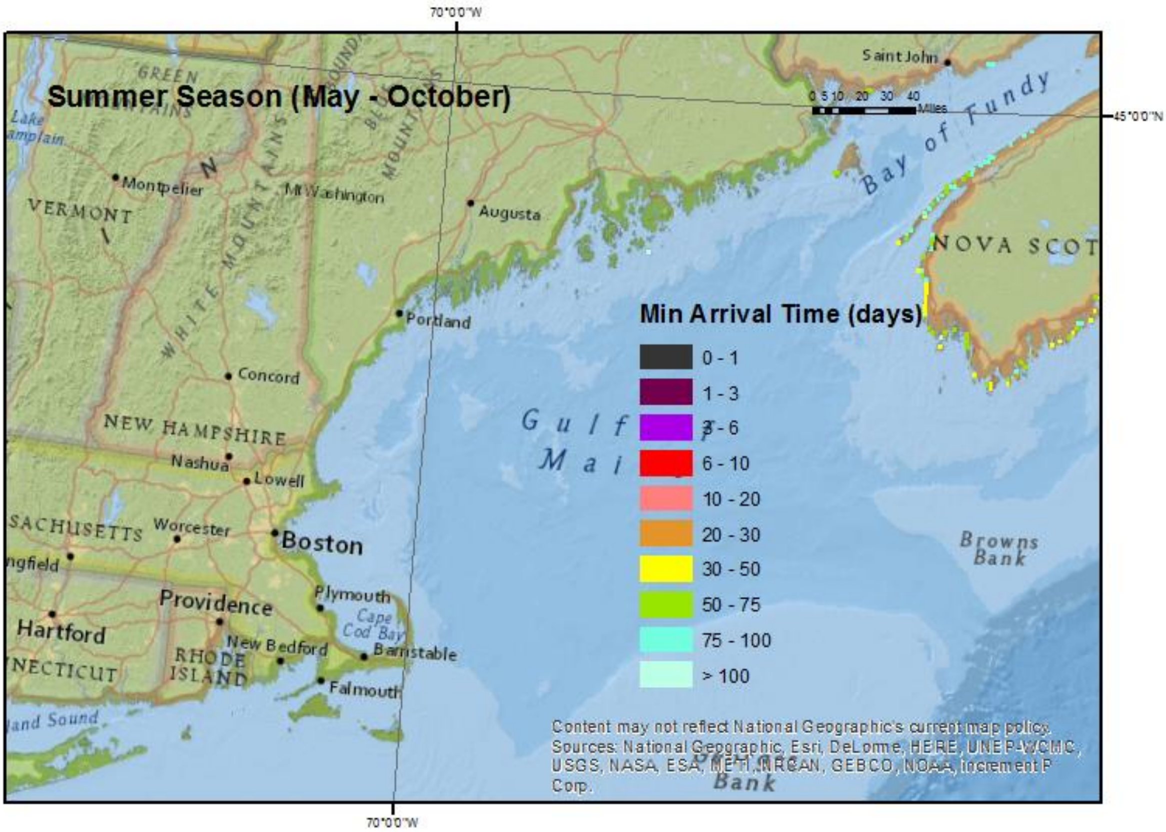
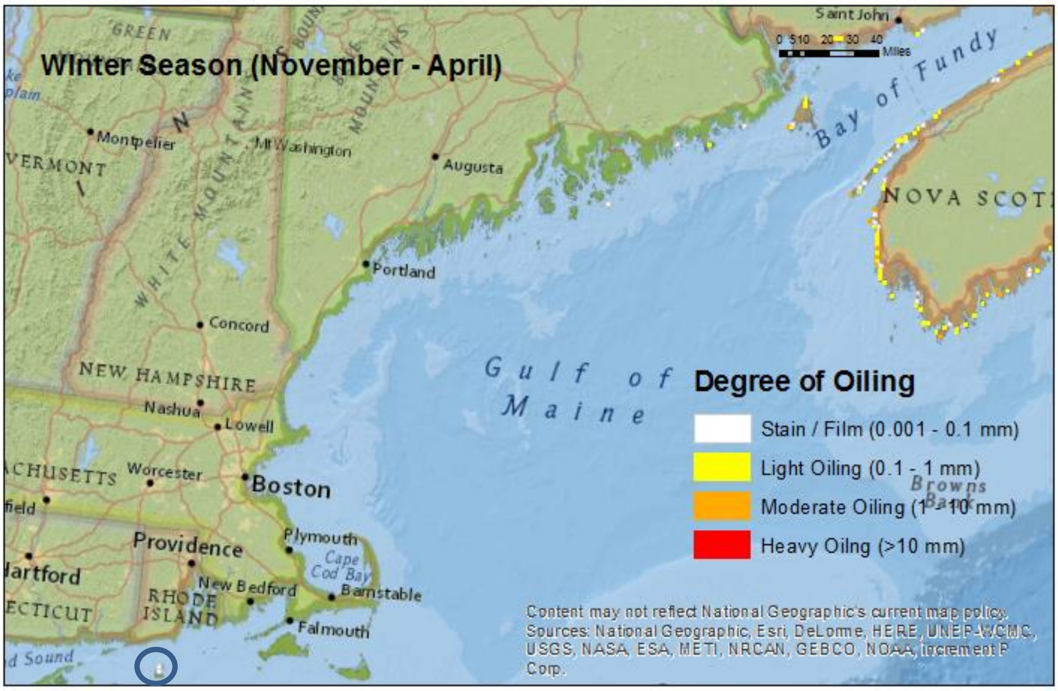


Figure A4.17 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the maximum accumulated emulsion thickness on the shoreline in accumulated amounts that exceed the minimum thickness threshold of 1 micron (1 g/m²). (Degree of oiling categorised according to the International Tank Owners Pollution Federation (ITPOF) guidelines for the recognition of oil on shorelines [(19)])



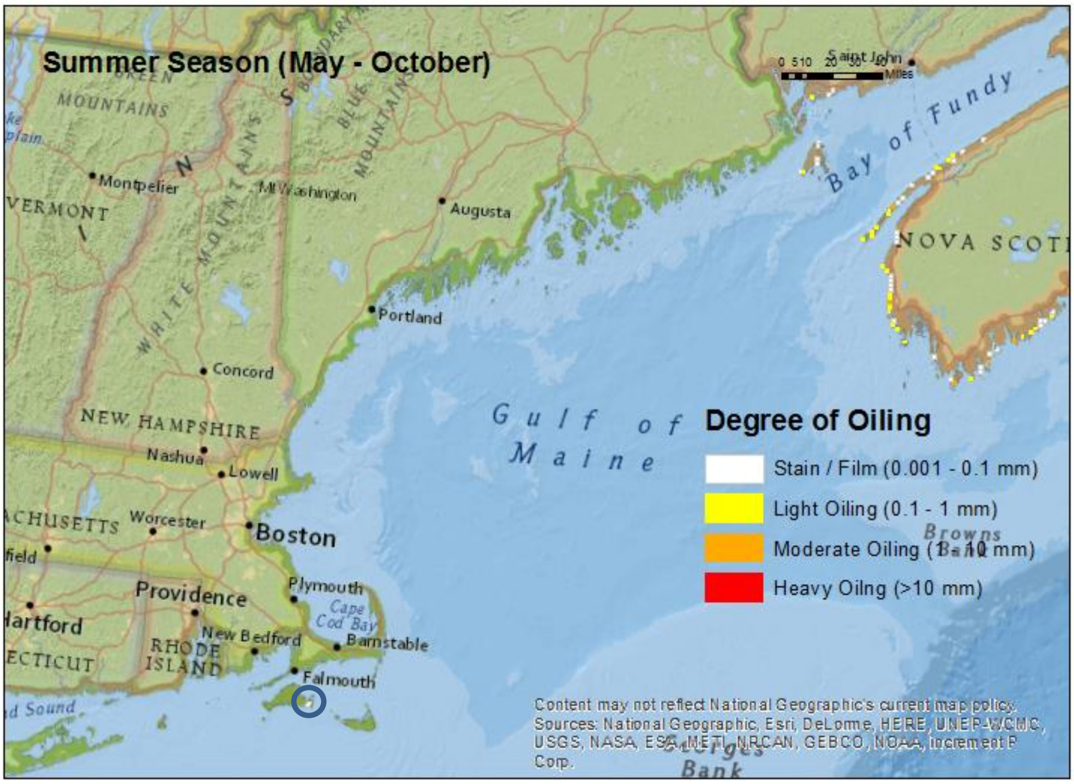
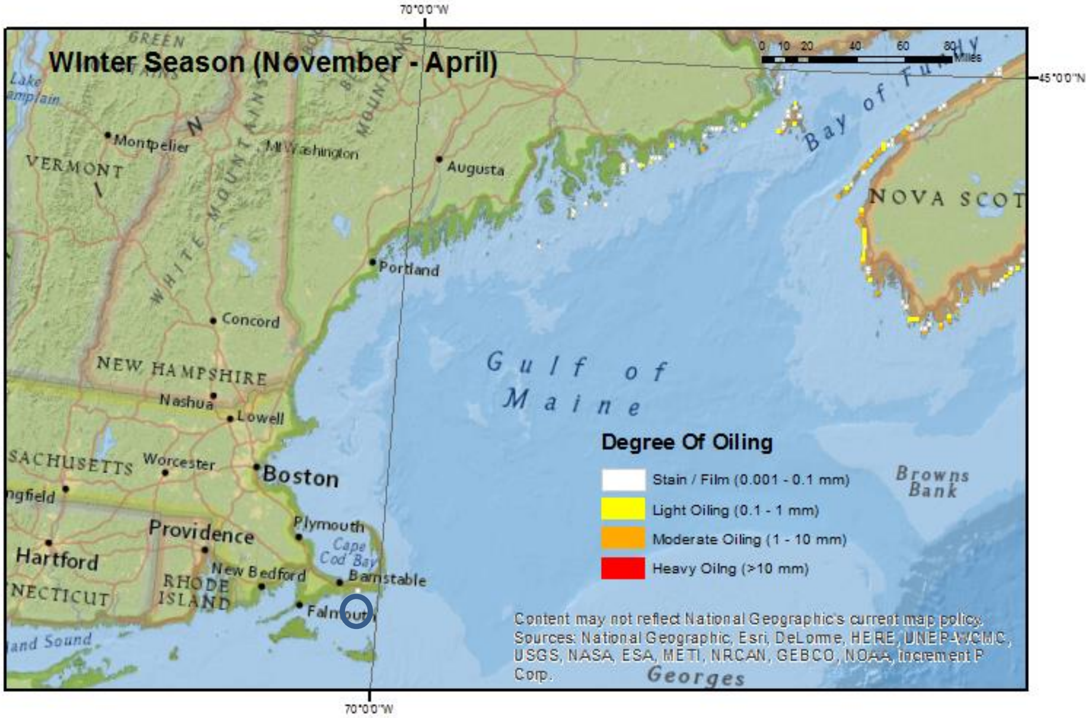
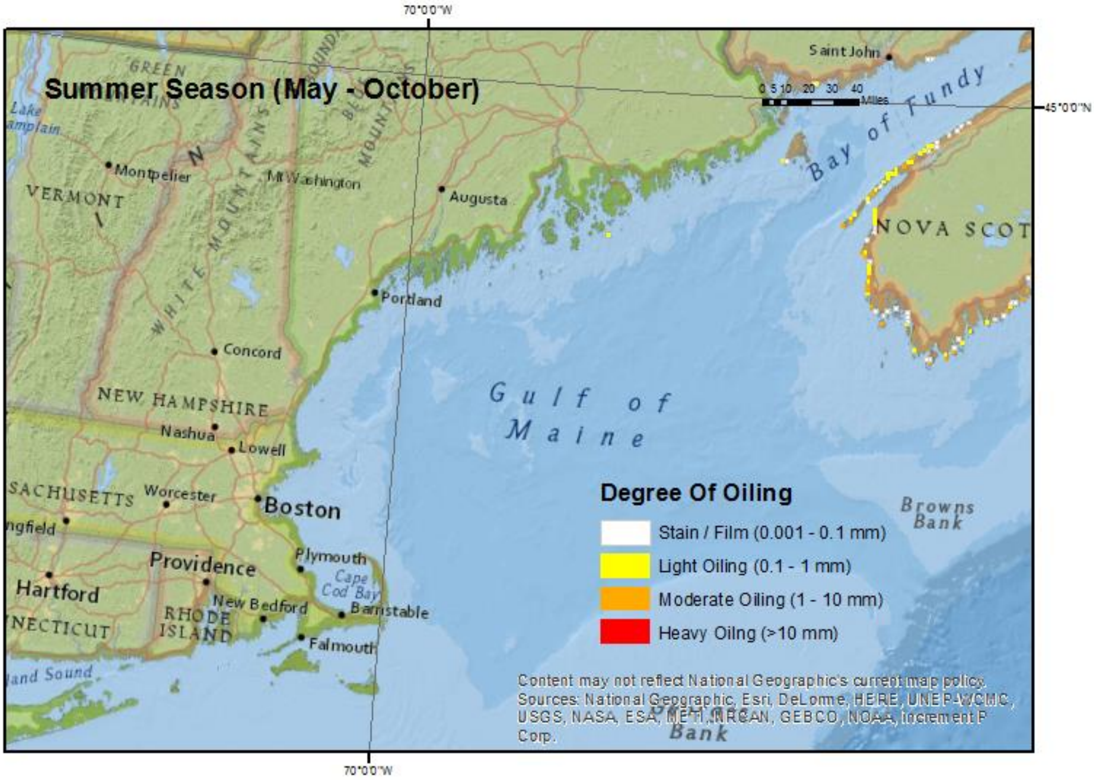


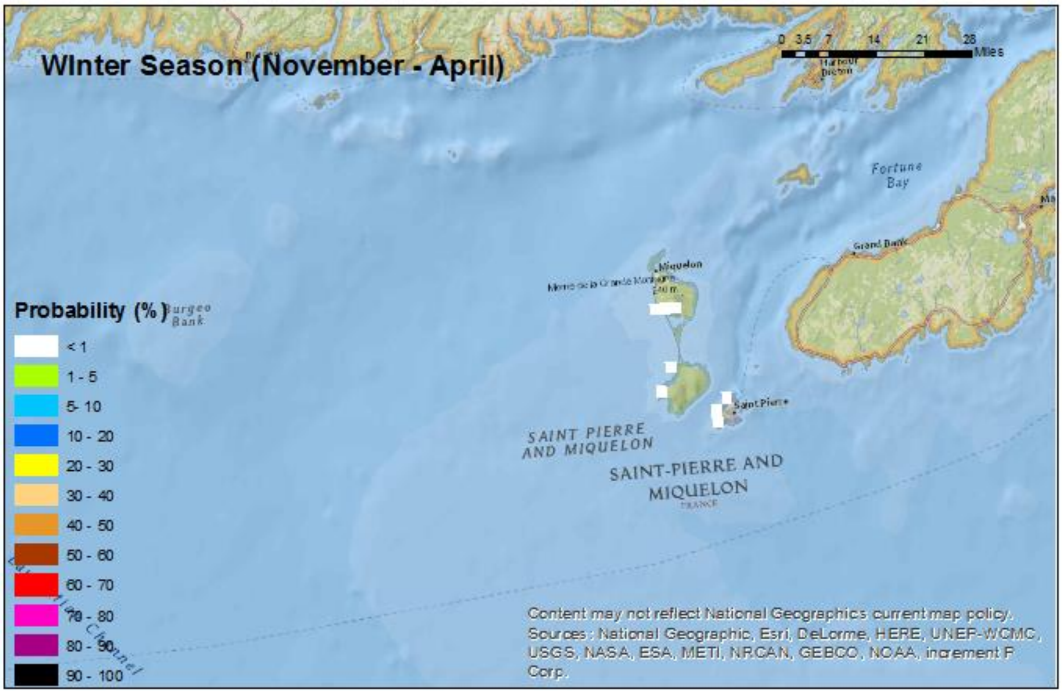
Figure A4.18 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the maximum accumulated emulsion thickness on the shoreline in accumulated amounts that exceed the minimum thickness threshold of 1 micron (1 g/m²). (Degree of oiling categorised according to the International Tank Owners Pollution Federation (ITPOF) guidelines for the recognition of oil on shorelines [(19)])





St Pierre and Miquelon and Grand Bank / Fortune Bay

Figure A4.19 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the probability of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)



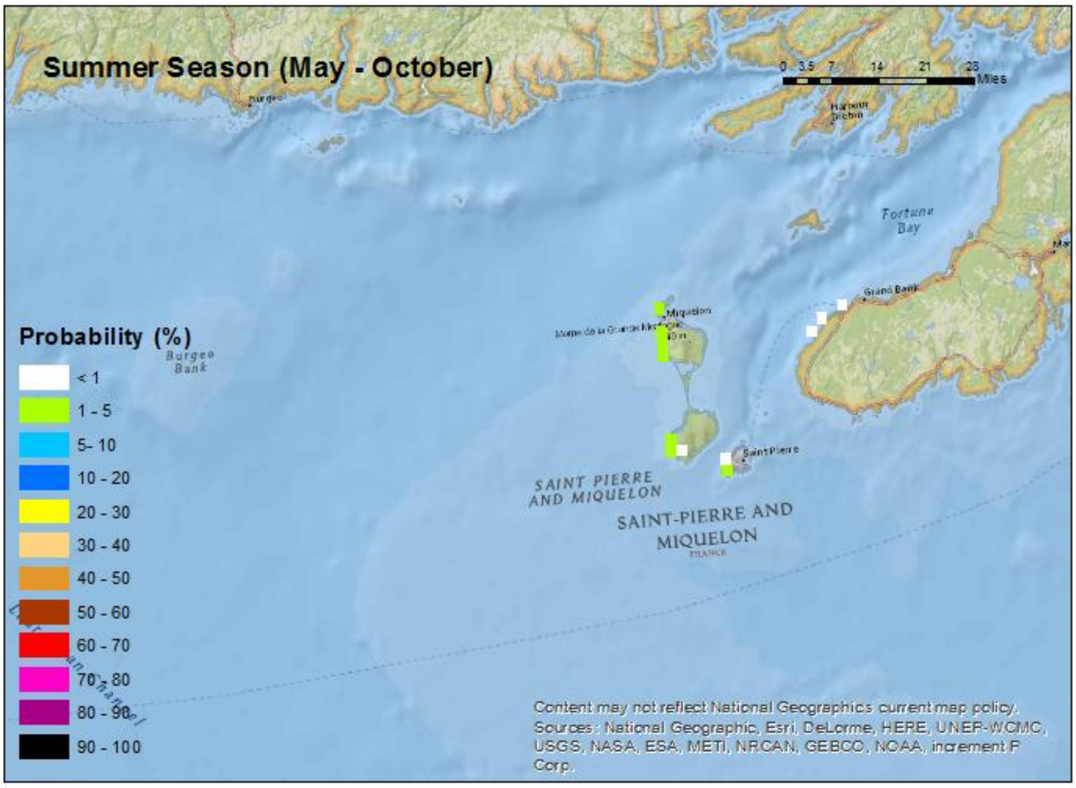
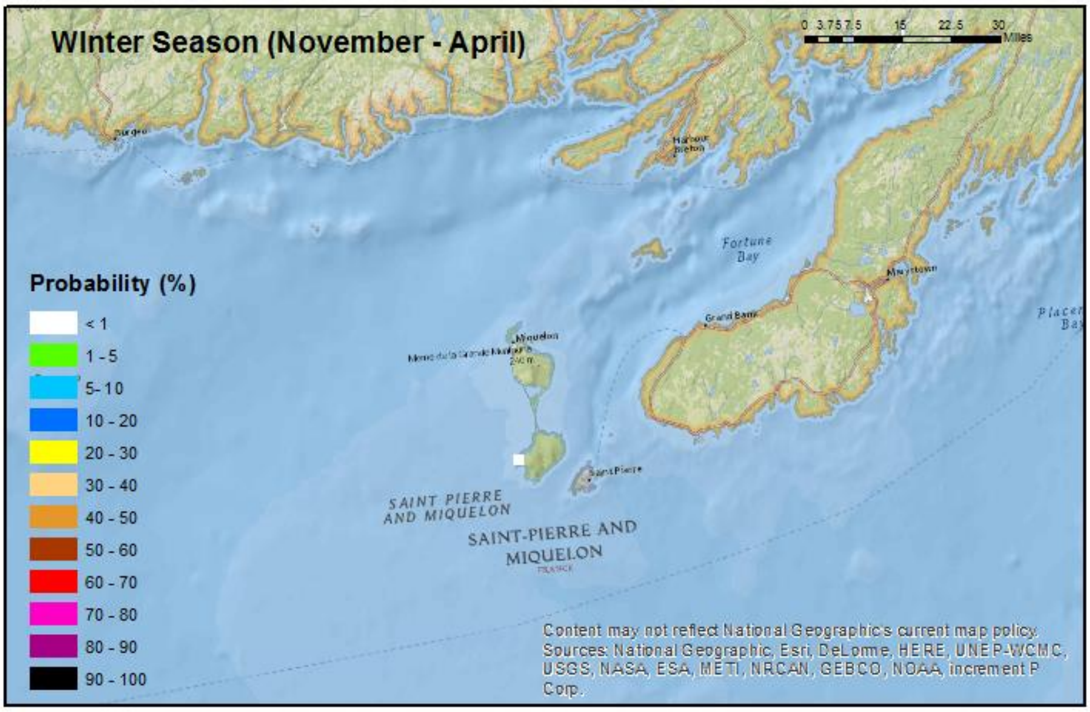


Figure A4.20 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the probability of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m^2)



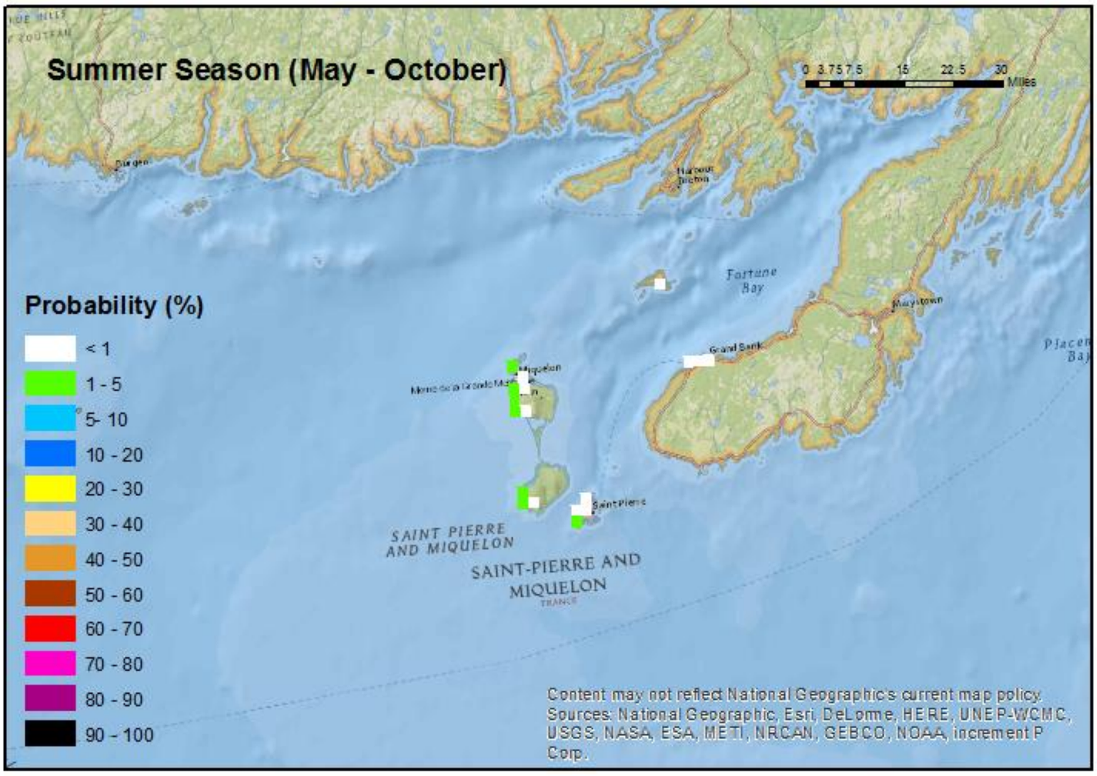
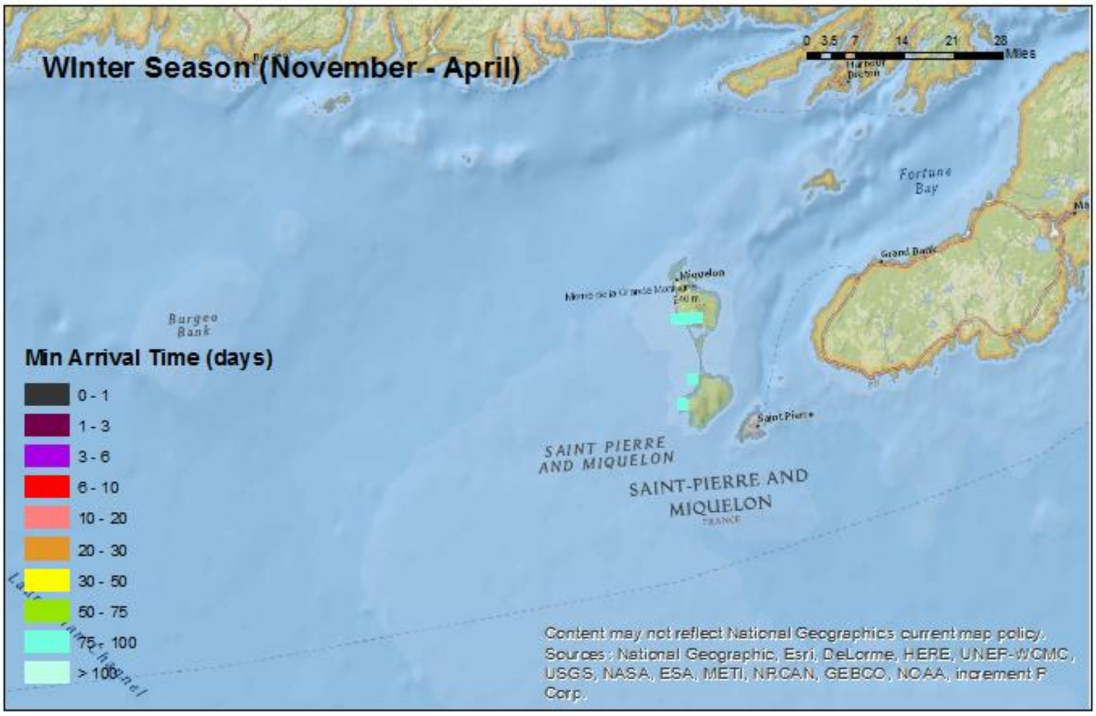


Figure A4.21 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the minimum arrival time of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m²)



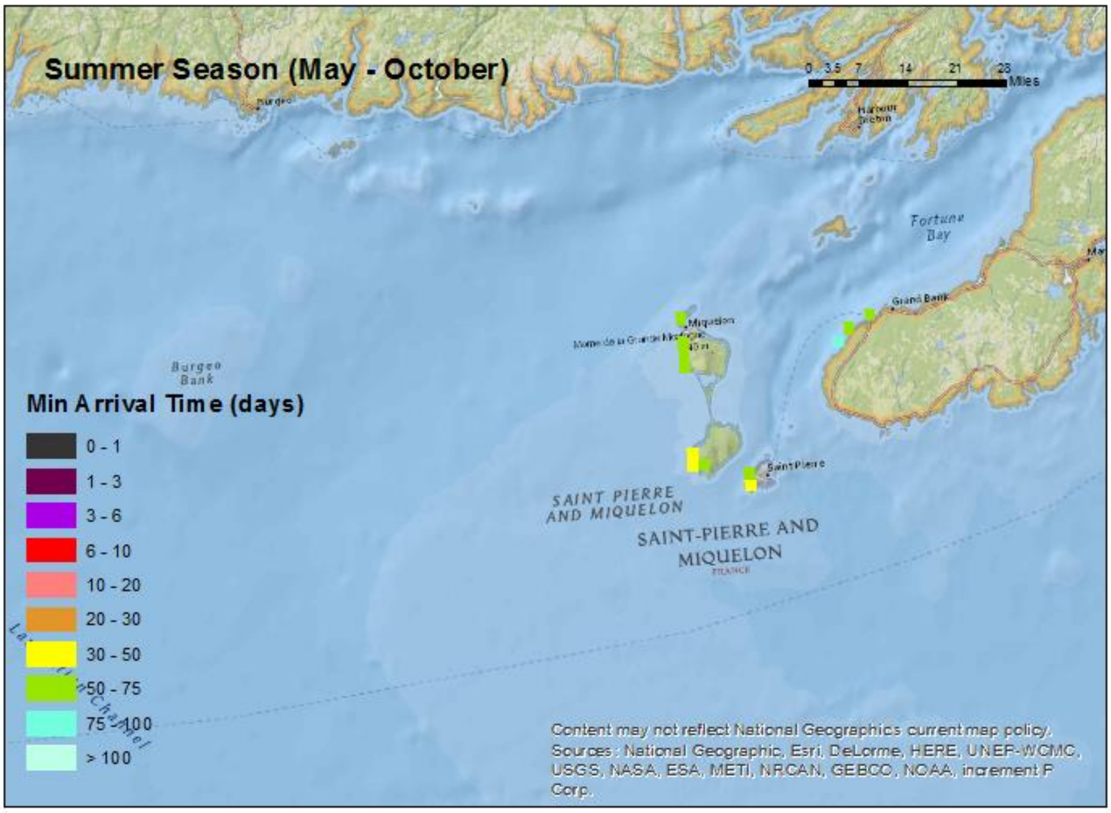
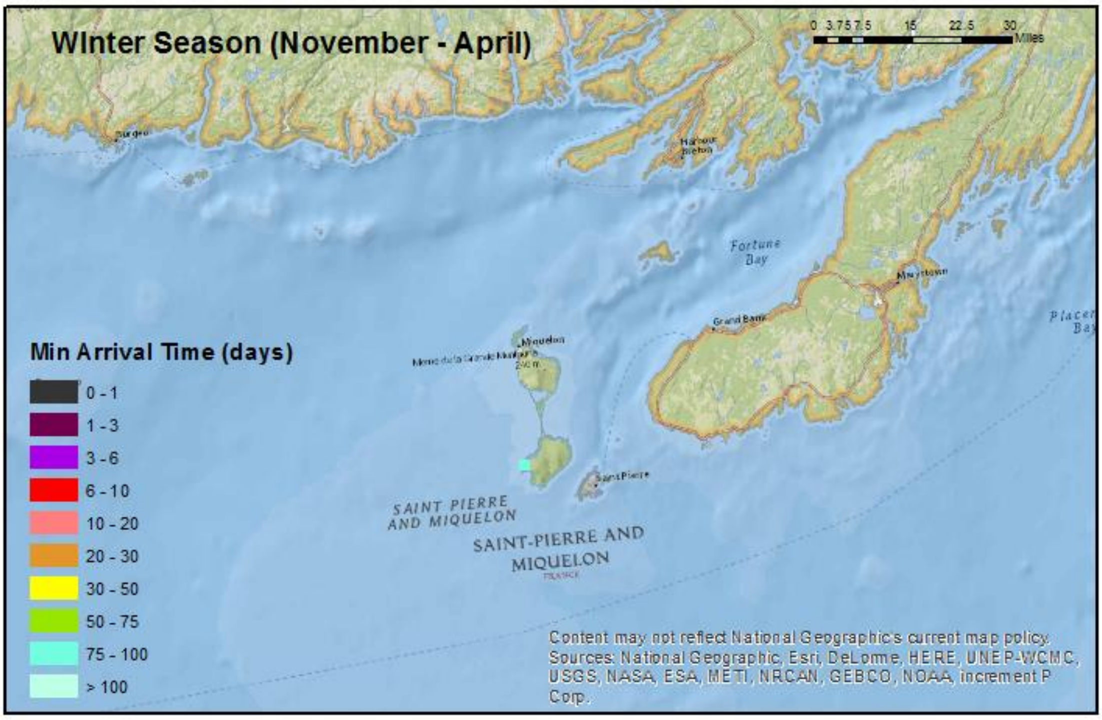


Figure A4.22 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the minimum arrival time of oil being stranded on the shoreline in accumulated amounts that exceed the minimum film or sheen thickness threshold of 1 micron (1 g/m^2)



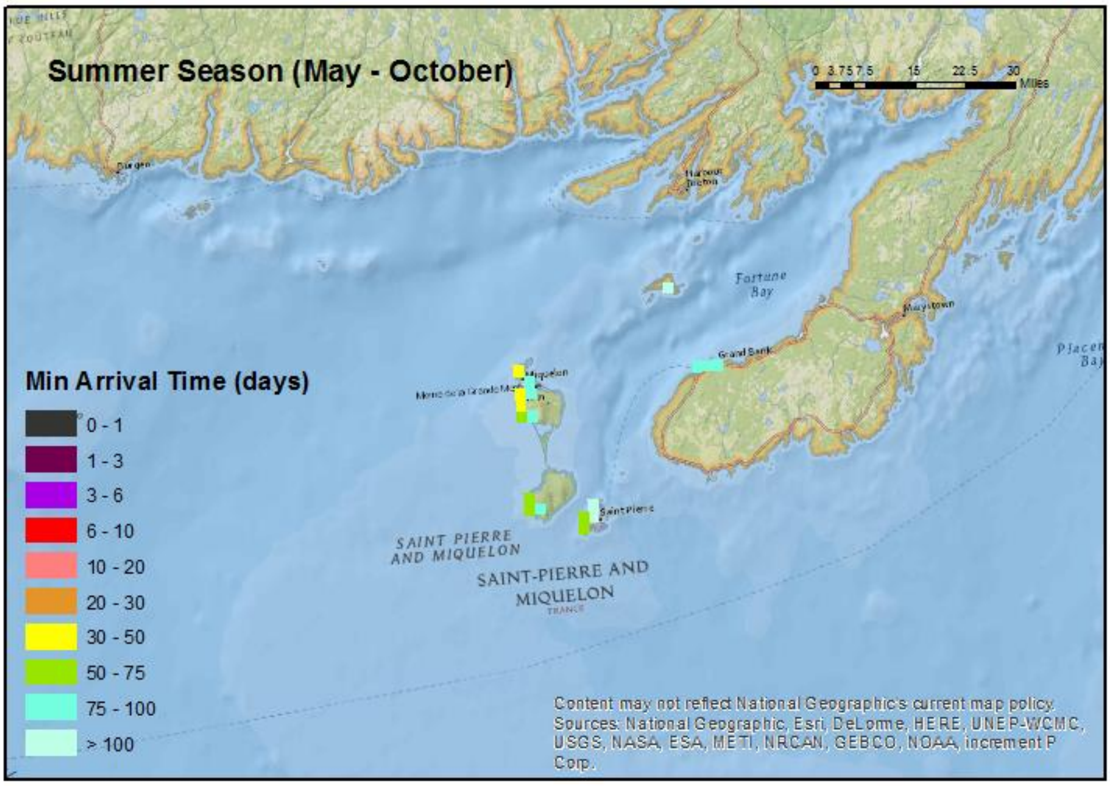
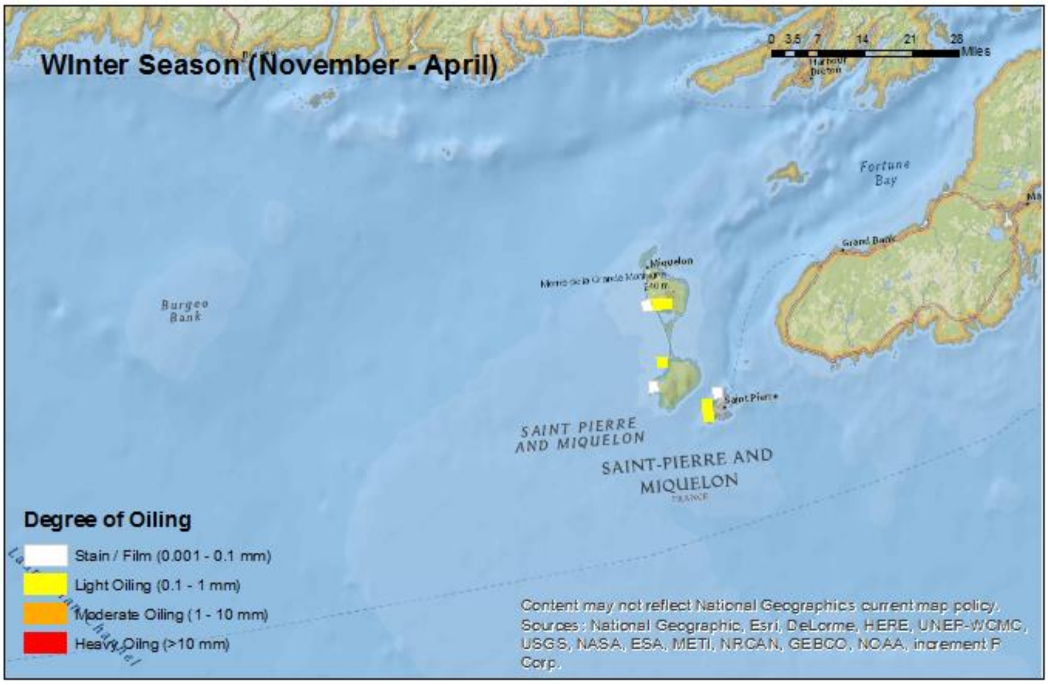


Figure A4.23 Case 1A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the maximum accumulated emulsion thickness on the shoreline in accumulated amounts that exceed the minimum thickness threshold of 1 micron (1 g/m^2). (Degree of oiling categorised according to the International Tank Owners Pollution Federation (ITPOF) guidelines for the recognition of oil on shorelines [(19)])



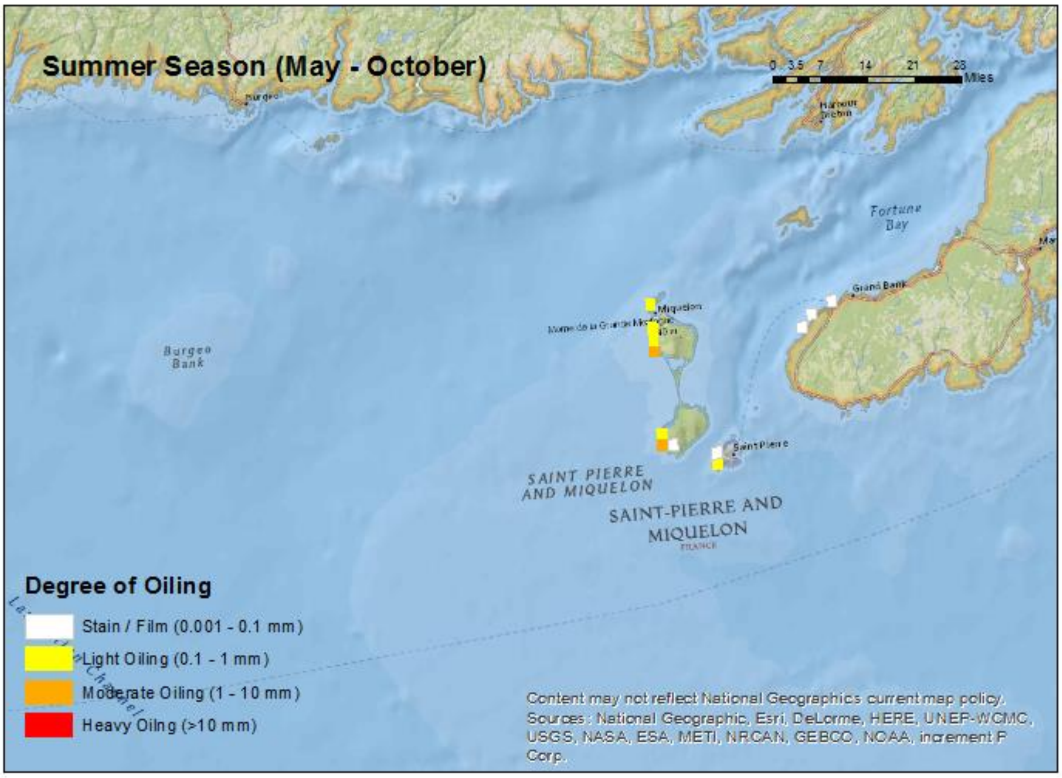
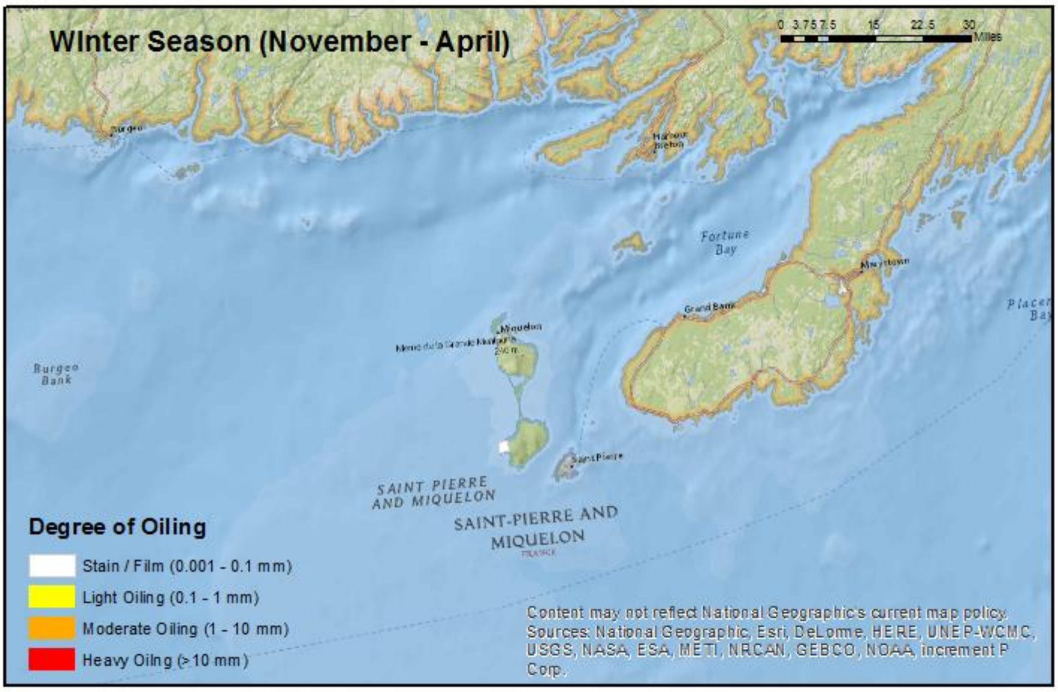
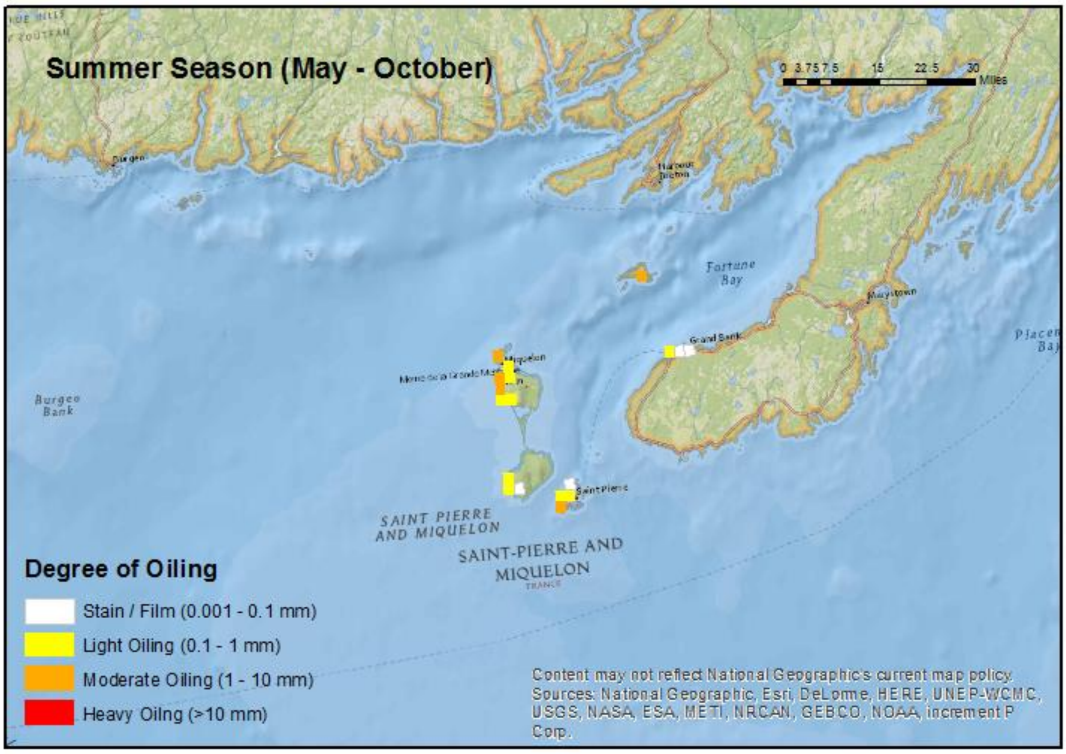


Figure A4.24 Case 2A: Well NS-1 capping stack containment scenario (30 day duration), Statistical maps showing the maximum accumulated emulsion thickness on the shoreline in accumulated amounts that exceed the minimum thickness threshold of 1 micron (1 g/m^2). (Degree of oiling categorised according to the International Tank Owners Pollution Federation (ITPOF) guidelines for the recognition of oil on shorelines [(19)])





Appendix 5 GIS analysis of potential subsea blowout oil spill intersections with Protected Area, Ecologically and Biologically Sensitive Areas and World Maritime Boundaries

The following tables provide a ranking of the Protected Areas, EBSAs and WMBs most likely to be impacted by either stranded oil, oil on the sea surface, or oil in the upper water column resulting from the NS-1 subsea blowout release scenarios.

The tables provide a quantitative breakdown of oil intersections with PAs, EBSAs and WMBs in terms of:

- The area of intersection (km^2);
- The average, maximum and minimum probabilities of oil contact within each intersection;
- The average, maximum and minimum arrival/travel time for oil contact with each intersection;
- The average, maximum and minimum exposure time of oil contact with each intersection;
- The average, maximum and minimum degree of oiling (emulsion oil thickness / THC / dissolved oil concentration) with each intersection

A5.1 Well: NS-1 Case 1A – (Winter Season)

Stranded oil

Table A5.1

Stranded Oil Intersections with Protected Areas

Name	Designation	Country	IUCN Category	Sum of Intersect Area (Sq km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average Degree of oiling	Max Degree of oiling	Min Degree of oiling
Block Island	National Wildlife Refuge	USA	IV	0.66	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Bonnell Beach	Private Conservation Land	USA	V	0.03	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Bonnett Lake Barrens	Wilderness Area	CAN	Ib	7.11	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Canso Coastal Barrens	Wilderness Area	CAN	Ib	6.66	0.6	1.0	0.5	50	51	49	Moderate	Heavy	Moderate
Cape Cod South	Closure Area	USA	V	11.65	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Cape St. Mary's Ecological Reserve	Ecological Reserve	CAN	VI	2.37	0.5	0.5	0.5	94	94	94	Stain/Film	Stain/Film	Stain/Film
Champlin Farm Block Island	Conservation Preserve	USA	Ia	0.00	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Charleston	Private Conservation Land	USA	V	0.01	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Conant	Private Conservation Land	USA	III	0.02	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Cross Island	National Wildlife Refuge	USA	IV	2.45	0.5	0.5	0.5	104	104	104	Stain/Film	Stain/Film	Stain/Film
Cross Island Archipelago	National Wildlife Refuge	USA	IV	2.36	0.5	0.5	0.5	104	104	104	Stain/Film	Stain/Film	Stain/Film
Duncans Cove	Nature Reserve	CAN	Ia	0.24	1.0	1.0	1.0	54	54	54	Light	Light	Stain/Film
Isthme de Miquelon-langlade	Terrain acquis par le Conservatoire du Littoral	FRA	IV	0.15	0.5	0.5	0.5	98	98	98	Light	Light	Light
Kejimkujik National Park and National Historic site of Canada (Seaside Adjunct)	National Park of Canada	CAN	II	2.75	0.5	0.5	0.5	98	98	98	Light	Light	Light
Little Hardwood Island	Preserve	USA	Ia	0.02	1.0	1.0	1.0	80	80	80	Light	Light	Light
McCluskey	Private Conservation Land	USA	V	0.02	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Murphy	Private Conservation Land	USA	V	0.01	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Nevas-Gree	Conservation Preserve	USA	V	0.01	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
New River Beach Provincial Park	Provincial Park	CAN	II	1.85	0.5	0.5	0.5	118	118	118	Light	Light	Light
North End Block Island	Conservation Preserve /National Wildlife Refuge	USA	Ia, V, IV	0.14	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Northeast	Closure Area	USA	V	18.02	0.6	1.0	0.5	101	114	80	Light	Light	Stain/Film
Northern Inshore State Trap/Pot Waters Area	Marine Protected Area	USA	V	30.74	0.5	1.0	0.5	84	114	53	Stain/Film	Light	Stain/Film
Northern Nearshore Trap/Pot Waters Area	Marine Protected Area	USA	V	30.74	0.5	1.0	0.5	85	114	53	Light	Light	Stain/Film
Other Northeast	Gillnet Waters Area	USA	V	26.12	0.6	1.0	0.5	82	114	53	Light	Light	Stain/Film
Pinney	Private Conservation Land	USA	V	0.02	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Rookery	Private Conservation Land	USA	V	0.00	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Sable Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	Ia	15.86	19.3	23.0	16.3	6	6	6	Heavy	Heavy	Moderate
Sable Island National Park Reserve of Canada	National Park Reserve of Canada	CAN	II	15.41	19.3	23.0	16.3	6	6	6	Heavy	Heavy	Moderate
Southwest Block Island	Conservation Preserve	USA	Ia	0.09	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Southwest Block Island Macrosite	Private Conservation Land	USA	V	0.05	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
Terence Bay	Wilderness Area	CAN	Ib	2.11	0.5	0.5	0.5	93	93	93	Stain/Film	Stain/Film	Stain/Film
Town of Block Island	Conservation Preserve	USA	Ia	0.01	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film
West Beach	Conservation Preserve	USA	V	0.04	0.5	0.5	0.5	53	53	53	Stain/Film	Stain/Film	Stain/Film

* Probability of stranded oil emulsion mass exceeding the 0.0019 tonnes/km (or 0.001 litres / m2 = 1 micron), minimum threshold for "Stain / Film" oiling.

Surface Oil

Table A5.2

Surface Oiling Intersects with Protected Areas

Name	Designation	Country	IUCN	Sum of Intersect Area (Sq km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Gully Marine Protected Area	Marine Protected Area	CAN	Not Reported	2,371.28	30.4	52.6	6.7	14	34	4	5	11	2	DTOC	CTOC	Sheen	Metallic	DTOC	Sheen
Lydonia Canyon	Closed Area	USA	V	169.83	16.4	19.1	13.4	34	45	29	3	4	2	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Oceanographer Canyon	Closed Area	USA	V	258.69	9.9	14.4	6.7	43	50	37	2	3	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Other Northeast	Gillnet Waters Area	USA	V	148,634.60	5.0	40.7	0.5	65	120	20	2	8	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Sable Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	Ia	15.18	4.9	10.0	1.9	20	50	6	1	3	1	CTOC	CTOC	Sheen	Metallic	DTOC	Sheen
Offshore Trap/Pot Waters	Marine Protected Area	USA	V	157,584.94	4.8	40.7	0.5	67	120	20	2	8	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Sable Island National Park Reserve of Canada	National Park Reserve of Canada	CAN	II	14.45	4.7	10.0	1.9	21	50	6	1	3	1	CTOC	CTOC	Sheen	Metallic	DTOC	Sheen
SAM East	Marine Protected Area	USA	V	5,072.12	0.9	2.9	0.5	89	119	41	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Northeast	Closure Area	USA	V	616.63	0.9	2.4	0.5	98	120	69	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Offshore	Closure Area	USA	V	2,742.02	0.6	2.4	0.5	99	119	56	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Waters off New Jersey	Closure	USA	V	2,103.52	0.6	1.9	0.5	97	120	62	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Northern Nearshore Trap/Pot Waters Area	Marine Protected Area	USA	V	4,161.74	0.6	2.4	0.5	92	120	41	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Mid-Atlantic Coastal Waters	Marine Protected Area	USA	V	12,281.95	0.5	1.9	0.5	101	120	62	1	3	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Great South Channel	Restricted Gillnet Area	USA	V	629.85	0.5	1.0	0.5	98	119	85	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Cape Cod South	Closure Area	USA	V	565.47	0.5	1.0	0.5	92	120	51	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Southern Mid-Atlantic Waters	Closure Area	USA	V	10,086.76	0.5	1.4	0.5	102	120	70	1	3	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Great South Channel Restricted Trap/Pot Area	Marine Protected Area	USA	V	642.11	0.5	1.0	0.5	98	119	85	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Southern Nearshore Trap/Pot Waters	Marine Protected Area	USA	V	1,950.17	0.5	1.4	0.5	109	120	86	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Northern Inshore State Trap/Pot Waters Area	Marine Protected Area	USA	V	138.04	0.5	1.0	0.5	79	115	51	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Great South Channel Sliver	Restricted Gillnet Area	USA	V	12.15	0.5	0.5	0.5	95	95	95	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Canso Coastal Barrens	Wilderness Area	CAN	Ib	0.08	0.5	0.5	0.5	49	49	49	1	1	1	CTOC	CTOC	CTOC	CTOC	CTOC	CTOC
Cashes Ledge	Closure Area	USA	V	46.19	0.5	0.5	0.5	105	105	104	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Duncans Cove	Nature Reserve	CAN	Ia	0.05	0.5	0.5	0.5	54	54	54	1	1	1	Rainbow	Rainbow	Rainbow	Rainbow	Rainbow	Rainbow
Mid-Coast	Closure Area	USA	V	9.09	0.5	0.5	0.5	102	107	97	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Salkeld Islands	Protected Natural Area	CAN	Ib	0.10	0.5	0.5	0.5	118	118	118	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
SAM West	Marine Protected Area	USA	V	9.60	0.5	0.5	0.5	94	94	94	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 μm (BAOAC "Sheen") thickness threshold

Table A5.3

Surface Oiling Intersects with EBSAs

Name	Sum of Intersect Area (Sq km)	% Surface EBSA Area contacted by emulsified oil > 0.04 micron thickness	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Scotian Slope	72,678	100%	70.1	100.0	1.4	11	64	1	9	19	1	DTOC	CTOC	Sheen	Rainbow	DTOC	Sheen
Haddock Box	12,797	100%	53.15	84.69	21.05	9	21	4	9	18	3	Metallic	CTOC	Rainbow	Rainbow	Metallic	Sheen
Emerald Western Sable Banks Complex	17,929	100%	48.9	87.6	3.8	8	29	2	8	18	2	DTOC	CTOC	Rainbow	Rainbow	Metallic	Sheen
Northeast Channel	2,592	100%	47.2	59.3	25.8	21	28	15	6	12	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Northeast Channel Coral Conservation Area - NEC restricted bottom fishing zone	392	100%	46.79	55.50	39.71	21	25	15	5	10	4	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Northeast Channel Coral Conservation Area	425	100%	45.59	55.50	37.80	21	25	15	5	10	3	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Northeast Channel Coral Conservation Area - NEC limited bottom fishing zone	34	100%	41.03	44.98	37.80	22	23	22	4	5	3	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Emerald Basin and the Scotian Gulf	8,527	100%	33.0	77.0	3.3	16	46	6	6	13	1	Rainbow	CTOC	Sheen	Sheen	Rainbow	Sheen
Laurentian Channel Cold Seep	50	100%	27.6	30.1	25.8	25	25	25	4	5	3	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Browns Bank	4,313	100%	22.3	42.6	8.1	28	51	13	4	7	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Eastern Scotian Shelf Canyons	7,446	100%	22.2	63.6	1.4	21	64	3	4	14	1	DTOC	CTOC	Sheen	Rainbow	DTOC	Sheen
Sambro Bank Sponge Conservation Area	63	100%	20.62	27.75	18.18	14	20	14	6	9	5	Rainbow	Rainbow	Rainbow	Sheen	Sheen	Sheen
Bowtie	4,068	100%	16.90	26.79	5.74	28	42	14	4	7	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Roseway Basin	3,162	100%	16.7	25.8	3.3	29	50	13	4	7	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Canadian portion of Georges Bank	7,006	100%	12.5	42.6	0.5	39	91	18	2	7	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
Emerald Sponge Conservation Area	197	100%	10.09	13.88	4.31	26	46	18	4	7	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
NAFO Fishing Closure Area (4) Seamount Areas	14,185	87%	8.33	45.93	0.48	82	120	52	3	20	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Stone Fence and Laurentian Environs	45	100%	5.7	10.0	3.3	54	61	34	2	2	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Sable Island Shoals	1,246	96%	5.4	12.9	0.5	12	50	5	2	5	1	DTOC	CTOC	Sheen	Metallic	CTOC	Sheen
NAFO Fishing Closure Area (1) Sponge, Coral & Seapen Protected Areas	14,298	100%	4.67	12.44	0.48	61	117	24	2	5	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
NAFO Fishing Closure Area (5) Seamount Areas	241,297	87%	3.35	25.84	0.48	47	120	11	1	4	1	Sheen	DTOC	Sheen	Sheen	Metallic	Sheen
Middle Bank	2,753	100%	3.0	10.0	0.5	27	54	10	3	6	1	Metallic	CTOC	Sheen	Rainbow	DTOC	Sheen
Laurentian Channel slope	7,410	34%	2.7	10.5	0.5	70	120	34	1	4	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Eastern Shoal	3,155	93%	2.3	9.1	0.5	64	119	18	1	3	1	Rainbow	Metallic	Sheen	Sheen	Rainbow	Sheen
NAFO Fishing Closure Area (3) Seamount Areas	34,204	82%	1.21	4.31	0.48	87	120	52	1	3	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Jordan Basin and the Rock Garden	1,219	67%	1.2	4.3	0.5	78	116	40	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Canso Bank and Canso Basin	4,041	98%	1.0	2.4	0.5	48	69	14	2	6	1	Metallic	CTOC	Sheen	Metallic	CTOC	Sheen
Misaine Bank	4,148	90%	0.8	1.9	0.5	59	76	48	2	6	1	Rainbow	Rainbow	Sheen	Sheen	Rainbow	Sheen

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold

Table A5.4

Surface Oiling Intersects with World Maritime Boundaries

Name	Sum of Boundary Intersect Length (km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Canada - Atlantic Ocean	1,470	40.1	73.2	0.5	27	111	7	4	8	1	Rainbow	DTOC	Sheen	Sheen	Rainbow	Sheen
Canada - Saint-Pierre et Miquelon	543	14.2	50.2	0.5	49	118	14	3	9	1	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Canada - United States	431	9.3	40.7	0.5	61	118	20	2	6	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
United States - Atlantic Ocean	433	7.9	26.3	0.5	55	120	30	2	6	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Bermuda - Atlantic Ocean	305	0.8	2.4	0.5	92	120	57	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold

Oil in the Upper water column (<100 m water depth)

Table A5.5

Water Column Dispersed and Dissolved Oil Intersects with Protected Areas

Name	Designation	Country	IUCN	Sum of Intersect Area (Sq km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Gully Marine Protected Area	Marine Protected Area	CAN	Not Reported	1,454	0.72	7.18	0.48	27	88	5	1	4	1	88	587	58	0	2	0
Offshore Trap/Pot Waters	Marine Protected Area	USA	V	154	0.48	0.48	0.48	90	98	40	1	1	1	119	188	58	0	0	0
Other Northeast	Gillnet Waters Area	USA	V	154	0.48	0.48	0.48	90	98	40	1	1	1	120	188	58	0	0	0
Sable Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	Ia	1	0.48	0.48	0.48	8	8	8	1	1	1	189	189	189	0	0	0
Sable Island National Park Reserve of Canada	National Park Reserve of Canada	CAN	II	1	0.48	0.48	0.48	20	43	8	1	1	1	148	189	65	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold

Table A5.6

Water Column Dispersed and Dissolved Oil Intersects with EBSAs

Name	Sum of Intersect Area (Sq km)	% Surface EBSA Area contacted by THC > 58 ppb	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Scotian Slope	51,363	70.8%	31.64	100.00	0.48	10	89	1	7	32	1	320	1973	58	2	30	0
Emerald Western Sable Banks Complex	15,699	87.7%	9.33	44.98	0.48	14	59	2	3	12	1	201	906	58	1	20	0
Haddock Box	11,771	92.1%	7.54	36.36	0.48	16	59	3	3	12	1	183	844	58	1	9	0
Eastern Scotian Shelf Canyons	2,786	37.5%	1.44	20.10	0.48	26	88	4	1	5	1	103	587	58	0	4	0
Emerald Basin and the Scotian Gulf	4,186	49.2%	1.15	6.22	0.48	38	72	7	2	7	1	140	553	58	0	1	0
Lobster Fisheries Act Closure Area	91	1.4%	0.66	1.44	0.48	52	75	45	1	1	1	78	90	64	0	0	0
Sable Island Shoals	393	30.3%	0.63	1.44	0.48	22	45	6	1	3	1	96	370	58	0	1	0
Middle Bank	1,341	48.8%	0.52	0.96	0.48	43	52	9	1	3	1	95	424	58	0	1	0
Canso Bank and Canso Basin	841	20.4%	0.50	0.96	0.48	48	55	15	1	2	1	94	499	59	0	0	0
Northeast Channel	183	7.1%	0.48	0.96	0.48	67	77	39	1	1	1	75	145	60	0	0	0
NAFO Fishing Closure Area (5) Seamount Areas	709	0.3%	0.48	0.96	0.48	47	75	14	1	1	1	69	107	58	0	0	0
Georges Bank	194	1.3%	0.48	0.48	0.48	55	82	39	1	1	1	84	136	58	0	0	0
Bowtie	74	1.8%	0.48	0.48	0.48	29	42	27	1	1	1	91	95	70	0	0	0
Misaine Bank	32	0.7%	0.48	0.48	0.48	52	56	49	1	1	1	75	85	67	0	0	0
Roseway Basin	30	1.0%	0.48	0.48	0.48	42	42	42	1	1	1	70	70	70	0	0	0
Emerald Sponge Conservation Area	0.4	0.2%	0.48	0.48	0.48	42	42	42	1	1	1	79	79	79	0	0	0
North Atlantic Right Whale - Roseway Basin	11	0.3%	0.48	0.48	0.48	48	61	42	1	1	1	140	280	70	0	0	0
Northeast Channel Coral Conservation Area	8	1.8%	0.48	0.48	0.48	58	77	39	1	1	1	98	136	60	0	0	0
Northeast Channel Coral Conservation Area - NEC restricted bottom fishing zone	8	2.0%	0.48	0.48	0.48	58	77	39	1	1	1	98	136	60	0	0	0
NAFO Fishing Closure Area (4) Seamount Areas	136	0.8%	0.48	0.48	0.48	106	119	88	1	1	1	82	163	58	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold

Table A5.7

Water Column Dispersed and Dissolved Oil Intersects with World Maritime Boundaries

Name	Sum of Intersect Length (km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Canada - Atlantic Ocean	284	0.69	2.39	0.48	42	87	12	1	2	1	83	336	58	0	0	0
Canada - Saint-Pierre et Miquelon	6	0.48	0.48	0.48	43	43	43	1	1	1	83	83	83	0	0	0
Canada - United States	3	0.48	0.48	0.48	40	40	40	1	1	1	60	60	60	0	0	0
United States - Atlantic Ocean	0.02	0.48	0.48	0.48	82	82	82	1	1	1	73	73	73	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold

A5.2 Well: NS-1 Case 1A – (Summer Season)

Stranded oil

Table A5.8

Stranded Oil Intersections with Protected Areas

Name	Designation	Country	IUCN Category	Sum of Intersect Area (Sq km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average Degree of oiling	Max Degree of oiling	Min Degree of oiling
Sable Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	Ia	15.86	55.5	66.2	50.0	5	7	4	Heavy	Heavy	Heavy
Sable Island National Park Reserve of Canada	National Park Reserve of Canada	CAN	II	15.41	55.5	66.2	50.0	5	7	4	Heavy	Heavy	Heavy
Duncans Cove	Nature Reserve	CAN	Ia	0.24	4.0	5.2	2.9	28	29	27	Moderate	Moderate	Light
Canso Coastal Barrens	Wilderness Area	CAN	Ib	17.94	1.2	1.9	0.5	42	59	25	Moderate	Moderate	Light
Kejimkujik National Park and National Historic site of Canada (Seaside Adjunct)	National Park of Canada	CAN	II	5.31	1.0	1.4	0.5	63	64	62	Light	Light	Stain/Film
Terence Bay	Wilderness Area	CAN	Ib	6.48	0.7	1.0	0.5	44	44	44	Stain/Film	Stain/Film	Stain/Film
Bonnett Lake Barrens	Wilderness Area	CAN	Ib	17.61	0.6	1.0	0.5	44	61	34	Moderate	Moderate	Moderate
Cape Cod South	Closure Area	USA	V	0.96	0.5	0.5	0.5	113	113	113	Stain/Film	Stain/Film	Stain/Film
Chappy Avenue / Narragenset Avenue / Ames / Rogers Road	Local Land Trust Preserve	USA	V	0.002	0.5	0.5	0.5	113	113	113	Stain/Film	Stain/Film	Stain/Film
Edgartown Pond	Local Land Trust Preserve	USA	V	0.05	0.5	0.5	0.5	113	113	113	Stain/Film	Stain/Film	Stain/Film
Fortune Head Ecological Reserve	Ecological Reserve	CAN	II	0.25	0.5	0.5	0.5	68	68	68	Stain/Film	Stain/Film	Stain/Film
Getsinger / Patterson	Local Land Trust Preserve	USA	V	0.01	0.5	0.5	0.5	113	113	113	Stain/Film	Stain/Film	Stain/Film
Local Land Trust Preserve	Local Land Trust Preserve	USA	V	0.003	0.5	0.5	0.5	113	113	113	Stain/Film	Stain/Film	Stain/Film
Long Point Chappy	Local Land Trust Preserve	USA	V	0.04	0.5	0.5	0.5	113	113	113	Stain/Film	Stain/Film	Stain/Film
Northern Inshore State Trap/Pot Waters Area	Marine Protected Area	USA	V	3.43	0.5	0.5	0.5	113	113	113	Stain/Film	Stain/Film	Stain/Film
Sampson Hill / Ames	Local Land Trust Preserve	USA	V	0.04	0.5	0.5	0.5	113	113	113	Stain/Film	Stain/Film	Stain/Film
Scatarie Island	Wilderness Area	CAN	Ib	1.49	0.5	0.5	0.5	112	112	112	Light	Light	Light
V Packard	Local Land Trust Preserve	USA	V	0.01	0.5	0.5	0.5	113	113	113	Stain/Film	Stain/Film	Stain/Film
Northern Nearshore Trap/Pot Waters Area	Marine Protected Area	USA	V	3.43	0.5	0.5	0.5	113	113	113	Stain/Film	Stain/Film	Stain/Film
Other Northeast	Gillnet Waters Area	USA	V	2.89	0.5	0.5	0.5	113	113	113	Stain/Film	Stain/Film	Stain/Film

* Probability of stranded oil emulsion mass exceeding the 0.0019 tonnes/km (or 0.001 litres / m2 = 1 micron), minimum threshold for “Stain / Film” oiling.

Surface Oil

Table A5.9

Surface Oiling Intersects with Protected Areas

Name	Designation	Country	IUCN	Sum of Intersect Area (Sq km)	Average Probability (%)	Max Probability (%)	Min Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Gully Marine Protected Area	Marine Protected Area	CAN	Not Reported	2,371.28	61.1	77.6	33.3	7	11	4	9	13	5	CTOC	CTOC	Metallic	Metallic	Metallic	Rainbow
Sable Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	Ia	15.18	28.5	42.9	17.6	8	10	4	4	6	2	CTOC	CTOC	DTOC	Metallic	DTOC	Rainbow
Sable Island National Park Reserve of Canada	National Park Reserve of Canada	CAN	II	14.45	28.4	42.9	17.6	9	13	4	4	8	2	CTOC	CTOC	DTOC	Metallic	DTOC	Rainbow
Offshore Trap/Pot Waters	Marine Protected Area	USA	V	73,647.97	3.2	19.5	0.5	66	120	22	2	7	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
Other Northeast	Gillnet Waters Area	USA	V	73,614.41	3.2	19.5	0.5	66	120	22	2	7	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
Lydonia Canyon	Closed Area	USA	V	169.83	2.9	4.3	1.9	55	63	51	2	3	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Oceanographer Canyon	Closed Area	USA	V	258.69	2.3	4.8	1.0	68	92	47	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Duncans Cove	Nature Reserve	CAN	Ia	0.05	1.9	1.9	1.9	27	27	27	1	1	1	Rainbow	Rainbow	Rainbow	Rainbow	Rainbow	Rainbow
Musquodoboit Harbour	Ramsar Site, Wetland of International Importance	CAN	Not Reported	0.42	1.0	1.4	0.5	74	83	64	1	1	1	Rainbow	Rainbow	Sheen	Sheen	Rainbow	Sheen
Terence Bay	Wilderness Area	CAN	Ib	4.90	0.7	1.0	0.5	64	88	40	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Canso Coastal Barrens	Wilderness Area	CAN	Ib	24.25	0.7	1.0	0.5	39	50	39	1	1	1	Metallic	Metallic	Rainbow	Metallic	Metallic	Rainbow
Northern Nearshore Trap/Pot Waters Area	Marine Protected Area	USA	V	943.99	0.6	1.4	0.5	102	120	48	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Southern Mid-Atlantic Waters	Closure Area	USA	V	410.83	0.5	1.0	0.5	101	115	80	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Mid-Atlantic Coastal Waters	Marine Protected Area	USA	V	669.65	0.5	1.0	0.5	102	115	80	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
SAM East	Marine Protected Area	USA	V	1,022.04	0.5	1.0	0.5	92	120	52	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Offshore	Closure Area	USA	V	398.92	0.5	1.0	0.5	106	116	69	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Waters off New Jersey	Closure	USA	V	253.83	0.5	0.5	0.5	103	112	98	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Southern Nearshore Trap/Pot Waters	Marine Protected Area	USA	V	106.76	0.5	0.5	0.5	99	99	98	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Northeast	Closure Area	USA	V	67.50	0.5	0.5	0.5	119	120	96	2	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Great South Channel	Restricted Gillnet Area	USA	V	173.03	0.5	0.5	0.5	116	120	80	2	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Great South Channel Restricted Trap/Pot Area	Marine Protected Area	USA	V	173.04	0.5	0.5	0.5	116	120	80	2	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Isthme de Miquelon-langlade	Terrain acquis par le Conservatoire du Littoral	FRA	IV	8.40	0.5	0.5	0.5	74	74	74	1	1	1	Rainbow	Rainbow	Rainbow	Rainbow	Rainbow	Rainbow
Northern Inshore State Trap/Pot Waters Area	Marine Protected Area	USA	V	60.53	0.5	0.5	0.5	118	120	102	2	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Alice M. Lawrence	Exempt Site	USA	V	0.03	0.5	0.5	0.5	117	117	117	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Cape Cod South	Closure Area	USA	V	7.97	0.5	0.5	0.5	119	119	119	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Kejimkujik National Park and National Historic site of Canada (Seaside Adjunct)	National Park of Canada	CAN	II	0.85	0.5	0.5	0.5	87	87	87	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Mid-Coast	Closure Area	USA	V	7.66	0.5	0.5	0.5	117	117	117	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Scatarie Island	Wilderness Area	CAN	Ib	1.60	0.5	0.5	0.5	112	112	112	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Stellwagen Bank/Jeffreys Ledge	Restricted Area	USA	V	7.66	0.5	0.5	0.5	117	117	117	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 μm (BAOAC “Sheen”) thickness threshold

Table A5.10

Surface Oiling Intersects with EBSAs

Name	Sum of Intersect Area (Sq km)	% Surface EBSA Area contacted by emulsified oil > 0.04 micron thickness	Average Probability (%)	Max Probability (%)	Min Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Scotian Slope	72,678	100%	69.3	100.0	5.2	9	48	1	10	19	1	DTOC	CTOC	Sheen	Rainbow	DTOC	Sheen
Emerald Western Sable Banks Complex	17,929	100%	57.6	98.1	19.0	8	19	2	8	17	3	DTOC	CTOC	Rainbow	Rainbow	Metallic	Sheen
Haddock Box	12,797	100%	55.0	96.7	24.8	10	19	2	8	17	3	DTOC	CTOC	Rainbow	Rainbow	Metallic	Sheen
Eastern Scotian Shelf Canyons	7,446	100%	51.6	81.9	21.4	9	20	4	9	15	5	CTOC	CTOC	Rainbow	Rainbow	Metallic	Rainbow
Laurentian Channel Cold Seep	50	100%	32.7	35.2	30.0	19	21	18	4	5	4	Rainbow	Metallic	Rainbow	Sheen	Rainbow	Sheen
Sable Island Shoals	1,246	96%	31.4	50.5	13.3	8	14	4	5	9	2	CTOC	CTOC	Metallic	Metallic	DTOC	Rainbow
Emerald Basin and the Scotian Gulf	8,527	100%	28.2	66.2	12.4	17	28	8	6	12	3	Rainbow	DTOC	Sheen	Sheen	Rainbow	Sheen
Stone Fence and Laurentian Environs	45	100%	26.2	28.6	23.8	15	19	13	5	6	4	DTOC	DTOC	Rainbow	Rainbow	Rainbow	Rainbow
Stone Fence coral conservation area	15	100%	25.7	28.1	23.8	14	16	13	5	6	4	DTOC	DTOC	Rainbow	Rainbow	Rainbow	Rainbow
Sambro Bank Sponge Conservation Area	63	100%	25.0	29.5	23.3	14	18	14	6	8	6	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Emerald Sponge Conservation Area	197	100%	22.9	26.2	19.0	23	27	18	4	6	3	Rainbow	Metallic	Rainbow	Sheen	Rainbow	Sheen
Northeast Channel	2,592	100%	19.6	29.0	9.0	24	40	17	5	12	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Eastern Shoal	3,403	100%	19.0	43.8	3.8	22	39	12	5	9	1	Metallic	CTOC	Rainbow	Rainbow	Metallic	Sheen
Middle Bank	2,753	100%	17.7	25.2	11.0	14	24	7	6	9	4	DTOC	CTOC	Rainbow	Rainbow	Metallic	Rainbow
Northeast Channel Coral Conservation Area - NEC restricted bottom fishing zone	392	100%	17.6	24.8	12.9	25	39	19	4	7	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Northeast Channel Coral Conservation Area	425	100%	16.8	24.8	12.4	26	39	19	4	7	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Northeast Channel Coral Conservation Area - NEC limited bottom fishing zone	34	100%	13.5	13.8	12.4	27	39	21	3	5	2	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Browns Bank	4,313	100%	8.5	19.0	1.9	31	54	22	2	7	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Georges Bank	13,531	93%	7.81	26.67	0.48	41	119	19	2	7	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Lobster Fisheries Act Closure Area	6,561	100%	7.7	21.9	1.4	32	54	22	2	7	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
NAFO Fishing Closure Area (1) Sponge, Coral & Seapen Protected Areas	14,311	100%	7.0	13.8	1.0	37	68	24	2	5	1	Rainbow	CTOC	Sheen	Sheen	Metallic	Sheen
NAFO Fishing Closure Area (4) Seamount Areas	14,288	88%	6.6	39.0	0.5	59	120	40	2	9	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
Laurentian Channel slope	12,548	58%	6.6	34.8	0.5	47	118	12	2	9	1	Metallic	CTOC	Sheen	Rainbow	DTOC	Sheen
North Atlantic Right Whale - Roseway Basin	3,319	100%	6.58	13.81	0.95	28	70	17	2	5	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
Bowtie	4,068	100%	6.3	13.8	0.5	31	98	17	2	6	1	Rainbow	CTOC	Sheen	Sheen	Metallic	Sheen
Roseway Basin	3,162	100%	6.0	13.8	0.5	29	98	17	2	5	1	Rainbow	DTOC	Sheen	Sheen	Rainbow	Sheen
Canso Bank and Canso Basin	4,110	100%	5.2	14.8	0.5	26	54	12	3	7	1	Metallic	CTOC	Sheen	Metallic	DTOC	Sheen
Laurentian Channel (AOI)	12,647	77%	4.6	18.6	0.5	50	118	16	2	6	1	Rainbow	CTOC	Sheen	Sheen	Metallic	Sheen
Canadian portion of Georges Bank	6,409	91%	4.6	16.7	0.5	47	119	21	2	4	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Misaine Bank	4,603	100%	4.2	11.4	0.5	33	56	15	2	6	1	Metallic	CTOC	Sheen	Rainbow	DTOC	Sheen
NAFO Fishing Closure Area (5) Seamount Areas	226,219	82%	2.1	12.9	0.5	52	120	12	1	4	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
NAFO Fishing Closure Area (3) Seamount Areas	27,783	67%	0.9	4.3	0.5	84	120	39	1	2	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
St Anns Bank Area of Interest	527	12%	0.9	2.4	0.5	71	113	43	1	2	1	Sheen	Metallic	Sheen	Sheen	Metallic	Sheen
Jordan Basin and the Rock Garden	551	30%	0.6	1.4	0.5	63	116	51	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
St. Anns Bank	222	5%	0.5	0.5	0.5	94	112	43	1	1	1	Rainbow	Metallic	Sheen	Rainbow	Metallic	Sheen
North Atlantic Right Whale - Grand Manan Basin	31	4%	0.48	0.48	0.48	110	111	79	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold

Table A5.11

Surface Oiling Intersects with World Maritime Boundaries

Name	Boundary Intersect Length (km)	Average Probability (%)	Max Probability (%)	Min Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Canada - Atlantic Ocean	1,483	38.1	82.9	0.5	23	110	9	4	11	1	Metallic	CTOC	Sheen	Sheen	Metallic	Sheen
Canada - Saint-Pierre et Miquelon	791	16.7	55.2	0.5	34	100	12	3	11	1	Metallic	CTOC	Sheen	Rainbow	Metallic	Sheen
Canada - United States	280	7.0	19.5	0.5	55	117	22	3	7	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
United States - Atlantic Ocean	248	3.9	15.2	0.5	54	107	22	2	6	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Bermuda - Atlantic Ocean	251	1.4	2.4	0.5	60	117	44	2	3	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold

Oil in the Upper water column (<100 m water depth)

Table A5.12

Water Column Dispersed and Dissolved Oil Intersects with Protected Areas

Name	Designation	Country	IUCN	Sum of Intersect Area (Sq km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Gully Marine Protected Area	Marine Protected Area	CAN	Not Reported	2,371	13.18	31.90	1.43	10	22	4	5	9	1	231	776	82	1	9	0
Sable Island National Park Reserve of Canada	National Park Reserve of Canada	CAN	II	4	1.68	3.81	0.48	22	36	10	1	2	1	82	291	62	0	1	0
Sable Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	Ia	4	1.57	3.81	0.48	22	36	12	1	2	1	76	152	62	0	0	0
Offshore Trap/Pot Waters	Marine Protected Area	USA	V	75	0.48	0.48	0.48	70	75	41	1	1	1	75	84	59	0	0	0
Other Northeast	Gillnet Waters Area	USA	V	75	0.48	0.48	0.48	70	75	41	1	1	1	75	84	59	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold

Table A5.13

Water Column Dispersed and Dissolved Oil Intersects with EBSAs

Name	Sum of Intersect Area (Sq km)	% Surface EBSA Area contacted by THC > 58 ppb	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Scotian Slope	62,997	86.8%	30.97	100.00	0.48	11	81	1	7	32	1	322	2054	58	2	19	0
Emerald Western Sable Banks Complex	16,417	91.7%	11.64	69.05	0.48	12	56	2	3	13	1	219	1029	58	1	14	0
Eastern Scotian Shelf Canyons	7,446	100.2%	8.76	33.81	0.48	14	46	4	3	12	1	192	776	58	1	9	0
Haddock Box	10,890	85.2%	7.29	55.24	0.48	14	56	3	2	12	1	192	893	58	1	11	0
Sable Island Shoals	1,060	81.8%	4.01	8.57	0.48	13	45	7	2	5	1	185	516	58	1	5	0
Emerald Basin and the Scotian Gulf	3,998	47.0%	2.73	10.48	0.48	26	53	11	3	10	1	147	584	58	0	2	0
Northeast Channel	1,314	50.8%	1.78	3.81	0.48	43	67	29	2	4	1	84	144	58	0	0	0
Stone Fence and Laurentian Environs	35	0.8%	1.56	3.33	0.48	30	40	18	1	2	1	105	149	61	0	0	0
Middle Bank	2,581	93.9%	1.26	5.71	0.48	25	51	10	1	4	1	102	446	58	0	2	0
Stone Fence coral conservation area	12	83.9%	1.26	3.33	0.48	30	40	18	1	2	1	85	109	61	0	0	0
Eastern Shoal	1,608	47.3%	1.14	4.29	0.48	32	61	14	1	3	1	81	383	58	0	1	0
Laurentian Channel Cold Seep	21	41.5%	0.93	1.43	0.48	22	24	21	1	1	1	61	64	59	0	0	0
Georges Bank	340	2.3%	0.82	3.33	0.48	51	81	29	1	3	1	72	113	58	0	0	0
Laurentian Channel slope	889	4.1%	0.62	2.38	0.48	36	59	13	1	1	1	74	380	58	0	0	0
Misaine Bank	430	9.3%	0.58	1.90	0.48	39	49	16	1	2	1	84	382	58	0	0	0
Canso Bank and Canso Basin	1,288	31.3%	0.54	1.90	0.48	32	50	17	1	2	1	82	421	58	0	0	0
NAFO Fishing Closure Area (5) Seamount Areas	613	0.2%	0.49	0.95	0.48	50	69	27	1	1	1	69	124	58	0	0	0
Laurentian Channel (AOI)	102	0.6%	0.48	0.48	0.48	41	50	16	1	1	1	94	114	60	0	0	0
Emerald Sponge Conservation Area	16	7.9%	0.48	0.48	0.48	36	48	22	1	1	1	72	102	59	0	0	0
NAFO Fishing Closure Area (1) Sponge, Coral & Seapen Protected Areas	30	0.2%	0.48	0.48	0.48	66	74	40	1	1	1	62	64	59	0	0	0
Northeast Channel Coral Conservation Area	32	7.6%	0.48	0.48	0.48	45	57	29	1	1	1	66	87	58	0	0	0
Northeast Channel Coral Conservation Area - NEC restricted bottom fishing zone	32	8.3%	0.48	0.48	0.48	45	57	29	1	1	1	66	87	58	0	0	0
NAFO Fishing Closure Area (4) Seamount Areas	72	0.4%	0.48	0.48	0.48	52	107	49	1	1	1	60	81	60	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold

Table A5.14

Water Column Dispersed and Dissolved Oil Intersects with World Maritime Boundaries

Name	Boundary Intersect Length (km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Canada - Saint-Pierre et Miquelon	215	1.96	5.24	0.48	25	54	12	1	3	1	122	348	59	0	0	0
Grand Total	937	1.33	7.14	0.48	30	75	9	1	3	1	102	483	58	0	1	0
Canada - Atlantic Ocean	712	1.15	7.14	0.48	31	65	9	1	3	1	96	483	58	0	1	0
Canada - United States	9	0.48	0.48	0.48	54	75	41	1	1	1	73	84	59	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold

A5.3 Well: NS-1 Case 2A – (Winter Season)

Stranded oil

Table A5.15

Stranded Oil Intersections with Protected Areas

Name	Designation	Country	IUCN Category	Sum of Intersect Area (Sq km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Max Emulsion Thickness (mm)	Max of Max Emulsion Thickness (mm)	Min of Max Emulsion Thickness (mm)	Average Degree of oiling	Max Degree of oiling	Min Degree of oiling
Sable Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	Ia	15.86	11.8	13.9	9.1	15	18	11	25.62	65.54	7.67	Heavy	Heavy	Moderate
Sable Island National Park Reserve of Canada	National Park Reserve of Canada	CAN	II	15.41	11.8	13.9	9.1	15	18	11	25.62	65.54	7.67	Heavy	Heavy	Moderate
Kejimkujik National Park and National Historic site of Canada (Seaside Adjunct)	National Park of Canada	CAN	II	3.79	1.9	2.4	1.4	61	75	46	0.18	0.26	0.09	Light	Light	Stain/Film
Little Hardwood Island	Preserve	USA	Ia	0.02	1.4	1.4	1.4	92	92	92	1.29	1.29	1.29	Moderate	Moderate	Moderate
Cross Island	National Wildlife Refuge	USA	IV	2.45	1.0	1.0	1.0	92	92	92	0.05	0.05	0.05	Stain/Film	Stain/Film	Stain/Film
Cross Island Archipelago	National Wildlife Refuge	USA	IV	2.36	1.0	1.0	1.0	92	92	92	0.05	0.05	0.05	Stain/Film	Stain/Film	Stain/Film
Turtle Island	Preserve	USA	Ia	0.40	1.0	1.0	1.0	88	88	88	0.05	0.05	0.05	Stain/Film	Stain/Film	Stain/Film
Acadia	National Park	USA	IV	31.46	0.9	1.4	0.5	89	95	88	0.10	0.26	0.03	Light	Light	Stain/Film
Terence Bay	Wilderness Area	CAN	Ib	6.48	0.7	1.0	0.5	91	91	91	0.31	0.48	0.15	Light	Light	Light
Northern Nearshore Trap/Pot Waters Area	Marine Protected Area	USA	V	73.15	0.7	1.4	0.5	95	114	84	0.23	1.29	0.00	Light	Moderate	Stain/Film
Northern Inshore State Trap/Pot Waters Area	Marine Protected Area	USA	V	74.17	0.7	1.4	0.5	96	114	84	0.20	1.29	0.00	Light	Moderate	Stain/Film
Other Northeast	Gillnet Waters Area	USA	V	71.19	0.7	1.4	0.5	96	114	84	0.23	1.29	0.02	Light	Moderate	Stain/Film
Northeast	Closure Area	USA	V	71.33	0.7	1.4	0.5	96	114	84	0.22	1.29	0.02	Light	Moderate	Stain/Film
Baker / Brum / Bearse / Nerney / Barrow	Local Land Trust Preserve	USA	V	0.01	0.5	0.5	0.5	109	109	109	0.00	0.00	0.00	Stain/Film	Stain/Film	Stain/Film
Baker Homes Gift	Municipal Conservation Area	USA	V	0.00	0.5	0.5	0.5	109	109	109	0.00	0.00	0.00	Stain/Film	Stain/Film	Stain/Film
Burgess	Local Land Trust Preserve	USA	V	0.00	0.5	0.5	0.5	109	109	109	0.00	0.00	0.00	Stain/Film	Stain/Film	Stain/Film
Burr	Municipal Conservation Area	USA	V	0.00	0.5	0.5	0.5	109	109	109	0.00	0.00	0.00	Stain/Film	Stain/Film	Stain/Film
Chamberlain	Municipal Conservation Area	USA	V	0.01	0.5	0.5	0.5	109	109	109	0.00	0.00	0.00	Stain/Film	Stain/Film	Stain/Film
Duncans Cove	Nature Reserve	CAN	Ia	0.24	0.5	0.5	0.5	103	110	95	0.03	0.05	0.01	Stain/Film	Stain/Film	Stain/Film
Local Land Trust Preserve	Local Land Trust Preserve	USA	V	0.12	0.5	0.5	0.5	109	109	109	0.00	0.00	0.00	Stain/Film	Stain/Film	Stain/Film
Marshall Island Phase I	Local Conservation Area	USA	V	1.30	0.5	0.5	0.5	91	91	91	0.03	0.03	0.03	Stain/Film	Stain/Film	Stain/Film
Nowotne / Hill	Local Land Trust Preserve	USA	V	0.00	0.5	0.5	0.5	109	109	109	0.00	0.00	0.00	Stain/Film	Stain/Film	Stain/Film
Petit Manan	National Wildlife Refuge	USA	IV	0.13	0.5	0.5	0.5	114	114	114	0.03	0.03	0.03	Stain/Film	Stain/Film	Stain/Film
Rice	Municipal Conservation Area	USA	V	0.00	0.5	0.5	0.5	109	109	109	0.00	0.00	0.00	Stain/Film	Stain/Film	Stain/Film
Roque Bluffs	State Park	USA	V	1.25	0.5	0.5	0.5	92	92	92	0.04	0.04	0.04	Stain/Film	Stain/Film	Stain/Film
Ten Pound Island	Private Conservation Land	USA	III	0.11	0.5	0.5	0.5	114	114	114	0.05	0.05	0.05	Stain/Film	Stain/Film	Stain/Film
Town of Dennis Conservation Commission Land	Municipal Conservation Area	USA	V	0.01	0.5	0.5	0.5	109	109	109	0.00	0.00	0.00	Stain/Film	Stain/Film	Stain/Film
Upper St John Watershed Reserve	National Wildlife Refuge	USA	IV	0.26	0.5	0.5	0.5	114	114	114	0.03	0.03	0.03	Stain/Film	Stain/Film	Stain/Film

* Probability of stranded oil emulsion mass exceeding the 0.0019 tonnes/km (or 0.001 litres / m2 = 1 micron), minimum threshold for “Stain / Film” oiling.

Surface Oil

Table A5.16

Surface Oiling Intersects with Protected Areas

Name	Designation	Country	IUCN	Sum of Intersect Area (Sq km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Lydonia Canyon	Closed Area	USA	V	169.83	24.1	27.3	21.5	37	45	21	5	8	3	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Oceanographer Canyon	Closed Area	USA	V	259	20.6	24.9	15.3	33	35	32	3	6	2	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Gully Marine Protected Area	Marine Protected Area	CAN	Not Reported	2,371	19.0	42.6	3.3	23	65	12	3	8	1	Rainbow	DTOC	Sheen	Sheen	Rainbow	Sheen
Other Northeast	Gillnet Waters Area	USA	V	184,073	8.5	60.8	0.5	59	120	15	2	8	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
Offshore Trap/Pot Waters	Marine Protected Area	USA	V	205,341	7.9	60.8	0.5	62	120	15	2	8	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
Sable Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	Ia	14.23	1.5	3.3	0.5	42	71	11	1	1	1	CTOC	CTOC	Sheen	DTOC	DTOC	Sheen
Sable Island National Park Reserve of Canada	National Park Reserve of Canada	CAN	II	13.69	1.4	3.3	0.5	48	71	11	1	1	1	CTOC	CTOC	Sheen	DTOC	DTOC	Sheen
SAM East	Marine Protected Area	USA	V	6,421	1.2	5.3	0.5	78	120	45	1	3	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Waters off New Jersey	Closure	USA	V	7,473	1.1	3.8	0.5	85	119	58	1	3	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Machias Seal Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	III	10.48	1.0	1.0	1.0	102	102	102	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Offshore	Closure Area	USA	V	3,799	0.9	2.9	0.5	75	120	56	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Mid-Atlantic Coastal Waters	Marine Protected Area	USA	V	29,194	0.8	3.8	0.5	95	120	55	1	3	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Northern Nearshore Trap/Pot Waters Area	Marine Protected Area	USA	V	9,728	0.8	2.9	0.5	91	120	32	1	3	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Northeast	Closure Area	USA	V	1,763	0.7	2.4	0.5	98	120	66	1	3	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Acadia	National Park	USA	IV	4.15	0.7	1.0	0.5	95	96	95	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Southern Mid-Atlantic Waters	Closure Area	USA	V	21,511	0.7	2.4	0.5	99	120	55	1	3	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Northern Inshore State Trap/Pot Waters Area	Marine Protected Area	USA	V	472	0.7	1.4	0.5	95	118	83	1	2	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Cape Cod South	Closure Area	USA	V	2,689	0.6	2.9	0.5	102	120	32	1	3	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Southern Nearshore Trap/Pot Waters	Marine Protected Area	USA	V	3,721	0.6	1.4	0.5	100	120	65	1	3	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Great South Channel	Restricted Gillnet Area	USA	V	305	0.6	1.4	0.5	90	120	77	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Great South Channel Restricted Trap/Pot Area	Marine Protected Area	USA	V	305	0.6	1.4	0.5	90	120	77	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Wheaton Island & Islands	National Wildlife Refuge	USA	IV	0.05	0.5	1.0	0.5	95	95	95	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Cross Island	National Wildlife Refuge	USA	IV	0.31	0.5	0.5	0.5	87	87	87	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Kejimkujik National Park and National Historic site of Canada (Seaside Adjunct)	National Park of Canada	CAN	II	5.33	0.5	0.5	0.5	76	78	76	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Double Head Shot Island	National Wildlife Refuge	USA	IV	0.09	0.5	0.5	0.5	87	87	87	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Duncans Cove	Nature Reserve	CAN	Ia	2.48	0.5	0.5	0.5	95	95	95	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
North and South Green Islands	Protected Natural Area	CAN	Ib	0.13	0.5	0.5	0.5	77	77	77	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Old Man Island	National Wildlife Refuge	USA	IV	0.02	0.5	0.5	0.5	87	87	87	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
SAM West	Marine Protected Area	USA	V	15.51	0.5	0.5	0.5	113	113	113	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Terence Bay	Wilderness Area	CAN	Ib	0.97	0.5	0.5	0.5	91	91	91	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Whitehorse Island	Protected Natural Area	CAN	Ia	0.02	0.5	0.5	0.5	118	118	118	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Cross Island Archipelago	National Wildlife Refuge	USA	IV	0.01	0.5	0.5	0.5	87	87	87	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Scotch Island	National Wildlife Refuge	USA	IV	0.05	0.5	0.5	0.5	87	87	87	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Heron Neck (ANP)	National Wildlife Refuge	USA	IV	2.19	0.5	0.5	0.5	90	90	90	1	1	1	Rainbow	Rainbow	Rainbow	Rainbow	Rainbow	Rainbow

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold

Table A5.17

Surface Oiling Intersects with EBSAs

Name	Sum of Intersect Area (Sq km)	% Surface EBSA Area contacted by emulsified oil > 0.04 micron thickness	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Scotian Slope	72,678	100%	70.0	100.0	0.5	12	91	1	9	21	1	DTOC	CTOC	Sheen	Rainbow	DTOC	Sheen
Northeast Channel	2,592	100%	67.4	78.9	45.0	16	26	11	6	11	4	Rainbow	Rainbow	Rainbow	Sheen	Sheen	Sheen
Northeast Channel Coral Conservation Area	425	100%	64.33	71.77	56.46	17	22	12	6	9	5	Rainbow	Rainbow	Rainbow	Sheen	Sheen	Sheen
Northeast Channel Coral Conservation Area - NEC restricted bottom fishing zone	392	100%	64.30	71.77	56.46	16	22	12	6	9	5	Rainbow	Rainbow	Rainbow	Sheen	Sheen	Sheen
Northeast Channel Coral Conservation Area - NEC limited bottom fishing zone	34	100%	63.76	67.94	58.37	19	19	16	6	7	5	Rainbow	Rainbow	Rainbow	Sheen	Sheen	Sheen
Haddock Box	12,797	100%	52.39	88.04	22.01	8	18	3	8	16	4	Metallic	CTOC	Rainbow	Rainbow	Metallic	Sheen
Emerald Western Sable Banks Complex	17,929	100%	46.1	91.4	3.3	9	48	2	8	16	1	DTOC	CTOC	Sheen	Rainbow	Metallic	Sheen
Emerald Basin and the Scotian Gulf	8,527	100%	37.8	85.6	3.3	14	35	4	5	14	1	Metallic	CTOC	Sheen	Sheen	Metallic	Sheen
Browns Bank	4,313	100%	31.1	57.4	12.4	25	46	11	4	9	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Georges Bank	14,530	100%	30.43	76.08	0.48	29	93	12	4	10	1	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Lobster Fisheries Act Closure Area	6,561	100%	28.9	62.7	12.4	26	46	11	4	9	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
North Atlantic Right Whale - Roseway Basin	3,319	100%	23.86	44.50	10.53	25	38	14	4	9	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Sambro Bank Sponge Conservation Area	63	100%	21.91	27.75	18.66	17	18	15	3	7	3	Rainbow	Rainbow	Rainbow	Sheen	Sheen	Sheen
Canadian portion of Georges Bank	7,022	100%	21.3	62.2	1.0	31	93	16	3	7	1	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Bowtie	4,068	100%	20.25	35.89	5.74	25	44	16	4	8	1	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Roseway Basin	3,162	100%	20.0	35.9	4.8	25	36	16	4	7	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Laurentian Channel Cold Seep	50	100%	20.0	21.1	18.2	28	29	23	3	4	3	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Eastern Scotian Shelf Canyons	7,362	99%	16.9	55.0	0.5	33	120	10	3	12	1	Rainbow	CTOC	Sheen	Sheen	Metallic	Sheen
Emerald Sponge Conservation Area	197	100%	12.46	17.70	5.26	20	31	16	4	6	1	Rainbow	Metallic	Sheen	Sheen	Rainbow	Sheen
NAFO Fishing Closure Area (4) Seamount Areas	14,572	90%	8.90	45.93	0.48	79	120	47	3	17	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
NAFO Fishing Closure Area (5) Seamount Areas	267,199	97%	6.45	38.76	0.48	44	120	9	1	5	1	Sheen	DTOC	Sheen	Sheen	Rainbow	Sheen
Stone Fence and Laurentian Environs	45	100%	3.6	7.2	2.4	66	75	57	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
NAFO Fishing Closure Area (1) Sponge, Coral & Seapen Protected Areas	14,265	87%	3.35	9.09	0.48	66	119	25	1	4	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Stone Fence coral conservation area	15	100%	3.32	6.70	2.39	68	75	57	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Middle Bank	2,677	97%	2.7	12.0	0.5	36	80	14	2	6	1	Rainbow	Metallic	Sheen	Rainbow	Rainbow	Sheen
Sable Island Shoals	1,158	89%	2.6	8.1	0.5	27	90	10	1	2	1	DTOC	CTOC	Sheen	Metallic	CTOC	Sheen
Laurentian Channel slope	6,969	32%	1.7	9.1	0.5	84	120	46	1	3	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Jordan Basin and the Rock Garden	1,430	78%	1.7	7.2	0.5	71	116	47	1	3	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
NAFO Fishing Closure Area (3) Seamount Areas	38,373	92%	1.61	5.26	0.48	76	120	42	1	3	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Eastern Shoal	2,192	65%	1.5	7.2	0.5	88	118	42	1	3	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Laurentian Channel (AOI)	5,827	35%	0.8	2.9	0.5	94	120	61	1	3	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Canso Bank and Canso Basin	1,160	28%	0.5	1.9	0.5	59	88	47	1	2	1	Rainbow	Rainbow	Sheen	Rainbow	Rainbow	Sheen
North Atlantic Right Whale - Grand Manan Basin	607	82%	0.52	1.44	0.48	74	77	56	1	2	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Misaine Bank	306	7%	0.5	0.5	0.5	63	64	63	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold

Table A5.18

Surface Oiling Intersects with World Maritime Boundaries

Name	Sum of Boundary Intersect Length (km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Canada - Atlantic Ocean	1,492	44.6	76.1	0.5	28	120	7	4	10	1	Rainbow	CTOC	Sheen	Sheen	Rainbow	Sheen
Canada - United States	496	14.3	60.3	0.5	59	119	16	2	8	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
United States - Atlantic Ocean	503	14.2	45.5	0.5	50	118	26	2	6	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen
Canada - Saint-Pierre et Miquelon	499	13.0	44.0	0.5	50	120	22	2	5	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Bermuda - Atlantic Ocean	393	1.0	2.4	0.5	84	119	55	1	3	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold

Oil in the Upper water column (<100 m water depth)

Table A5.19

Water Column Dispersed and Dissolved Oil Intersects with Protected Areas

Name	Designation	Country	IUCN	Sum of Intersect Area (Sq km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Gully Marine Protected Area	Marine Protected Area	CAN	Not Reported	297	0.76	2.87	0.48	39	61	9	1	2	1	88	128	58	0	0	0
Offshore Trap/Pot Waters	Marine Protected Area	USA	V	1,144	0.57	0.96	0.48	63	101	37	1	1	1	81	479	58	0	0	0
Other Northeast	Gillnet Waters Area	USA	V	1,144	0.57	0.96	0.48	63	101	37	1	1	1	81	479	58	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold

Table A5.20

Water Column Dispersed and Dissolved Oil Intersects with EBSAs

Name	Sum of Intersect Area (Sq km)	% Surface EBSA Area contacted by THC > 58 ppb	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Scotian Slope	56,182	77.4%	36.79	99.52	0.48	9	101	1	8	27	1	367	2166	58	2	34	0
Emerald Western Sable Banks Complex	15,507	86.6%	8.77	50.72	0.48	11	58	3	3	17	1	199	1164	58	1	18	0
Haddock Box	12,650	99.0%	7.14	39.71	0.48	11	51	3	3	13	1	190	1164	59	1	18	0
Emerald Basin and the Scotian Gulf	5,058	59.4%	3.09	22.49	0.48	15	67	5	2	8	1	123	966	58	0	3	0
Northeast Channel	1,384	53.4%	1.40	3.35	0.48	42	95	16	1	3	1	90	214	58	0	1	0
Georges Bank	894	6.2%	1.19	2.87	0.48	53	95	16	1	2	1	84	415	58	0	0	0
Northeast Channel Coral Conservation Ar	215	54.9%	1.19	2.87	0.48	50	65	18	1	2	1	83	126	59	0	0	0
Northeast Channel Coral Conservation Ar	215	50.5%	1.19	2.87	0.48	50	65	18	1	2	1	83	126	59	0	0	0
NAFO Fishing Closure Area (4) Seamount	249	1.5%	1.09	1.91	0.48	103	119	86	2	2	1	85	305	58	0	0	0
Eastern Scotian Shelf Canyons	689	9.3%	0.89	3.83	0.48	37	67	9	1	4	1	80	153	58	0	0	0
Browns Bank	79	1.8%	0.60	1.44	0.48	52	58	19	2	2	1	77	92	59	0	0	0
Lobster Fisheries Act Closure Area	167	2.5%	0.58	1.91	0.48	50	91	19	1	2	1	119	152	60	0	0	0
NAFO Fishing Closure Area (5) Seamount	971	0.4%	0.48	0.96	0.48	48	101	12	1	1	1	83	319	58	0	0	0
Middle Bank	37	1.4%	0.48	0.48	0.48	49	49	48	1	1	1	144	147	84	0	0	0
North Atlantic Right Whale - Roseway Ba	46	1.4%	0.48	0.48	0.48	55	61	53	1	1	1	141	152	70	0	0	0
Canadian portion of Georges Bank	8	0.1%	0.48	0.48	0.48	37	40	34	1	1	1	65	69	60	0	0	0
Canso Bank and Canso Basin	2	0.0%	0.48	0.48	0.48	49	49	49	1	1	1	93	93	93	0	0	0
Laurentian Channel Cold Seep	6	11.3%	0.48	0.48	0.48	43	43	43	1	1	1	68	68	68	0	0	0
Emerald Sponge Conservation Area	15.4	7.8%	0.48	0.48	0.48	28	31	25	1	1	1	68	69	68	0	0	0
Sambro Bank Sponge Conservation Area	11	17.9%	0.48	0.48	0.48	41	42	39	1	1	1	66	73	58	0	0	0
Sable Island Shoals	88	6.8%	0.48	0.48	0.48	27	39	11	1	1	1	97	208	59	0	0	0
Roseway Basin	108	3.4%	0.48	0.48	0.48	52	62	50	1	1	1	89	152	62	0	0	0
Bowtie	100	2.5%	0.48	0.48	0.48	52	70	50	1	1	1	89	152	62	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold

Table A5.21

Water Column Dispersed and Dissolved Oil Intersects with World Maritime Boundaries

Name	Sum of Intersect Length (km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Canada - Atlantic Ocean	590	2.29	8.13	0.48	28	79	8	2	3	1	117	509	58	0	2	0
Canada - United States	20	0.52	0.96	0.48	72	73	57	1	1	1	89	126	59	0	0	0
United States - Atlantic Ocean	4	0.48	0.48	0.48	59	59	59	1	1	1	60	60	60	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold

A5.1 Well: NS-1 Case 2A – (Summer Season)

Stranded oil

Table A5.22

Stranded Oil Intersections with Protected Areas

Name	Designation	Country	IUCN Category	Sum of Intersect Area (Sq km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average Degree of oiling	Max Degree of oiling	Min Degree of oiling
Sable Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	Ia	15.86	43.7	52.4	40.0	9	9	7	Heavy	Heavy	Heavy
Sable Island National Park Reserve of Canada	National Park Reserve of Canada	CAN	II	15.41	43.7	52.4	40.0	9	9	7	Heavy	Heavy	Heavy
Duncans Cove	Nature Reserve	CAN	Ia	0.237	5.0	6.2	3.8	36	44	28	Moderate	Moderate	Moderate
Kejimkujik National Park and National Historic site of Canada (Seaside Adjunct)	National Park of Canada	CAN	II	3.79	3.3	4.3	2.4	39	41	37	Moderate	Moderate	Moderate
Tangier Grand Lake	Wilderness Area	CAN	Ib	0.33	1.9	1.9	1.9	42	42	42	Moderate	Moderate	Moderate
Canso Coastal Barrens	Wilderness Area	CAN	Ib	8.43	1.0	1.4	0.5	54	56	51	Moderate	Moderate	Stain/Film
Terence Bay	Wilderness Area	CAN	Ib	11.37	0.6	1.4	0.5	34	45	24	Moderate	Heavy	Moderate
Bonnett Lake Barrens	Wilderness Area	CAN	Ib	5.81	0.5	0.5	0.5	57	57	57	Moderate	Moderate	Moderate
Bowers Meadows	Wilderness Area	CAN	Ib	0.36	0.5	0.5	0.5	72	72	72	Stain/Film	Stain/Film	Stain/Film
Isthme de Miquelon-langlade	Terrain acquis par le Conservatoire du Littoral	FRA	IV	0.15	0.5	0.5	0.5	94	94	94	Light	Light	Light
Scatarie Island	Wilderness Area	CAN	Ib	1.49	0.5	0.5	0.5	61	61	61	Moderate	Moderate	Moderate
Spinneys Heath	Nature Reserve	CAN	Ia	0.26	0.5	0.5	0.5	64	64	64	Stain/Film	Stain/Film	Stain/Film
Northeast	Closure Area	USA	V	2.45	0.5	0.5	0.5	103	103	103	Light	Light	Light
Northern Inshore State Trap/Pot Waters Area	Marine Protected Area	USA	V	2.53	0.5	0.5	0.5	103	103	103	Light	Light	Light
Northern Nearshore Trap/Pot Waters Area	Marine Protected Area	USA	V	2.53	0.5	0.5	0.5	103	103	103	Light	Light	Light
Other Northeast	Gillnet Waters Area	USA	V	1.846	0.5	0.5	0.5	103	103	103	Light	Light	Light

* Probability of stranded oil emulsion mass exceeding the 0.0019 tonnes/km (or 0.001 litres / m2 = 1 micron), minimum threshold for “Stain / Film” oiling.

Surface Oil

Table A5.23

Surface Oiling Intersects with Protected Areas

Name	Designation	Country	IUCN	Sum of Intersect Area (Sq km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Gully Marine Protected Area	Marine Protected Area	CAN	Not Reported	2,371.28	53.6	71.9	26.7	11	17	7	9	15	3	DTOC	CTOC	Rainbow	Rainbow	Metallic	Rainbow
Sable Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	Ia	15.18	16.6	25.7	8.6	13	19	9	3	3	1	CTOC	CTOC	Metallic	DTOC	DTOC	Rainbow
Sable Island National Park Reserve of Canada	National Park Reserve of Canada	CAN	II	14.45	16.5	25.7	8.6	13	19	9	3	4	1	CTOC	CTOC	Metallic	DTOC	DTOC	Rainbow
Lydonia Canyon	Closed Area	USA	V	169.83	8.1	9.5	7.1	38	44	35	3	5	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Oceanographer Canyon	Closed Area	USA	V	258.69	7.7	9.5	6.7	31	51	26	3	5	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Other Northeast	Gillnet Waters Area	USA	V	112,819.45	4.8	28.1	0.5	65	120	18	2	11	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
Offshore Trap/Pot Waters	Marine Protected Area	USA	V	113,610.18	4.8	28.1	0.5	65	120	18	2	11	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
Musquodoboit Harbour	Ramsar Site, Wetland of International Importance	CAN	Not Reported	6.22	1.7	2.4	0.5	49	49	49	1	2	1	Rainbow	Rainbow	Sheen	Sheen	Rainbow	Sheen
Duncans Cove	Nature Reserve	CAN	Ia	3.46	0.9	1.4	0.5	46	52	40	1	2	1	Rainbow	Rainbow	Sheen	Sheen	Rainbow	Sheen
Kejimkujik National Park and National Historic site of Canada (Seaside Adjunct)	National Park of Canada	CAN	II	15.03	0.7	1.0	0.5	61	84	36	1	1	1	CTOC	CTOC	Sheen	DTOC	CTOC	Sheen
SAM East	Marine Protected Area	USA	V	2,799.76	0.7	2.4	0.5	82	120	49	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Offshore	Closure Area	USA	V	264.21	0.5	1.0	0.5	101	116	67	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Great South Channel	Restricted Gillnet Area	USA	V	816.31	0.5	1.0	0.5	91	120	69	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Northern Nearshore Trap/Pot Waters Area	Marine Protected Area	USA	V	1,686.64	0.5	1.0	0.5	91	119	53	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Great South Channel Restricted Trap/Pot Area	Marine Protected Area	USA	V	956.74	0.5	1.0	0.5	89	120	69	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Southern Mid-Atlantic Waters	Closure Area	USA	V	610.31	0.5	1.0	0.5	109	120	93	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Mid-Atlantic Coastal Waters	Marine Protected Area	USA	V	931.19	0.5	1.0	0.5	111	120	93	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Waters off New Jersey	Closure	USA	V	312.46	0.5	0.5	0.5	115	120	101	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
SAM West	Marine Protected Area	USA	V	163.96	0.5	0.5	0.5	114	119	106	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Southern Nearshore Trap/Pot Waters	Marine Protected Area	USA	V	318.75	0.5	0.5	0.5	115	120	98	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Cape Cod South	Closure Area	USA	V	289.24	0.5	0.5	0.5	104	118	73	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Great South Channel Sliver	Restricted Area	USA	V	140.24	0.5	0.5	0.5	72	117	69	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Canso Coastal Barrens	Wilderness Area	CAN	Ib	0.08	0.5	0.5	0.5	58	58	58	1	1	1	Rainbow	Rainbow	Rainbow	Rainbow	Rainbow	Rainbow
Grand Codroy Estuary	Ramsar Site, Wetland of International Importance	CAN	Not Reported	5.26	0.5	0.5	0.5	111	111	111	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Isthme de Miquelon-langlade	Terrain acquis par le Conservatoire du Littoral	FRA	IV	0.09	0.5	0.5	0.5	94	94	94	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Little Thatch Island	Local Land Trust Preserve	USA	V	0.003	0.5	0.5	0.5	114	114	114	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Mid-Coast	Closure Area	USA	V	137.35	0.5	0.5	0.5	101	101	101	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Northeast	Closure Area	USA	V	23.92	0.5	0.5	0.5	82	109	73	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Northern Inshore State Trap/Pot Waters Area	Marine Protected Area	USA	V	9.54	0.5	0.5	0.5	114	114	114	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Scatarie Island	Wilderness Area	CAN	Ib	0.23	0.5	0.5	0.5	62	62	62	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Terence Bay	Wilderness Area	CAN	Ib	4.90	0.5	0.5	0.5	43	45	41	1	1	1	CTOC	CTOC	CTOC	CTOC	CTOC	CTOC

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold

Table A5.24

Surface Oiling Intersects with EBSAs

Name	Sum of Intersect Area (Sq km)	% Surface EBSA Area contacted by emulsified oil > 0.04 micron thickness	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Scotian Slope	72,678	100%	74.4	100.0	16.2	8	37	1	11	21	3	DTOC	CTOC	Sheen	Rainbow	DTOC	Sheen
Haddock Box	12,797	100%	57.0	92.4	24.8	8	17	2	10	16	4	DTOC	CTOC	Rainbow	Rainbow	Metallic	Sheen
Emerald Western Sable Banks Complex	17,929	100%	55.4	97.1	16.2	8	19	2	9	16	3	CTOC	CTOC	Rainbow	Metallic	Metallic	Sheen
Eastern Scotian Shelf Canyons	7,446	100%	44.5	75.2	17.6	13	24	6	8	16	2	DTOC	CTOC	Rainbow	Rainbow	Metallic	Sheen
Emerald Basin and the Scotian Gulf	8,527	100%	34.9	79.0	13.8	15	25	5	7	14	3	Metallic	CTOC	Rainbow	Rainbow	Metallic	Sheen
Northeast Channel	2,592	100%	33.6	46.2	14.8	18	29	9	6	14	2	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Northeast Channel Coral Conservation Area - NEC restricted bottom fishing zone	392	100%	31.1	38.1	24.3	19	27	13	4	6	2	Rainbow	Rainbow	Rainbow	Sheen	Sheen	Sheen
Northeast Channel Coral Conservation Area	425	100%	30.5	38.1	23.3	19	29	13	4	6	2	Rainbow	Rainbow	Rainbow	Sheen	Sheen	Sheen
Laurentian Channel Cold Seep	50	100%	29.5	32.9	27.1	22	31	20	4	4	3	Metallic	Metallic	Rainbow	Sheen	Rainbow	Sheen
Sambro Bank Sponge Conservation Area	63	100%	29.5	31.9	27.1	19	20	18	7	11	5	Rainbow	Metallic	Rainbow	Sheen	Rainbow	Sheen
Northeast Channel Coral Conservation Area - NEC limited bottom fishing zone	34	100%	27.7	30.0	23.3	20	29	20	3	3	2	Rainbow	Rainbow	Rainbow	Sheen	Sheen	Sheen
Stone Fence and Laurentian Environs	45	100%	24.6	31.0	21.9	17	18	14	6	7	5	Metallic	Metallic	Rainbow	Rainbow	Rainbow	Sheen
Stone Fence coral conservation area	15	100%	23.7	27.6	21.9	18	18	17	6	7	5	Rainbow	Metallic	Rainbow	Rainbow	Rainbow	Sheen
Emerald Sponge Conservation Area	197	100%	22.9	28.6	18.6	16	22	12	6	10	4	Metallic	CTOC	Rainbow	Rainbow	Metallic	Rainbow
Sable Island Shoals	1,246	96%	20.1	35.7	4.3	12	27	7	3	5	1	CTOC	CTOC	Metallic	Metallic	DTOC	Rainbow
Browns Bank	4,313	100%	16.4	35.2	6.2	24	36	14	4	9	2	Rainbow	CTOC	Sheen	Rainbow	Metallic	Sheen
Lobster Fisheries Act Closure Area	6,561	100%	15.3	35.7	6.2	24	36	14	4	9	2	Rainbow	CTOC	Sheen	Sheen	Metallic	Sheen
North Atlantic Right Whale - Roseway Basin	3,319	100%	14.88	25.24	6.19	21	33	15	4	8	2	Rainbow	CTOC	Sheen	Sheen	Metallic	Sheen
Middle Bank	2,753	100%	14.3	19.5	7.6	18	28	11	5	8	3	DTOC	CTOC	Rainbow	Metallic	DTOC	Rainbow
Georges Bank	14,417	99%	13.91	40.00	0.48	34	99	9	3	9	1	Rainbow	Metallic	Sheen	Sheen	Rainbow	Sheen
Bowtie	4,068	100%	13.0	21.9	3.3	22	37	13	4	8	1	Rainbow	DTOC	Sheen	Sheen	Rainbow	Sheen
Roseway Basin	3,162	100%	12.8	21.4	3.8	23	37	16	4	8	1	Rainbow	DTOC	Sheen	Sheen	Rainbow	Sheen
Eastern Shoal	3,402	100%	12.5	34.8	0.5	30	115	15	4	9	1	Metallic	CTOC	Sheen	Rainbow	DTOC	Sheen
NAFO Fishing Closure Area (1) Sponge, Coral & Seapen Protected Areas	14,311	100%	9.6	22.4	2.9	40	62	23	2	8	1	Rainbow	CTOC	Sheen	Sheen	Metallic	Sheen
Canadian portion of Georges Bank	7,022	100%	8.5	31.4	0.5	37	73	13	2	6	1	Rainbow	Metallic	Sheen	Sheen	Rainbow	Sheen
NAFO Fishing Closure Area (4) Seamount Areas	14,890	92%	8.1	44.3	0.5	68	120	45	2	11	1	Sheen	Rainbow	Sheen	Sheen	Rainbow	Sheen
Laurentian Channel slope	10,403	48%	7.8	31.9	0.5	42	120	12	2	12	1	Metallic	CTOC	Sheen	Rainbow	CTOC	Sheen
Laurentian Channel (AOI)	11,778	71%	4.6	19.5	0.5	42	118	16	2	6	1	Rainbow	CTOC	Sheen	Sheen	Metallic	Sheen
Canso Bank and Canso Basin	4,048	98%	4.6	12.9	0.5	36	73	15	2	6	1	Metallic	CTOC	Sheen	Metallic	DTOC	Sheen
NAFO Fishing Closure Area (5) Seamount Areas	258,231	93%	3.7	22.9	0.5	44	120	12	1	6	1	Sheen	Metallic	Sheen	Sheen	Rainbow	Sheen
Misaine Bank	3,986	87%	1.7	4.3	0.5	44	99	22	2	5	1	Metallic	CTOC	Sheen	Metallic	CTOC	Sheen
NAFO Fishing Closure Area (3) Seamount Areas	35,140	84%	1.3	5.2	0.5	77	120	47	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
North Atlantic Right Whale - Grand Manan Basin	292	39%	0.64	1.43	0.48	83	113	57	1	2	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
Jordan Basin and the Rock Garden	515	28%	0.6	1.4	0.5	78	119	46	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
St. Anns Bank	363	8%	0.6	1.0	0.5	70	112	54	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen
St Anns Bank Area of Interest	511	12%	0.5	1.0	0.5	87	117	54	1	1	1	Sheen	Sheen	Sheen	Sheen	Sheen	Sheen

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold

Table A5.25

Surface Oiling Intersects with World Maritime Boundaries

Name	Boundary Intersect Length (km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Max Time-Averaged Bonn Thickness	Max of Max Time-Averaged Bonn Thickness	Min of Max Time-Averaged Bonn Thickness	Average of Average Time-Averaged Bonn Thickness	Max of Average Time-Averaged Bonn Thickness	Min of Average Time-Averaged Bonn Thickness
Canada - Atlantic Ocean	1,481	50.6	88.1	0.5	21	112	7	6	12	1	Metallic	CTOC	Sheen	Rainbow	Metallic	Sheen
Canada - Saint-Pierre et Miquelon	830	16.4	63.8	0.5	33	117	12	4	14	1	Metallic	CTOC	Sheen	Rainbow	Metallic	Sheen
Canada - United States	314	9.9	27.6	0.5	44	118	18	3	10	1	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
United States - Atlantic Ocean	372	7.2	25.2	0.5	54	120	21	3	10	1	Rainbow	Rainbow	Sheen	Sheen	Sheen	Sheen
Bermuda - Atlantic Ocean	258	0.7	1.4	0.5	73	116	36	1	3	1	Sheen	Rainbow	Sheen	Sheen	Sheen	Sheen

* Probability of sea surface emulsified oil thicknesses exceeding the 0.04 µm (BAOAC "Sheen") thickness threshold

Oil in the Upper water column (<100 m water depth)

Table A5.26

Water Column Dispersed and Dissolved Oil Intersects with Protected Areas

Name	Designation	Country	IUCN	Sum of Intersect Area (Sq km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Gully Marine Protected Area	Marine Protected Area	CAN	Not Reported	2,370	6.51	17.14	0.48	14	33	7	3	6	1	192	550	75	1	33	0
Offshore Trap/Pot Waters	Marine Protected Area	USA	V	5,185	1.68	6.67	0.48	41	90	20	1	3	1	95	248	58	0	0	0
Other Northeast	Gillnet Waters Area	USA	V	5,183	1.68	6.67	0.48	41	90	20	1	3	1	94	248	58	0	0	0
Sable Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	CAN	Ia	5	0.71	1.90	0.48	27	40	14	1	2	1	90	110	63	0	0	0
Sable Island National Park Reserve of Canada	National Park Reserve of Canada	CAN	II	5	0.70	1.90	0.48	27	41	14	1	2	1	86	110	59	0	0	0
Oceanographer Canyon	Closed Area	USA	V	8	0.48	0.48	0.48	64	64	64	1	1	1	61	61	61	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold

Table A5.27

Water Column Dispersed and Dissolved Oil Intersects with EBSAs

Name	Sum of Intersect Area (Sq km)	% Surface EBSA Area contacted by THC > 58 ppb	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Scotian Slope	68,691	94.7%	36.01	100.00	0.48	10	83	1	8	30	1	380	2120	58	3	177	0
Emerald Western Sable Banks Complex	17,831	99.6%	12.69	61.90	0.48	11	50	2	5	19	1	248	1225	58	1	33	0
Haddock Box	12,672	99.2%	10.83	50.95	0.48	11	50	2	5	19	1	235	1225	58	1	33	0
Eastern Scotian Shelf Canyons	7,052	94.9%	4.41	26.67	0.48	19	59	6	2	13	1	159	632	58	0	33	0
Stone Fence coral conservation area	15	100.3%	3.49	4.76	1.43	24	30	17	1	2	1	111	158	77	0	0	0
Stone Fence and Laurentian Environs	41	91.9%	3.12	4.76	1.43	23	30	17	1	2	1	106	158	77	0	0	0
Emerald Basin and the Scotian Gulf	7,298	85.7%	2.13	21.90	0.48	24	74	6	2	8	1	129	579	58	0	5	0
Northeast Channel	1,705	65.9%	2.03	7.14	0.48	30	73	10	2	5	1	102	365	58	0	1	0
Sable Island Shoals	981	75.7%	1.74	6.67	0.48	23	43	9	1	4	1	116	493	59	0	7	0
Northeast Channel Coral Conservation Ar	243	57.1%	1.41	3.81	0.48	35	52	12	1	2	1	95	203	59	0	1	0
Northeast Channel Coral Conservation Ar	243	62.1%	1.41	3.81	0.48	35	52	12	1	2	1	95	203	59	0	1	0
Emerald Sponge Conservation Area	191	97.1%	1.35	3.81	0.48	24	60	15	2	4	1	135	520	61	0	0	0
Middle Bank	2,469	89.8%	1.30	2.86	0.48	33	53	12	1	4	1	109	490	59	0	0	0
Georges Bank	1,700	11.7%	1.10	3.81	0.48	37	83	12	1	3	1	79	203	58	0	1	0
Eastern Shoal	853	25.1%	1.08	4.29	0.48	32	56	15	1	3	1	87	183	59	0	0	0
Sambro Bank Sponge Conservation Area	51	82.3%	1.04	1.43	0.48	35	48	29	1	2	1	97	116	61	0	0	0
Laurentian Channel slope	655	3.0%	0.93	3.33	0.48	36	91	17	1	2	1	84	219	58	0	0	0
Laurentian Channel Cold Seep	50	100.1%	0.64	0.95	0.48	32	46	23	1	1	1	107	488	84	0	0	0
Canso Bank and Canso Basin	864	21.0%	0.63	1.43	0.48	44	65	18	1	2	1	122	561	59	0	0	0
Browns Bank	135	3.1%	0.62	0.95	0.48	36	53	18	1	1	1	86	100	62	0	0	0
Lobster Fisheries Act Closure Area	262	4.0%	0.52	0.95	0.48	37	65	18	1	1	1	87	235	58	0	0	0
North Atlantic Right Whale - Roseway Ba	262	7.9%	0.51	0.95	0.48	39	50	12	1	1	1	96	111	58	0	0	0
Misaine Bank	238	5.2%	0.51	0.95	0.48	49	65	25	1	1	1	78	109	59	0	0	0
Laurentian Channel (AOI)	106	0.6%	0.51	0.95	0.48	56	62	40	1	1	1	79	137	58	0	0	0
NAFO Fishing Closure Area (5) Seamount	1,185	0.4%	0.51	0.95	0.48	40	73	12	1	1	1	82	185	58	0	0	0
Roseway Basin	120	3.8%	0.48	0.48	0.48	35	50	12	1	1	1	84	227	58	0	0	0
NAFO Fishing Closure Area (1) Sponge, C	13	0.1%	0.48	0.48	0.48	58	69	52	1	1	1	111	176	78	0	0	0
St. Anns Bank	7	0.2%	0.48	0.48	0.48	59	59	59	1	1	1	85	85	85	0	0	0
St Anns Bank Area of Interest	7	0.2%	0.48	0.48	0.48	59	59	59	1	1	1	85	85	85	0	0	0
Canadian portion of Georges Bank	85	1.2%	0.48	0.48	0.48	58	77	39	1	1	1	65	132	58	0	0	0
Bowtie	131	3.2%	0.48	0.48	0.48	28	50	12	1	1	1	63	89	58	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold

Table A5.28

Water Column Dispersed and Dissolved Oil Intersects with World Maritime Boundaries

Row Labels	Boundary Intersect Length (km)	Average of Probability (%)	Max of Probability (%)	Min of Probability (%)	Average of Min Arrival Time (days)	Max of Min Arrival Time (days)	Min of Min Arrival Time (days)	Average of Maximum Exposure Time (days)	Max of Maximum Exposure Time (days)	Min of Maximum Exposure Time (days)	Average of Maximum Time-Averaged TPH Concentration (ppb)	Max of Maximum Time-Averaged TPH Concentration (ppb)	Min of Maximum Time-Averaged TPH Concentration (ppb)	Average of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Max of Maximum Time-Averaged Dissolved Oil Concentration (ppb)	Min of Maximum Time-Averaged Dissolved Oil Concentration (ppb)
Canada - Atlantic Ocean	1,012	3.51	15.24	0.48	22	54	8	2	5	1	147	532	59	0	3	0
Grand Total	1,292	3.15	15.24	0.48	24	90	8	2	5	1	140	547	58	0	3	0
Canada - United States	69	2.02	5.24	0.48	37	49	24	1	3	1	99	175	64	0	0	0
Canada - Saint-Pierre et Miquelon	196	1.48	3.33	0.48	28	73	12	1	3	1	117	547	58	0	1	0
United States - Atlantic Ocean	15	0.50	0.95	0.48	39	90	35	1	1	1	78	161	59	0	0	0

* Probability of THC (Dispersed and dissolved oil) in the water column exceeding the 58 ppb concentration threshold