# Comparison of Differences in Old Harry Oil Spill Fate Modelling Conducted by Applied Science Associates, SL Ross Environmental Research and Environment Canada

Prepared

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# Contents

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## 1. Background

The original oil fate and behaviour modelling conducted by SL Ross Environmental Research Ltd (SL Ross) for the Corridor Resources Inc. (Corridor) Old Harry prospect was criticized by Environment Canada (EC) (see Appendix I for the latest comments from EC and detailed responses by Corridor). There is a considerable difference of opinion between EC and SL Ross on the likely surface persistence of the Cohasset crude oil that has been selected as the type of oil likely to be encountered at this exploration site.

SL Ross`s modelling indicates that this light oil will persist for a few hours once spilled. This is based on the properties of Cohasset crude oil as measured by EC and the Mackay evaporation model (Mackay et al., 1980) and Audunson's dispersion algorithm (Audunson, 1980) usually employed by SL Ross in its oil spill model. The short surface persistence of this light crude oil is supported by two actual blowout events: the Uniacke blowout off Sable Island in 1984 (Environment Canada, 1984) and the Elgin blowout off Scotland in 2012 (Government of Scotland, 2013). In both of these cases, the light oil from the above-sea blowouts dissipated by evaporation and natural dispersion in less than 24 hours.

An Environment Canada consultant conducted modelling using Applied Science Associate's (ASA) OilMap software products and the Cohasset data set present in the US National Oceanic and Atmospheric Administration's (NOAA's) ADIOS model's database. This modelling resulted in surface persistence of the Cohasset oil in excess of 30 days, in some cases. ASA was commissioned by Corridor Resources to conduct additional modelling of batch spills of diesel and Cohasset crude for comparison purposes due to the significant differences in model results between EC and SL Ross with the goal of identifying the reasons for the major discrepancies.

There are three primary differences in the modelling and interpretation of the modelling results that have been completed by SL Ross, ASA and EC for the Old Harry Environmental Assessment (EA) (Stantec Consulting Ltd, 2013), as described below:

- Whether Cohasset oil will, or will not, form a water-in-oil emulsion if spilled;
- The fundamental principle that light crude oil or diesel slicks will, or will not, naturally disperse permanently in the presence of breaking waves; and
- The belief that light crude oil and diesel spills will, or will not, evaporate and naturally disperse completely within a day in wind speeds that generate breaking wave conditions.

Each of the three differences will be addressed in the sections below. In addition, supplementary modelling completed by SL Ross is presented later in this report (Section 5) to show output from SL Ross Oil Spill Model (SLROSM) using the Delvigne and Sweeney (1988) dispersion algorithm, which is the same as the algorithm used in the ASA and EC modelling work. This modelling was conducted for comparison purposes to illustrate that the original SL Ross modelling is appropriate for the Old Harry environmental assessment process and that the modelling conducted using the Delvigne and Sweeney (1988) dispersion algorithm does not materially affect the zone of influence and therefore it would not change the EA conclusions.

## 2. Oil Emulsification

The EC modelling assumes that the Cohasset oil will emulsify when spilled in the marine environment. This is not an accurate portrayal of how Cohasset crude oil will behave, based on published spill-related properties from the EC database. EC published data for this light oil shows that it will not form emulsions when evaporated up to 25.6% by volume (See Appendix II). The oil also has 0% asphaltene content at all degrees of weathering, suggesting that it will not form emulsions at any time post-spill. EC's own data does not support the formation of emulsions in spills of Cohasset crude. Therefore, fate modelling of spills of this oil should exclude emulsion formation. The EC modelling also claims that the crude oil (MC 252) released from the Macondo well is very similar to the Cohasset crude. A comparison of the fresh and weathered properties of the two crudes, included in Appendix II, clearly demonstrates that the Cohasset crude is much lighter than the MC 252 crude and the two oils are not similar.

## 3. Natural Dispersion

EC has stated in its comments on the Old Harry prospect modelling by SL Ross that there is no historical evidence that surface oil slicks will completely evaporate and naturally disperse. EC has also stated that natural dispersion will not occur in winds less than 30 knots (15.4 m/s).

The modelling conducted by ASA and EC utilized a natural dispersion model (Delvigne and Sweeney, 1988) that assumes no natural dispersion will occur at wind speeds less than 5 m/s (approximately 10 knots). It is important to note that this assumption is based on research focused on winds speeds of 5 m/s or greater. In other words, Delvigne and Sweeney (1988) did not study oil entrainment in water for wind speeds less than 5 m/s. For the Old Harry modelling work, SL Ross used a dispersion model developed by Audunson (1980) that predicts natural dispersion will occur at lower wind speeds than those proposed by Delvigne and Sweeney (1988) and suggested by EC. SL Ross believes that its' spill modelling is appropriate for EA purposes and contends that the 5 m/s cutoff imposed by Delvigne and Sweeney (1988) is likely too constrictive for the Cohasset oil.

It is well known that currents, wind and wave action form a well-defined mixing layer in the upper part of the water column. Oil spilled on the sea surface can be dispersed in the mixing layer by a number of natural processes, including breaking waves. Field observations and laboratory work (Delvigne and Sweeney, 1988; Milgram et. al., 1978; Mackay et al., 1980) have demonstrated that natural dispersion of fluid oils will occur in water as long as breaking waves are present, and these studies have even indicated that dispersion may also occur in non-breaking wave conditions as well.

Tkalich and Chan (2002) developed a mathematical model of oil droplet mixing by breaking waves. Li et al. (2008) used a wave tank to study the dispersed oil particle size. They note that "Under natural conditions, the dispersion of oil slicks is enhanced in the presence of waves. The waves provide mixing energy to break the surface oil film and propel oil droplets into the water column" (Li et al., 2008). Fingas (2011) notes that "…diesel fuel and even light oil crudes can disperse significantly…" The preponderance of evidence clearly indicates that oil dispersion is widely accepted.

A key consideration is the wind speed required to produce a wave of sufficient magnitude to facilitate the mixing of oil and the dispersion of an oil slick. The internationally recognized Beaufort wind scale indicates that breaking waves will occur in winds as low as 3.6 m/s. The NOAA oil spill model ADIOS2 assumes that whitecap formation (breaking waves) and natural dispersion begins at 3 m/sec (W. Lehr, 2001). This supports SL Ross's contention that the 5 m/s cutoff imposed by Delvigne and Sweeney (1988) is likely too constrictive and that EC's assertion that dispersion does not begin until winds reach 30 knots (15.4 m/s) is incorrect.

## 4. Slick Survival Time

EC has indicated in its reports that the light Cohasset crude oil and diesel oil will persist on the surface for up to 30 days. EC has stated that oil spills do not completely evaporate and disperse from the water surface and there is no historical evidence to support this.

Other respected agencies have different opinions than EC on the possible behaviour of light oil and diesel spills. For example:

- The NOAA's Office of Response and Restoration states on its web site: "Small diesel spills will usually evaporate and disperse naturally within a day or less. This is particularly true for typical spills from a fishing vessel (500-5,000 gallons), even in cold water. Thus, seldom is there any oil on the surface for responders to recover."

(http://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/resources/small-diesel-spills.html).

- The International Tanker Owners Pollution Federation (ITOPF) states: "Group I oils (non-persistent oils with densities less than 0.8 g/cc) tend to dissipate completely through evaporation within a few hours and do not normally form emulsions." (http://www.itopf.com/marine-spills/fate/models/). The density of Cohasset crude oil is 0.79 g/cc at 15 °C based on EC measurements.
- The French government research group Centre of Documentation, Research and Experimentation on Accidental Water Pollution (Cedre) indicates that "fluid oils can disperse totally within a few days." (http://www.cedre.fr/fr/publication/colloque/obs/1_oil_charater_beha.pdf) .
- The American Petroleum Institute (API, 1999) states that "Following evaporation, natural dispersion is the most important process in the breakup and disappearance of a slick."

The following are a few examples of actual spill events where the complete evaporation and dispersion of oil was documented to have occurred within a day or a few days from the release of the oil.

Uniacke Blowout (Environment Canada, 1984). Environment Canada's own publication describing the fate of oil from the Uniacke blowout off Nova Scotia's shore indicates that the oil completely evaporated and naturally dispersed and was not present on the surface less than 24 hours after the blowout was stopped (Environment Canada, 1984). The oil released in this blowout had a very similar API gravity to that of Cohasset crude and the winds between the well kill and the overflight that could find no oil were approximately 8 knots or 4.2 m/s.

Elgin Blowout (Government of Scotland, 2012). Reports from the Elgin platform blowout off Scotland in 2012 indicate that the oil released during this event evaporated and naturally dispersed within 24 hours (http://www.scotland.gov.uk/Resource/0039/00394137.pdf).

North Cape Spill, east coast US, 1988. Some 828,000 gallons of No. 2 Fuel (home heating oil) escaped into Rhode Island Sound. No. 2 heating oil is a refined product similar to diesel fuel, and because the wind and wave action was so intense on the night of the spill, the oil quickly mixed into the water column.

Arthur J dredge barge, Lake Huron, 2012. 1500 gallons of diesel oil was spilled when the barge sank. Environment Canada was among the agencies that monitored the spill. Environment Canada provided modelling and predictions of the dispersion of diesel fuel. An Environment Canada spokesperson was quoted in a news report as saying "At this point, given local meteorological conditions and the type of pollutant, it is anticipated that much of the pollutant will evaporate."

(http://blogs.windsorstar.com/2012/07/19/diesel-fuel-spill-in-lake-huron-after-barge-sinks/)

F/V Rough Seas, August, 2007. 300 to 1500 gallons of diesel fuel spilled when a fishing boat grounded in Little Egg Inlet N.J. at 1600 EDT on July 31, 2007. An overflight on August 2 found no oil sheen in the vicinity of the spill site. (http://www.incidentnews.gov/incident/7682)

USS New Orleans, August, 2007. 1000 gallons of Navy diesel was spilled from the USS New Orleans. Incident occurred on August 30 at 2000 hours south west of San Clemente Is., CA. The afternoon over-flight at 1815 hours on August 31 was unable to locate the spill. (http://www.incidentnews.gov/incident/7690)

Katsheshuk, April, 2002. The shrimp trawler "Katsheshuk" sank off Cape St. Francis, approximately 20 kilometres north of St. John's, Newfoundland. A spokesperson for the Coast Guard said Wednesday that the fuel was down to a 50 by 100-foot area and was dispersing quickly. At the time of the sinking, there were approximately 430,000 litres of diesel fuel on board the vessel. (Source: CBC News, 3 April 2002) When the vessel sank, the action of the wind and the waves dispersed the oil and its impact on the environment was considered minimal. (http://www.tsb-bst.gc.ca/eng/rapports-reports/marine/2002/m02n0007/m02n0007.asp)

## 5. New Modelling to Compare SLROSM Results to ASA OilMap Results

The SL Ross Oil Spill Model (SLROSM) was modified to use the Delvigne and Sweeney (1988) natural dispersion algorithm and run using the same EC-measured Cohasset crude oil properties and environmental input parameters as those used by ASA to demonstrate that the dispersion algorithm being used is the same as that in ASA's OilMap product. Figure 1 shows the comparison of the two model's results at various wind speeds. The agreement between the two model results is consistent.

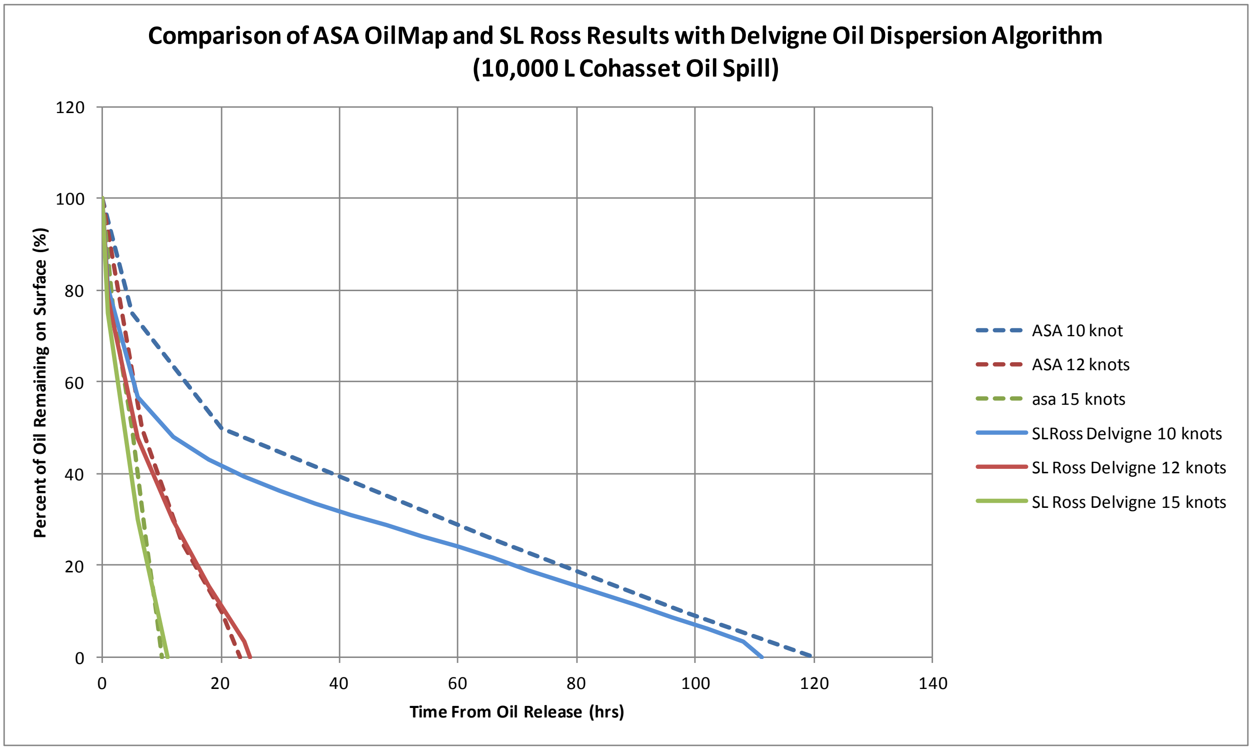


Figure 1: Comparison of OilMap and SLROSM Model Results Using Delvigne and Sweeny (1988) Natural Dispersion

SLROSM was then re-run for surface blowouts from the Old Harry location using the 52 years of MSC50 wind data. A slick, representative of the continuous release of oil from a surface blow out, is selected every 6 hours and its fate and behaviour are determined under the prevailing environmental conditions that follow its time of release using the 52 years of hourly wind data. The trajectories of all of the slicks, for all months, and all 52 years of predictions have been plotted on one image to identify the maximum possible area of effect from a blowout from the Old Harry prospect assuming the same dispersion algorithm as that used in the ASA OilMap software (i.e. Delvigne and Sweeney (1988)). Figure 2 shows the results of this analysis.

Even with the 5 m/s restriction on the onset of dispersion imposed by the Delvigne and Sweeney (1988) algorithm, the maximum likely area that could be affected by a blowout from the operation is still relatively small and would not result in any contact of oil with shorelines.

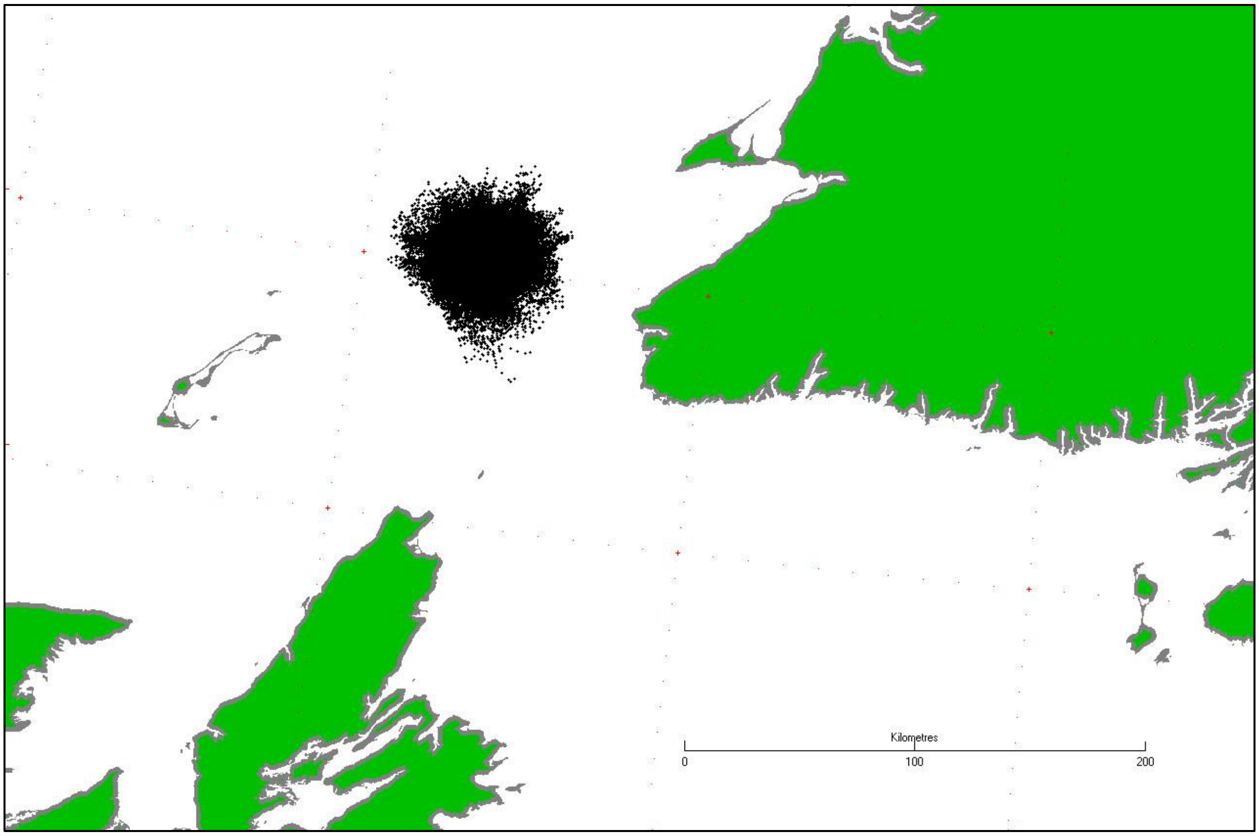


Figure 2: Trajectories of Above-Sea Blowouts: All 52 Years and All Months

A more instructive view is provided in Figure 3. This figure shows all of the trajectories for the months of May, June and July for one year (2004). These months were selected because they have the most calm wind periods of the year based an assessment of 52 years of MSC50 wind data (see Table 1). Three months were selected as this would be the maximum likely time required prior to achieving well control should a blowout occur. As can be seen in Figure 3, most slicks dissipate within 20 to 30 kilometres from the spill site. There are a few cases with longer spill persistence due to prolonged calm periods, but these are few in a given three month period.

The percentage of time that winds are less than 10 knots, between 10 and 12 knots and greater than 12 knots has been extracted from the MSC50 data set for grid point 13347 (located at -60.3° longitude 48.0° latitude, very close to the proposed Old Harry drill site) and are provided in Table 1. It is evident from the historical wind statistics in Table 1 that calmer winds are more prevalent in the summer months. Note that winds greater than 10 knots occur more than 50 percent of the time. Figure 4 shows all of the trajectories for the months of November, December and January (2004). There are fewer instances of longer persistent slicks in these months, as would be expected based on the wind data in Table 1.

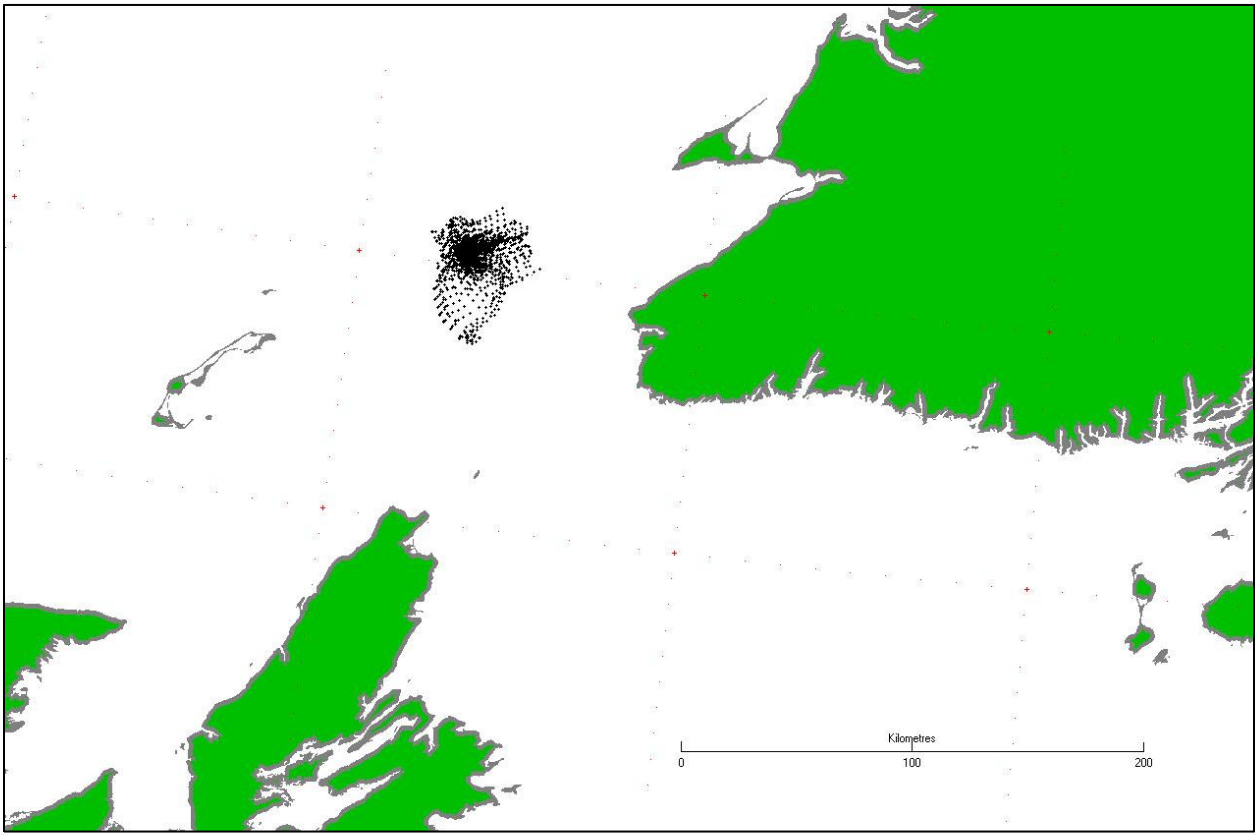


Figure 3: Trajectories of Above-Sea Blowouts: May, June and July of 2004

Table 1: Wind Statistics MSC50 Grid Point 13347

| Month | Percentage of Wind Observations (from 1954 TO 2005 data) | | |
|---|---|---|---|
| | 0 to 10 knots | 10 to 12 knots | > 12 knots |
| January | 9.5 | 6.4 | 84.1 |
| February | 21.5 | 8.9 | 69.6 |
| March | 24.9 | 9.1 | 66.0 |
| April | 29.6 | 10.8 | 59.5 |
| May | 42.0 | 11.1 | 46.9 |
| June | 46.3 | 11.6 | 42.1 |
| July | 44.4 | 13.5 | 42.1 |
| August | 36.4 | 13.7 | 49.9 |
| September | 24.9 | 11.3 | 63.8 |
| October | 15.9 | 8.6 | 75.5 |
| November | 11.3 | 7.2 | 81.5 |
| December | 9.2 | 6.0 | 84.8 |

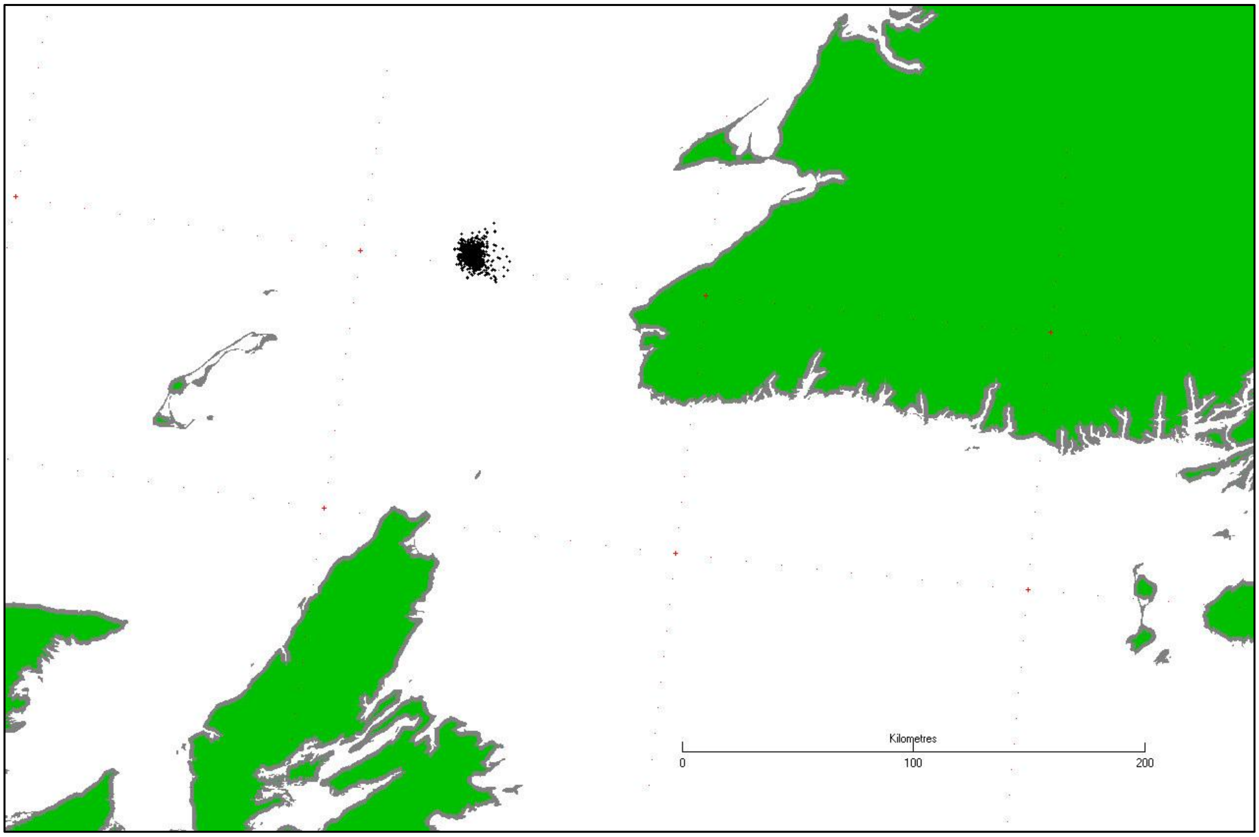


Figure 4: Trajectories of Above-Sea Blowouts: November, December and January of 2004

Figures 2 through 4 can be compared to Figure 12 from the original SL Ross oil fate and behaviour report prepared for the Corridor Resources EA. This figure is reproduced below as Figure 5. The oil footprint from the original modelling effort is smaller than that in Figures 2 and 3, as would be expected due to the different dispersion algorithms used. However, the oil footprint in Figures 2 and 3 is still relatively small, would not interact with any shoreline, and would not result in any material change from an EA perspective (i.e., the zone of influence is not materially affected such that it would change EA conclusions). Tables 2 and 3 are provided to allow comparison, between the new and previous modelling results, of the minimum and maximum surface oil slick persistence times for each month. The new work models a surface blowout discharge scenario whereas the original work models batch accumulations of oil released every 6 hours. The minimum slick persistence values were actually longer in the old modelling. The maximum persistence recorded in the new modelling was about 4 times longer than in the original work.

Table 4 shows the percentage of slicks surviving for a given time range. It is instructive to note that over 90% of the slicks released from the blowout in the summer months persisted for less than 3 days and over 90% of the slicks released in the winter months persisted for less than 1 day.

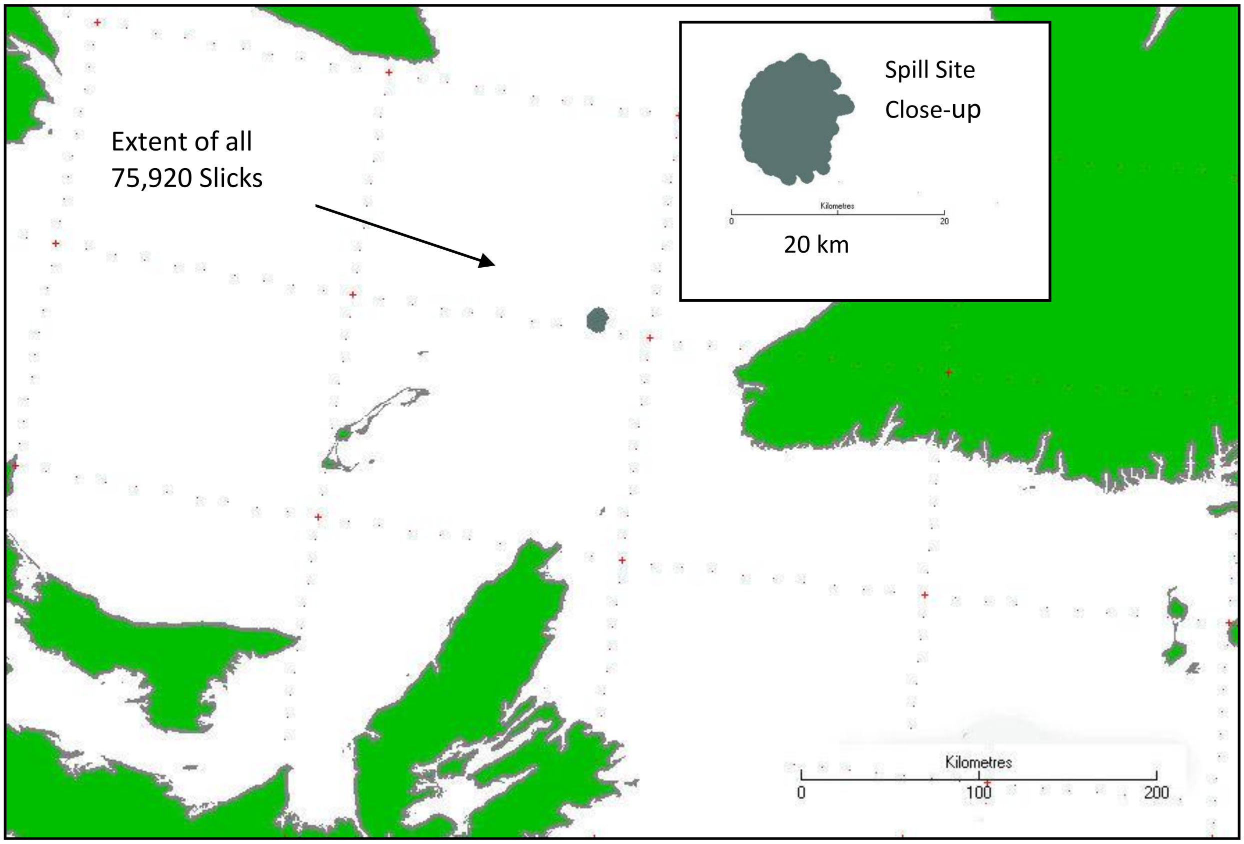


Figure 5: Maximum Area of Ocean Surface Swept by Oil from 52 Years of Simulations Using a Reasonably Conservative Modelling Approach (old Figure 12)

Table 2: Slick Shoreline Contact and Slick Life at Sea: Surface Blowouts (as modeled by SL Ross using the Delvigne and Sweeny (1988) dispersion algorithm)

| Month | Number of Slicks Tracked | % of Slicks Tracked Reaching Shore | Minimum Slick Life at Sea (hours) | Maximum Slick Life at Sea (hours) |
|---|---|---|---|---|
| January | 6448 | 0.0 | 0.25 | 91.6 |
| February | 5824 | 0.0 | 0.31 | 123.9 |
| March | 6448 | 0.0 | 0.32 | 135.0 |
| April | 6240 | 0.0 | 0.34 | 223.6 |
| May | 6448 | 0.0 | 0.39 | 188.2 |
| June | 6240 | 0.0 | 0.50 | 186.6 |
| July | 6448 | 0.0 | 0.50 | 211.5 |
| August | 6448 | 0.0 | 0.42 | 168.9 |
| September | 6240 | 0.0 | 0.27 | 144.7 |
| October | 6448 | 0.0 | 0.25 | 116.3 |
| November | 6240 | 0.0 | 0.24 | 84.5 |
| December | 6448 | 0.0 | 0.23 | 72.0 |

Table 3: Slick Shoreline Contact and Slick Life at Sea: Reasonable Worst-Case Modelling Approach (from SL Ross's Original Report using Audunson dispersion algorithm – old Table 10)

| Month | Number of Slicks Tracked | % of Slicks Tracked Reaching Shore | Minimum Slick Life at Sea (hours) | Maximum Slick Life at Sea (hours) |
|---|---|---|---|---|
| January | 6448 | 0.0 | 0.5 | 18.4 |
| February | 5824 | 0.0 | 0.6 | 25.6 |
| March | 6448 | 0.0 | 0.7 | 29.5 |
| April | 6240 | 0.0 | 0.7 | 34.7 |
| May | 6448 | 0.0 | 0.8 | 51.4 |
| June | 6240 | 0.0 | 0.9 | 38.3 |
| July | 6448 | 0.0 | 0.8 | 36.7 |
| August | 6448 | 0.0 | 0.7 | 34.7 |
| September | 6240 | 0.0 | 0.6 | 31.5 |
| October | 6448 | 0.0 | 0.5 | 24.3 |
| November | 6240 | 0.0 | 0.6 | 24.9 |
| December | 6448 | 0.0 | 0.5 | 15.3 |

Table 4: Slick Survival Statistics Using Delvigne and Sweeney Dispersion Algorithm in SL Ross model for Surface Blowout Cohasset Crude

| Month | Number of Slicks Tracked | Percentage of Slicks Surviving in Time Range (days) | | | | |
|---|---|---|---|---|---|---|
| | | 0 to 0.5 | 0.5 to 1.0 | 1.0 to 3.0 | 3.0 to 5.0 | 5.0 to 10.0 |
| January | 6448 | 84.0 | 11.6 | 4.3 | 0.1 | 0.0 |
| February | 5824 | 67.0 | 17.2 | 14.9 | 0.9 | 0.0 |
| March | 6448 | 64.7 | 17.4 | 16.1 | 1.8 | 0.1 |
| April | 6240 | 57.3 | 17.6 | 21.2 | 3.1 | 0.8 |
| May | 6448 | 43.5 | 18.3 | 29.8 | 6.8 | 1.6 |
| June | 6240 | 38.4 | 17.5 | 34.0 | 8.3 | 1.8 |
| July | 6448 | 38.0 | 17.6 | 33.7 | 8.0 | 2.7 |
| August | 6448 | 46.5 | 19.6 | 28.6 | 4.9 | 0.4 |
| September | 6240 | 62.3 | 17.6 | 17.8 | 2.2 | 0.1 |
| October | 6448 | 75.3 | 14.8 | 9.3 | 0.6 | 0.0 |
| November | 6240 | 81.0 | 12.6 | 6.3 | 0.1 | 0.0 |
| December | 6448 | 83.8 | 11.3 | 4.9 | 0.0 | 0.0 |
| All Months | 75800 | 61.8 | 16.1 | 18.4 | 3.1 | 0.6 |

## 6. Summary

The following points support the validity of the original SL Ross modelling work as appropriate for the Old Harry EA:

- Evidence has been provided from EC's own dataset and actual documented spill examples that the light, Cohasset oil surrogate will **not** emulsify. Therefore only modelling results that exclude emulsion formation are appropriate in this case. Note that the ASA modelling (September 20, 2012) used an emulsification factor only to demonstrate that a model of the Cohasset oil will emulsify if the default values in OILMAP are used. ASA notes that emulsification is not appropriate for a very light oil such as Cohasset;
- Actual spill examples and scientific references are provided as evidence that natural dispersion plays an important role in the fate of diesel and the light, Cohasset crude oil used as a surrogate for the potential Old Harry product;
- Scientific references presented in this report indicate that natural dispersion will occur as long as breaking waves are present and breaking waves are known to begin in offshore waters at wind speeds as low as 7 knots (3.6 m/s);
- It is Corridor's view, in agreement with SL Ross, that spill models appropriate for Old Harry should account for natural dispersion through the full range of wind speeds when breaking waves are present;
- Winds greater than 10 knots (5 m/s) exist in the vicinity of the Old Harry project for more than 50% of the time in all seasons, so wind speeds higher than 10 knots need to be considered when looking at realistic modelling scenarios;
- The full variability of winds in the region has been accounted for in past modelling efforts through the use of the 52 years of hourly MSC 50 time series wind data, which is the most appropriate dataset to use in our view; and
- New modelling by SL Ross using a natural dispersion cut-off at 10 knot (5 m/s) wind speeds shows that the area potentially impacted from the operations is small, would not interact with any shoreline, and would not result in any material change from an EA perspective (i.e., the zone of influence is not materially affected such that it would change EA conclusions).

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## Appendix I

**Corridor Resources Inc. (Corridor's) Detailed Responses to Environment Canada's January 25, 2013 Letter**

| Environment Canada Comments | Corridor Responses | Reference |
|---|---|---|
| In their letter, the proponent refers to a report authored by ASA, proprietor of the Oilmap software used by EC, in its initial review of the proponent's Oil Spill Modelling Report. EC has reviewed the additional information and provides a detailed response in the attached report. The key points within the report are summarized within this letter.<br><br>Both the ASA modelling presented by the proponent and the EC modelling results show the potential for significant amounts of oil remaining on the water for 20 to 25 days under normally expected conditions. | The 20 to 25 day persistence is only predicted if the oil is assumed to form a water-in-oil emulsion. The oil chosen as a surrogate for the Old Harry Prospect will not form an emulsion based on EC's own analysis of the oil. The SL Ross modelling, and a subset of the ASA modelling, assumed that emulsions would not form, which is in agreement with EC published data. The author of the ASA report (dated September 20, 2012) stated on page 5 of his report that "additional simulations were run with a maximum water content of 0% assuming that the Cohasset oil does not emulsify. This is a reasonable assumption as the Environment Canada data indicate that the Cohasset Crude has a zero emulsion formation tendency up to 25.6 percent volume evaporation."<br><br>The key issue here is the persistence of slicks of light crude from an exploratory well blowout at the Old Harry Prospect. There have been two actual blowouts from offshore wells involving similar crudes: the Uniacke blowout off the coast of Nova Scotia in 1984 and the Elgin blowout off Scotland in 2012. In both of these actual incidents, the surface slicks generated by the blowouts dissipated in less than 24 hours, which supports the SL Ross view that rapid natural dispersion will occur.<br><br>• Uniacke Blowout (Environment Canada, 1984). Environment Canada's own publication describing the fate of oil from the Uniacke blowout off Nova Scotia's shore indicates that the oil completely evaporated and naturally dispersed and was not present on the surface less than 24 hours after the blowout was stopped (Environment Canada, 1984). The oil released in this blowout had a very similar API gravity to that of Cohassett crude and the winds between the well kill and the overflight that could find no oil were approximately 8 knots or 4.2 m/s. | File No. 4194-10 letter, Page. 1 |

| | | |
|---|---|---|
| | • Elgin Blowout (Government of Scotland, 2012). Reports from the Elgin platform blowout off Scotland in 2012 indicate that the oil released during this event evaporated and naturally dispersed within 24 hours (http://www.scotland.gov.uk/Resource/0039/00394137.pdf). | |
| The SL Ross modelling, therefore, is the outlier of these three reports. Specifically, using the corrected Cohasset Crude specification (ASA report, Figure 4) at wind speeds of 10 knots or less, encountered 40% of the time in summer, the ASA report indicates 20% of oil remaining on water after 3 days compared to the 25% predicted by EC using Oilmap 4.3, and 0% predicted in the SL Ross model. | The EC report that presently resides on C-NLOPB website (dated 24/05/2012) indicating that 95% of the oil will remain on the surface after 3 days using the OilMap 4.3 is in stark contrast to the 25% identified above. Subsequent reports by Environment Canada (dated March 31, 2012 and July 2012) report 25% remaining with no explanation of the reason for the difference between earlier and more recent EC documents. If the EC report residing on the C-NLOPB website is in error and the 25% value reported above is considered the correct EC result, as previously requested, the old report should be removed from the C-NLOPB website. Unfortunately, the public has reviewed a report that appears to contain inaccurate information. | File No. 4194-10, Page 1 |
| All of the models show that wind speed is a significant factor in the eventual fate of the oil. It is therefore important that the modelling use wind speeds that can reasonably be expected in the area. | The original oil spill modelling completed by SL Ross for Corridor Resources used over 50 years of wind data from the Meteorological Service of Canada (a part of Environment Canada formerly called the Atmospheric Environment Service - AES): the MSC 50 data set. These data are considered very representative of the winds occurring in the vicinity of the proposed exploration site and provide a spatially and temporally varying wind data time series for the region. We strongly believe that this is the best wind data set for offshore oil spill fate and behavior modelling. SL Ross has successfully used this wind data for oil spill modelling in dozens of spill modelling projects on Canada's east coast and a similar MSC wind data set for the Beaufort Sea. | File No. 4194-10, Page 1 |
| The SL Ross cover letter emphasizes this point when it states "The estimated persistence of the Cohasset crude by the two models (Oilmap and SLROSM) is not too different from an offshore spill response and impact perspective, with the exception of 10 knot wind speeds." Yet, as indicated in the screening report, wind speeds of 10 | Realistic wind historical time series have been used by SL Ross in the fate and behavior modelling completed for Corridor Resources as described above. These wind histories accurately portray the magnitudes of wind speeds and directions as well as their persistence, including calm wind periods. The issue is not that winds of 10 knots (5 m/s) or less occur. The issue is whether natural dispersion of oil occurs under wind speeds below 10 knots. There is evidence that light oils will disperse as long as breaking waves exist. | File No. 4194-10, Page 1 |

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| knots or less occur frequently and are well within the bounds of probability. Even if the average wind speed was higher, any regular occurrence of lower wind speeds would need to be considered if one wants to be conservative when modelling. | The universally accepted Beaufort Wind Scale indicates, in winds from 7 to 10 knots (3.6 to 5.144 m/s), that wave crests break and scattered whitecaps exist in open water areas. Evidence is provided in the main body of this response to support the contention that dispersion of light oils will occur as long as breaking waves exist and that for very light oils, like Cohasset crude, the 5 m/s dispersion cutoff used in the Delvigne and Sweeney (1988) algorithm employed by Environment Canada may be too conservative. | |
| A further key consideration is the fate of entrained oil. Once dispersed into the water column the droplets remain buoyant and will resurface. The ASA report states that "Under changing wind conditions where wind speed drops below 10 knots the entrained oil could rise to the surface and form a slick." Thus natural dispersion is not a sink of oil but merely a temporary reservoir. | Some portion of naturally dispersed oil (the larger oil drops), but not all (the smaller oil drops), may rise during periods of calm but the re-surfaced oil will be re-entrained during the periods of heavier seas. Natural dispersion is recognized as a potential 'sink' for oil in all oil spill models including ASA's OilMap products. | File No. 4194-10, Page 1 |
| Given that wind speeds below 10 knots are a regular occurrence, especially during the season where drilling is likely to take place, the ultimate fate and potential effects of this oil should be considered. | As identified above, the original modelling completed by SL Ross utilized historical wind time series (MSC50) that included fully representative seasonal winds. A sample of the statistical variation of the wind data used in the modelling is provided in Section 5 of the main body of this report. Winds greater than 10 knots exist in the area in higher regularity than those 10 knots or less throughout all seasons (i.e. greater than 50% of the time). | File No. 4194-10, Page 2 |
| Cohasset oil has been identified as a probable surrogate for modelling purposes only. We should be mindful that the characteristics of any oil occurring at Old Harry are unknown. We therefore recommend that the Assessment take a conservative approach appreciating the limitations of working with surrogates for an unknown crude oil. | A detailed description of the scientific approach undertaken by Corridor to identify a suitable surrogate oil is provided in the EA. In summary, Corridor undertook geochemical studies to identify the types of organic material in the shale rocks; conducted petroleum systems modelling to simulate the type of hydrocarbons that may be generated from the organic material; and compared the geological setting of the basin and the modelled oil to other areas to identify a suitable surrogate. The modelling showed that, based on the organic material in the shale, the hydrocarbons likely to be encountered at Old Harry would be very light oils and natural gas with API gravity between 45 and 56 degrees (Cohassett oil is 47 degrees API). It | File No. 4194-10, Page 2 |

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| | should be noted that of the 10 wells drilled in the Gulf of St Lawrence, half of them encountered non-commercial quantities of natural gas and none encountered oil. In addition, the geological formations found at the Old Harry site compare favourably to the geological conditions in the Scotian Basin. That is, both basins are rift type basins, were deposited in fluvial-deltaic environments, and both contain natural gas and light oil prone shale rocks. For these reasons, oil spill modelling that assumes the best available Cohassett oil properties (those from Environment Canada's own analysis) are considered appropriate for the project. Cohasset crude did not form water-in-oil emulsions when tested by Environment Canada and has 0% asphaltene content (another strong indicator that this oil will not form an emulsion). See the Appendix II for published dataset from Environment Canada. | |
| Finally, the Board should consider that the ASA modelling is limited to batch spills of 10,000 litres. The screening report also includes modelling of a 10-day blow out. Since the ASA model predicts persistence of oil on water longer than a few hours, the proponent should revisit their blow-out modelling as well. | SL Ross has conducted new modelling of surface oil well blowouts using the SL Ross model, recompiled with the Delvigne and Sweeney (1988) dispersion algorithm employed by ASA. The details of this modelling, as well as a comparison of these results with those presented in the original modelling report prepared for Corridor Resources, is provided in Section 5 of the main report. The results show that spills of Cohasset crude from the Old Harry site would not interact with any shoreline, (based on modelling using 52 years of historical wind data), and would not result in any material change from an EA perspective (i.e., the zone of influence is not materially affected such that it would change the conclusions of the EA). | File No. 4194-10, Page 2 |
| EC recommends that a more conservative modelling approach should be taken, considering that the type of oil and its characteristics are unknown and wind conditions variable. | As discussed above, due diligence was undertaken by Corridor Resources to identify an appropriate surrogate oil for modelling purposes and industry-recognized, long-term historical wind data was used in the modelling. | File No. 4194-10, Page 2 |
| Furthermore, EC recommends that the C-NLOPB subject the proposed undertaking to a modelling exercise based on conservative scenarios, and base subsequent impact predictions and oil spill | New modelling has been conducted using the more conservative Delvigne and Sweeney dispersion algorithm. The results of this modelling show a slightly larger potential surface oil footprint than that identified in the original modelling, but not anywhere near the size suggested by the Environment Canada modelling. The new | File No. 4194-10, Page 2 |

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| readiness on those outcomes. | modelling confirms that a potential spill is not likely to impact any shorelines and these results do not affect the conclusions of the EA Report, which had assumed no shoreline contact. | |
| The major concern with the proponent's model is that they predict that any oil from the Old Harry release will dissipate within one day. This is quite unrealistic and has never occurred in the history of oil spills. | Environment Canada's own publication (Environment Canada, 1984) describing the fate of oil from the Uniacke blowout off Nova Scotia's shore indicates that slicks extended only a few kilometres from the stricken platform and the oil (actually slightly more dense than Cohassett) was not present on the surface less than 24 hours after the blowout was stopped. Reports from the Elgin platform blowout off Scotland in 2012 also indicate that the light oil released during this event evaporated and dispersed within 24 hours and extended only a short distance from the platform (http://www.scotland.gov.uk/Resource/0039/00394137.pdf). Reports of diesel spills that have dissipated within a day or two of release include the Arthur J Barge in Lake Huron, the F/V Rough Seas off New Jersey, the USS New Orleans off California, and the Katsheshuk off Newfoundland. Additional details on these spills are provided in Section 4 of the main report. Based on these actual examples, SL Ross's modelling is realistic and appropriate.<br>Other respected agencies have different opinions than those of Environment Canada on the possible behaviour of light oil and diesel spills.<br>• For example, the US National Oceanic and Atmospheric Administration's (NOAA's) Office of Response and Restoration states on its website: "Small diesel spills will usually evaporate and disperse naturally within a day or less. This is particularly true for typical spills from a fishing vessel (500-5,000 gallons), even in cold water. Thus, seldom is there any oil on the surface for responders to recover." (http://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/resources/small-diesel-spills.html).<br>• The International Tanker Owners Pollution Federation (ITOPF) states: "Group I oils (non-persistent oils with densities less than 0.8 g/cc) tend to dissipate completely through evaporation within a few hours and do not normally form emulsions." (http://www.itopf.com/marine-spills/fate/models/). The density of | Comments on Issues Related to the Old Harry Modelling Scenarios, Background # 2 |

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| | Cohasset crude oil is 0.79 g/cc at 15 °C based on Environment Canada measurements.<br>• The French government research group Centre of Documentation, Research and Experimentation on Accidental Water Pollution (Cedre) indicates that “fluid oils can disperse totally within a few days.” (http://www.cedre.fr/fr/publication/colloque/obs/1_oil_charater_beha.pdf).<br>• The American Petroleum Institute (API, 1999) states that “Following evaporation, natural dispersion is the most important process in the breakup and disappearance of a slick.” | |
| Actual evaporation data of Panuke oil a sister of Cohasset oil. What can be better than actual data? | The modelling completed by SL Ross and ASA uses data for Cohasset crude oil prepared by Environment Canada. This includes actual evaporation data for the Cohasset crude oil and is the most appropriate dataset to use. | Comments on Issues Related to the Old Harry Modelling Scenarios, Background # 2a |
| Modelling of Cohasset as that, with the correction that natural dispersion in the models is reduced and then removed, also as a light crude oil in both ADIOS and both ASA models- still all approaches yielded about the same results. | Based on Environment Canada’s own published dataset and what is known about the properties of the Cohasset oil, it is unclear as to Environment Canada’s justification for modelling the fate of Cohasset with natural dispersion reduced from their own published data or turned off completely in the modelling exercise. Natural dispersion is recognized as an oil spill fate process, especially important for light oils that do not emulsify. In a recent book on oil spill science and technology, it was noted “Depending on oil conditions and the amount of sea energy available, natural dispersion can be insignificant **or it can remove the bulk of the oil (emphasis added)**. Heavy oils such as Bunker C or a heavy crude will not disperse naturally to any significant extent, **whereas diesel fuel and even light crudes can disperse significantly if the saturate content is high and the asphaltene and resin contents are low (emphasis added)** (Fingas, 2011).<br>No results from ADIOS modelling have been presented in any of the reports provided by Environment Canada so we cannot comment on | Comments on Issues Related to the Old Harry Modelling Scenarios, Background # 2c |

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<tr><td></td><td>the statement comparing the results of ADIOS and OilMap results.</td><td></td></tr>
<tr><td>Modelling of the Cohasset oil using ADIOS II- this is the second-most used model in the world. ADIOS II yields similar results as the OiiMap model.</td><td>No results from ADIOS modelling have been presented in any of the reports provided by Environment Canada so we cannot comment on the validity of the statement.</td><td>Comments on Issues Related to the Old Harry Modelling Scenarios, Background # 2d</td></tr>
<tr><td>There was concern that the SL Ross model is not peer-reviewed, used by others and is relatively unknown.</td><td>SL Ross has been responsible for the modelling of the fate and behavior of potential spills for almost all of the exploration and development operations on Canada’s east coast since the early 1980’s. A list of some of the operations for which SL Ross has completed oil spill modelling for EA purposes on Canada’s east coast is included below. These reports have all been reviewed and accepted by the appropriate government agencies, including Environment Canada, over this extensive time period. We respectively submit that the model is well known in the region.<br><br>SL Ross has modelled the fate and behavior of hypothetical blowouts and batch spills from various exploration and development projects on Canada's East Coast using their SLROSM software. These modelling efforts include, but are not limited to, the projects outlined in the table below:<br><br>
<table>
<tr><th>Operator</th><th>Projects</th></tr>
<tr><td>Husky Energy Inc.</td><td>Sydney Basin; White Rose; and White Rose Extension</td></tr>
<tr><td>Canadian Superior</td><td>Mayflower; Marconi and Marauder</td></tr>
<tr><td>Marathon Canada Petroleum LLC</td><td>Cortland and Empire</td></tr>
<tr><td>PanCanadian Ltd</td><td>Deep Panuke</td></tr>
<tr><td>Shell Canada Ltd</td><td>Man-O-War</td></tr>
<tr><td>ExxonMobil</td><td>Hibernia and Cree</td></tr>
<tr><td>Imperial Oil Ltd</td><td>EL 2378/2379</td></tr>
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</td><td>Comments on Issues Related to the Old Harry Modelling Scenarios, Background # 2f</td></tr>
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<tr><td></td><td><table><tr><td>PetroCanada</td><td>Terra Nova; Flemish Pass; Sweet Bay; Tucamore; and Mizzen</td></tr><tr><td>Chevron Canada</td><td>Orphan Basin Deep Water</td></tr><tr><td>Conoco Phillips</td><td>Laurentian Channel and Labrador SEA</td></tr></table></td><td></td></tr>
<tr><td>Corridor Resources hired ASA to model the same spills but only gave them the winds of 10 to 20 knots- in reality too high.</td><td>The modelling completed by ASA was designed to provide OilMap model results as prepared by an expert in the use of the model software to compare with the EC results which appeared to be questionable for light oil and diesel spills. It was an exercise to determine if there were errors in EC’s use of the OilMap software.<br><br>The early EC modelling results (dated 25/04/2012, report presently on C-NLOPB website) indicated that 92 % of the volume of a 10,000 litre batch of light non-emulsifying crude oils and 30% of the volume of a 1000 litre batch spill of diesel would persist on the surface after 10 days. The EC reports also indicate that up to 70% of Cohasset crude could evaporate within 10 days. This inconsistency in statements, along with other issues in the web-posted EC modelling results, led to the commissioning of ASA to conduct independent modelling. The EC report dated March 31, 2012 also indicated that Cohasset oil and diesel spills would persist on the surface for over 30 days. Such long-term persistence of light oils and diesel fuel is contrary to actual spill experience and the general understanding of the fate of offshore spills of products of these types. This is supported by the NOAA, ITOPF, Cedre and API descriptions of the general behavior of these products reported above.</td><td>Comments on Issues Related to the Old Harry Modelling Scenarios, Background # 2f</td></tr>
<tr><td>In fact the winds of 10 knots yielded almost identical result to that produced by Environment Canada, showing that indeed there is a lot of oil remaining on the surface.</td><td>The 10 knot modelling results provided by ASA with rapid emulsification to 74% water content yield nearly identical results to those presented by EC for evaporation alone in their March, 2012 data report. The EC results from their April web-posted report are very different from both the ASA results and EC’s March data report. None of the ASA modelling results using OilMap are ‘nearly identical’ to EC’s modelling results using the OilMap products. This can be</td><td>Comments on Issues Related to the Old Harry Modelling Scenarios, Background #</td></tr>
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| | seen in the comparison graphs presented in Appendix III. Regardless, it is our contention that the modelling results assuming that the Cohasset oil forms an emulsion should not be considered as reasonable or appropriate. | 2f |
| Further at high winds there still is oil remaining at times of concern. | The ASA modelling identified that at 12 knots all oil would be evaporated and dispersed from a spill of Cohasset crude or diesel fuel within 24 hours and 12 hours, respectively, and at 15 knots within 11 hours and 5.5 hours, respectively. | Comments on Issues Related to the Old Harry Modelling Scenarios, Background # 2f |
| A similar situation arose in the DeepWater Horizon spill. That light oil, not too dissimilar from Cohasset, was predicted to also dissipate within a short time by some individuals. This proved to be more than wrong! | The MC252 crude oil spilled in the Deep Water Horizon incident was very different than Cohasset crude oil as it does form an emulsion after evaporating and thus will have longer on-water persistence. Since the modelling referenced in the comment is not provided nor are any references to support the statement, we cannot comment any further on this statement. Oil property data sets for both the Macondo (MC252) and Cohasset crude oils are provided in Appendix II to show their differences in properties. These two oils are different and they should not be described as being similar. | Comments on Issues Related to the Old Harry Modelling Scenarios, Background # 2g |
| The main issue is that spilled oil simply does not go away. The use of 'natural dispersion algorithms' in oil spill models is incorrect and in recent years has come under heavy criticism. Many major spills in recent times have been modeled and the models predicted that the oil would go away by natural dispersion. The prime example of this is during the Macondo spill which involved a very light oil not too dissimilar from Cohasset. | The contention that natural dispersion algorithms used in all oil spill models is incorrect is not substantiated. SL Ross has validated its spill model results against actual spill events to ensure that their results are representative. As mentioned earlier, the MC 252 crude oil is very different than Cohasset crude in that it is a heavier product than Cohasset and it has been shown to form water-in-oil emulsions both in laboratory tests and in the field. | Comments on Issues Related to the Old Harry Modelling Scenarios, 1. The Main Issue |
| Several models predicted that the oil would be continually dispersed naturally and that none would come ashore. This proved to be more than wrong. Further even with very | After high wind events during the Macondo event, surface oil was difficult to find away from the spill site. This was experienced by SL Ross personnel on two scientific missions during the Macondo spill event. This behavior suggests that natural dispersion did occur | Comments on Issues Related to the Old Harry |

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| high winds, no natural dispersion was observed. | during the Macondo incident. | Modelling Scenarios, 1. The Main Issue |
| This same phenomenon has been noted in many spills in the past decade. | There are no references provided to support the claim that natural dispersion does not occur in higher winds. On the contrary, several references are provided in Section 3 of the main body of this report that describe natural dispersion. Diesel spills are often not responded to because they are known to evaporate and disperse naturally. See the comments from NOAA, ITOPF, Cedre and API on dispersion of light crude and diesel products above and in Section 4 of the response document. | Comments on Issues Related to the Old Harry Modelling Scenarios, 1. The Main Issue |
| Natural dispersion should only account for a few percent of the oil at any time, under normal conditions. OiiMap 6.7.1 shows that ASA has reduced natural dispersion since OiiMap 4.3. | SL Ross has had discussions with senior ASA oil spill modeller, Chris Galagan, who verified that OilMap versions 4.3 and 6.7.1 both use the same natural dispersion algorithms by Delvigne and Sweeney (1988). He also indicated that other changes to the maximum oil drop size in natural dispersion and the change in oil viscosity with evaporation in OilMap 6.7.1 would result in slightly higher natural dispersion rates than in the older version 4.3. This is contrary to the EC comment. | Comments on Issues Related to the Old Harry Modelling Scenarios, 1. The Main Issue<br>Comments on how natural dispersion should look compared to how it does look in Current Models 1.1 |
| This could still go down further. High natural dispersion is not observed at actual spills. This is a much-discussed topic among modellers today. There are plans in ADIOS to scale natural dispersion way back.<br><br>Natural dispersion should onset at a higher | The work by Delvigne and Sweeny (1988), Milgram et al. (1978), Mackay et al. (1980) and many others has indicated that natural dispersion will occur as long as breaking waves are present and breaking waves are known to begin in offshore waters at wind speeds as low as 7 knots (3.6 m/s). | Comments on Issues Related to the Old Harry Modelling Scenarios, 1. The Main |

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| wind condition- probably more like 30 knots for a light crude oil. | | Issue Comments on how natural dispersion should look compared to how it does look in Current Models 1.1 & 1.2 |
| OilMap onsets at just over 10 knots, too low. The only spill that ever showed a high natural dispersion was the Braer spill where the winds reached as high as 80 knots. Much of the oil was sedimented by the high particulate loading in the area. The Deep Water Horizon showed no natural dispersion despite the fact that it was light crude oil (despite many model predictions that it would). | Environment Canada claims that no spill, other than the Braer, ever showed high natural dispersion is unjustified. Many light crude oil and diesel spills have dissipated naturally. Examples have been provided in Section 4 of this response document. | Comments on Issues Related to the Old Harry Modelling Scenarios, 1. The Main Issue Comments on how natural dispersion should look compared to how it does look in Current Models 1.2 |
| Natural dispersion should actually decrease over time. This is because the natural dispersion droplets are not very stable and would return to the surface. Dissolved material leaves at the surface similar to evaporation. OilMap models show this tendency to a certain extent, but probably should have a shorter half live of dispersions (probably about a few hours). | The treatment of natural dispersion in oil spill models is based on laboratory measurements of oil drop size distributions measured in the laboratory (Delvigne and Sweeney (1988) and others) and field measurements of oil drop distributions (Lunel 1993 and others). See Section 3 of this response document for a more complete discussion. | Comments on Issues Related to the Old Harry Modelling Scenarios, 1. The Main Issue Comments on how natural |

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| | | dispersion should look compared to how it does look in Current Models 1.3 |
| Diesel may show some natural dispersion at higher winds, but all current models overdo this- so much so that models are hard to use for diesel spills. Often this is avoided by turning off natural dispersion or by using a different petroleum product in the modelling exercise. | Readers are directed to the NOAA, ITOPF, Cedre and API discussions of the likely fate of light oil and diesel spills provided in Section 4 in the main body of this report for a different view on the fate of diesel spills. | Comments on Issues Related to the Old Harry Modelling Scenarios, 1. The Main Issue Comments on how natural dispersion should look compared to how it does look in Current Models 1.4 |
| Naturally dispersed oil does not go away. Models should record a fate for it. Typically it resurfaces. In high mineral particulate areas, oil can sediment to a degree. Current models need to do more in this regard to be more realistic. | Oil considered naturally dispersed by spill models is in the form of small droplets that are permanently held in open ocean water bodies by natural turbulence. The oil droplets diffuse to lower and lower concentrations and are eventually bio-degraded by naturally occurring bacteria. Oil that is dispersed in small droplets by wave action does not resurface to form new oil slicks. | Comments on Issues Related to the Old Harry Modelling Scenarios, 1. The Main Issue Comments on how natural dispersion should look compared to how it does |

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| | | look in Current Models 1.5 |
| The ASA results are presented for 10,12,15 and 20 knots of wind for both instantaneous discharges of Cohasset and Diesel fuel. Basically the ASA results for Cohasset and Diesel (at 10 knots) are nearly identical to those presented by Environment Canada. Other results also show that there is oil remaining after a period of time. The relevant wind will be dealt with in the next section, but as will be shown, only the 10 knot winds are appropriate because that fits the region and because the natural dispersion model kicks on in the ASA models after 10 knots. This is known to be a problem. | Winds greater than 10 knots exist in the vicinity of the Old Harry project more that 50% of the time in all seasons, so higher wind speeds also needs to be considered when looking at realistic modelling scenarios. The full variability of winds in the region was accounted for in the original Old Harry modelling efforts by SL Ross. An analysis of historical wind speed in the vicinity of the Old Harry site is provided in Section 5 of the main report. | Comments on Issues Related to the Old Harry Modelling Scenarios, 1. The Main Issue The ASA Results 2 |
| It is no surprise that the ASA results are nearly identical to those of Environment Canada since Environment Canada used the models (as well as others) and also the wind level of knots is about the average of the actual winds in the Old Harry area, using the actual winds for the Magdalen Islands. | Please refer to Appendix III for a complete comparison of equivalent ASA and EC modelling results. Even though OilMap products were used by both ASA and EC, model outputs do differ. Modelling results where water-in-oil emulsification formation occurs should not be considered since the Cohasset oil has been shown to not form water-in-oil emulsions (Appendix II). | Comments on Issues Related to the Old Harry Modelling Scenarios, 1. The Main Issue The ASA Results 2 |
| The prime issue of these discussions has been that SLR predicted no oil level at the one day level for all scenarios. It should be noted that the ASA models and the data submitted by Environment Canada show that significant amounts of oil remain on the surface at the one day mark. This necessitates more extensive model by Corridor Resources to show where the oil would go and what its fate would be. | The only model comparisons that are appropriate for the project include those where water-in-oil emulsification does not occur. If the published Environment Canada property data is honoured (Appendix II), then Cohasset crude oil persistence on the surface is limited to less than 24 hours by ASA's predictions assuming 12 knot winds and 120 hours with steady 10 knot winds. It must be stressed, however, that the 10-knot or less winds must persist for the full five day period for the slick to persist for this time period. The SL Ross model results show a higher dispersion of these light oils when the original dispersion algorithm is used and the slicks are estimated to persist | Comments on Issues Related to the Old Harry Modelling Scenarios, 1. The Main Issue The ASA Results 2 |

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| | for a few hours. As noted previously, the dispersion algorithms used by ASA may under predict natural dispersion in wind speeds between 7 and 10 knots (See Section 3 in the main report). | |
| The results of the ASA modelling at 10 knots wind speed are nearly identical to that of Environment Canada's results using actual winds on the Magdalen Islands. | The 10 knot modelling results provided by ASA with rapid emulsification to 74% water content yield nearly identical results to those presented by EC for evaporation alone in their March, 2012 data report. The EC results from their April report are very different from both the ASA results and EC's March data report. No explanation has been provided by EC for these differences. None of the ASA modelling results using OilMap are 'nearly identical' to EC's modelling results using the OilMap products when equivalent runs are compared. This can be seen in the comparison graphs that are included in Appendix III. Regardless, the modelling results assuming that the Cohasset oil forms an emulsion should not be considered in this application (see Appendix II). | Comments on Issues Related to the Old Harry Modelling Scenarios, 2. The ASA Results Comparison of Results – Cohasset Oil |
| EC Figure 1 - This diagram clearly shows that under the conditions specified, that the Cohasset oil would persist for at least 4 days as predicted by both models and both assumptions. The assumptions are that either high or low dispersion exists. Only the SLR model shows that the dispersion removes all the oil immediately.<br>The issue of whether high or low dispersion is used should be noted here. The Cohasset oil as in the ADIOS data base contains an emulsification factor of 70% which if left, reduces its dispersion very much in either the ADIOS model or the OilMap model. If removed, natural dispersion is large. ASA ran the Cohasset both ways and so did Environment Canada. | ASA only ran their model with emulsification allowed up to 74% to match what they assumed was modeled by EC based on the ADIOS data set for Cohasset. This was a scenario tested to try to determine how the OilMap software could have been used to arrive at results for diesel and a light crude that are contrary to how they are known to behave. ASA indicates in their report that it is reasonable to assume that emulsification will not occur with this oil and also modeled the fate of oil with 0% emulsification. The ASA results with 0% emulsification are the most applicable to the project. This is a critical point in the interpretation of the ASA work. | Comments on Issues Related to the Old Harry Modelling Scenarios, 2. The ASA Results Comparison of Results – Cohasset Oil |
| ASA claimed that the inclusion of this factor is a corruption of the data base. | The ASA report states: "When data are missing from the database, both the ADIOS and OilMap model utilize default values or calculations based on proxy oils that can have significant effects on | Comments on Issues Related to the Old |

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| | the fate of the oil". "The Cohasset oil specification in the ADIOS database does not include a value for the maximum allowable water content. In the OilMap model, if the maximum water content is not specified, a default value of 0.74 is used for crude oils and the oil is allowed to emulsify to this limit." This is not appropriate for modelling the Cohasset oil which does not form an oil-in-water emulsion. | Harry Modelling Scenarios, 2. The ASA Results Comparison of Results – Cohasset Oil |
| A check with NOAA shows that these are deliberately put in to reduce dispersion if there is at all a potential for emulsification. In any case, the models were run both ways, so this is irrelevant. In either case the models show that oil still persists for several days at a realistic wind. | Since the published Environment Canada analysis of Cohasset crude oil (Appendix II) shows that it will not form an emulsion, only those model results where emulsion formation was not allowed should be considered. It is our understanding that EC assumed emulsion formation up to 74% in all of their modelling. We have seen no data in the EC reports showing modelling of Cohasset spills with emulsification turned off. | Comments on Issues Related to the Old Harry Modelling Scenarios, 2. The ASA Results Comparison of Results – Cohasset Oil |
| The batch spill of diesel oil was modeled using the ASA models as described earlier. The following figure shows the comparison between the three model runs:<br><br>This graph clearly shows that both the ASA and EC models predict that the diesel would persist for at least 3 to 4 days. The SLR model has the oil entirely gone within hours. | Again, this assumes that only 10 knot winds will exist in the study area and that dispersion will not occur in winds less than 10 knots. Winds greater than 10 knots occur more than 50% of the time, even during summer. Therefore, the full range of wind speeds must be considered and, as discussed in Section 3 of this response document, dispersion does play a role in the fate of the diesel oil. | Comments on Issues Related to the Old Harry Modelling Scenarios, 2. The ASA Results Comparison of Results – Diesel Batch Spill |
| Thus is both cases, the ASA and Environment Canada's predictions are the same<br>- E.g. That the fuels will at least persist for days spilled under conditions that are | A detailed comparison of the diesel modelling results has not been conducted in this review, as much of the same justification for the modelling approach discussed for the Cohasset model results apply for the diesel spills. | Comments on Issues Related to the Old Harry Modelling |

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| relevant to the area. | | Scenarios, 2. The ASA Results Comparison of Results – Diesel Batch Spill |
| A critical point to these discussions is the wind velocity.  A high wind speed should not be used unless it is realistic. The current models have a severe limitation, in that at high winds the dispersion portion of the model kicks in and the oil is predicted to disperse naturally to a high degree. Until further scientific work is carried out to fix this, caution must always be taken to model oil spills at winds below the trigger points (typically over 10 knots) as well as at realistic winds.  In this case, the winds at about 10 knots are appropriate as analysis of the Magdalen Island winds shows an average of about 10 knots. | Winds greater than 10 knots exist in the vicinity of the Old Harry project in all seasons, so higher wind speeds also need to be considered when looking at realistic modelling scenarios (See Table 1 in the main report). The full variability of winds in the region has been accounted for in past modelling efforts through the use of the 52 years of hourly MSC 50 time series wind data. Section 5 includes a statistical breakdown of the wind speeds from a 52 year history of hourly winds from a site near the proposed Old Harry drill site. This assessment shows that in all month's winds greater than 10 knots are more likely than winds 10 knots or less. | Comments on Issues Related to the Old Harry Modelling Scenarios, 3. Wind Conditions |
| This small example shows that the winds in the area are highly variable and that a realistic approach would be to use these actual winds rather than an average. If an average were to be used, 10 knots is appropriate. In Environment Canada's modelling, 13 months of actual data from the Magdalen Islands were used. These were grouped by seasons.<br>Thus there are two reasons a wind speed of about 10 knots is appropriate for this modelling:<br>a) It is realistic compared to the actual winds at the closest weather station | Winds greater than 10 knots exist in the vicinity of the Old Harry project in all seasons, so higher wind speeds also need to be considered when looking at realistic modelling scenarios (See Table 1 in the main report). The full variability of winds in the region has been accounted for in past modelling efforts through the use of the 52 years of hourly MSC 50 time series wind data. Section 5 includes a statistical breakdown of the wind speeds from a 52 year history of hourly winds from a site near the proposed Old Harry drill site. This assessment shows that in all month's winds greater than 10 knots are more likely than winds 10 knots or less. | Comments on Issues Related to the Old Harry Modelling Scenarios, 3. Wind Conditions |

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| b) It is in the region of known model stability. | | |
| A small point is that of temperature. It was noted that ASA modelling was carried out at a sea temperature of 10 °C. The sea temperature in the area is typically below this. It is felt that this would not change results significantly, however might increase the prediction of dispersion somewhat. The following graph shows typical sea temperatures between the Magdalen Islands and the Old Harry site. | Average monthly air and water temperatures were used in the original modelling completed for the project (see section 2.3.4, Table 4 of original SL Ross report to Corridor Resources). A single temperature was chosen to complete the ASA modelling to simplify the comparison to the EC and SL Ross results, not to provide a complete picture of oil behavior under different environmental conditions. | Comments on Issues Related to the Old Harry Modelling Scenarios, 4. Temperature |
| Another issue that should be raised is that of the blowout scenarios. The modelling discrepancies between the SLR and Environment Canada model were also applicable to those scenarios. ASA did not model these. Since these are quite important, the validity of these scenarios need to be addressed. The basic issue is that SLR had predicted that all the oil would be dispersed in the immediate area of the blowout and thus there were no further trajectories or fate necessary. Since similar results would have been obtained by Environment Canada and ASA, it is suggested that the scenarios similar to that created by Environment Canada would still need to be created. | The ASA modelling was completed on batch spills only to provide a basis for comparison with the EC data presented in tabular form in their initial report dated April 25, 2012 and a previous report dated March 31, 2012. The spill volumes used in the ASA modelling were selected to match those used in the batch scenarios presented by EC for as direct a comparison as possible. The primary goal of the ASA modelling was to determine if the EC modelling using the OilMap software was accurate. It has been shown that there is considerable disagreement between the EC modelling results using the ASA OilMap products and the results presented by the expert modellers of ASA. Most, but not all, of the differences between the ASA results and the more recent EC data relate to whether or not the oil is allowed to emulsify. There are even more significant differences between EC's modelling results posted on the C-NLOPB website in their initial report (dated April 24, 2012) and the ASA results.<br><br>Section 5 of this report contains new modelling completed by SL Ross using the Delvigne and Sweeney (1988) dispersion algorithm (used by ASA in their model) to replace the original SL Ross dispersion algorithm. The results are compared to the original blowout modelling analysis completed by SL Ross to demonstrate that the ultimate difference in oil behavior using the less aggressive dispersion model does not result in any material change from an EA perspective (i.e., the zone of influence is not materially affected such | Comments on Issues Related to the Old Harry Modelling Scenarios, 5. Blowout Scenarios |

| | | |
|---|---|---|
| | that it would change EA conclusions). It is our view that additional modelling is not warranted. | |
| Since the ASA modelling confirms that oil will still persist after a few days, as Environment Canada has more modelling needs to be carried out. Further the modelling should use:<br><br>Realistic winds such as the data sets from the Magdalen Islands | Section 5 of this report contains new modelling completed by SL Ross using the Delvigne and Sweeney (1988) dispersion algorithm (used by ASA in their model) to replace the original SL Ross dispersion algorithm. The results are compared to the original blowout modelling analysis completed by SL Ross to demonstrate that the ultimate difference in oil behavior using the less aggressive dispersion model does not result in any material change from an EA perspective (i.e., the zone of influence is not materially affected such that it would change EA conclusions). It is our view that additional modelling is not warranted.<br><br>The 52 year long Meteorological Service of Canada wind data (MSC50 data set) used by SL Ross in the original oil fate and behavior modelling effort is the best wind data available for this application. | Comments on Issues Related to the Old Harry Modelling Scenarios, 6. What Actions are Required |
| Stochastic models to ensure that all probabilities are accounted for | The original modelling investigated the behavior and trajectory of spills released on every day over a 52 year period. As such, the modelling investigated the widest possible range of oil fate and trajectory. | Comments on Issues Related to the Old Harry Modelling Scenarios, 6. What Actions are Required |
| Models that do not over-emphasize natural dispersion or with that factor turned down | New modelling has been completed by SL Ross using the Delvigne and Sweeney (1988) dispersion algorithm in use by ASA in their OilMap product and is presented in Section 5 of this report. The fate and trajectory of the surface oil released on a daily basis over a 52 year period from surface oil blowouts has been provided. The results show a somewhat larger footprint than presented in the original SL Ross report to Corridor Resources as would be expected due to the reduced natural dispersion predicted by the Delvigne and Sweeney algorithm with winds between 3.6 and 5 m/s (7 to 10 knots). The area that could be potentially impacted from the operations is still small, | Comments on Issues Related to the Old Harry Modelling Scenarios, 6. What Actions are Required |

| | | |
|---|---|---|
| | would not interact with any shoreline (see Figure 2), and would not result in any material change from an EA perspective (i.e., the zone of influence is not materially affected such that it would change EA conclusions). | |
| Verification by several models and approaches to ensure that anomalies do not occur | The extensive comparison of model results from ASA and SL Ross that has been completed to date demonstrates a more than adequate effort to ensure that the model results are reasonable for the intended purpose of the modelling, that being environmental impact assessment of a single exploratory well. | Comments on Issues Related to the Old Harry Modelling Scenarios, 6. What Actions are Required |
| Modelling on all the oil released, without removal by questionable processes | The modelling completed by SL Ross and ASA utilizes common oil fate and behavior process algorithms employed by the industry and no oil is removed "by questionable processes" by these models. Different models may use different process algorithms as is the case with the dispersion algorithms that have been discussed. A case can be made for different dispersion methods based on field and laboratory data. Which model is best for a specific application can only be determined after a spill has occurred and if sufficient data is collected on the oil properties, weather conditions and ultimate fate of the oil to permit a detailed modelling of the event. Such data is rare. | Comments on Issues Related to the Old Harry Modelling Scenarios, 6. What Actions are Required |
| Environment Canada has carried out this type of modelling and the proponents are welcome to use these scenarios if they wish. | The original EC modelling results (March, 2012) appear to be in error. Corridor is of the opinion that its consultants, SL Ross and ASA, have conducted sufficient modelling for the purposes of environmental assessment for a single exploration well. The additional information contained within this Corridor response, in conjunction with information contained within previous responses, adequately characterize the potential fate of oil for EA purposes, in the unlikely event that a spill or blowout occurs. | Comments on Issues Related to the Old Harry Modelling Scenarios, 6. What Actions are Required |

# Appendix II

**Comparison of Physical Oil Properties of Fresh and Weathered Macondo (MC252) and Cohasset Crude Oil**

| Oil | Cohasset Crude Oil | | | MC 252 Crude Oil (BP Macondo Spill) | | | |
|---|---|---|---|---|---|---|---|
| Data Source | Whiticar et.al. 1993 | | | Lehr et al. 2010 | | | |
| Evaporation Loss (Volume %) | 0 | 11.2 | 25.6 | 0 | 34.5 | 44.7 | 54.8[!] |
| | | | | | | | |
| Density @ 15 °C | 0.7900 | 0.8046 | 0.8469 | 0.839 | 0.882 | 0.897 | |
| Kinematic Viscosity (cSt) @ 15 °C | 2.06 | 2.7 | 4.83 | 4.8 | 49 | 95 | |
| Pour Point (°C) | -30 | -18 | -12 | <-9 | 6 | 6 | |
| | | | | | | | |
| Emulsion Formation Tendency | Unlikely | Unlikely | Unlikely | Unlikely | Unlikely | Unlikely | Likely |
| Emulsion Formation Stability | Unstable | Unstable | Unstable | Unstable | Unstable | Unstable | Stable |
| Emulsion Water Content (%) | 0 | 0 | 0 | 0 | 0 | 0 | 57 |
| | | | | | | | |

**Notable differences in oils include:**

- Lower fresh and weathered densities and viscosities for the Cohasset crude compared to MC252
- Higher pour points for the MC252 crude
- Emulsions formed for the heavily weathered MC252 crude. No emulsions were found to form in tests with the Cohasset crude. Emulsions were observed to have formed during the BP Macondo incident (MC 252 oil), but not during the Shell Uniacke G-72 incident (Environment Canada, 1984, where oil very similar to Cohasset crude was spilled)

**References**

Environment Canada. 1984. Summary Report of the Regional Environmental Emergencies Team (REET) Involvement in the Uniacke G-72 Blowout Volume 1. Prepared for COGLA-NS by Environmental Emergencies Division, Environmental Protection Service Atlantic Region.

Lehr, B., S. Bristol, A. Possolo. 2010. Oil Budget Calculator Deepwater Horizon TECHNICAL DOCUMENTATION. A Report to the National Incident Command. Appendix B

Whiticar, S., M. Bobra, M. Fingas, P. Jokuty, P. Liuzzo, S. Callaghan, F. Akerman, J. Cao. 1993. A Catalogue of Crude Oil and Oil Product Properties (1992 Edition). Report EE-144, February 1993.

# Appendix III

**Comparison of ASA OilMap and Environment Canada OilMap Modelling Results for a 10,000 Litre Cohasset Oil Spill**

A number of oil spill modelling results and reports have been presented to the C-NLOPB pertaining to the oil spill modelling component of the environmental assessment (EA) for the single well Old Harry Exploratory Drilling Project. In an effort to help the reader develop an understanding of the various modelling results, a comparison of key modelling results as described in the various summary reports is presented herein, namely:

- Environment Canada (EC) OilMap modelling report dated April 24, 2012[1]: This report describes in their Table 1 very low evaporation and dispersion rates for Cohasset oil for a hypothetical 10,000 litre batch spill.
- EC OilMap modelling report dated March, 2012[1]: This report describes in their Table 1 higher and more reasonable evaporation rates, based on EC measured oil properties, than the April report. ASA OilMap modelling report dated September 20, 2012: This report was completed only on 10,000 litre batch spills to provide a basis for direct comparison with the EC data presented in the aforementioned reports. The spill volumes used in the ASA modelling were intentionally selected to match those used in the batch scenarios presented by EC in their April and March, 2012 reports.

Published oil property data from EC is presented in Appendix II for Cohasset crude. The EC spill model results for the 10,000 litre Cohasset spill from their April and March reports are very different (see Figure A-III-1 below) and are not consistent with the published Cohasset oil property data. No explanation has been provided by EC for these differences.

The primary goal of the ASA modelling was to compare the oil mass balance for surface, evaporated and entrained oil for two different specifications of Cohasset crude and one diesel product. However, the focus of this summary document is the Cohasset crude specifications. The modelling was completed by ASA expert modellers under three different constant wind conditions, namely 10, 12 and 15 knots. The ASA modelling results were compared to the EC modelling to better understand the low evaporation and dispersion rates reported by EC in their April and March reports. This comparison is presented in Figures A-III-1 and A-III-2.

As mentioned above, two specifications of Cohasset crude oil were used in the ASA modelling: 1) published oil specification from EC; and 2) the default oil specification from the OilMap software. The default oil specification from the OilMap software database (ASA, 2012) does not include a value for the maximum allowable water content (emulsification).

[1] The EC Reports are presented in this Appendix in the order in which they were received by Corridor (i.e. the April 24, 2012 report was downloaded from the C-NLOPB website after receipt of the April 25, 2012 consolidated comments, and the March, 2012 report was received on July 17, 2012.

In the OilMap software, if the maximum allowable water content is not specified, a default value of 0.74 is used for crude oils. The default oil specification for Cohasset crude in OilMap does not include a value for the maximum allowable water content and, therefore, the default value of 0.74 is used (ASA, 2012). The implications of this are that the default crude specification for Cohasset oil in the OilMap software allows the Cohasset oil to emulsify to 74% water content. This value is appropriate for many crude oils, but it is not appropriate for a very light crude oil such as Cohasset (ASA, 2012), with a zero emulsion formation tendency up to 25.6 percent volume evaporation (Appendix II).

Figures A-III-1 and A-III-2 present a comparison of the various modelling results for the percentage of oil remaining on the surface for a hypothetical batch spill. The presentation of the EC modelling results is the same in both figures. The key difference between the figures is the Cohasset crude oil specification used by ASA (2012). Figure A-III-1 presents a comparison of the EC results with the ASA results for Cohasset oil specification published by EC (without emulsification) and Figure A-III-2 presents a comparison of the EC model results with the ASA modelling results for the default Cohasset oil specification from the OilMap software (with oil emulsification).

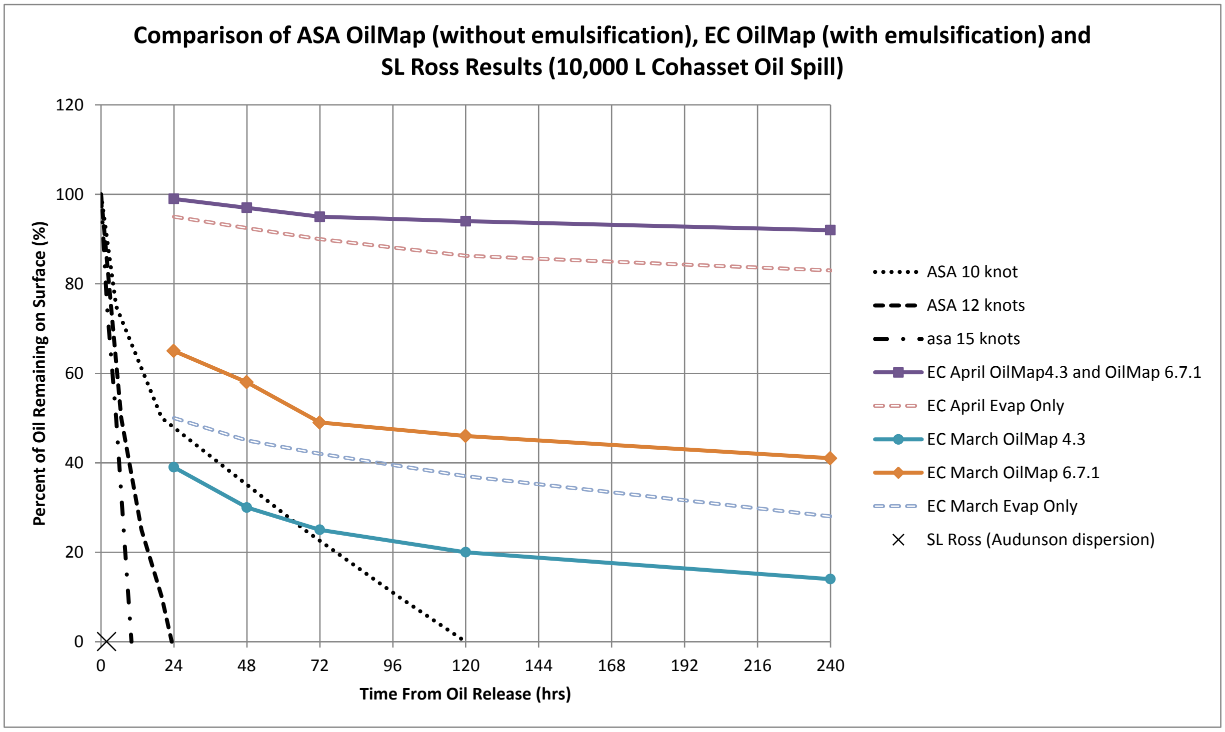


Figure A-III-1: A comparison of the EC results with the ASA (2012) results for Cohasset oil specification published by EC (without emulsification).

The EC results presented in the April, 2012 report are shown in Figures A-III-1 and A-III-2 by the purple solid line and the pink dashed line (see legend at right side of figure). These curves show more than 80% of Cohasset crude oil remaining on the surface for full 240 hours (10 days) presented in the graph. Similarly, the EC results presented in the March, 2012 report are displayed in the figures by blue and orange solid lines and a blue dashed line. These curves show between approximately 40% to 65% of Cohasset crude remaining on the surface at 24 hours and between approximately 15% to 40% remaining on surface after 240 hours.

Although the EC results presented in Figures A-III-1 and A-III-2 are the same, the ASA results are significantly different in the two figures depending on the Cohasset oil specification used. Note that the ASA results are presented according to wind speed. In Figure A-III-1, the ASA model results indicate that all of the Cohasset oil (based on EC published data) will disperse or evaporate within about 10, 24 or 120 hours for wind speeds of 15, 12 or 10 knots, respectively. None of the ASA (2012) model results from OilMap for the Cohasset oil specification published by EC agree with the April or March EC model results from OilMap.

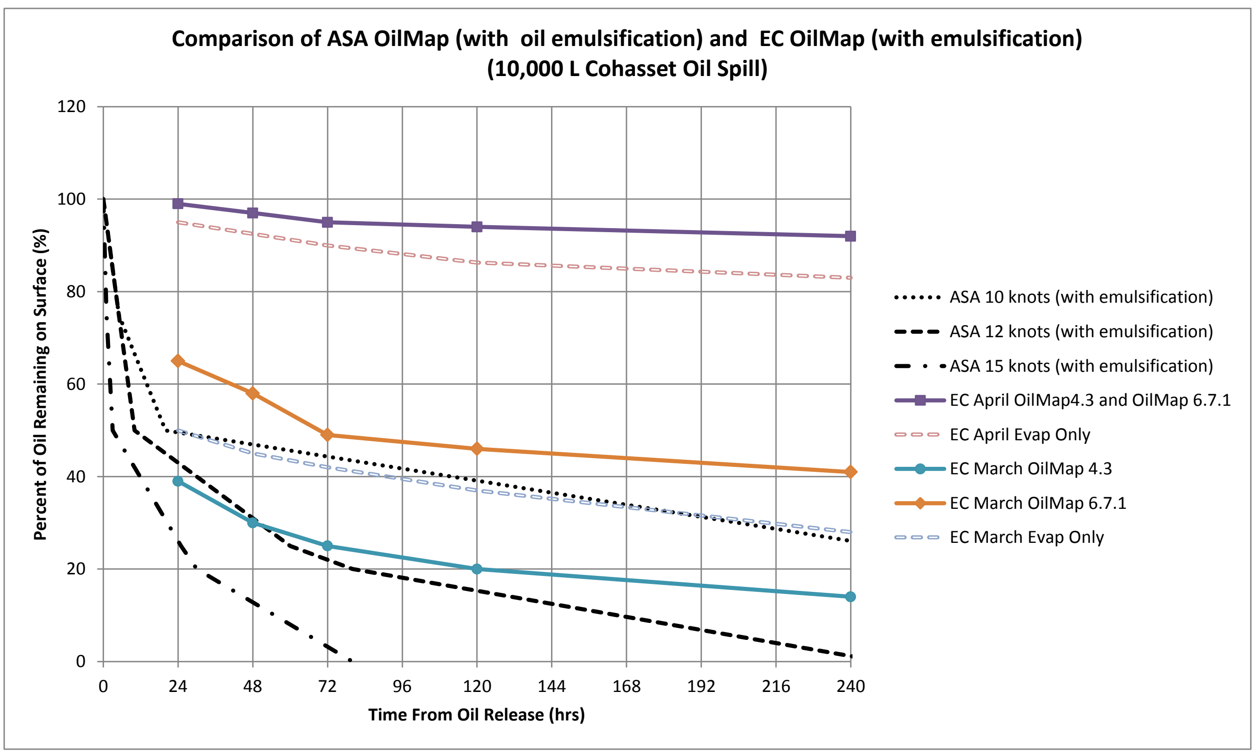


Figure A-III-2: A comparison of EC modelling results with the ASA modelling results for the default Cohasset oil specification from the OilMap software (with oil emulsification).

Figure A-III-2 shows a comparison of the ASA (2012) model results for the default Cohasset oil specification from the OilMap software (i.e. with oil emulsification). The ASA model results show a significant amount of oil remaining on the surface for the three modelled wind speeds, and the curves representing the 10 and 12 knot winds speeds are similar to some of the EC results presented in the March, 2012 report. In fact, the 10 knot curve (black dotted line) for the ASA model results with rapid emulsification to 74% water content for the 10 knot winds speed is nearly identical to the EC curve (blue dashed line) for **evaporation only** from the March, 2012 report. The March EC OilMap 4.3 and 6.7.1 results lie below and above the ASA OilMap 10 knot wind speed results, respectively. This may suggest that the EC modelling work presented in the April and March reports used Cohasset oil specifications that included an emulsification factor rather than the published EC Cohasset oil specification.

Based on the foregoing discussion, it would appear that most, **but not all**, of the differences between the ASA results and the EC model results relate to whether or not the Cohasset oil is allowed to emulsify. We emphasize that **not all** of the difference in results is due to emulsification because none of the EC results using OilMap closely match the ASA OilMap modeling results (ASA, 2012). The closest match exists between the ASA 10 knot wind modelling with oil emulsification and the EC March evaporation only results. ASA (2012) indicates in their report that it is reasonable to assume that emulsification will not occur with the Cohasset oil. Since the published EC analysis of Cohasset crude oil (Appendix II) shows that it will not form an emulsion, only those model results where emulsion formation was not allowed should be considered for spill models involving Cohasset crude oil (i.e. those models that used the published EC Cohasset crude specification).

## Reference

ASA, 2012. Results from Model Simulations of Cohasset Crude. Contract Report Submitted to Corridor Resources, September 20, 2012, 14 p.