Hebron

HEBRON PROJECT

Comprehensive Study Report:
Sections 14.2 and 14.3 (revised)
February 2011

ExxonMobil Chevron Suncor Energy Statoil nalcor energy

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

14 ACCIDENTAL HYDROCARBON SPILL EVENTS

14.1 Hydrocarbon Spill Probabilities

14.2 Fate and Behaviour of Hebron Hydrocarbon Spills in the Nearshore Study Area (Trajectory Modelling)

A spill trajectory modelling exercise, specific for Hebron Project activities in Bull Arm, Trninty Bay, was undertaken. This section provides an overview of the results of the modelling. The full report is provided in Applied Science Associates (ASA) 2010a.

The objective of this work is to undertake spill trajectory modelling for the accidental release of marine diesel fuels in Bull Arm, Trinity Bay. ASA used its SIMAP model system to simulate spills of fuel oil in Bull Arm, Trinity Bay. The model uses wind data obtained from model hindcasts and field measurements and current data from a hydrodynamic model. The SIMAP model was used in stochastic and deterministic modes to determine the range of possible water surface, subsurface and shoreline hydrocarbon contact predicted to occur. A complete description of the spill trajectory model is provided in the full report (ASA 2010a).

14.2.1 Model Inputs and Spill Scenarios

In the event of an accidental release of diesel at the Bull Arm construction site, the primary objective would be to stop the flow and implement spill countermeasures as quickly as possible. Spill response equipment will be contained on-site and staff will be trained to effectively respond to any accidental event.

Marine-based activities may primarily involve vessels that use standard marine diesel. The estimated maximum fuel storage capaticty is approximately 100 m^3 per vessel. The mating of the topsides with the GBS, and likely towout of the GBS to the offshore location, (single events) may require larger vessels that use a heavier marine diesel product, Intermediate fuel oil (IFO-180). The total fuel capacity of these vessels is approximately 1,000 m^3. Therefore, for the purposes of environmental assessment, two fuels were used in the simulation of spills. Simulations were performed for both summer and winter conditions. The following spill scenarios were modelled.

- Instantaneous surface release of 100 m^3 of marine diesel fuel, summer, winter (no ice), and winter with approximately 65 percent ice coverage (ice coverage in Bull Arm can range from 0 to 100 percent through the winter season, depending on the month and the severity of the winter. Vessel operations during the construction of the Hebron GBS will likely not occur when ice concentration exceeds 65 percent broken ice coverage; therefore, all winter spill scenarios with sea ice present assume that Bull Arm and Trinity Bay are covered with a 65 percent concentration.

- Instantaeous surface release of 1,000 m^3 of (IFO-180), summer, winter (no ice), and winter with approximately 65 percent ice coverage
- All models were run for 30 days

Two separate hydrodynamic simulations were carried out using the HYDROMAP model in order to capture the combined tide and wind-driven currents in Bull Arm and Trinity Bay. Tidal current simulations were conducted to develop tidally-driven surface currents over the entire region. Wind-driven current simulations were conducted for eight wind directions using a constant wind speed of 8 m/s and then added to the tidal current simulation to create a combined current. This results in a current field covering Trinity Bay and Bull Arm that accounts for tide and wind driven currents and is used to drive the oil spill simulations. A total of 18 scenarios were modelled for the nearshore area.

Spill trajectories were simulated for 30 days because at this point, the fuel oil has lost its most of its volatile components, has reached its minimum thickness, and if it has exited Trinity Bay, is moving out into the open sea by the end of the 30-day period.

14.2.2 Model Outputs

14.2.2.1 Stochastic Model Results

The stochastic model was used to determine the probability of finding diesel on the water surface, on the shoreline, and in the water column exceeding the following thickness and concentration thresholds:

- Surface diesel average thickness >0.01 mm (10 µm)
- Shoreline diesel average thickness over a shoreline segment >0.01 mm (10 µm)
- Subsurface diesel (entrained in water) average concentration >10 ppb

The stochastic analysis provides two types of information to describe the potential spills: 1) areas that might have oil contact and the associated probability; and 2) the shortest time required for hydrocarbons to reach any location and/or threshold in the areas predicted to have oil contact. This information is presented for surface oil, shoreline oil, and subsurface oil in maps and in summary tables in this report. Total hydrocarbons, the group of chemical that make up crude oil, are divided into two categories, aromatic hydrocarbons, the toxic component of oil, and aliphatic hydrocarbons. For this study only the non-dissolved total hydrocarbons are tracked.

All results describe probabilities of oil occurring at the suface, in the water column, or at the shoreline; they do not depict an actual spill event, nor do they include the use of any spill countermeasures (*e.g.*, booms, skimmer, dispersants).

SIMAP's stochastic simulation results provide insight into the probable behavior of potential oil spills under the environmental conditions expected to occur in the study area during each season. The 100 individual model simulations from each stochastic model scenario were ranked to determine the individual spill resulting in the 95th percentile for shoreline oiling, water surface oiling and for oil entrained in the water column. For example, the 95th percentile spill for surface oiling is the single spill resulting in a surface area oiled at a thickness exceeding 0.01mm that is greater than or equal to 95% of all spills simulated.

Summer winds are more often from the southwest, which can drive diesel onto the northeast coast of Bull Arm. Any diesel exiting Bull Arm in the summer will most likely be driven northeastward up Trinity Bay. Winter winds are most often from the northwest, which can move surface oil out of Bull Arm and onto the shoreline at the southern end of Trinity Bay, and less frequently towards the northeast and the mouth of Trinity Bay. The probability and minimal arrival time from a release of 100 m^3 marine diesel and 1,000 m^3 IFO-180 in summer and winter are provided in Figures 14-1 to 14-4. Note, for any of these simulations, they were modelled without the use of spill response equipment (i.e., booms, skimmers, dispersants, etc.).

The following figures do not represent the size of a potential spill; rather, the figures show the probability of finding 0.01 mm of diesel on the surface of the water at any location. Hence, the time for surface oiling, also shows the time for the probability of suface oiling to occur, and does not represent an actual slick. In addition, the results do not include the use of any spill countermeasures (i.e., booms, skimmers, absorbants, dispersants).

Entrained marine diesel oil is predicted to exceed a concentration of 10 ppb 100 percent of the time within Bull Arm during the summer and winter seasons. Probabilities drop quickly outside of Bull Arm to 10 to 30 percent during summer and winter seasons for a small area of southwest Trinity Bay. IFO-180 is a highly viscous fuel that shows almost no entrainment into the water column.

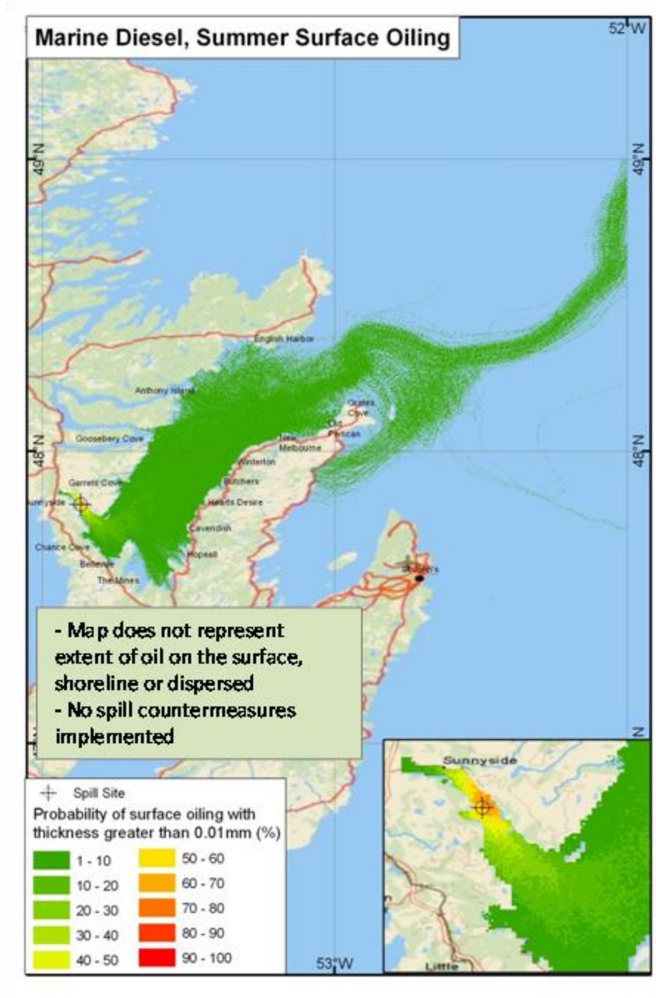


Figure 14-1 Probability of Surface Contact from a Release of 100 m^3 of Marine Diesel at the Bull Arm Site in Summer

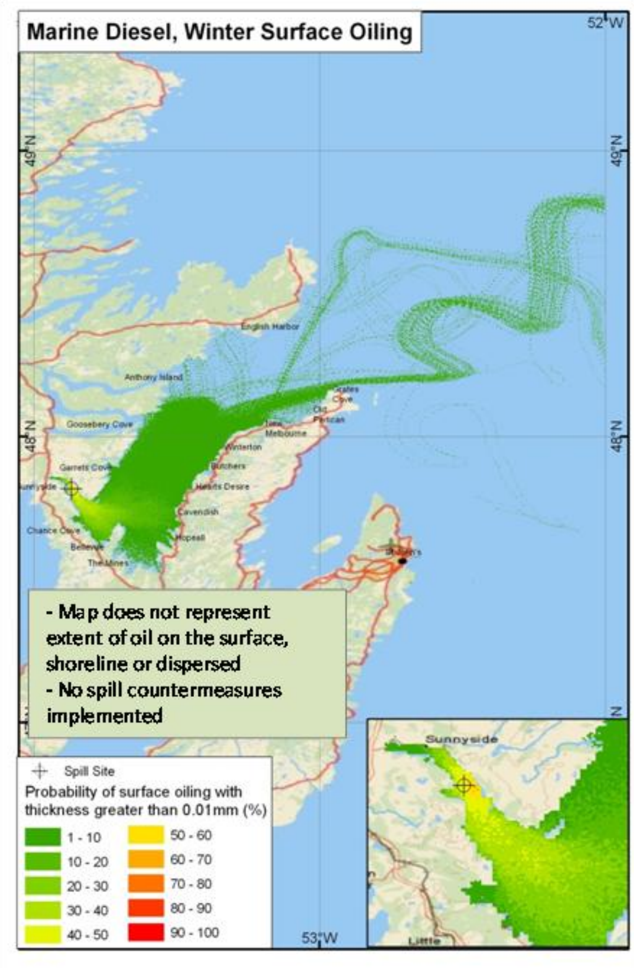


Figure 14-2 Probability of Surface Contact from a Release of 100 m^3 of Marine Diesel at the Bull Arm Site in Winter

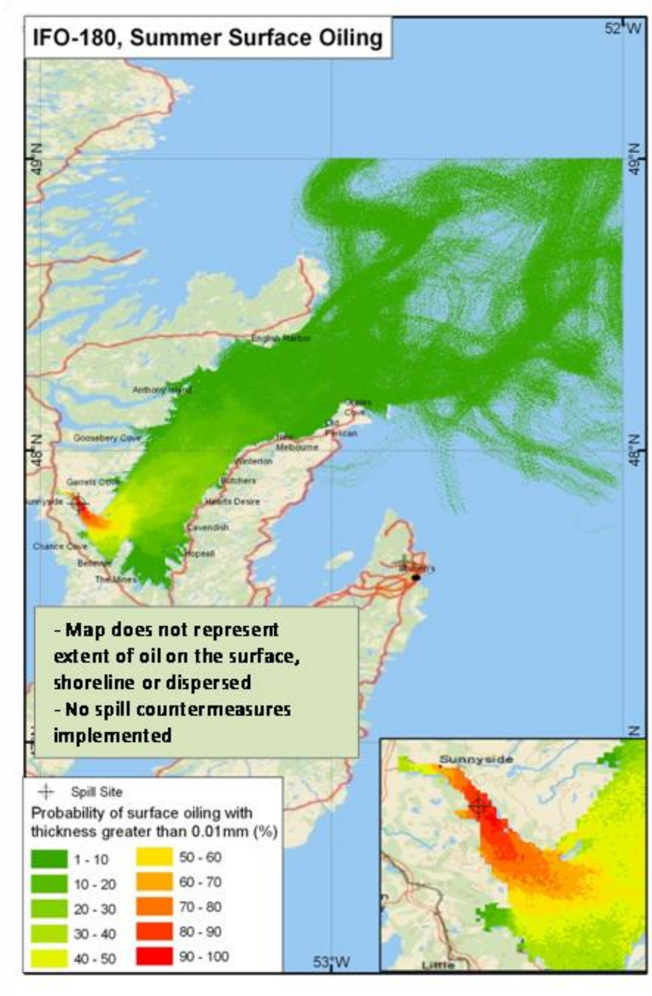


Figure 14-3 Probability of Surface Contact from a Release of 1,000 m^3 of Intermediate Fuel Oil (IFO-180) at the Bull Arm Site in Summer

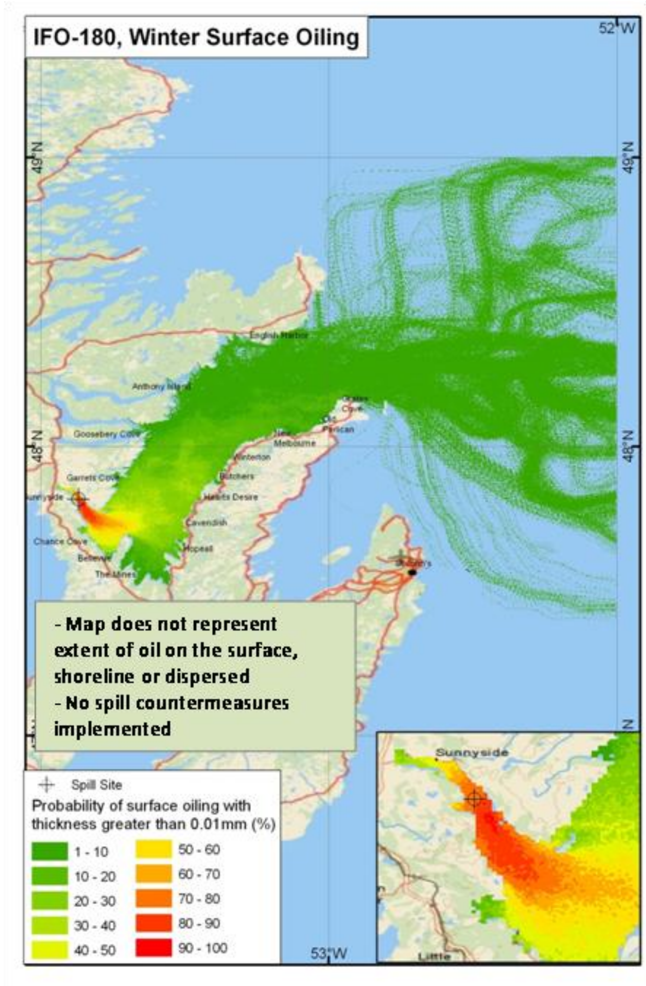


Figure 14-4 Probability of Surface Contact from a Release of 1,000 m^3 of Intermediate Fuel Oil (IFO-180) at the Bull Arm Site in Winter

Without the use of spill countermeasures, the smaller volume 100 m^3 marine diesel spills are predicted to have a 10 to 20 percent probability of leaving Bull Arm during the summer and a 30 to 40 percent probability of leaving Bull Arm under winter conditions. Spills of 1,000 m^3 of IFO-180 have a 60 to 70 percent probability of leaving Bull Arm during the summer, and a 70 to 80 percent probability of entering Trinity Bay during the winter season.

The model predicts that oil from both the marine diesel and IFO-180 spills have a small (<5 percent) probability of leaving Trinity Bay (via the northeast corner of the model grid. This oil is >10 days old, the volatile components have evaporated, the oil is at the minimum thickness and moving into open ocean.

Marine diesel has a 60 percent chance of making contact with the Bull Arm shoreline in summer, and a predicted 30 percent probability in the winter season. IFO-180 spills have a 100 percent chance of contacting the Bull Arm shoreline in the summer and a 90 percent chance during the winter season. The minimum time to potential shoreline contact is 0 to 1 days within Bull Arm.

14.2.2.2 Deterministic Model Results

The deterministic trajectory and fate simulations using the 3D Fates Model are performed for the 95th percentile simulations identified in each stochastic analysis as defined in Section 14.2.2. The 95th percentile result is chosen because it represents the upper end of the possible results (only 5% of simulations result in a larger value). The 18 simulations (three oil threshold criteria times six spill scenarios) provide a time history of oil weathering over the duration of the spill, expressed as the volume of spilled oil on the water surface, on the shore, evaporated, entrained in the water column and decayed.

Each scenario simulates the movement and weathering of the spilled oil for a period of thirty days, a length of time sufficient to allow for all of the weathering processes to occur. The mass balance results for all of the deterministic spill scenarios at the end of the 30-day simulation are provided in Table 14-2.

Table 14-1 Summary of Deterministic Model Mass Balance at the End of the 30-day Simulations

Oil Release	95th Percentile for:	Season	Surface Oil (m^3)	Evaporated Oil (m^3)	Entrained Oil (m^3)	Oil Ashore (m^3)	Decayed Oil (m^3)
			>0.01 mm Thickness		> 10 ppb	>0.01 mm Thickness	
100 m^3 Marine Diesel	Sea Surface Oiling	Summer	0	52	19	16	13
		Winter - No Ice	0	13	65	0	22
		Winter – Ice	0	49	0	44	7
	Shoreline Oiling	Summer	0	56	18	14	12
		Winter - No Ice	0	25	46	10	19
		Winter – Ice	0	50	1	42	7
	Subsurface Oiling	Summer	0	18	59	2	21
		Winter - No Ice	0	11	66	1	22
		Winter – Ice	0	51	1	42	6
1,000 m^3 IFO-180	Sea Surface Oiling	Summer*	30	170	0	420	220
		Winter - No Ice*	20	160	0	510	210
		Winter – Ice	0	160	25	655	160
	Shoreline Oiling	Summer	0	170	0	610	220
		Winter - No Ice*	0	160	0	610	220
		Winter – Ice	0	180	20	675	125
	Subsurface Oiling	Summer*	0	155	0	475	200
		Winter - No Ice	25	155	0	570	210
		Winter – Ice	80	170	10	570	170

Results of the deterministic modelling for shoreline exposure to hydrocarbons with average thickness greater than 0.01 mm are depicted in Figures 14-5 to 14-10.

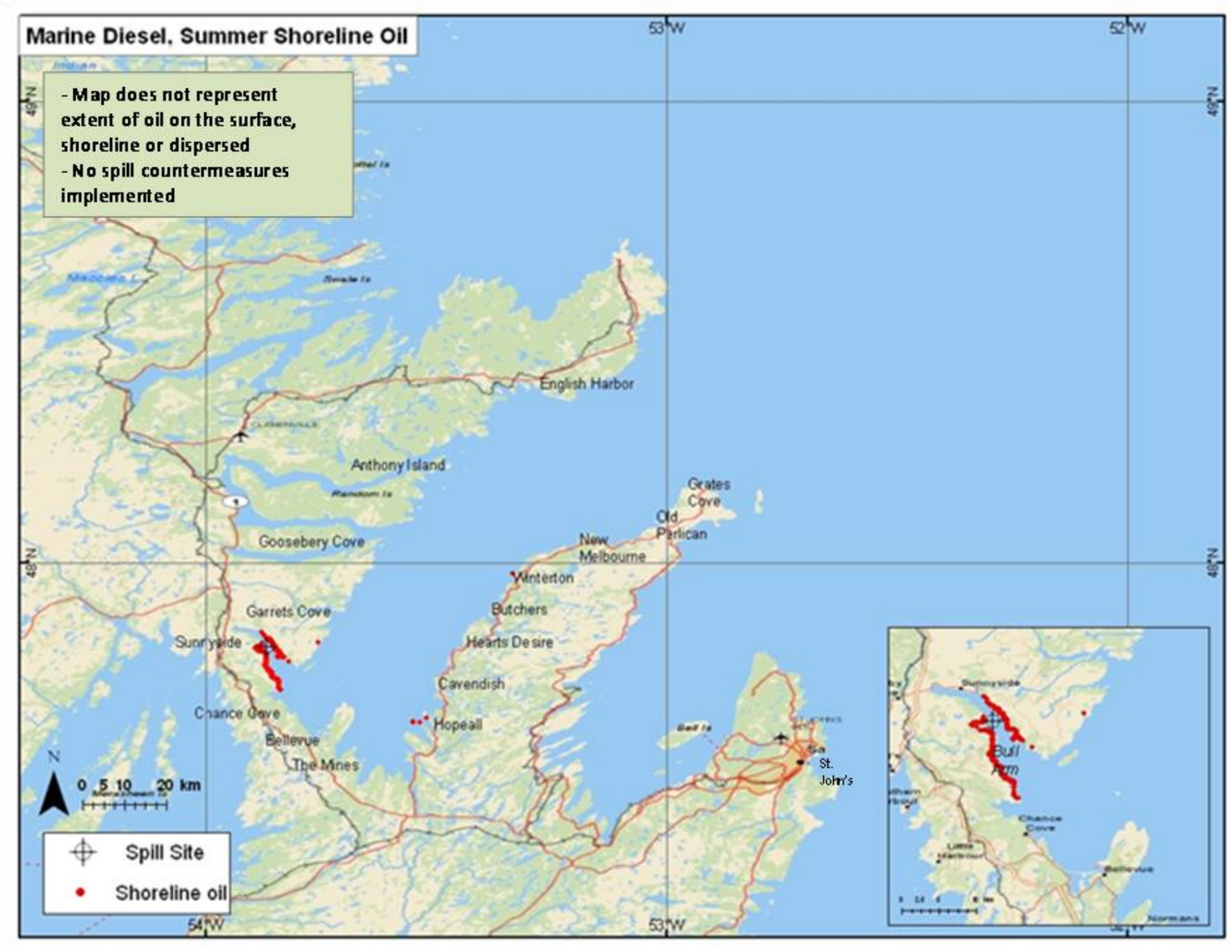
If a spill of marine diesel or IFO-180 were to occur, and spill countermeasures were not implemented, the spill trajectory model predicts the following results. Spills of 100 m^3 of marine diesel, representing the 95^{th} percentile for surface contact, are predicted to remain entirely within Trinity Bay during the winter and to result in small amounts of weathered oil leaving the Bay during summer. In the winter season, approximately 12 percent of the diesel fuel is predicted to evaporate by the end of the 30-day simulation; more than 50 percent of the diesel fuel is predicted to evaporate in the summer season spill. The difference in evaporation is due to higher winter wind speeds, which entrain more oil in the water column, making it unavailable for evaporation.

Without the implementation of spill countermeaures, spills of 100 m^3 of marine diesel representing the 95^{th} percentile for shoreline contact are predicted to affect much of the Bull Arm shoreline and isolated segments of the Trinity Bay shoreline in both the summer and winter seasons.

Spills of 100 m^3 of marine diesel representing the 95^{th} percentile for entrained oil are predicted to exceed the 10 ppb concentration threshold for all of Bull Arm and for an area of southwest Trinity Bay in both the summer and winter seasons.

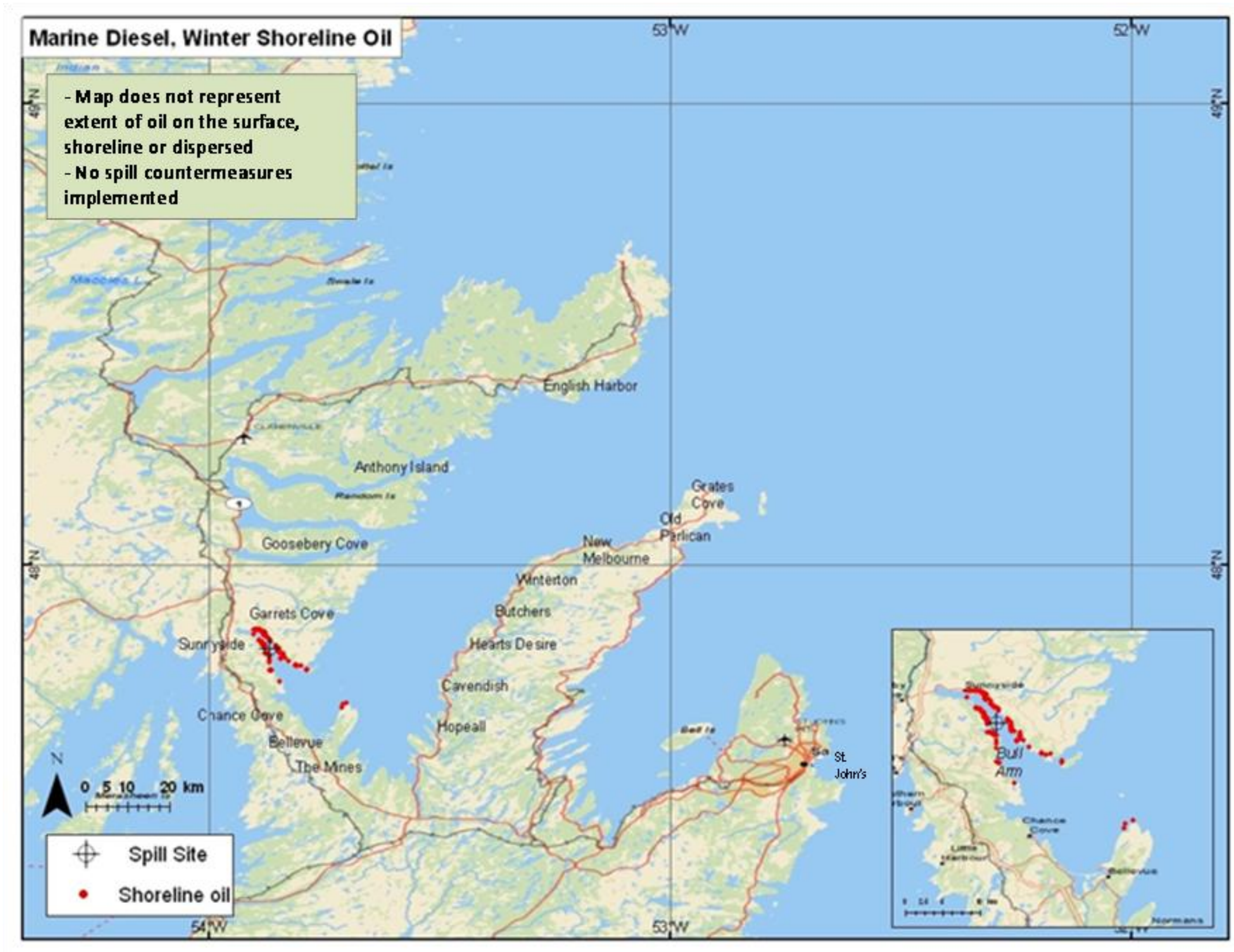
The presence of 65 percent ice cover reduces the sea surface area covered by marine diesel oil but results in more widespread shoreline effects. The presence of ice on the sea surface restricts the movement of surface oil, resulting in a reduced surface oil footprint. Because the surface oil footprint is reduced, the thickness of that surface slick must be increased to contain the same volume of oil. It is likely that the thicker surface slick contains sufficient oil volume so that when it goes ashore, the thickness threshold for shoreline contact is exceeded. Ice cover substantially reduces the area predicted to exceed the entrained oil concentration of 10 ppb. This is because the presence of 65 percent ice cover reduces the effectiveness of the wind to entrain oil into the water column.

Spills of 1,000 m^3 IFO-180 are predicted to make surface contact in Bull Arm and extend the length of Trinity Bay during the summer and winter seasons. Approximately 16 percent of the IFO-180 is predicted to evaporate by the end of the 30-day simulation during both the summer and winter seasons. The IFO-180 is highly viscous, which limits its entrainment and enhances conditions for evaporation.



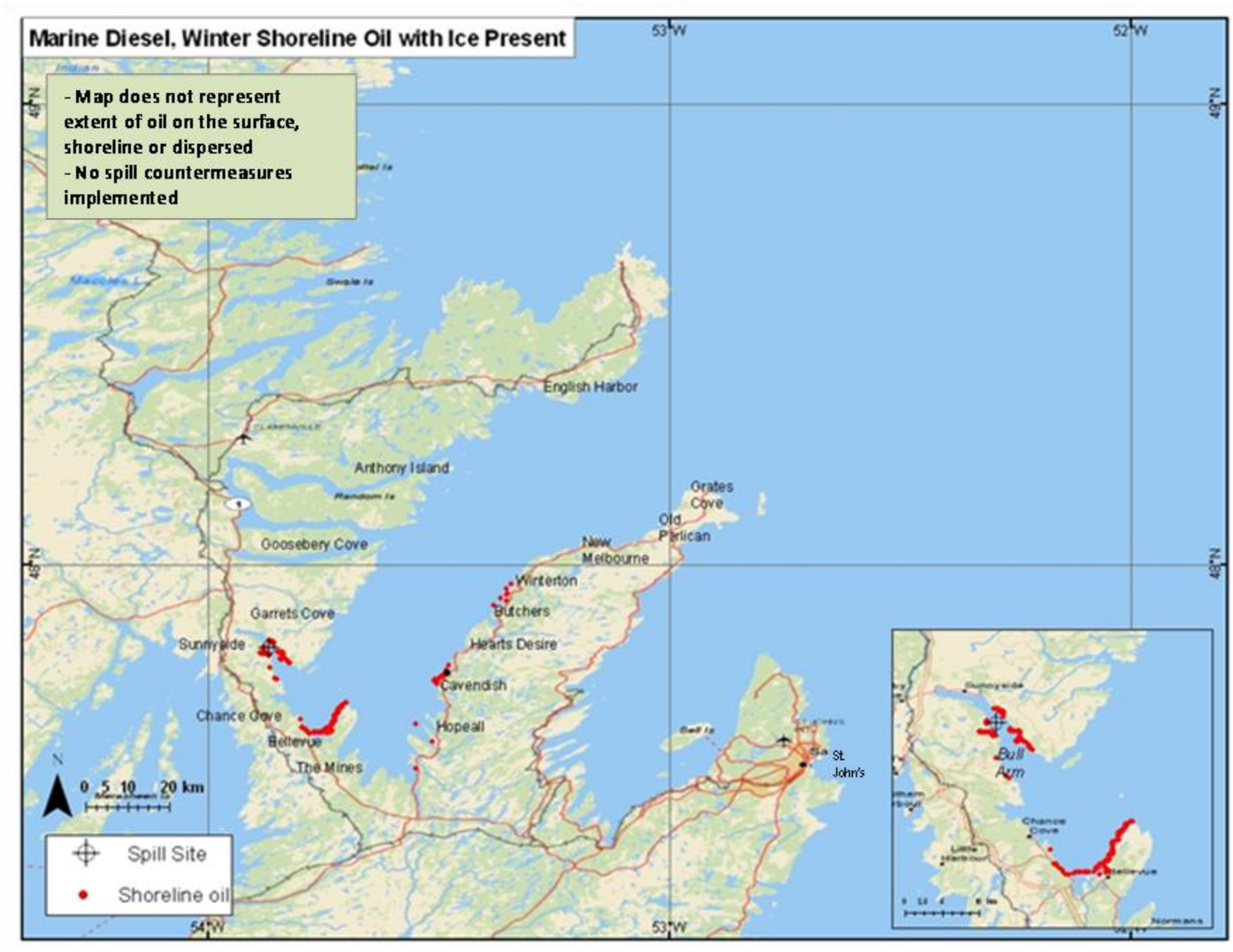
Note: Red color highlights the areas of predicted shoreline contact.

Figure 14-5 Shoreline Exposure to Hydrocarbons (mm) for 95th Percentile Run with Average Thickness Greater than 0.01 mm for a 100 m^3 Release of Marine Diesel in the Summer



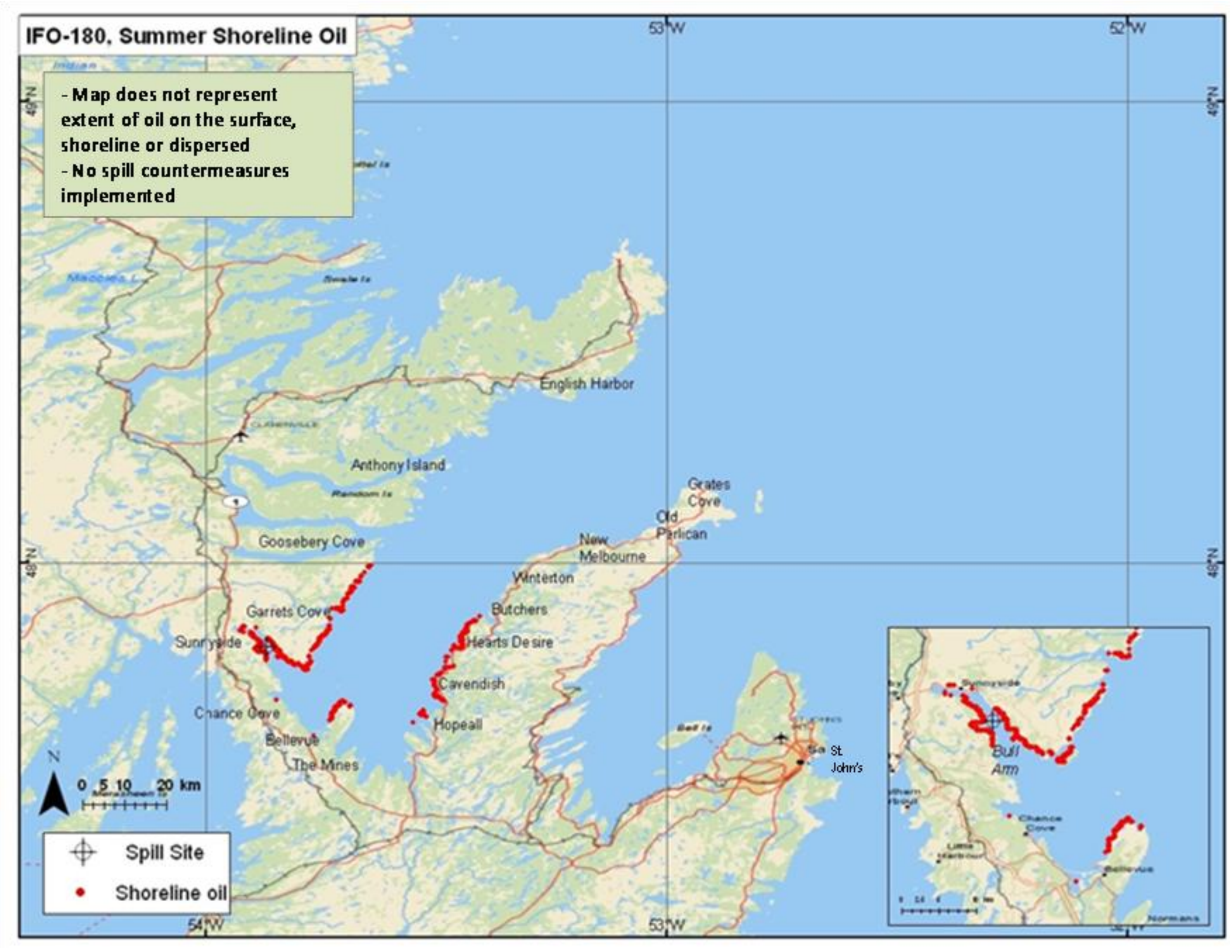
Note: Red color highlights the areas of predicted shoreline contact.

Figure 14-6 Shoreline Exposure to Hydrocarbons (mm) for 95th Percentile Run with Average Thickness Greater than 0.01 mm for a 100 m^3 Release of Marine Diesel in the Winter



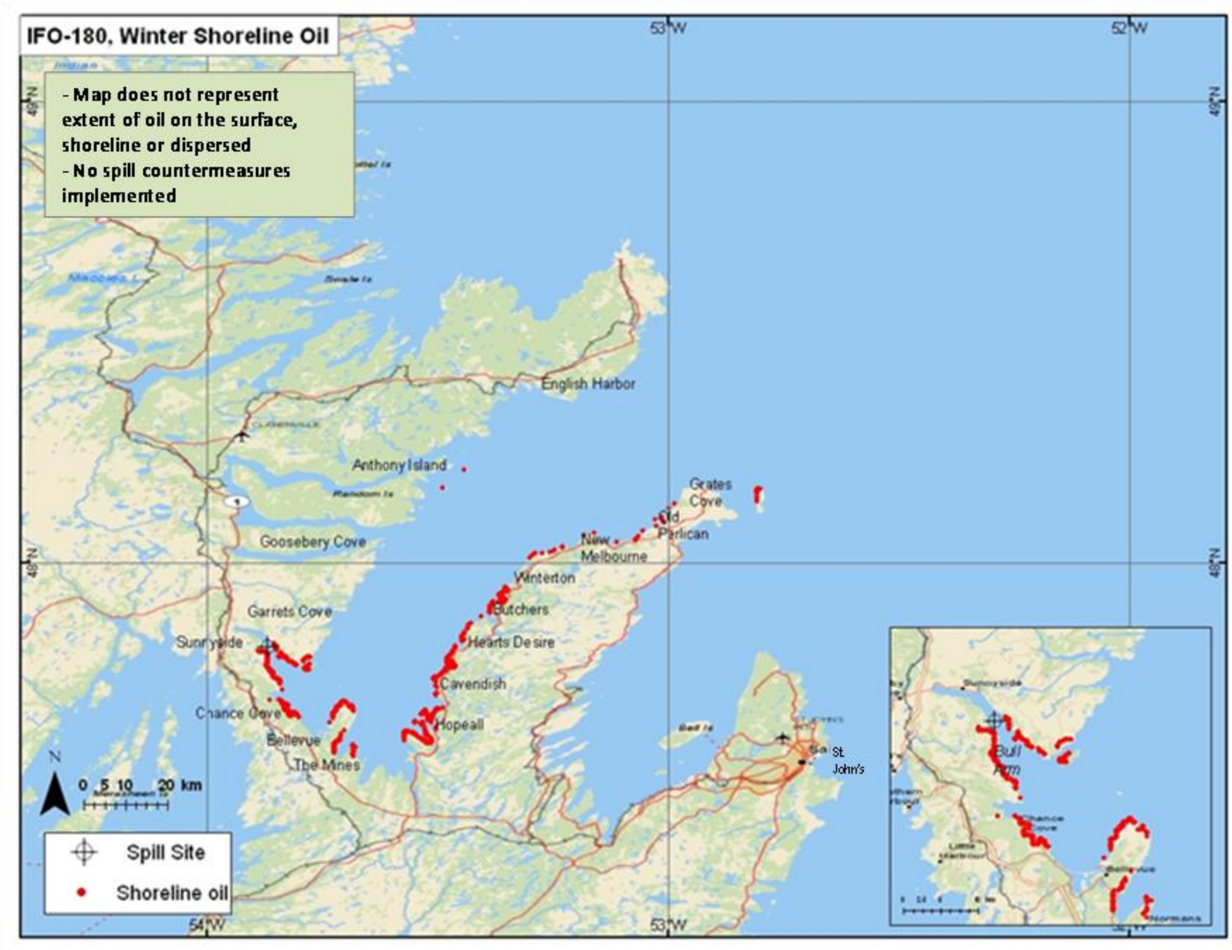
Note: Red color highlights the areas of predicted shoreline contact.

Figure 14-7 Shoreline Exposure to Hydrocarbons (mm) for 95th Percentile Run with Average Thickness Greater than 0.01 mm for a 100 m^3 Release of Marine Diesel in the Winter with 65% Ice Coverage



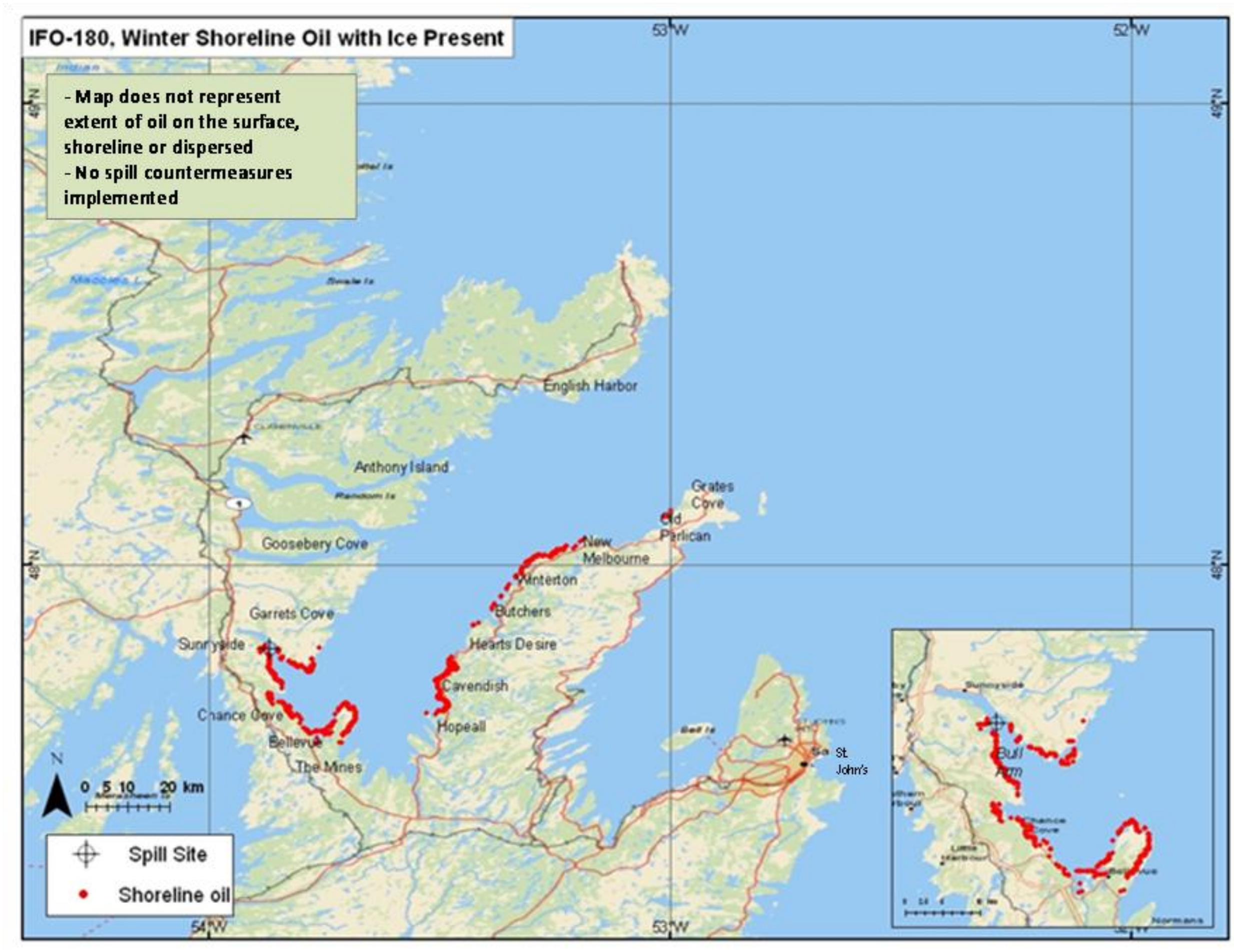
Note: Red color highlights the areas of predicted shoreline contact.

Figure 14-8 Shoreline Exposure to Hydrocarbons (mm) for 95th Percentile Run with Average Thickness Greater than 0.01 mm for a 1,000 m^3 Release of IFO-180 in the Summer



Note: Red color highlights the areas of predicted shoreline contact.

Figure 14-9 Shoreline Exposure to Hydrocarbons (mm) for 95th Percentile Run with Average Thickness Greater than 0.01 mm for a 1,000 m^3 Release of IFO-180 in the Winter



Note: Red color highlights the areas of predicted shoreline contact.

Figure 14-10 Shoreline Exposure to Hydrocarbons (mm) for 95th Percentile Run with Average Thickness Greater than 0.01 mm for a 1,000 m^3 Release of IFO-180 in the Winter with 65% Ice Coverage

Spills of 1,000 m^3 of IFO-180, representing the 95^{th} percentile for shoreline contact, are predicted to make contact with much of the Bull Arm shoreline and segments of the Trinity Bay shoreline in both the summer and winter seasons. The summer shoreline contact is restricted to the east and west shorelines in the southern half of Trinity Bay. Winter season shoreline contact is restricted to primarily the east coast of Trinity Bay.

Spills of 1,000 m^3 of IFO-180, representing the 95^{th} percentile for entrained oil, are predicted to exceed the 10 ppb concentration threshold for small areas of Bull Arm close to the release site. The IFO-180 is highly viscous and does not readily entrain.

The presence of 65 percent ice cover reduces the sea surface area covered by IFO-180 and does not substantially change shoreline contacts compared with the no-ice condition. The presence of 65 percent ice cover is predicted to eliminate any entrained oil concentrations greater than 10 ppb.