8.0 Accidental Events

This chapter assesses the effects of accidental blowouts and spills in the Project Area. The first part discusses the probabilities of occurrence of various types of accidental events. Subsequent sections describe the potential fate, behaviour, and trajectories of released oil, and effects predictions for the seven VECS.

8.1 Probability of Accidental Events

Husky is proposing the development of four new drill centres and subsequent production operations using these drill centres. A maximum of 30 development wells are proposed for the Project Area during the four-year period between fall 2007 and summer 2011.

In the oil and gas industry a distinction is made between two stages of petroleum field drilling: (1) exploration drilling (including “delineation” drilling) where knowledge of the geological and depositional environment is speculative or limited, and (2) development drilling where the structure is better defined. This EA includes only development drilling.

Two types of accidents that could occur during the Project are blowouts and “batch” spills. Blowouts are continuous spills lasting hours, days or weeks that could involve the discharge of petroleum gas into the air and certain amounts of crude oil into surrounding waters. Batch spills are short-duration discharges of oil that could occur from accidents on the dredging vessel, drilling platforms, FPSO or support vessels where fuel oil and other petroleum products are stored and handled. The purpose of this section of the EA is to provide estimates on the probabilities of spills.

8.1.1 General Oil Pollution Record of the Offshore Exploration and Production Industry

An in-depth study by the US National Academy of Sciences (Table 3-2 in NAS 2003) indicates that the oil extraction industry worldwide contributes only <3% of the total petroleum input to the environment. The record is particularly good in the US Outer Continental Shelf (OCS) where 28,000 wells were drilled and over 10 billion (10^9) barrels[3] of oil and condensate were produced from 1972 to 2000; yet only ten blowouts occurred that involved any discharge of oil or condensate. The total oil discharged in the ten events was only 751 barrels.

Because this EA derives spill and blowout statistics for the new drill centre Project from worldwide statistics, it is assumed that the practices and technologies that will be used during development of the new drill centres and subsequent production will be at least as safe as those

[3] The international oil and gas industry primarily works with the oil volume unit of petroleum barrel (which is different than a US barrel and a British barrel). There are 6.29 petroleum barrels in one cubic metre (m^3). Most spill statistics used in this report are taken from publications of the US Minerals Management Service, which works exclusively with the oil volume units of barrels.

used in other offshore oil and gas operations around the world and in accordance with the accepted practices of the international petroleum industry. Because statistics on US offshore oil and gas operations are used extensively in this analysis, it is specifically assumed that the Jeanne d'Arc Basin operations are comparable from a safety viewpoint to operations in US OCS waters.

8.1.2 Sources of Information

Statisticians at the US Minerals Management Service (MMS) have produced a large body of literature on marine oil-spill probability in the US OCS. Because these oil-spill statistics have been peer-reviewed and are updated regularly, they are used as the primary source for this review. Much of the data are now available on the Internet at http://www.mms.gov/stats/index.htm. Another reference is a study by Scandpower (2000), which analyzes blowout statistics related to activities in the Norwegian and UK sectors of the North Sea, as well as the US Gulf of Mexico OCS region (GOM OCS).

8.1.3 Categories of Accidental Event Size

For ease of analyses, five spill size categories were selected for detailed analyses. The first category is for "extremely large" spills, arbitrarily defined as spills larger than 150,000 bbl (23,800 m^3). Good worldwide statistics are available for this size range. The second and third categories are for "very large" and "large" spills, defined by the US Minerals Management Service as spills larger than 10,000 barrels (1,590 m^3) and 1,000 barrels (159 m^3), respectively. The fourth category is for spills in the range 50 to 999 bbl, and the fifth category is for spills in the 1 to 49 bbl category. The spill size classifications used in this study are summarized in Table 8.1.

Note that the top three categories are cumulative (i.e., the large-spill category (>1,000 bbl) includes the very large and extremely large spills, and the very large category includes extremely large spills).

Table 8.1. Spill Size Categories.

Spill Category Name	Spill Size Range (in barrels)	Spill Size Range (in m^3 and tonnes)
Extremely Large spills	>150,000 bbl	(>23,850 m^3 or >20,830 tonnes)
Very Large spills	>10,000 bbl	(>1,590 m^3 or >1390 tonnes)
Large spills	>1,000 bbl	(>159 m^3 or >139 tonnes)
Medium spills	50 - 999 bbl	(7.95 m^3 - 158.9 m^3)
Small spills	1 - 49.9 bbl	(0.08 m^3 - 7.94 m^3)

8.1.4 Extremely Large, Very Large and Large Accidental Events

8.1.4.1 Historical Statistics for Extremely Large and Very Large Spills

The main concern from a safety, environmental and economic perspective, is the possibility of a well blowout occurring and discharging large quantities of oil into the marine environment. In the US, only two moderate-size oil-well blowouts involving oil spills greater in size than 50,000 barrels have occurred since offshore drilling began in the mid-fifties. One must therefore look beyond the US to find a reasonable database on very large and extremely large oil-well blowouts. Table 8.2 lists all worldwide blowouts involving the spillage of more than 10,000 barrels each.

With respect to "extremely large" spills (i.e., oil spills ≥ 150,000 barrels in size), there have been five such spills in the history of offshore drilling, two of which occurred during development drilling and two of which occurred during production or work-over activities. The fifth was from exploration drilling, namely the 1979 Ixtoc 1 oil-well blowout in the Bay of Campeche, Mexico. This largest oil spill in history was caused by drilling procedures (used by PEMEX, Mexico's national oil company) that are not practiced in US or Canadian waters. These drilling procedures are contrary to US and Canadian regulations and to the accepted practices within the international oil and gas industry.

Table 8.2. Historical Very Large (>10,000 bbl) Oil Spills from Offshore Blowouts, 1970-present.

Area	Spill Size (bbl)	Date	Operation Underway
Mexico (Ixtoc 1)	3,000,000	1979	Exploratory Drilling
Dubai	2,000,000	1973	Development Drilling
Iran[a]	?	1983	Production
Mexico	247,000	1986	Work-over
Nigeria	200,000	1980	Development Drilling
North Sea/Norway	158,000	1977	Work-over
Iran	100,000	1980	Development Drilling
USA, Santa Barbara	77,000	1969	Production
Saudi Arabia	60,000	1980	Exploratory Drilling
Mexico	56,000	1987	Exploratory Drilling
USA, S. Timbalier 26	53,000	1970	?
USA, Main Pass 41	30,000	1970	Production
USA, Timbalier Bay/Greenhill	11,500	1992	Production
Trinidad	10,000	1973	Development Drilling

[a] The Iranian Norwuz oil-well blowouts in the Gulf of Arabia, which started in February 1983, were not caused by exploration or drilling accidents but were a result of military actions during the Iraq/Iran war.
Source: Gulf 1981, updated to 2001 by reference to the Oil Spill Intelligence Report.

Spill frequencies are best expressed in terms of a risk exposure factor such as number of wells drilled. On a worldwide basis it has been estimated that 11,737 exploration wells and 24,896 development wells were drilled from 1955 to 1980 (Gulf Canada 1981). The total number of exploration and development wells drilled up to 1988 has been estimated to be 20,000 and

51,000, respectively (Sharples et al. 1989). It is estimated from a number of Internet sources that the number of exploration and development wells drilled to date is approximately 35,000 and 75,000, respectively. There have been only two extremely large spills (>150,000 bbl) during offshore development drilling (Table 8.2), so the frequency up to the present is 2.66 x 10^{-5} spills per well drilled (2/75,000). [4]

A similar analysis can be done for so-called "very large" spills (i.e., those larger than 10,000 barrels). Table 8.2 indicates that four development drilling blowouts have produced spills in the "very large" spill category (including Ixtoc 1), resulting in a spill frequency for "very large" spills of 5.33 x 10^{-5} spills per well drilled (4/75,000).

8.1.4.2 Historical Statistics for Large Spills (>1,000 bbl) from Blowouts

Almost no historical information is available on blowout-related spills in the size range of 1,000 bbl to 10,000 bbl. These likely have occurred with greater regularity than very large spills (>10,000 bbl), but historical information is lacking. Certainly no large spills (>1,000 bbl) from blowouts have occurred in US GOM OCS operations since 1972. However, it seems likely that several have occurred elsewhere.

To check this possibility, spill statistics published by the Oil Spill Intelligence Report (OSIR) (Cutter Information Corp., Arlington, MA) were analyzed. OSIR publishes annual lists detailing all worldwide spills larger in size than 10,000 gallons (238 bbl). Annual reports from 1994 to 1999 were available and surveyed.

Only one large spill (>1,000 bbl) from a blowout occurred during this six-year period. It happened on March 15, 1998 off India, and involved 100,000 gallons (2,380 bbl) of crude. It can be estimated that during this six-year period, approximately 20,000 exploration and development wells were drilled offshore on a worldwide basis. This translates to a frequency of 5.0 x 10^{-5} large spills (>1,000 bbl) per well drilled. This frequency is smaller than the above-calculated value for very large (>10,000) bbl spills, which is 5.33 x 10^{-5}. The lower value can be explained by a number of factors including incompleteness of data. It is certainly possible that better blowout prevention methods were developed and used in the 1990s compared to the 1970s and 1980s when most offshore blowout occurred (Table 8.2). For the purposes of this EA, spills in this size category are not discussed further because of uncertainties associated with the database.

8.1.4.3 Calculated Probability for Husky's Development of New Drill Centres Project

Based on 30 development wells being drilled over a four year period, the spill frequencies estimated for the Drilling Phase of the development of new drill centres Project would be as follows:

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[4] In this and other similar calculations in the report, spill frequency rates are kept as three-decimal data, and the probability numbers are rounded off to two decimal points.

Predicted frequency of extremely large oil spills (>150,000 bbl) from blowouts during the Drilling Phase based on an exposure of thirty wells drilled is 30 x 2.66 x 10^{-5} = 7.98 x 10^{-4} spills. This equates to an annual spill probability during the Drilling Phase of one in 5,012.

Predicted frequency of very large oil spills (>10,000 bbl) from blowouts during the Drilling Phase based on an exposure of wells drilled is 30 x 5.33 x 10^{-5} = 1.60 x 10^{-3} spills. This equates to an annual spill probability during the Drilling Phase of one in 2,500.

Predicted frequency of large oil spills (>1,000 bbl) from blowouts during the Drilling Phase based on an exposure of wells drilled is 30 x 5.0 x 10^{-5} = 3.42 x 10^{-3} spills. This equates to an annual spill probability during the Drilling Phase of one in 2,667.

8.1.5 Blowouts Involving Gas Only or Small Discharges of Oil

Gas blowouts from offshore wells that do not involve a discharge of liquid petroleum are generally believed to be relatively innocuous to the marine environment. Such blowouts do, however, represent a threat to human life and property because of the possibility of explosion and fire.

Two sources are used for historical statistics on blowouts involving only gas or small oil discharges. A particularly good source for US blowouts is the MMS web site because MMS keeps track of spills down to one barrel in size. This is not the case in other parts of the world. A good source for blowouts in the North Sea and in the US GOM is Scandpower (2000), although no reference is given as to whether or not oil spills were involved in the reported blowouts.

8.1.5.1 MMS US GOM OCS Statistics

Data representing the 29-year period from 1972 to 2000 are contained in Table 8.3. Note that there are no large spills (>1,000 bbl) in the entire database. However, if the database had started in 1970, two very large blowout spills would have been included of 30,000 barrels and 53,000 barrels respectively (Table 8.2).

The total number of exploration and development wells drilled in the US OCS from 1972 to 2002 is not shown in Table 8.3, but it is derived from other sections of MMS (1997), the E&P Forum (1996), and from current Internet sources. The approximate numbers of exploration and development wells drilled in the US during the thirty-year period are 10,000 and 20,000, respectively.

Table 8.3. Blowouts and Spillage from US Federal Offshore Wells, 1972-2002.

Year	Well Starts	Drilling Blowouts				Non-drilling Blowouts								
		Exploration		Development		Production		Workover		Completion		Total Blowouts		OCS Production
		No.	bbl	No.	bbl	No.	bbl	No.	bbl	No.	bbl	No.	bbl	MMbbl
1972	845	2	0	2	0	1	0	0	0	0	0	5	0	396.0
1973	820	2	0	1	0	0	0	0	0	0	0	3	0	384.8
1974	802	1	0	1	0	4	275	0	0	0	0	6	275	354.9
1975	842	4	0	1	0	0	0	1	0	1	0	7	0	325.3
1976	1,078	1	0	4	0	1	0	0	0	0	0	6	0	314.5
1977	1,240	3	0	1	0	1	0	3	0	1	0	9	0	296.0
1978	1,164	3	0	4	0	0	0	3	0	1	0	11	0	288.0
1979	1,140	4	0	1	0	0	0	0	0	0	0	5	0	274.2
1980	1,158	3	0	1	0	2	1	1	0	1	0	8	1	274.7
1981	1,208	1	0	2	0	1	0	3	64	3	0	10	64	282.9
1982	1,255	1	0	4	0	0	0	4	0	0	0	9	0	314.5
1983	1,180	5	0	5	0	0	0	2	0	0	0	12	0	350.8
1984	1,352	3	0	1	0	0	0	1	0	0	0	5	0	385.1
1985	1,169	3	0	1	0	0	0	2	40	0	0	6	40	380.0
1986	694	0	0	1	0	0	0	1	0	0	0	2	0	384.3
1987	845	2	0	0	0	3	0	1	0	2	60	8	60	358.8
1988	950	1	0	1	0	0	0	1	0	0	0	3	0	332.7
1989	947	2	0	[1]5	0	3	0	1	0	0	0	11	0	313.7
1990	1,018	1	0	1	0	0	0	3	9	1	0	6	9	304.5
1991	726	3	0	[2]3	0	0	0	0	0	0	0	6	0	326.4
1992	431	2	100	0	0	0	0	0	0	0	0	2	100	337.9
1993	879	0	0	[3]4	0	0	0	0	0	0	0	4	0	352.7
1994	845	0	0	0	0	0	0	1	0	0	0	1	0	370.4
1995	798	1	0	0	0	0	0	0	0	0	0	1	0	429.2
1996	889	1	0	2	0	0	0	0	0	1	0	4	0	433.1
1997	954	1	0	4	0	0	0	0	0	0	0	5	0	466.0
1998	993	1	0	5	2	0	0	0	0	0	0	6	2	490.5
1999	962	1	0	4	0	0	0	0	0	0	0	5	0	534.6
2000	973	4	200	4	0	0	0	0	0	0	0	8	200	551.6
2001	[5]954	1	0	4	1	3	0	1	0	1	0	10	1	588.6
2002	[5]954	1	0	2	0	2	350	1	1	0	0	6	351	608.9
Total	**30,065**	**58**	**300**	**69**	**3**	**[4]21**	**626**	**30**	**114**	**12**	**60**	**190**	**1103**	**11805.6**

[1]Two of the drilling blowouts occurred during drilling for sulphur.
[2]Two of the drilling blowouts occurred during drilling for sulphur.
[3]Two of the drilling blowouts occurred during drilling for sulphur on the same well.
[4]The number in the original source (36) is a typographical error.
[5]Estimated based on average of previous five years.

The indicated number of blowouts from development is 69. Therefore, the blowout frequency is 69/20,000 or 3.45 x 10^{-3} blowouts per well drilled, or one blowout for every 290 development wells drilled. Two of the blowouts involved an oil spill, one of size 200 bbl and the other 100 bbl. These statistics suggest that most blowouts occurred in gas-prone fields or were shallow-gas blowouts.

8.1.5.2 Calculated Probability for Husky's Development of New Drill Centres

There are a maximum of thirty development wells to be drilled during the four year Drilling Phase between fall 2007 and summer 2011. The calculated blowout frequency is 30 x 3.45 x 10^{-3} = 1.04 x 10^{-1} or a one-in-ten chance of a blowout occurring over the 30-well Drilling Phase. However, the chances of having an oil discharge associated with the blowout are extremely low, actually 3.4% (two oil spills from 58 exploratory well blowouts) according to the statistics in Table 8.3. This means the chance of having a blowout involving any oil is 0.034 x 3.45 x 10^{-3} or 1.2 x 10^{-4} per well drilled (for the 30-well Drilling Phase, 30 x 1.2 x 10^{-4} = 3.6 x 10^{-3}, or a probability of one-in-278 during the 30-well Drilling Phase).

8.1.6 Smaller Platform Spills

8.1.6.1 Historical Record

Small spills occur with some regularity at offshore platforms. Table 8.4 lists spills of size larger than one barrel of all pollutants from facilities and operations on federal OCS leases from the period 1971 to 1995. It is derived from a more detailed table in MMS (1997) and from data at the MMS web site.

Table 8.4. Spill Frequency from Platforms for Spills in the Ranges of 1 to 49 bbl and 50 to 999 bbl (US OCS 1971 to 1995).

Spill Size Range	Number of Spills	Spills per Well Drilled
1 to 49 bbl	1,857	7.7 x 10^{-2}
50 to 999 bbl	86	3.6 x 10^{-3}

Total volume of 1,857 + 86 spills = 122,232 barrels.

The spills involved various pollutants including crude oil, condensate, refined product, mineral oil, and diesel. The period between 1971 and 1995 involved the production of 8.5 billion barrels of oil and condensate and the drilling of 24,065 wells (MMS 1997). This means that 1,857/24,065 = 7.7 x 10^{-2} spills having size between 1 and 49 barrels occurred for every well drilled, and that 86/24,065 or 3.6 x 10^{-3} spills having size in the range of 50 to 999 barrels occurred for every well drilled.

It is of interest to note that the small spill frequencies in the Gulf of Mexico OCS were relatively high in its early stages, but have decreased by almost a factor of ten over the past 25 years. This is shown in Figure 8.1. The spill frequency statistics in Table 8.4 represent the average over the 25-year period.

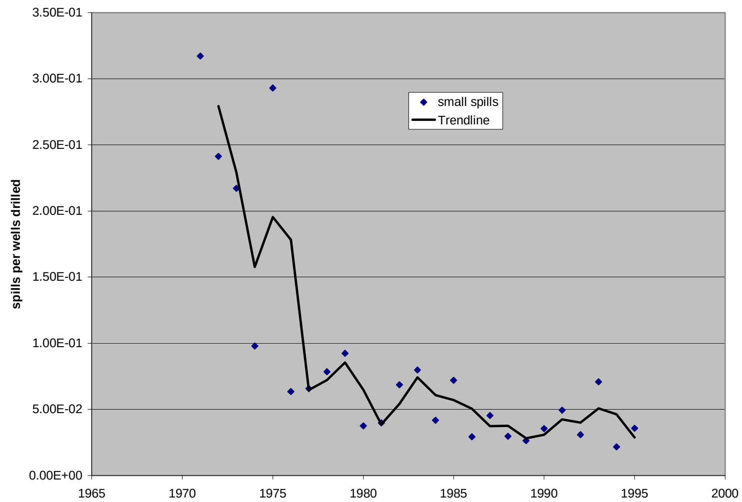

Figure 8.1 Frequency of Small Platform Spills (1 to 49 bbl) in the US GOM, 1971 to 1995.

Similar spill statistics for 1997 through 2000 are shown for operations off Newfoundland in Table 8.5 and Figure 8.2 (C-NLOPB web site). No medium spills (>50 bbl) have occurred in the years shown. Note that these statistics do not include the recent production-related spill of approximately 1,000 barrels at Terra Nova, in November 2004, because a complete record of spills and wells drilled has yet to be published for 2004. It is interesting to note that the GOM statistic of 3.6×10^{-3} "medium" spills per well drilled corresponds to one such spill per 280 wells drilled and the total number of wells drilled to date in the Newfoundland offshore area is approaching 280. It is seen that small-spill frequencies have been dropping, but values are significantly higher than current values reported above for the US Gulf of Mexico OCS region. This may be due to start-up issues in Newfoundland, as were experienced in the US GOM area, but perhaps more likely due to better reporting procedures in Newfoundland. [Note that spill statistics with the same breakdown by volume are no longer available from C-NLOPB, so the record in Table 8.5 cannot be updated. Nonetheless, Table 8.5 provides some comparison based on the "small" category, comparable to the more extensive US GOM statistics.]

Table 8.5. Spill and Well Statistics from Platforms off Newfoundland.

Year	Wells Drilled	Small Spills 1 bbl < Volume < 50 bbls		Small spills per wells drilled
		Drilling rigs	Hibernia & Terra Nova	
1997	5	0	4	0.80
1998	9	3	2	0.56
1999	19	5	5	0.53
2000	17	1	4	0.29
Total	50	9	15	0.48

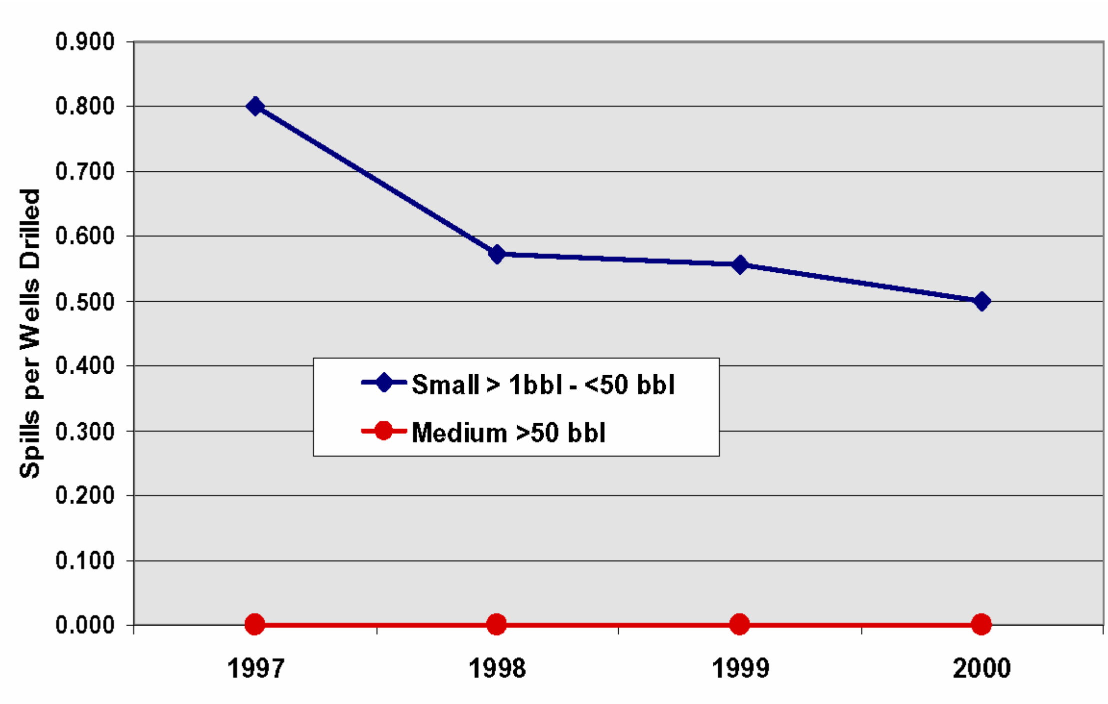

Figure 8.2 Frequency of Small and Medium Spills from Platforms off Newfoundland.

This section of the EA considers the drilling of 30 wells during the four year Drilling Phase, and thus the small and medium spill frequency ranges in Table 8.6 are simply the values indicated in Table 8.5 and Figure 8.2 multiplied by 30.

Table 8.6. Predicted Small and Medium Spill Frequencies for Drilling Phase of New Drill Centre Project.

Spill Size Range	US GOM Experience, 1971 to 1995, spills/well drilled	Newfoundland Experience, 1997 to 2000, spills/well drilled	Number of Spills During Drilling Phase
Small Spill 1 to 49 bbl	7.7×10^{-2}	4.8×10^{-1}	2.3 to 14.4
Medium Spill >50 bbl	3.6×10^{-3}	0	0 to 0.11

8.1.6.2 Calculated Frequencies for the Drilling Phase of Husky's Development of New Drill Centres Project

Table 8.7 indicates the calculated accidental event statistics for the Drilling Phase of this Project.

Table 8.7. Predicted Number of Blowouts and Spills for Four-Year Drilling Phase of Husky's Development of New Drill Centres Project.

Event	Historical Frequency[a]	No. of Events (30-well Drilling Phase)	Probability
Gas blowout during development drilling	3.45×10^{-3}/well drilled	1.0×10^{-1}	1 in 10
Development drilling blowout with oil spill > 10,000 bbl	5.33×10^{-5}/well drilled	1.6×10^{-3}	1 in 625
Development drilling blowout with oil spill > 150,000 bbl	2.66×10^{-5}/well drilled	8.0×10^{-4}	1 in 1,253
Platform-based oil spill, 50 to 999 bbl	3.6×10^{-3}/well-drilled	1.08×10^{-1}	1 in 10
Platform-based oil spill, 1 to 49 bbl	7.7×10^{-2}/well drilled	2.3	1 in 0.4

[a] The US GOM

8.1.7 Summary of Blowout and Spill Frequencies

The calculated oil spill frequencies are summarized in Table 8.7. The highest frequencies are for the smallest, platform-based spills (i.e., 1 to 49 bbl) which have a >100% chance of occurring during the 30-well Drilling Phase of the development of new drill centres. The average size of this small spill type can be expected to be less than 10 barrels. There is a 10% chance that a platform-based spill larger than 50 barrels might occur over the course of the entire Drilling Phase.

The chances of an extremely large (>150,000 bbl) and very large (>10,000 bbl) oil well blowouts from development drilling are very small: 0.08% and 0.16%, respectively. These predictions are based on worldwide blowout data and are strongly influenced by blowouts that have occurred in Mexico, Africa and the Middle East, where drilling and production regulations may be less rigorous than in North America. It might be reasonable to expect even lower frequencies for the Drilling Phase of this Project in the Jeanne d'Arc Basin given the significant improvement of technology and/or practice over the past 15 years. There could be about a 10% chance of having a blowout involving gas only.

8.2 Oil Spill Behaviour and Fate from Hypothetical Blowouts and Spills

The objective in this part of the EA is to assess the behaviour of oil spills that might occur during the Husky White Rose Development Project: New Drill Centre Construction & Operations Program. It is based on modelling done for Husky's Lewis Hill drilling EA (LGL 2003) and subsequently applied in the Husky Delineation/Exploration Drilling Program for Jeanne d'Arc Basin Area Environmental Assessment (LGL 2005a). A number of hypothetical oil spills were selected that cover the main concerns. Their fate and behaviour have been described in detail. These spill scenarios, involving various spill types and sizes, serve subsequently as the basis for impact assessment and countermeasures analyses.

At this time, it is assumed that the properties of the oil that will be produced from the new drill centres will be similar to that of the White Rose crude. This oil is "waxy" and behaves in an unusual manner when spilled in cold waters. Because of this unique behaviour and its influence on both spill impact and cleanup potential, considerable time was spent in the White Rose Oilfield Comprehensive Study describing laboratory analysis of the oil and its implications to spill impact and spill persistence. This description is provided in Husky (2000) and SL Ross (2002b). White Rose crude oil spills, depending on volume, would be highly persistent, perhaps lasting weeks and even months on the water surface.

Provided below is a description of the scenarios selected for the Lewis Hill Project (and used for this EA) and the environmental conditions to which the spills would be subjected. This is followed by a discussion of the results of computer/mathematical modelling that was completed to estimate the behaviour and fate of these hypothetical spills. Further, an assessment was made of the chances of any spilled oil reaching shore from the Jeanne d'Arc area by relying on the extensive spill trajectory modelling exercise conducted for the Comprehensive Study.

8.2.1 Oil Characteristics

Analysis of White Rose crude oil (from well L-08) has shown that the oil is highly waxy (SL Ross 2000). This means that for some spill situations the oil will form near-solid particles when spilled in cold water that could potentially persist for weeks and even months on the water surface. This behaviour has a dramatic influence on both spill impact and cleanup potential.

Table 8.8 lists the important spill-related physical properties of the White Rose crude as compared to other Grand Banks oils. It is seen that the viscosity and pour point of the White Rose crude are higher than any of the other Grand Banks crude oils analysed. The pour point of the White Rose crude is higher than the average summer water temperature, and this has significant implications for the behaviour of spills of the oil.

Another key spill-related property of all of the White Rose and Terra Nova crude oils analysed to date is that they form very stable water-in-oil emulsions when spilled, even when the oil is fresh (i.e., before evaporation has occurred). The formation of stable emulsions has implications for spill behaviour, particularly the persistence of the oil on the surface.

The remainder of the spill-related physical properties of the White Rose crude are typical of a medium-gravity crude oil.

Table 8.8. Properties of White Rose Crude Compared to Other Grand Bank Crudes.

Crude Property	Oil Type			
	Hibernia[a]	**Terra Nova[b]**	**Hibernia[c]**	**White Rose[d]**
API gravity	30.4	32.5	35.0	33
Density, kg/m^3 @ 15EC	874	862	850	859
Viscosity, (mm^2/s) @ 25EC	25	18.2	30	38
Air/oil Interfacial tension (mN/m)	27.2	29	28.8	30
Oil/seawater Interfacial tension (mN/m)	21	29.6	9.2	25
Pour Point, (EC)	9	12	-6	18
Flash Point, (EC)	14	< 21	12.5	<0
Emulsion Formation Tendency and Stability @ 1EC and 15EC	very stable	very stable	not stable	very stable
Aqueous Solubility (g/m^3) in Saltwater @ 22EC	17	18.78	not measured	not measured

[a] B-27 well (SL Ross and DMER 1988 and SL Ross 1984).
[b] K08 well DST.4 (SL Ross 1985).
[c] Hibernia as produced (SL Ross 1999).
Note that this oil was very different (less waxy, low stability emulsions) than the oil tested in 1984.
[d] White Rose L-08 (SL Ross 2000).

8.2.2 Selection of Blowout/Spill Scenarios

In this section, hypothetical oil spills from oil well blowouts and batch fuel oil spills from vessel or platform activities have been selected for study. These were used in the following sections as a basis for describing the fate and behaviour of hypothetical spills.

The specific objective is to develop detailed spill scenarios that are illustrative of what one might expect if a major spill occurred during the new drill centre Project. There are two main possibilities for large spills from this Project: the first is a continuous spill from a subsea oil-well blowout and the second is a continuous spill from a surface blowout. Small fuel oil spills from the platform or vessels supporting the operations are also possible.

8.2.3 Blowout/Spill Scenarios

Table 8.9 shows the scenarios that were selected for the drilling EAs for both Lewis Hill and Jeanne d'Arc Basin, and are re-employed here. The worst-case blowout scenarios selected are identical to those used in the White Rose Oilfield Comprehensive Study.

Table 8.9. Summary Selected Spill Scenarios.

Spill Type	Source	Flow	Duration (days)
Blowout	Subsea	20,250 BOPD (3,218 m^3/day)	7
		4,170 BOPD (663 m^3/day)	45
	Platform	15,900 BOPD (2,525 m^3/day)	7
Batch	Vessel or Platform	10 bbl (1.59 m^3)	instantaneous
		100 bbl (and 15.90 m^3)	instantaneous

8.2.3.1 Blowouts

The methodology used to select and size the various blowout scenarios was originally developed for use in the Beaufort Sea (Adams Pearson Associates 1991). The specific techniques used to calculate fluid escape paths, flowrates and incident durations are beyond the scope of this document.

8.2.3.2 Batch Spills

Fuel oils are transferred and handled on the platforms and vessels that are used in offshore activities. Past experience in the other areas of the world suggests that small spills of marine fuel oils could occur.

8.2.3.3 Environmental Conditions Assumed for Scenarios

For each scenario, calculations of oil slick behaviour and fate were made for two sets of seasonal environmental conditions. Average monthly temperatures and winds for the area (Table 8.10) are taken from the Environmental Setting component of the Terra Nova EIS.

Table 8.10. Environmental Data (adapted from Terra Nova EIS).

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ave. Air T (ºC)	0	-1	1	2	4	7	11	14	12	9	5	2
Ave. Water T (ºC)	1	0	0	1	3	8	11	14	13	10	7	4
Ave. Wind (km/h)	42.5	42.5	37	33	32	32	32	28	32	36	39	42.5

For the seasonal generic scenarios modelled at the oilfield site, a winter spill was defined as occurring with air and water temperatures of 2ºC and winds of 42.5 km/h (12 m/s); a summer spill had air and water temperatures of 11ºC and winds of 32 km/h (9 m/s).

8.2.4 Modeling and Description of Selected Blowout/Spill Scenarios

In referring to the fate and behaviour of marine oil spills, one usually takes "fate" to mean the three-dimensional movement of the spill as it is driven by winds and currents, and "behaviour" to mean the processes that the spill is undergoing (spreading, evaporation, dispersion, etc.). These processes change the oil's properties (e.g., viscosity, density, etc.) and change its distribution in the environment (air, water surface, and water column). This section focuses on the behaviour of the selected hypothetical spills. The following section concentrates on the fate or trajectory of the spilled oil.

Of particular interest is the behaviour of large blowout spills at and near the platform, because it is here where spill control measures can be most effective. Also important are the distribution and "stickiness" of the oil particles on the surface as a function of time because these factors will influence impacts on birds that utilize the surface waters.

The predictions used in this section were generated using a state-of-the-art spill behaviour and fate model. For the scenario descriptions, average seasonal temperatures and winds were used. (For the trajectory analysis in the following section time-varying winds were used.) The model used as input the properties of White Rose crude (SL Ross 2000, 2002b). Spill behaviour predictions were made for the five scenarios summarized in Table 8.9, for both summer and winter conditions.

8.2.4.1 Blowout Scenarios

The near-source behaviour of the hypothetical platform blowout is described first, followed by the descriptions for the two subsea blowouts.

8.2.4.1.1 15,900 BOPD Platform Blowout Lasting Seven Days in Summer.

A blowout occurs at the on-site rig resulting in a discharge of 15,900 BOPD of crude with a gas-to-oil ratio (GOR) of 130 m^3/m^3 (730 ft^3/bbl) (Table 8.11). The platform and rig are not damaged and remain in position throughout the 7-day blowout period. The gas exits at the drill floor (25 m above the water surface) at high velocity and shatters the oil into small diameter droplets. These droplets are shot upward by the jet of gas, impact on the derrick and agglomerate to a size of about 0.75 mm. [This median drop size has been selected for all surface blowout modeling based on model calibration results using data from the Ekofisk blowout.] These droplets rain down on the water beside the rig. Most of the droplets fall onto the water surface within about 300 metres of the rig in a swath about 70 metres wide and re-coalesce to form a slick. Throughout the seven days required to kill the well, the air and water temperatures average 11ºC. The surface water current is 0.25 m/s.

Table 8.11. Spill Behaviour for 15,900 BOPD Platform Blowout during Summer and Winter.

Time Since Spill		Season	Total Slick Width (m)	Slick Thick. (mm)	Water Content (%)	Viscosity (mPas)	Pour Point (°C)	% Evap.	% Disp.
Hours	Days								
0	0	S	70	6.8	0	7600	17.9	4.8	0
		W	85	6.3	0	131,000	17.4	3.1	0
1	0.04	S	79	6.7	46	50,000	18.3	6.0	0.01
		W	86	6.3	60	semisolid	17.5	3.4	0
6	0.25	S	154	6.5	74	654,000	19.4	9.2	0.01
		W	97	6.2	75	semi-solid	17.9	4.9	0
12	0.5	S	230	6.3	75	semi-solid	20.0	11.2	0.015
		W	114	6.1	75	semi-solid	18.5	6.5	0
24	1	S	350	6.2	75	semi-solid	20.7	13.3	0.02
		W	147	5.9	75	semi-solid	19.4	9.2	0
48	2	S	534	6.0	75	semi-solid	21.5	15.4	0.04
		W	200	5.7	75	semi-solid	20.5	12.6	0
120	5	S	890	5.6	75	semi-solid	22.5	18.3	0.17
		W	310	3.8	75	semi-solid	22.0	16.8	0
240	10	S	1250	4.7	75	semi-solid	23.4	20.7	0.70
		W	440	3.6	75	semi-solid	23.0	19.5	0.01
480	20	S	1590	3.6	75	semi-solid	24.1	23.1	2.8
		W	610	3.4	75	semi-solid	23.9	21.8	0.03
720	30	S	1720	2.9	75	semi-solid	25.0	24.4	5.7
		W	730	3.3	75	semi-solid	24.4	23.2	0.07

The slick at source is about 70 m wide and 6.8 mm thick. The oil making up the slick has lost about five percent of its volume to evaporation of the oil as droplets in the air. The resulting oil has a viscosity of 7650 mPas and a pour point of 18ºC (higher than the average summer temperature). Within the first hour of exposure to the environment, the oil has formed an emulsion containing 50 percent water. The water content increases to 75% after 12 hours. The emulsion is estimated to be semi-solid within about 12 hours.

The extremely high viscosity values reported in this document should be used only as an indicator that these oils will indeed be very viscous, semi-solid in many instances, and thus persistent. These highly viscous products are non-Newtonian fluids and thus the shear rate at which the viscosity is reported is necessary for the estimate to be of any practical use. Models for the prediction of such rheological information for oil spills do not exist. Where viscosities have been estimated to be greater than about 1 million mPas, by the simple model used (Mackay et al. 1980), the oil has been reported to be semi-solid.

As the oil drifts from the site, wave action breaks the slick up into viscous mats of oil which move away from each other under the influence of oceanic turbulence. Because the oil is thick and viscous it survives for a very long time at sea. After 30 days seventy percent (70%) of the oil discharged is still on the surface. The makeup of this oil will depend on the harshness of the environment over this period. It is likely that after 30 days the oil will be broken into small tar-balls spread over a large area, with the oil particles separated by large expanses of water.

8.2.4.1.2 15,900 BOPD Platform Blowout Lasting Seven Days in Winter

This is identical to the previous accident, except that it occurs in winter conditions (higher winds, 12m/s, and colder temperatures, 2°C) (Table 8.11). The higher winds results in a longer hang time for the droplets (they fall out within 400 m of the rig) and a slightly wider slick (85 m). The colder temperatures result in slightly less initial evaporation (3% by volume) but a higher initial viscosity (131,000 mPas). As with the summer scenario, the oil emulsifies rapidly (60% water content in one hour) to form extremely persistent mats of emulsion. Even with the higher average winter winds and higher sea-states, 75% of the oil discharged is estimated to remain on the sea surface after 30 days.

8.2.4.1.3 20,250 BOPD Subsea Blowout Lasting Seven Days in Summer

In this scenario, the blowout occurs through the casing shoe and the oil and gas flow to the seabed through a fracture in the rock (Table 8.12). The oil flowrate is 20,250 BOPD and the GOR is 130 m^3/m^3 (730 ft^3/bbl). The fluids erupt from the seabed and the gas breaks the oil up into small droplets that are carried to the surface by the water being drawn up by the gas. Throughout the seven days before the wellbase collapses, sealing off the flow, the temperatures are 11ºC and the wind is 9 m/s.

At the surface the oil drops do not spread to form a slick because the ambient temperature is below the oil's pour point. The entrained water flow creates a hyperbolic-shaped slick that extends 250 metres up current of the gas boil zone (located at the focus of the hyperbole) and that is 1,570 metres wide down stream of the gas boil. The droplets of oil are widely scattered in this zone and occupy only about 10% of the surface area. By the time the slick has spread to 1,570 metres the oil droplets have lost 10% of their volume to evaporation; this increases to 15% after six hours, 20% after 24 hours up to a maximum of about 30% after several days.

The slick spreads slowly from its initial width to reach 1630 metres after 48 hours. The fresh oil viscosity at the summer temperature is 3400 mPas. Evaporation raises the viscosity of the droplets, which do not emulsify, to 99,000 mPas after 12 hours and 155,000 mPas after 24 hours. Evaporation also slightly reduces the diameter of the droplets, from 1.1 mm initially to 0.98 mm after 24 hours.

Table 8.12. Spill Behaviour for 20,250 BOPD Subsea Blowout during Summer and Winter.

Time Since Spill		Season	Total Slick Width (m)	Particle Diameter (mm)	Water Content (%)	Viscosity (mPas)	Pour Point (°C)	% Evap.	% Disp.
Hours	Days								
0	0	S	1570	1.06	0	3370	16.5	0	0
		W	1170	1.06	0	77,000	16.5	0	0
1	0.04	S	1570	1.02	0	20,500	19.7	10.0	0
		W	1180	1.05	0	145,000	17.6	3.6	0
6	0.25	S	1580	1.0	0	63,500	21.6	15.7	0
		W	1190	1.02	0	513,000	19.8	10.4	0
12	0.5	S	1580	0.99	0	99,000	22.4	17.9	0
		W	1195	1.01	0	semi-solid	21.1	14.1	0
24	1	S	1600	0.98	0	155,000	23.2	20.0	0
		W	1205	0.99	0	semi-solid	22.2	17.2	0
48	2	S	1625	0.97	0	243,000	24.0	22.1	.01
		W	1225	0.98	0	semi-solid	23.1	19.8	0
120	5	S	1700	0.96	0	440,000	25.0	24.7	.04
		W	1275	0.97	0	semi-solid	24.3	22.7	0
240	10	S	1800	0.95	0	690,000	25.8	26.7	0.1
		W	1350	0.96	0	semi-solid	25.1	24.8	0
480	20	S	1990	0.94	0	semi-solid	26.6	28.6	0.25
		W	1490	0.95	0	semi-solid	25.9	26.8	0.02
720	30	S	2150	0.94	0	semi-solid	27.0	29.7	0.46
		W	1605	0.95	0	semi-solid	26.3	27.9	0.03

The droplets are extremely persistent, losing only 30% of their volume after 30 days, primarily through evaporation. Little or no dispersion is expected.

8.2.4.1.4 20,250 BOPD Subsea Blowout Lasting Seven Days in Winter

This scenario is identical to the previous one, except that it occurs in winter with higher winds (12 m/s) and colder temperatures (2ºC) (Table 8.12). The upstream extent of the slick (190 m) from the gas boil is slightly less than in summer and its downstream width is also less (1,170 m). This is due to the higher wind-driven water current. The colder temperatures also slow the evaporation rate of the droplets, even in higher winds.

The fresh oil viscosity at the average winter temperature is 77,000 mPas. Evaporation raises the viscosity of the droplets, which do not emulsify, to a semi-solid state within 12 hours. As with the summer spill, the oil is very persistent, with only 28% lost in 30 days at sea with little or no dispersion expected.

8.2.4.1.5 4,170 BOPD Subsea Blowout in Summer

This scenario is similar to the previous subsea blowout, except that the oil and gas flowrates are lower (Table 8.13). As a result, larger oil droplets are generated at the seabed (5.1 mm) and the upstream extent (190 m) and downstream width (925 m) are less than for the 20,250 BOPD situation.

The oil droplets lose 5% of their volume to evaporation in the first hour, 13% by 12 hours and 17% after 48 hours. The droplets do not emulsify, but the evaporative loss increases their viscosity to 23,500 mPas in 6 hours and 56,300 mPas in 24 hours. The droplets are extremely persistent. Only 30% of their volume is lost over 30 days, primarily through evaporation.

8.2.4.1.6 4,170 BOPD Subsea Blowout in Winter

The only differences between this scenario (Table 8.13) and the previous one are higher winds (12 m/s) and lower temperatures (2ºC) (see Table 7.14). The higher winds generate faster surface currents which make for a narrower slick (696 m) with a smaller upstream extent (110 m). The colder temperatures reduce the evaporation rate slightly when compared to the summer scenario. The oil droplets lose 3% of their volume to evaporation in the first hour, 10% by 12 hours and 15% after 48 hours. The droplets do not emulsify, but the evaporative loss increases their viscosity to 288,000 mPas in six hours and to a semi-solid state within 24 hours. The oil is much more viscous than in summer due to the colder temperatures. The droplets are extremely persistent. Only 25% of their volume is lost over 30 days, primarily through evaporation.

Table 8.13. Spill Behaviour for 4,170 BOPD Subsea Blowout during Summer and Winter.

Time Since Spill		Season	Total Slick Width (m)	Particle Diameter (mm)	Water Content (%)	Viscosity (mPas)	Pour Point (°C)	% Evap.	% Disp.
Hours	Days								
0	0	S	924	5.1	0	3370	16.5	0	0
		W	696	5.1	0	77,000	16.5	0	0
1	0.04	S	927	5.0	0	8480	18.1	5.2	0
		W	698	5.07	0	124,000	17.3	2.7	0
6	0.25	S	940	4.9	0	23,500	19.9	10.6	0
		W	706	5.0	0	288,000	18.8	7.4	0
12	0.5	S	950	4.9	0	32,000	20.7	12.9	0.01
		W	715	4.9	0	480,000	19.7	10.1	0
24	1	S	975	4.8	0	56,000	21.44	15.1	0.02
		W	730	4.9	0	semi-solid	20.6	12.8	0
48	2	S	1015	4.8	0	88,000	22.2	17.4	0.04
		W	760	4.8	0	semi-solid	21.5	15.3	0
120	5	S	1130	4.7	0	159,000	23.3	20.3	0.12
		W	840	4.8	0	semi-solid	22.6	18.4	0.01
240	10	S	1290	4.7	0	249,000	24.0	22.5	0.33
		W	960	4.7	0	semi-solid	23.4	20.7	0.02
480	20	S	1580	4.6	0	391,000	24.8	24.7	1.0
		W	1160	4.7	0	semi-solid	24.1	23.0	0.07
720	30	S	1840	4.6	0	509,000	25.3	26.0	2.04
		W	1340	4.6	0	semi-solid	24.6	24.3	0.15

8.2.4.2 Vessel or Platform Release Modeling Results

Two diesel fuel spill scenarios have been considered with spill volumes of 10 and 100 barrels (1.6 m^3 and 15.9 m^3). Spills of diesel fuels from the platform or support vessels of larger volumes are highly unlikely. Table 8.14 shows the fate of the hypothetical "batch" spills.

The percentage of the spilled diesel that will evaporate will be about 36% in the summer and about 29% in the winter. The higher winter winds tend to disperse the spills faster even with the colder and slightly more viscous oil. The diesel fuel from the 10-barrel batch spill scenarios will disperse or evaporate from the surface within about 14 hours in the winter and 26 hours in the summer. These survival times increase to 21 and 35 hours for the 100-barrel spills. The slicks from the 10-barrel spills will dissipate at a distance of about 15 to 20 km from the source assuming average wind and water current conditions. The 100-barrel slicks will travel up to 20 to 30 km before complete dispersion.

The distances traveled by the slicks will be similar in the summer and winter seasons because the higher winter winds will have the dual effect of dissipating the slicks faster and moving them along the surface faster. The net result is a travel distance similar for both seasons.

The peak diesel concentration in the upper 10 metres is estimated to be 1.0 to 2.0 ppm for the 10 barrel spills, 1.6 to 3.6 ppm for the 100-barrel releases. The higher concentrations would be present in the winter scenarios due to the increased dispersion rate caused by the stronger winter winds.

Within 16 hours the oil clouds from the winter 10-barrel spills will grow to a width of about 1.2 kilometres and diffuse to 0.1 ppm oil concentration (assuming a conservative 10 m mixing depth). The summer 10-barrel spill will diffuse to 0.1 ppm within 10 hours and have a width of about 0.75 km at this point. The dispersed oil clouds from the 100-barrel spills will diffuse to 0.1 ppm within about 41 hours in both seasons. The dispersed oil clouds from the 100-barrel releases will reach diameters of about 3.7 km.

The dispersed oil clouds from the winter 10-barrel spills will travel a total of about 20 km prior to reaching 0.1 ppm. In the summer the dispersed oil clouds will travel only about five km prior to concentrations dropping below 0.1 ppm. The dispersed oil clouds from the 100-barrel spills will travel about 35 km in the winter and 30 km in the summer.

8.3 Spill Trajectories

The previous section discusses what happens to the oil when it is released based on most recent Husky modeling of oil behaviour (LGL 2003). This section discusses where the oil may go once it is released. It is based on the most recent trajectory information for the Jeanne d'Arc area

Table 8.14. Diesel Spill Characteristics.

Spill Volume (bbl) and Season	Initial Slick Width (m)	Slick Survival Time (hr)	Maximum Slick Width (m)	Total Evaporation %	Distance to Loss of Slick (km)	Peak Dispersed Oil Concentration (ppm)	Time to Peak Concentration (hr)	Time to 0.1 ppm (hr)	Cloud Width at 0.1 ppm (km)	Distance to 0.1 ppm (km)
10 Winter	10	15	51	30	20	1.82	1.5	16	1.2	20
10 Summer	10	27	55	37	22	0.9	1.5	10	0.72	7
100 Winter	32	22	123	29	28	3.3	3.0	42	3.8	34
100 Summer	32	37	132	36	30	1.63	3.0	40	3.6	33

which is contained in the White Rose Oilfield Comprehensive Study (Husky 2000). It should be noted that different scenarios were used for the behaviour section than were used for the trajectory section based on the decision to use the most recent available Husky modeling data.

The spilled oil will be moved by currents and wind until it very slowly disperses in the water and diffuses on the surface to low concentration, or contacts land. As noted in the previous sections, White Rose oil spills are expected to be highly persistent, and survival times of weeks and even months are not inconceivable.

8.3.1 Hibernia and Terra Nova Analyses

For the Hibernia EIS, Seaconsult (1984) modeled potential slick movement at Hibernia using 30 years (1945 to 1975) of meteorological and oceanographic data. Results showed that a slick from a large surface blowout would move over large portions of the Grand Banks during its calculated survival time, while a worst-case batch spill would pass over a much smaller area, despite a longer indicated survival time. Modelled trajectories generally showed that under the prevailing wind and current regimes, most slicks would tend to move offshore, to the east and northeast. Only during the months of November, December, January, and March, was there a possibility of shoreline contact (Table 8.15). Of the 11,000 trajectories run during the analyses, only 11 reached land.

Table 8.15. Impact and Closest Point of Approach to Shoreline for Hibernia Oil Slick Models.

Month	Impact				Closest Approach	
	Number of Trajectories Reaching Shore	Trajectories Reaching Shore (%)	Earliest Time to Reach Shore (d)	Shoreline Location	Time from Start of Spill (d)	Distance From Shore (km)
January	4	0.43	9.8	Southeast Avalon	-	-
February	0	-	-	-	8.5	51
March	2	0.22	29	Southwest Burin	-	-
April	0	-	-	-	29	76
May	0	-	-	-	10.7	150
June	0	-	-	-	19	150
July	0	-	-	-	16	144
August	0	-	-	-	10.2	194
September	0	-	-	-	74	103
October	0	-	-	-	13.2	134
November	5	0.56	17.2	Southeast Avalon	-	-
December	1	0.11	27.2	Southeast Avalon	-	-

Subsequent to the Hibernia work, an updated IIP water current grid and additional AES wind data became available. The IIP water current data for 1995 and the AES wind data from 1946 to 1989 were used for the Terra Nova trajectory analysis (SL Ross 1995). The trajectories were run for 30 days, until they hit land, or they moved out of the study area. The number of slicks predicted to reach land from Terra Nova modeling is presented in Table 8.16. These results are very similar to those found in the earlier Hibernia study. The percentage of the spills that reached land in the Terra Nova modeling was approximately 0.2 percent. The modeling for Hibernia indicated that 0.1 percent of trajectories would reach land. Contact happened primarily in winter months in both analyses.

Table 8.16. Terra Nova Spill Trajectories Reaching Land.

Month/Year ***(Days During the Month When Slicks Released)***	**Time to Shore** **(Hrs)**
March 1951 *24, 25, 26, 27*	342 to 474
April 1978 *1, 2, 3, 4, 5, 6, 7, 8, 9*	534 to 672
January 1979 *18, 19, 20, 21, 22, 23, 24*	432 to 552
March 1987 *9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20*	492 to 702
Total Slicks Reaching Land = 32 Total Scenarios Run = 15,900	

8.3.2 White Rose Spill Trajectories

A more recent and improved historical wind data set than that used for the Terra Nova modeling was used for the White Rose Comprehensive Study. This data set was prepared by the US National Centres for Environmental Prediction (NCEP) and the US National Centre for Atmospheric Research (NCAR) (Kalnay et al. 1996). A 10,000 m^3 batch release at White Rose was modeled for every day of the year, for the 40 years of available wind data, and each spill was modeled for 30 days. The 10,000 m^3 spill was selected for analysis because it was the same size used in similar modeling for the Terra Nova and Hibernia assessments and it is the largest spill size used for planning purposes under the *Canada Shipping Act's* Response Organizations Standards (Fisheries and Oceans 1995). Monthly average air and water temperatures were used in these simulations (Table 5.8-4 in Husky 2000).

A total of 14,600 trajectories were modeled in the White Rose analysis. It was found that there were no shoreline contacts from any of the spill trajectories originating at the White Rose site using the upgraded wind data and the IIP water current data for 1995. As stated in Section 6.0, the Study Area of this EA is based on this trajectory modeling.

The trajectory data were further processed, on a monthly basis, to identify the likelihood of a slick reaching a given area on the Grand Banks. A 1 km x 1 km grid was overlain on the Grand Banks. The slick movements for all spills released in a given month of the year, for the 40 years of data, were tracked to identify what percentage of the spills entered each grid cell. The movements of 1,240 slicks (31 days x 40 years of wind data) were combined to generate the figures for months with 31 days. A total of 1,200 spill trajectories were used to generate the figures for those months with 30 days and 1,120 trajectories for the month of February [see Figures 5.8-1 through 5.8-12 in Husky (2000)]. It is important to note that these figures do not represent the distribution of oil from an individual oil spill. The figures are spill trajectory composites that show over 1,100 probable oil trajectories originating at the White Rose site for each month.

Small areas near the spill site have a high probability (50 to 100 percent) that oil from a potential spill will pass through them. This is represented by a bright red colour that is not visible on the figures at the scale shown. The bright orange colour, barely visible on the figures near the spill source, represents areas where 25 to 50 percent of the slicks pass. The dark brown colour, seen primarily in the summer and early fall months, shows areas where 10 to 25 percent slicks will likely pass. The yellow colour represents zones where 5 to 10 percent of the slicks are likely to pass. The green colour shows the area where 1 to 10 percent of the slicks pass. Less than one percent of the slicks pass through the light blue areas. Thus, these figures indicate the probability of oil reaching a selected point during any month of the year.

8.3.3 White Rose Spill Areas and Concentrations of Dispersed Oil

It was necessary to calculate estimates of the total areas potentially exposed to oil from accidental blowouts or spills at the White Rose site for effects assessment purposes. The areas potentially influenced by oil released during the different scenarios are summarized in Table 8.17. The "thick oil area" basically remains unchanged throughout the 30-day modelling period because of the semi-solid nature of the oil. However, the thick oil will not be a continuous slick by the end of the 30-day period but rather, a large number of small mats, particles, and "wax" balls spread throughout the total slick area. The "total slick(let) area" represents the area influenced by both thick and sheen oil in the batch spills, or an individual slicklet from a blowout, at the end of the 30-day modelling period without considering movement of the oil by wind. The average slick(let) width is an average of the initial and 30-day total slick(let) widths.

In the White Rose Comprehensive Study, the "oil sweep area" was used as the estimate for "geographic extent" in the effects assessment. It includes the total area that is "swept" by the average slick width over the 30-day modeling period and assumes that the seasonal average winds drive the movement of the slicks. The distance traveled by a slick was assumed to be 700 km in the summer and 933 km in the winter (3 percent of average wind speeds for summer 9 m/s and winter 12 m/s multiplied by the 30-day modeling period; Nerella and Jarvis 1980). For the blowout scenarios, it was assumed that a "unique" slick is generated every 6 h. For blowouts lasting seven days, areas of 28 slicks were combined to calculate a total sweep area. Similarly,

Table 8.17. Areas Potentially Exposed to White Rose Oil from an Accidental Batch Spill or Blowout during Summer and Winter.

Scenario	Season	Thick Oil Area (km^2)	Total Slick(let) Area (m^2)	Average Width of Slick (let) (km)	Total Oil Sweep Area (km^2)
800 m^3 Batch Spill	S	0.04	147	6.99	4,900
	W	0.04	75	5.10	4,760
10,000 m^3 Batch Spill	S	0.5	169	8.35	5,850
	W	0.5	90	6.45	6,000
30,000 m^3 Batch Spill	S	1.5	193	9.70	6,800
	W	1.5	110	7.90	7,400
7 day Subsea Blowout	S	0.21	3.8	1.86	36,500
	W	0.12	2.1	1.39	36,300
45 day Subsea Blowout	S	0.0052	2.7	1.38	174,000
	W	0.0029	1.4	1.02	171,000
7 day Surface Blowout	S	0.0037	2.5	0.90	17,640
	W	0.0056	0.45	0.41	10,500

for a 45-day blowout, a total of 180 slick areas were combined to calculate an estimate of the total surface area affected by the blowout. It should be noted that using this "sweep approach" to estimate a geographic extent of effects is likely a large overestimation in cases such as plankton because near surface organisms rather than being "swept over" may well drift more or less with the slick.

As previously mentioned, the waxy nature of White Rose oil will limit dispersion of the oil in the water column. For effects assessment purposes, the maximum dispersed oil concentrations were predicted for the various batch spill and blowout scenarios (Table 8.18). It has been assumed that all dispersed oil accumulates and is homogenous in the 10 m directly below the slick to arrive at these concentration estimates. Concentrations of dispersed oil are low due to the high persistence of this oil on the surface that results from its tendency to form stable emulsions and its high pour point.

8.3.4 Effects of Pack Ice on Oil Spills

The White Rose site lies close to the extreme southern limit of the regional pack ice (see Section 4.0 and Appendix 1 for a detailed discussion of pack ice distribution). Pack ice incursions within 15 km of White Rose occur about half the data years (1960 to 1999), centered on mid-March, with durations varying from one to 11 weeks. Mean sea ice concentrations on the Grand Banks south of 49 degrees latitude are fairly consistent at 6/10ths coverage. Coverages greater that 5/10ths occur by early February and continue through mid-April, at which time they slowly decrease to 2/10ths.

Table 8.18. Maximum Concentration of Dispersed White Rose Oil from an Accidental Batch Spill or Blowout during Summer and Winter.

Scenario	Season	Max. Conc of Disp. Oil (ppm)
800 m^3 Batch Spill	S	0.0038
	W	0.00009
10,000 m^3 Batch Spill	S	0.0048
	W	0.00015
30,000 m^3 Batch Spill	S	0.0052
	W	0.00018
7 day Subsea Blowout	S	0.00013
	W	0.000001
45 day Subsea Blowout	S	0.00008
	W	0.000013
7 day Surface Blowout	S	0.0075
	W	0.0

Oil behaviour in pack ice and the potential countermeasures have been studied extensively under the ESRF (Witherspoon et al. 1985; Abdelnour et al. 1986; SL Ross 1986; Brown and Goodman 1987; Comfort 1987; MacNeil and Goodman 1987; SL Ross and DF Dickins 1987). The general movement of a large oil spill in pack ice will be similar to that of the ice. The specific behaviour of the White Rose crude in or near pack ice will be dependent upon the degree and type of ice coverage (R. Belore, pers. comm.). In general, high concentrations of brash ice will keep the oil from spreading and oil spilled outside heavy pack will not penetrate far into it (SL Ross and DF Dickins 1987). Oil spilled under the pack ice will probably tend to coat the underside of the ice. The waxy nature of the White Rose crude will not affect these general conclusions concerning the effects of pack ice on the spill (R. Belore, pers. comm.).

In the unlikely event of a major oil spill at White Rose, the potential for interaction with pack ice only occurs for a small period of the year (0 to 11 weeks). The main effect of the presence pack ice on oil spills will be to hinder the drilling of relief wells and/or cleanup efforts. On the other hand, certain pack ice conditions may serve to contain the oil and thus make it more likely to burn, assuming it could be ignited.

Effects of oil on under-ice algae have been studied by Cross (1987) during the experimental Baffin Island Oil Spill (BIOS). He concluded that crude and dispersed crude did not impact primary productivity after a 12-day exposure.

In conclusion, the presence of pack ice during an oil spill or blowout was considered to increase the likelihood of interaction between an accidental oil spill and young seals.

8.4 Estimation of Potential Cleanup Effectiveness

For any major offshore oil spill there are environmental and technological constraints to response and cleanup. High sea states and visibility are examples of typical environmental constraints while examples of technological constraints include pumping capacity of oil recovery devices, effectiveness of chemical dispersants on viscous oils. These kinds of limitations apply even if the response organizations is perfectly prepared and trained and outfitted with the world's best available equipment.

8.4.1 Best-Practicable Containment/Recovery System

For blowouts the typical approach involves the deployment of a collection boom at a point downstream of but as close to the source as safe and practicable. Typically the boom might be deployed in a V-configuration to provide a sweep width of one-third the total boom length. A suitable oil recovery skimming system would be positioned at the apex of the ‘V’ and would discharge recovered oil to a storage barge or the tanks of a suitable support vessel. Surface blowouts tend to form relatively narrow slicks while subsea blow outs tend to form winder slicks. The effectiveness of the operation is driven by the encounter rate that is affected by slick width at the downstream oil collection location and the capability of the skimmer system or skimming rate.

For batch-type releases, often the containment and recovery system would sweep through the slick, with the encounter rate driven by the sweep speed (typically 1 knot), the sweep width (typically one-third of the total boom length depending on the equipment used), and the slick thickness. Obviously, the encounter rate and hence oil recovery efficiency will tend to decrease over the days following the spill as batch spills tend to break up into patches of oil that spread and drift apart creating an affected area greater than that affected by a coherent slick.

Clearly either of the scenarios will be strongly influenced by weather conditions at the time as well as safety and practical tactical decisions made by the response organization.

8.4.2 F_{TRP}: Fraction of Time that Recovery is Possible

From the perspective of considering an ideal scenario for spill clean up operations containment and recovery operations are best conducted in daylight with visibility greater than 0.5 kilometres, and when waves are less than one metre high for all wave periods or alternatively and when waves are between one and two metres high but have periods of six seconds or greater. Table 8.19 summarizes the estimated frequency that these conditions occur in the Newfoundland Offshore Area.

Table 8.19. Fraction of Time that Recovery is Possible.

Season	Fraction Daylight	Fraction Visibility[1]	Fraction Waves Favorable[2]	F_{TRP}
Summer	0.65	0.75	0.50	0.24
Winter	0.38	0.95	0.10	0.04
Average	0.50	0.85	0.30	0.13

[1] Visibility greater than 0.5 kilometres.
[2] Waves less than 1 metre, or between 1 and 2 metres with period greater than 6 seconds.

8.5 Alternatives to Containment and Recovery

Dispersants and *in situ* burning are possible alternative countermeasures that offer some advantages in certain spill situations. Dispersants are specially-formulated chemicals that, when applied to an oil slick, reduce the interfacial tension of the oil and enhance its dispersion into the water under the influence of wave action. Notwithstanding the fact that dispersants function by causing the oil to be dispersed from the sea surface into the water column for spills in an offshore environment, this can be a good trade-off in that the lower concentrations of subsurface oil are generally less harmful to the environment, and more readily degraded naturally, than the relatively high concentrations of oil in a surface slick. In addition, the potential for seabirds to encounter oil on the sea surface can be reduced. The main advantages of dispersant use over containment and recovery are that with appropriate equipment slick that cover large areas can be treated, the logistics involved in storing and disposing of recovered oil are avoided, and the rough sea conditions that prevail in the Newfoundland offshore complement and enhance the effectiveness of the dispersant.

To be most effective dispersants need to be used when the oil it is relatively fresh and before it emulsifies. Laboratory testing with other Grand Banks oils shows that fresh oil is highly dispersible in both summer and winter conditions and oil weathered to about 10% by volume is likely to be dispersible in both summer and winter conditions. However, in winter the oil would need to be treated as close to the spill site as possible before it weathers any further.

In general, this means that for situations where the oil has been subject to limited weathering, e.g. close to the source of subsea blow outs, dispersant use could be considered. In surface blowouts, where the oil is somewhat weathered by the time it lands on the water surface, dispersant use should be considered for summer conditions but less likely to be effective in winter conditions. In any situation where dispersant use might be indicated a monitoring program to evaluate its effectiveness and the environmental effects should be implemented.

For *in situ* burning the approach is to collect and thicken the oil slick with fire-resistant boom, ignite it, and burn the oil in place on the water surface. While its main advantage is that the logistics of storing and disposing of recovered oil are avoided, and that much higher treatment rates (i.e., versus skimming) are possible it offers no advantage when it comes to encounter rates. The oil must still be collected with a containment boom the effectiveness of which is constrained by sea state conditions. Apart from the potential limited availability of fire resistant booms more limiting is that burning is generally only effective on oils that are not emulsified or have suffered little emulsification. Since the oils modeled for the White Rose scenarios form highly viscous emulsions rapidly *in situ* burning is not likely to be an effective option.

8.6 Spill Response

Husky's plans for spill response are discussed in detail in two documents currently on file with the C-NLOPB. Specifically:

- East Coast Oil Spill Response Plan WR-ERP-PR-0001
- East Coast Offshore Operations - Stage 1 Spill Response Procedures WR-ERP-PR-0002

8.7 Potential Effects of Accidental Events

In this section, effects are assessed for the accidental event scenarios described in the preceding sections. Summer and winter scenarios are assessed together as the rankings for assessment categories are generally consistent across seasons. However, the reader is referred to the text for discussion of some seasonal nuances that could occur.

It should be noted that the various scenarios likely represent situations much worse than those that could realistically occur. For example, it is difficult to imagine any situation where a batch spill greater than 800 m^3 could occur during the Project. The worst diesel spill in the MMS database occurred in 1979 when an anchor-handling vessel collided with a drill rig in the Gulf of Mexico and released 1,500 bbl (238 m^3) of diesel (MMS 2001). Under typical conditions, an offshore diesel spill on the Grand Banks would evaporate and disperse very quickly without much environmental effect. Thus, the oil spill scenarios used in this EA represent absolute 'worst cases.' In addition, using the effects methodology from the White Rose Oilfield Comprehensive Study to estimate geographic extents also over-estimates effects.

8.7.2 Fish Habitat

There has been extensive study of the effects of oil spills on fish and fish habitat (Armstrong et al. 1995; Rice et al. 1996). Tables 8.20 to 8.22 present the potential interactions of accidental event scenarios and the fish habitat VEC, the assessment of potential residual effects of accidental events on the fish habitat VEC, and the residual effects summary, respectively. The four components of fish habitat considered in this assessment include water, sediment, plankton and benthos.

Table 8.20. Potential Interactions of Accidental Events and Fish Habitat VEC.

Valued Environmental Component: Fish Habitat				
Accidental Event Scenario	**Fish Habitat Components**			
	Water	**Sediment**	**Plankton**	**Benthos**
Subsea Blowout 7 Day	x	x	x	x
Subsea Blowout 45 Day	x	x	x	x
Above-surface Blowout 7 Day	x		x	
Batch Spill 800 m^3	x		x	
Batch Spill 10,000 m^3	x		x	
Batch Spill 30,000 m^3	x		x	

Table 8.21. Environmental Effects Assessment of Potential Effects of Accidental Events on Fish Habitat VEC.

Valued Environmental Component: Fish Habitat									
Habitat Component and Accidental Event Scenario	Potential Positive (P) or Negative (N) Environmental Effect	Regulative Mitigation	Project Specific Mitigation	Evaluation Criteria for Assessing Environmental Effects					
				Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural And Economic Context
Water									
Subsea Blowout 7 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Subsea Blowout 45 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Above-surface Blowout 7 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Batch Spill 800 m^3	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 10,000 m^3	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 30,000 m^3	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Sediment									
Subsea Blowout 7 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	1-2	<1	2	R	1
Subsea Blowout 45 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	1-2	<1	2	R	1
Above-surface Blowout 7	-	-	-	-	-	-	-	-	-

Day									
Batch Spill 800 m^3	-	-	-	-	-	-	-	-	-
Batch Spill 10,000 m^3	-	-	-	-	-	-	-	-	-
Batch Spill 30,000 m^3	-	-	-	-	-	-	-	-	-
Plankton									
Subsea Blowout 7 Day	Health Effects (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Subsea Blowout 45 Day	Health Effects (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Above-surface Blowout 7 Day	Health Effects (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Batch Spill 800 m^3	Health Effects (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 10,000 m^3	Health Effects (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 30,000 m^3	Health Effects (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Benthos									
Subsea Blowout 7 Day	Health Effects (N) Tainting (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	1-2	<1	2	R	1
Subsea Blowout 45 Day	Health Effects (N) Tainting (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	1-2	<1	2	R	1
Above-surface Blowout 7 Day	-	-	-	-	-	-	-	-	-
Batch Spill 800 m^3	-	-	-	-	-	-	-	-	-
Batch Spill 10,000 m^3	-	-	-	-	-	-	-	-	-
Batch Spill 30,000 m^3	-	-	-	-	-	-	-	-	-

Magnitude	Geographic Extent	Frequency	Duration	Reversibility (population level)
0 = Negligible	1 = < 1 km^2	1 = < 11 events/year	1 = < 1 month	R = Reversible
1 = Low	2 = 1-10 km^2	2 = 11-50 events/year	2 = 1-12 months	I = Irreversible
2 = Medium	3 = 11-100 km^2	3 = 51-100 events/year	3 = 13-36 months	
3 = High	4 = 101-1,000 km^2	4 = 101-200 events/year	4 = 37-72 months	
	5 = 1,001-10,000 km^2	5 = > 200 events/year	5 = > 72 months	
	6 = > 10,000 km^2	6 = continuous		

Ecological/Socio-Cultural and Economic Context

1 = Relatively pristine area or area not negatively affected by human activity

2 = Evidence of existing negative anthropogenic effects

Geographic extent differed between summer and winter for each scenario but both were always within the same category.
Effects on individuals irreversible but any population effects are likely reversible.

Table 8.22. Significance of Predicted Residual Effects of Accidental Events on Fish Habitat VEC.

Valued Environmental Component: Fish Habitat				
Accidental Event Scenario	**Significance of Predicted Residual Environmental Effects**		**Likelihood[a]**	
	Significance Rating	**Level of Confidence**	**Probability of Occurrence**	**Scientific Certainty**
Subsea Blowout 7 Day	NS	3	-	-
Subsea Blowout 45 Day	NS	3	-	-
Above-surface Blowout 7 Day	NS	3	-	-
Batch Spill 800 m^3	NS	3	-	-
Batch Spill 10,000 m^3	NS	3	-	-
Batch Spill 30,000 m^3	NS	3	-	-

Significance Rating (significance is defined as a medium or high magnitude (2 or 3 rating) and duration > 1 year (≥ 3 rating) and geographic extent > 100 km^2 (≥ 4 rating)
NS = Not significant negative environmental effect
S = Significant negative environmental effect
NS = Not significant negative environmental effect
P = Positive environmental effect

Level of Confidence (professional judgement)
1 = Low level of confidence
2 = Medium level of confidence
3 = High level of confidence

Probability of Occurrence (professional judgement)
1 = Low probability of occurrence
2 = Medium probability of occurrence
3 = High probability of occurrence

Level of Scientific Certainty (based on scientific information and statistical analysis or professional judgement)
1 = Low level of scientific certainty
2 = Medium level of scientific certainty
3 = High level of scientific certainty

[a] Only considered in the event of significant (S) residual effect

The highest polyaromatic hydrocarbon (PAH) concentration found in Prince William Sound at one and five m depths within the six-week period following the *Exxon Valdez* spill (a much worse case than an any plausible blowout scenario in Jeanne d'Arc Basin) was 0.00159 ppm, well below levels considered acutely toxic to marine fauna (Short and Harris 1996). The Hibernia and Terra Nova EISs and the White Rose and Jeanne d' Arc Basin EAs predicted that environmental (biophysical) effects on water quality and habitat would be *not significant*. Effects of spills on fish habitat during the proposed new drill centre Project are also predicted to be *not significant*. As described in the preceding section, the chance of an accidental event is extremely low.

8.7.2.1 Plankton

The fish habitat VEC includes plankton because it is a source of food for larvae and some adult fish thus, effects of an oil spill or blowout on plankton could affect fish. Dispersion and dissolution cause the soluble, lower molecular weight hydrocarbons to move from the slick into the water column. Effects of spills on pelagic organisms need to be assessed through examination of effects of water-soluble fractions of oil or light hydrocarbon products.

Effects of crude oil spills on plankton are short-lived, with zooplankton being more sensitive than phytoplankton. Zooplankon accumulate hydrocarbons in their bodies. The hydrocarbons may be metabolized and depurated (Trudel 1985). Hydrocarbons accumulated in zooplankton during a spill would be depurated within a few days after a return to clean water and thus, there is limited potential for transfer of hydrocarbons up the food chain (Trudel 1985). There is a potential for transfer of hydrocarbons up the food chain in an environment subject to chronic inputs of hydrocarbons, but there is no potential for biomagnification. Celewycz and Wertheimer (1996) concluded that the *Exxon Valdez* spill did not reduce the available prey resources, including zooplankton, of juvenile salmon in Prince William Sound.

Mortality of zooplankton can occur at diesel concentrations of 100 to 10,000 ppm (24 to 48 h LC_{50}, where LC_{50} is the concentration of toxicant that kills 50 percent of the test animals; Trudel 1985). Diesel oil is much more toxic, but shorter-lived in the open ocean than crude oil. There is great variability among species and some species are relatively insensitive. For example, the 96-h LC_{50} of crude oil for *Calanus hyperboreus*, a common cold water copepod, was 73,000 ppm (Foy 1982). Complete narcotization of copepods can occur after a 15-min exposure to 1,800 ppm of aromatic heating oil and mortality can occur after a 6-h exposure (Berdugo et al. 1979). Exposure to concentrations of 1,000 ppm of aromatic heating oil for three days had no apparent effect on mobility, but exposure for as little as 10 minutes shortened life span and total egg production (Berdugo et al. 1979). No. 2 fuel oil at concentrations of 250 to 1,000 ppm completely inhibited or modified copepod feeding behaviour, while concentrations of 70 ppm or lower may not affect feeding behaviour (Berman and Heinle 1980). Exposure to naphthalene at concentrations of 10 to 50 ppm for 10 days did not affect feeding behaviour or reproductive potential of copepods although egg development was not examined (Berdugo et al. 1979).

In summary, individual zooplankton could be affected by a blowout or spill through mortality, sublethal effects, or hydrocarbon accumulation if oil concentrations are high enough. However, the predicted maximum concentrations for batch and blowouts are well below those known to cause effects.

8.7.2.2 Benthos

Under some circumstances, oil spilled in nearshore waters can become incorporated into nearshore and intertidal sediments, where it can remain toxic and affect benthic animals for years after the spill (Sanders et al. 1990). Oil from an offshore spill in Jeanne d'Arc Basin will not likely become incorporated in the sediments. Oil released from an offshore blowout should quickly rise to the surface. Drilling will occur in open water and because of the depths involved, there is little chance of oil adhering to suspended sediments and being deposited on the bottom.

Thus, oil released during an offshore spill or blowout in Jeanne d'Arc Basin is not likely to interact with the benthos.

8.7.2.3 Overall Effect on Fish Habitat VEC

The effects of an accidental event on fish habitat is predicted to have *negligible to low* magnitude, *<1 to >10,000 km*^{2} geographic extent, depending on event scenario-habitat component interaction, and *1-12 month* duration. In all scenario-habitat component interactions, the residual effects of accidental events on fish habitat are predicted to be *not significant* (Tables 8.21 and 8.22).

8.7.3 Fish

A scenario approach was used to evaluate interactions between accidental events and the fish VEC. This VEC includes fish and invertebrate eggs and larvae, juvenile fish and invertebrates, adult pelagic fish and invertebrates, and adult groundfish/demersal invertebrates. Tables 8.23 to 8.25 present the potential interactions of accidental event scenarios and the fish VEC, the assessment of potential residual effects of accidental events on the fish VEC, and the residual effects summary, respectively.

Table 8.23. Potential Interactions of Accidental Events and Fish VEC.

Valued Environmental Component: Fish				
Accidental Event Scenario	Fish Life Stage			
	Eggs/Larvae	Juvenile[a]	Adult Pelagic	Adult Demersal
Subsea Blowout 7 Day	x	x	x	x
Subsea Blowout 45 Day	x	x	x	x
Above-surface Blowout 7 Day	x		x	
Batch Spill 800 m^3	x		x	
Batch Spill 10,000 m^3	x		x	
Batch Spill 30,000 m^3	x		x	

[a] Often closely associated with the substrate

8.7.3.1 Eggs and Larvae

Planktonic fish eggs and larvae (ichthyoplankton) are less resistant to effects of contaminants than are adults because they are not physiologically equipped to either detoxify them or actively avoid them. In addition, many eggs and larvae develop at or near the surface where oil exposure may be the greatest (Rice 1985; see also Section 4.0 for a detailed description of ichthyoplankton on the Grand Banks). It is estimated that sensitivities of fish larvae range from 0.1 to 1.0 ppm of soluble aromatic hydrocarbons, approximately 10 times the sensitivities of adults (Moore and Dwyer 1974). However, an organism's sensitivity to oiling is not simply a function of age.

Table 8.24. Environmental Effects Assessment of Potential Effects of Accidental Events on Fish VEC.

Valued Environmental Component: Fish									
Life Stage and Accidental Event Scenario	Potential Positive (P) or Negative (N) Environmental Effect	Regulative Mitigation	Project Specific Mitigation	Evaluation Criteria for Assessing Environmental Effects					
				Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural And Economic Context
Eggs/Larvae									
Subsea Blowout 7 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Subsea Blowout 45 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Above-surface Blowout 7 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Batch Spill 800 m^3	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 10,000 m^3	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 30,000 m^3	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Juveniles[a]									
Subsea Blowout 7 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	1-2	<1	2	R	1
Subsea Blowout 45 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	1-2	<1	2	R	1
Above-surface Blowout 7 Day	-	-	-	-	-	-	-	-	-
Batch Spill 800 m^3	-	-	-	-	-	-	-	-	-

Batch Spill 10,000 m^3	-	-	-	-	-	-	-	-	-
Batch Spill 30,000 m^3	-	-	-	-	-	-	-	-	-
Adult Pelagic									
Subsea Blowout 7 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Subsea Blowout 45 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Above-surface Blowout 7 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	6	<1	2	R	1
Batch Spill 800 m^3	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 10,000 m^3	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 30,000 m^3	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	5	<1	2	R	1
Adult Demersal									
Subsea Blowout 7 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	1-2	<1	2	R	1
Subsea Blowout 45 Day	Contamination (N)	Contingency Plan	Training, Preparation, Equipment, Inventory, Prevention	0-1	1-2	<1	2	R	1
Above-surface Blowout 7 Day	-	-	-	-	-	-	-	-	-
Batch Spill 800 m^3	-	-	-	-	-	-	-	-	-
Batch Spill 10,000 m^3	-	-	-	-	-	-	-	-	-
Batch Spill 30,000 m^3	-	-	-	-	-	-	-	-	-

Magnitude
0 = Negligible
1 = Low
2 = Medium
3 = High

Geographic Extent
1 = < 1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = > 10,000 km^2

Frequency
1 = < 11 events/year
2 = 11-50 events/year
3 = 51-100 events/year
4 = 101-200 events/year
5 = > 200 events/year
6 = continuous

Duration
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Reversibility (population level)
R = Reversible
I = Irreversible

Ecological/Socio-Cultural and Economic Context 1 = Relatively pristine area or area not negatively affected by human activity 2 = Evidence of existing negative anthropogenic effects [a] Often closely associated with the substrate Geographic extent differed between summer and winter for each scenario but both were always within the same category. Effects on individuals irreversible but any population effects are likely reversible.

Table 8.25. Significance of Predicted Residual Effects of Accidental Events on Fish VEC.

Valued Environmental Component: Fish				
Accidental Event Scenario	**Significance of Predicted Residual Environmental Effects**		**Likelihood[a]**	
	Significance Rating	**Level of Confidence**	**Probability of Occurrence**	**Scientific Certainty**
Subsea Blowout 7 Day	NS	3	-	-
Subsea Blowout 45 Day	NS	3	-	-
Above-surface Blowout 7 Day	NS	3	-	-
Batch Spill 800 m^3	NS	3	-	-
Batch Spill 10,000 m^3	NS	3	-	-
Batch Spill 30,000 m^3	NS	3	-	-

Significance Rating (significance is defined as a medium or high magnitude (2 or 3 rating) and duration > 1 year (≥ 3 rating) and geographic extent > 100 km^2 (≥ 4 rating)
NS = Not significant negative environmental effect
S = Significant negative environmental effect
NS = Not significant negative environmental effect
P = Positive environmental effect

Level of Confidence (professional judgement)
1 = Low level of confidence
2 = Medium level of confidence
3 = High level of confidence

Probability of Occurrence (professional judgement)
1 = Low probability of occurrence
2 = Medium probability of occurrence
3 = High probability of occurrence

Level of Scientific Certainty (based on scientific information and statistical analysis or professional judgement)
1 = Low level of scientific certainty
2 = Medium level of scientific certainty
3 = High level of scientific certainty

[a] Only considered in the event of significant (S) residual effect

Generally, fish eggs appear to be highly sensitive at certain stages and then become less sensitive just prior to larval hatching (Kühnhold 1978; Rice 1985). Larval sensitivity varies with yolk sac stage and feeding conditions (Rice et al. 1986). Eggs and larvae exposed to high concentrations of oil generally exhibit morphological malformations, genetic damage, and reduced growth. Damage to embryos may not be apparent until the larvae hatch. For example, although Atlantic cod eggs were observed to survive oiling, the hatched larvae were deformed and unable to swim (Kühnhold 1974). Atlantic herring larvae exposed to oil have exhibited behavioural abnormalities such as initial increased swimming activity followed by low activity, narcosis, and death (Kühnhold 1972). Similarly, Pacific herring (*Clupea pallasi*) eggs and larvae (possibly exposed as embryos) collected from beaches contaminated with *Exxon Valdez* oil in 1989 exhibited morphological and genetic damage (Hose et al. 1996; Norcross et al. 1996; Marty et al. 1997). Marty et al. (1997) indicated that herring larvae collected from oiled sites had ingested less food, displayed slower growth, and had a higher prevalence of cytogenetic damage than those sampled from ‘clean’ sites. However, these effects were not observed in eggs and larvae collected in later years (Hose et al. 1996; Norcross et al. 1996) and there is no conclusive evidence to suggest that these oiled sites posed a long-term hazard to fish embryo or larval survival (Kocan et al. 1996).

The natural mortality rate in fish eggs and larvae is so high that large numbers could be destroyed by anthropogenic sources before effects would be detected in an adult population (Rice 1985). Oil-related mortalities would probably not affect year-class strength unless >50% of the larvae in a large proportion of the spawning area died (Rice 1985). Herring are one of the most sensitive fish species to oiling. Hose et al. (1996) claim that even though 58% fewer than normally expected herring larvae were produced at a site oiled during the *Exxon Valdez* spill, no effect would be detected at the population level.

Ten-day exposures of large numbers of pink salmon smolt (*Oncorhynchus gorbuscha*) to the water-soluble fraction of crude oil (0.025 to 0.349 ppm) did not result in any detectable effects on their survival to maturity (Birtwell et al. 1999). However, it should be noted that pink salmon may be more resistant to environmental disturbance than other species because they spend so much time in the variable estuarine environment.

Approximately 45+ species of ichthyoplankton may occur in the Jeanne d'Arc Basin area (see Buchanan et al. 2004a). Their occurrence, abundance and distribution are highly variable by season and dependent on a variety of biological (e.g., stock size, spawning success, etc.) and environmental (temperature, currents, etc.) factors. In the unlikely event of a blowout or spill at Jeanne d'Arc Basin, there is potential for individual ichthyoplankters in the upper water column to sustain lethal and sublethal effects following contact with high concentrations of oil. The LC_{50} value at 25°C used by Hurlbut et al. (1991) to predict effects on ichthyoplankton was 0.0143 ppm.

As in the case of fish larvae, the sensitivity of invertebrate larvae to petroleum hydrocarbons varies with species, life history stage, and type of oil. Generally, invertebrate larvae are more sensitive to effects of oil than are adult invertebrates. Sublethal and lethal effects on individual larvae are possible during a spill or blowout at Jeanne d'Arc Basin.

American lobster larvae (Stages 1 to 4) showed a 24-h LC_{50} of 0.1 ppm to Venezuelan crude oil (Wells 1972). Larvae exposed to 0.1 ppm of South Louisiana crude oil swam and fed actively while those exposed to 1 ppm were lethargic (Forns 1977). Stage 1 crab larvae (king crab, *Paralithodes camtschatica* and Tanner crab (*Chionectes bairdi*)) succumbed to similar concentrations of crude oil (0.96 to 2 ppm; Brodersen et al. 1977) while larval shrimp generally had higher LC_{50} limits (0.95 to 7.9 ppm; Brodersen et al. 1977; Mecklenburg et al. 1977). Anderson et al. (1974) tested a variety of crude and refined oils and found that post-larval brown shrimp (*Penaeus aztecus*) were less sensitive than adult invertebrate species. Also, moulting larvae appear to be more sensitive to oil than intermoult larvae (Mecklenburg et al. 1977). Kerosene affected development of sea urchin embryos at concentrations of 15 ppb or greater, as did gasoline at concentrations of 28 ppb or greater (Falk-Petersen 1979).

Invertebrate larvae exposed to oil may exhibit reductions in food consumption and growth rate, and increases in oxygen consumption (Johns and Pechenik 1980). Despite these physiological changes, deleterious effects on invertebrate populations have not been detected, even after major oil spills (Armstrong et al. 1995). Larval distribution and settlement, fecundity, recruitment and growth of juveniles and subadult crab, pandalid shrimp, clams and scallops were not significantly affected by the *Exxon Valdez* oil spill (Armstrong et al. 1995).

There are four relevant ichthyoplankton species/species groups to consider in the present EA: (1) Atlantic cod, (2) wolffishes, (3) snow crab, and (4) northern shrimp. The above species are indicated based on the following criteria: (1) historical commercial importance within and near the Project Area, (2) planktonic eggs or larvae that occur in the surface planktonic community (i.e., upper 50 m), thus being at risk of exposure to spilled oil, and (3) listing under *SARA*.

The eggs and/or larvae of all six species potentially occur within or near the Project Area, most in the near-surface waters. These species' eggs and larvae may account for the bulk of the ichthyoplankton in the area. Three wolffish species are presently listed on Schedule 1 of *SARA*, two as threatened and the third as a species of special concern. The Newfoundland and Labrador population of Atlantic cod is listed as a species of special concern on Schedule 3 of *SARA*. Although it is a commercial fishery species in the general vicinity of the Project Area, Greenland halibut can be excluded because it does not spawn on the Grand Banks. More detail on the life histories of the most important species that likely spawn within or near the Project Area that (i.e., northern shrimp, snow crab, Atlantic cod, wolffishes) is available in Section 5.0.

The geographical and seasonal distribution of fish eggs and larvae in the region is highly variable. For example, in general, there are two peaks in abundance of ichthyoplankton on the Grand Banks. The first typically occurs in April-May and the second in August-September. As already indicated, the eggs and larvae of most of the above species are distributed in the upper 50 m of the water column. When all of the above ichthyoplankton are considered as a whole, the period of their occurrence in the plankton is quite broad (i.e., March to October). In all six accidental event scenarios (Table 8.23), the effects of oil spill exposure on the eggs and larvae of the above fish and invertebrate species are predicted to be negative.

Based on oil spill modeling using White Rose type crude, the maximum dispersed oil concentration (0.0075 ppm) in the upper 10 m of the water column was predicted for the seven-day above-surface blowout, summer scenario (Husky 2000). This can be considered the 'worst case scenario' in terms of oil concentrations in the water column for White Rose type oil. Predicted dispersed oil concentrations in the water column are low due to the high persistence of White Rose type crude, the oil's tendency to form stable emulsions, and because of its high pour point. The predictions assume that the oil is equally dispersed throughout the top 10 m of water column. The maximum dispersed oil concentration of 0.0075 ppm is well below levels in the literature that are consistently shown to have effects on fish and invertebrate eggs or larvae, particularly lethal ones (Husky 2000, 2001a). The lowest of three crude oil LC_{50} concentration used by Hurlbut et al. (1991) in their spill scenarios was 0.143 ppm, almost 20 times the maximum 10-m sub-slick concentration predicted for White Rose crude.

The magnitude of effects on fish eggs and larvae would be *negligible to low* for each finfish and invertebrate species in each blowout/spill scenario (Table 8.24). As stated in Husky (2000), the geographic extents for oil blowout and diesel spill scenarios are *greater than 10,000* km^2 and between *1,001 and 10,000* km^2, respectively. If the distances to 'loss of slick' and 'maximum slick' width are used to predict effects on water quality, geographic extent could range from 1,020 to 3,960 km^2. If 0.1 ppm is used as a 'cut-off' point for important biological effects, then geographic extent could range from 5 to 129 km^2. The geographic extent of actual measurable effects will likely be much less than the areas shown because concentrations of oil in the water column will likely be lower than those shown to produce demonstrable effects. Predicted frequency of large spills is much *less than one event/yr*, duration is *one to 12 months*, and environmental effects on the fish eggs/larvae in all scenarios are deemed *reversible* at the population level.

Considering that all magnitude ratings were *negligible to low* (Table 8.24), all negative environmental effects on fish eggs/larvae are predicted to be *not significant* (Table 8.25), as was predicted in a study of effects of oil spills on Grand Banks eggs and larvae by Hurlbut et al. (1991), and by the Hibernia and Terra Nova EISs, the White Rose and Jeanne d'Arc Basin EAs, and others. It should also be noted that the likelihood of an accidental event is extremely low. Based on the North Sea experience, SL Ross (2002) predicted the probability of one blowout for every 3,500 wells drilled.

8.7.3.2 Juveniles and Adults

There is an extensive body of literature regarding the effects of exposure to oil on juvenile and adult fish. Although some of the literature describes field observations, most refers to laboratory studies. Reviews of the effects of oil on fish have been prepared by Armstrong et al. (1995), Rice et al. (1996), and numerous other authors. If exposed to oil in high enough concentrations, fish may suffer effects ranging from direct physical effects (e.g., coating of gills and suffocation) to more subtle physiological and behavioural effects. Actual effects depend on a variety of factors such as the amount and type of oil, environmental conditions, species and life stage, lifestyle, fish condition, degree of confinement of experimental subjects, and others. Based on laboratory toxicity studies, pelagic fish tend to be more sensitive (LC_{50}s of 1 to 3 ppm) than either benthic (LC_{50}s of 3 to 8 ppm) or intertidal fish species (LC_{50}s of >8 ppm) (Rice et al. 1979). An LC_{50} is based upon controlled laboratory experiments using confined fish, usually in a container of standing water. The result is expressed as the concentration of a contaminant that achieves a mortality rate of 50%. There are recognized problems in applying LC_{50} data to the "real world" but they are useful for "ball park" comparative information, especially in situations where it is very difficult to obtain good controlled field data.]

Reported physiological effects on fish have included abnormal gill function (Sanders et al. 1981 and Englehardt et al. 1981 *in* Brzorad and Burger 1994), increased liver enzyme activity (Koning 1987; Payne et al. 1987), decreased growth (Swatrz 1985 *in* Brzorad and Burger 1994; Moles and Norcross 1998), organ damage (Rice 1985), and increased disease or parasites loads (Brown et al. 1973; Steedman 1991 *in* Brzorad and Burger 1994; Carls et al. (1998); Marty et al. 1999).

Reported behavioural effects include avoidance of contamination by migrating salmon (Weber et al. 1981), and cod in laboratory studies at refined petroleum levels in excess of 100 µg/L (Bohle 1986 *in* Crucil 1989), and altered natural behaviours related to predator avoidance (Gardner 1975; Pearson et al. 1984) or feeding (Christiansen and George 1995).

Juvenile (i.e., those past the egg and larval stages) and adult fish can and probably will avoid any crude oil by swimming from the blowout/spill region (Irwin 1997). Effects of oil spills on adult and juvenile fish are predicted to be *negligible*. This conclusion is consistent with the findings in the White Rose EA/Comprehensive Study, the Hibernia and Terra Nova EISs, the Lewis Hill EA, and the Jeanne d'Arc Basin EA. All of these concluded that neither surface spills nor subsea blowouts posed significant risks to either pelagic or demersal fish stocks (Mobil 1985; Petro-Canada 1996a,b; Husky 2000; LGL 2002, 2003).

The effects of an accidental event on juvenile and adult fish are predicted to have *negligible to low* magnitude, *<1 to >10,000* km^2 geographic extent, depending on event scenario-life stage component interaction, and *1-12 month* duration. In all scenario-life stage component interactions, the residual effects of accidental events on fish are predicted to be *not significant* (Tables 8.24 and 8.25).

8.7.4 Commercial Fishery

With respect to commercial fish harvesting, the present assessment concurs with the White Rose Comprehensive Study (Husky 2000) that effects on fish populations due to an oil spill or blow-out would be *not significant (*see Section 8). That study concluded that a large (>10,000 bbl) oil spill or blow-out would not cause significant effects on fish and fish habitat or result in tainting of fish flesh. Thus, effects on commercial fisheries as a result of physical effects on fish during an exploratory drilling-related spill are considered to be *not significant*.

Although physical effects on fish from a spill are deemed not significant, economic impacts might occur in the event of a spill, if the spill prevented or impeded a harvester's ability to access fishing grounds (because of areas temporarily excluded during the spill or spill clean-up), caused damage to fishing gear (through oiling) or resulted in a negative effect on the marketability of fish products (because of market perception resulting in lower prices, even without organic or organoleptic evidence of tainting).

Trajectory modelling for the White Rose study (Section 5.8.5.3), which modeled a batch release of approximately 63,000 bbls of oil, and calculated the probability that oil will reach any 1x1 km block on the Grand Banks over a 30 day period in all months, indicates the highest probability (25-100%) of occurrence being close to its source, within the current study's Project Area, where there is presently little or to no recorded fishing activity. However, the model indicates a 0-25% probability of oil travelling generally southeastwardly beyond the 200-mile EEZ, which would traverse snow crab fishing areas in Crab Fishing Area 3L200.

If a spill slick were to reach this area when fisheries were active, it is likely that fishing would be halted, owing to the possibility of fouling the buoy lines, or the crab pots if these were raised through the slick. Because potential release sites within the Project Area would be some distance from the snow crab fishing grounds, there would be time to notify fishers of the occurrence and prevent the setting or hauling of gear and thus prevent or minimize gear damage.

Exclusion from a spill area would be expected to be short-term, as typical sea and wind conditions in the Project Area would promote fairly rapid evaporation and weathering of the slick, and fishing vessels would likely be able to return within several days. Nevertheless, if fishers were required to cease fishing, harvesting might be disrupted (though, depending on the extent of the slick, alternative fishing grounds might be available within the CFA 3L200 area). An interruption could result in an economic impact because of reduced catches, or extra costs associated with having to relocate crab harvesting effort.

Effects due to market perceptions of poor product quality (no buyers or reduced prices, etc.) are more difficult to predict, since the actual (physical) impacts of the spill might have little to do with these perceptions. It would only be possible to quantify these effects by monitoring the situation if a spill were to occur and if it were to reach snow crab harvesting areas.

Such economic effects (caused by loss of access, gear damage or changes in market value) could be considered *significant* to the commercial fisheries. However, the application of appropriate mitigative measures (e.g. economic compensation) would reduce the potential impact to *not significant*. This mitigation is further discussed below.

8.7.4.1 Mitigation

In the past several years, the oil industry has expended a great deal of effort in the development of programs designed to compensate Atlantic Canada's fisheries industry in situations where offshore exploration and development activities might result in damage to fishing gear and vessels, or economic loss associated with interference to established fisheries harvesting activities.

These compensation programs (e.g., for the Sable and Hibernia projects, and those established by the Canadian Association of Petroleum Producers), developed in consultation with the fishing industry, include measures and mechanisms to address both attributable and unattributable economic loss associated with offshore oil and gas activities (see C-NLOPB and C-NSOPB 2002). Their purpose is to provide fair and timely compensation to commercial fish harvesters and processors who sustain actual loss because of the accidental release of petroleum (spills).

One of the basic principles of these programs is to compensate fisheries participants in a fair and timely manner for all actual loss with the aim of leaving them in no worse or better position than before the losses occurred.

These programs have been adopted as an alternative to making a claim through the Courts, or to the regulatory boards pursuant to the *Accord Implementation Acts* and associated regulations. Although claims for loss can be made under the laws of Canada, these industry programs offer a simpler, less expensive process for obtaining appropriate compensation. Thus, their purpose is to provide a mechanism for a fair and swift resolution of all legitimate claims, and the opportunity for all parties to minimize costs.

These principles will be an important component of Husky's response in the event that a spill results in economic consequences, and will ensure that any actual loss to the fisheries industry resulting from any oil spill is fully and adequately addressed.

8.7.5 Marine Birds

Seabirds are definitely the marine biota most at risk from oil spills and blowouts. The Grand Banks is a very important area for large numbers of seabirds (Section 5.7). Exposure to oil causes thermal and buoyancy deficiencies that typically lead to the deaths of affected seabirds. Although some may survive these immediate effects, long-term physiological changes may eventually result in death (Ainley et al. 1981; Williams 1985; Frink and White 1990; Fry 1990). Reported effects vary with bird species, type of oil (Gorsline et al. 1981), weather conditions, time of year, and duration of the spill or blowout. Although oil spills at sea have the potential to kill tens of thousands of seabirds (Clark 1984; Piatt et al. 1990), recent studies suggest that even spills of great magnitude may not have significant long-term effects on seabird populations (Clark 1984; Wiens 1995).

8.7.5.1 Immediate Effects

External exposure to oil occurs when flying birds land in oil slicks, diving birds surface from beneath oil slicks, and swimming birds swim into slicks. The external exposure results in matting of the feathers which effectively destroys the thermal insulation and buoyancy provided by the air trapped by the feathers. Consequently, oiled birds are likely to suffer from hypothermia and/or drown (Clark 1984; Hartung 1995). Most seabird losses occur during the initial phase of oil spills when large numbers of birds are exposed to floating oil (Hartung 1995). Birds living in coldwater environments, like the Grand Banks, are most likely to succumb to hypothermia (Hartung 1995).

8.7.5.2 Short-term Effects

Oiled birds that escape seek refuge ashore engage in abnormally excessive preening in an attempt to rid themselves of the oil (Hunt 1957 in Hartung 1995). The preening leads to the ingestion of significant quantities of oil which, only partially absorbed (McEwan and Whitehead 1980), can cause lethal effects. Noted effects on Common Murres and Thick-billed Murres oiled off Newfoundland's south coast include emaciation, renal tubular degeneration, necrosis of the duodenum and liver, anemia and electrolytic imbalance (Khan and Ryan 1991). Glaucous-winged Gulls (*Larus glaucescens*) experienced similar effects after they ingested bunker fuel oil during preening (Hughes et al. 1990). Another commonly observed effect is adrenal hypertrophy. This condition tends to make birds more vulnerable to adrenocortical exhaustion (e.g., Mallards [Hartung and Hunt 1966; Holmes et al. 1979], Black Guillemots [Peakall et al. 1980], and Herring Gulls [Peakall et al. 1982]). The adrenal gland maintains water and electrolyte balance that is essential for the survival of birds living in the marine environment. Hartung and Hunt (1966) found that ingested oils can cause lipid pneumonia, gastrointestinal irritation, and fatty livers in several species of ducks. Aromatic hydrocarbons have been detected in the brains of Mallards (Lawler et al. 1978) and are probably associated with observed symptoms (e.g., lack of coordination, ataxia, tremors and constricted pupils) of nervous disorders (Hartung and Hunt 1966).

Birds exposed to oil are also at risk of starvation (Hartung 1995). In addition, energy demands are higher because the metabolic rate of oiled birds increases to compensate for the heat loss caused by the reduced insulating capacity of their plumage. This can expedite starvation (Hartung 1967; McEwan and Koelink 1973).

8.7.5.3 Long-term Effects

It appears that direct, long-term sublethal toxic effects on seabirds are unlikely (Hartung 1995). The extent of bioaccumulation of the chemical components of oil in birds is limited because vertebrate species are capable of metabolizing them at rates that minimize bioaccumulation (Neff 1985 *in* Hartung 1995). Birds generally excrete much of the hydrocarbons within a short time period (McEwan and Whitehead 1980). However, nesting seabirds that are contaminated with oil but still survive, generally exhibit decreased reproductive success.

Nesting seabirds transfer oil from their plumage and feet to their eggs (Albers and Szaro 1978). Very small quantities of oil (1 to 20 µl) on eggs have produced developmental defects and mortality in avian embryos of many species (Albers 1977; Albers and Szaro 1978; Hoffmann 1978, 1979a; Macko and King 1980; Parnell et al. 1984; Harfenist et al. 1990). The resultant hatching and fledging success of young appears to be related to the type of oil (Hoffman 1979b; Albers and Gay 1982; Stubblefield et al. 1995) and the timing of exposure during incubation. Embryos are most sensitive to oil during the first half of incubation (Albers 1978; Leighton 1995). Breeding birds that ingest oil generally exhibit a decrease in fertilization (Holmes et al. 1978), egg laying and hatching (Hartung 1965; Ainley et al. 1981), chick growth (Szaro et al. 1978) and survival (Vangilder and Peterle 1980; Trivelpiece et al. 1984). Similar effects on ducklings occur when they ingest oil directly (Miller et al. 1978; Peakall et al. 1980; Szaro et al. 1981). Oil spills can also cause indirect reproductive failure. Eppley and Rubega (1990) suggest that exposure to an Antarctic oil spill caused changes in the normal parental behaviour of South Polar Skuas (*Catharacta maccormicki)*, thus exposing young to increased predation and contributing to reproductive failure in that population. In another case, abandonment of nesting burrows by oiled adult Leach's Storm-Petrels may have contributed to reproductive failure in that population (Butler et al. 1988). Therefore, a spill that occurs during the reproductive period could cause mortality of young even if the adults survived the exposure to oil.

There is no conclusive evidence that oil spills have either caused marked reductions in bird populations or have changed community structure at a large scale (Leighton 1995). Some studies have suggested that oil pollution is unlikely to have major long-term effects on bird productivity or population dynamics (Clark 1984; Butler et al. 1988; Boersma et al. 1995; Wiens 1995) while others suggest the opposite (Piatt et al. 1990; Walton et al. 1997). Natural interannual variation in other factors that affect populations (e.g., prey availability and weather) reduces the ability of scientists to assess the full effect of oil spills on bird populations.

8.7.5.4 Sensitive Species

It is clear that truly aquatic and marine species of birds are most vulnerable and most often affected by exposure to marine oil spills. Diving species such as Black Guillemots, murres, Atlantic Puffins, Dovekies, eiders, Oldsquaws, scoters, Red-breasted Mergansers, and loons are considered to be the most susceptible to the immediate effects of surface slicks (Leighton et al. 1985; Chardine 1995; Wiese and Ryan 1999). Alcids often have the highest oiling rate of seabirds recovered from beaches along the south and east coasts of the Avalon Peninsula, Newfoundland. They were the only group of seabirds to show an annual increase over a 13-yr period (2.7 percent) in the proportion of oiled birds (Wiese and Ryan 1999). Within the diving species group, murres appear to be the most affected by exposure to oil. Also, there also appears to be a strong seasonal effect as significantly higher proportions of alcids (along with other seabird groups) are oiled in winter versus summer (Wiese and Ryan 1999).

Other species such as Northern Fulmars, shearwaters, storm-petrels, gulls and terns are vulnerable to contact with oil because they feed over wide areas and make frequent contact with the water's surface. They are also vulnerable to the disturbance and habitat damage associated with oil spill cleanup (Lock et al. 1994). The greatest decrease in use of contaminated habitats immediately following a spill occurs in species that feed on or close to shore, and that either breed along the coast or are full-year residents (Wiens et al. 1996). In the Project Area, this would include species like terns and storm-petrels. Oil residues in bedrock habitat, like that used by most seabirds in Newfoundland, do not persist as long as residues in sedimentary habitat (e.g., sand beaches) (Gilfillan et al. 1995).

Birds are particularly vulnerable to oil spills during nesting, moulting, and prior to young seabirds gaining the ability to fly. Newly fledged murres and Northern Gannets are unable to fly for the first two to three weeks at sea, and are, therefore, less likely to avoid contact with oil during this time (Lock et al. 1994). Before and during moult, the risks of hypothermia and drowning (Erasmus and Wessels 1985) are increased because feather wear and loss reduce the ability to repel water by about 50% (Stephenson 1997).

8.7.5.5 Past Oil Spills In and Near the Study Area

Several major oil spills have occurred near the Project Area, and “small” oil releases (most likely from bilge pumping and de-ballasting by vessel traffic through the nearby shipping lanes) occur frequently. “Mystery” spills, most likely from ships that illegally dump waste oils into the ocean, killed an estimated 18,000 seabirds in Placentia Bay, Newfoundland (Anon. 1990). Many ships frequent the waters off the south coast of Newfoundland as they traverse between Europe and North America, thereby exposing seabirds to chronic levels of oil pollution (Chardine and Pelly 1994). In February 1970, the *Irving Whale* spilled between 3,000 and 7,000 gallons of Bunker C oil near St. Pierre and Miquelon, which subsequently spread along Newfoundland’s southeast coast. It was estimated that 7,000 birds, primarily Common Eiders, were killed (Brown et al. 1973). During the same month, the *Arrow* ran aground in Chedabucto Bay, Nova Scotia. Approximately 2.5 million gallons of Bunker C fuel oil were spilled and at least 2,300 birds were killed in the bay itself (Brown et al. 1973). Primarily diving birds were affected, most notably Oldsquaws, Red-breasted Mergansers, murres, Dovekies, and grebes (Brown et al. 1973). The spill spread offshore to Sable Island where mostly murres, Dovekies, and Northern Fulmars were killed. The lowest estimate of seabird mortality due to this part of the slick was 4,800 birds (Brown et al. 1973).

On a broader geographical scale, it is estimated that 21,000 birds die annually from operational spills on the Atlantic coast of Canada and that 72,000 birds die annually from all operational spills in Canada (Thomson et al. 1991). Clark (1984) estimates that 150,000 to 450,000 birds die annually in the North Sea and North Atlantic from oil pollution of all sources. There is no clear correlation between the size of an oil spill and numbers of seabirds killed (Burger 1993). The density of birds in a spill area, wind velocity and direction, wave action, and distance to shore may have a greater bearing on mortality than the size of the spill (Burger 1993).

Accordingly, even small spills can cause cumulative mass mortality of seabirds (Joensen 1972). A major spill that persists for several days near a nesting colony could kill a high proportion of the pursuit-diving birds (e.g., murres) within the colony (Cairns and Elliot 1987). In contrast, relatively low mortalities have been recorded from some huge spills. For example, the *Amoco Cadiz* spilled 230,000 tonnes of crude oil along the French coast, causing the recorded deaths of 4,572 birds (Clark 1984).

8.7.5.6 Rehabilitation

The rescue, cleaning, and rehabilitation of oiled birds have been practised in several parts of the world for a number of years (Clark 1984). Considerable effort has been made to improve rehabilitation techniques (Berkner et al. 1977; Williams 1985; Frink and White 1990), and release rates of birds have generally increased (Randall et al. 1980; Williams 1985; Frink 1987).

However, success of rehabilitation cannot be measured in terms of numbers of birds released from treatment centres because cleaned seabirds often die shortly after release (Sharp 1996). Oiled and cleaned Black Guillemots, White-winged Scoters, and Western Grebes (*Aechmophorus occidentalis)* in North America had a much lower survival rate than non-oiled controls, regardless of cleaning techniques (Sharp 1996). Similarly, Swennen (1977 *in* Sharp 1996) found that oiled, cleaned birds "released" into large enclosures had an annual mortality rate of 35 to 37% compared with a mortality rate of 7% for non-oiled controls. Radio-tagged brown pelicans (*Pelecanus occidentalis*) that had been oiled and cleaned also had a much lower survival rate than non-oiled birds (D. Anderson, pers. comm. in Sharp 1996).

Piatt et al. (1990) estimated that 100,000 to 300,000 birds were killed by oil from the *Exxon Valdez*. Therefore, the massive rescue attempts associated with the *Exxon Valdez* spill managed to release (not save) only 0.3 to 0.8 percent of the birds that were potentially fatally oiled by the spill.

Notwithstanding the foregoing, Husky recognizes that in the event of a spill offshore there would be considerable public concern for the welfare of seabirds as there has been almost uniformly throughout the world in the face of such incidents. In response to that expectation, Husky has begun and will continue to develop its capability to respond to oiled seabirds in collaboration with it industry partners and third party organizations with expertise in this area. Husky will conduct bird cleaning and rehabilitation programs on the basis of the following principles:

- Bird cleaning and rehabilitation operations will be carried out under the terms of permits issued by the Canadian Wildlife Service of Environment Canada;
- Procedures and protocols to ensure safe effective and humane cleaning and rehabilitation of birds under the guidance of a qualified veterinarian will be put in place pursuant to the aforementioned permits;
- Husky's procedures and protocols will make appropriate provision for triage and euthanasia under the direction of a qualified veterinarian and ensure appropriate focus for any endangered species that might be affected by an incident;
- Collection of birds offshore for cleaning and rehabilitation during a spill incident will be conducted with strict regard for safety of personnel involved.

8.7.5.7 Enhancement Techniques

In the unlikely event that seabird populations are significantly affected by oil spills (Clark 1984; Wiens 1995), it may be possible to restock populations. Although no efforts to restock birds in areas that have suffered from major oil spills have been conducted, there have been several programs to reintroduce birds into abandoned parts of their ranges. Approaches have included releasing captive-reared fledgling birds at natural or artificial nest sites (e.g., hacking of Peregrine Falcons), placing eggs from nests in one part of the range (or from captive birds) into nests of similar species in the areas of concern (e.g., Peregrine Falcon eggs into Prairie Falcon nests, Whooping Crane eggs into Sandhill Crane nests, Trumpeter Swan eggs into Mute Swan nests), and releasing juvenile and adult birds into selected receiving areas (e.g., Atlantic Puffins off the Maine coast and along the Brittany coast, and Canada Geese in many areas).

These efforts have met with variable success. They all involved much planning and the programs were multi-year efforts that required a long-term commitment of personnel and resources. The case most relevant to the Project Area involves the successful reestablishment of colonies of Atlantic Puffins in New England and France (Duncombe and Reille 1980; Clark 1984). Puffins are alcids, close relatives of the murres and Black Guillemots that also nest abundantly in southern Newfoundland. However, the puffins nest in burrows, whereas murres are cliff-nesters and Black Guillemots nest among rocks and coastal debris. Consequently, it is unclear whether the techniques used in the successful reestablishment of nesting puffins would also work with these other alcids.

The nesting success of some species can be improved by manipulation of nesting habitat. For example, in Alaska, Common Eider females nest preferentially in well-protected areas near logs and among driftwood and rocks (Johnson and Herter 1989). Therefore, numbers of nesting sites could be increased by adding and rearranging driftwood along coasts and on offshore islands (S.R. Johnson, pers. comm.). Similar manipulations of eider nesting habitat are already underway in Atlantic Canada to improve nesting success. Also, in Iceland, the nesting habitat of eiders is manipulated to improve nesting success and to facilitate the collection of the eider down that lines the nests.

One option for enhancing recovery of depleted species is the elimination of hunting of that species, if it is a hunted species. Depending upon the severity of the situation, hunting could be spatially and temporally curtailed to whatever degree necessary.

The techniques to rescue and rehabilitate oiled birds are not very effective. Consequently, the best mitigation technique is to do all that is possible to avoid an oil spill in the first place. Otherwise, deploy countermeasures that reduce the numbers of birds that become oiled (e.g., directing the oil away from seabird concentration areas). It is much better to direct efforts to techniques that prevent birds from becoming oiled in the first place. Successful and efficient techniques are not yet available to restore bird populations and habitat once they are oiled.

Effects interactions, assessment and significance predictions of accidental events associated with the proposed Jeanne d'Arc Basin delineation/exploratory drilling program on marine birds are detailed in presented in Tables 8.26 to 8.28.

Table 8.26. Potential Interactions of Accidental Events and Marine Bird VEC.

Valued Environmental Component: Marine Birds	
Accidental Event Scenario	**Marine Birds**
Subsea Blowout 7 Day	x
Subsea Blowout 45 Day	x
Above-surface Blowout 7 Day	x
Batch Spill 800 m^3	x
Batch Spill 10,000 m^3	x
Batch Spill 30,000 m^3	x

Table 8.27. Environmental Effects Assessment of Potential Effects of Accidental Events on Marine Bird VEC.

Valued Environmental Component: Marine Birds									
Habitat Component and Accidental Event Scenario	Potential Positive (P) or Negative (N) Environmental Effect	Regulative Mitigation	Project Specific Mitigation	Evaluation Criteria for Assessing Environmental Effects					
				Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural And Economic Context
Subsea Blowout 7 Day	Mortality (N)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	6	<1	2	I[a]	2
Subsea Blowout 45 Day	Mortality (N)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	6	<1	2	I[a]	2
Above-surface Blowout 7 Day	Mortality (N)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	6	<1	2	I[a]	2
Batch Spill 800 m^3	Mortality (N)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	5	<1	2	I[a]	2
Batch Spill 10,000 m^3	Mortality (N)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	5	<1	2	I[a]	2
Batch Spill 30,000 m^3	Mortality (N)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	5	<1	2	I[a]	2

Magnitude
0 = Negligible
1 = Low
2 = Medium
3 = High

Geographic Extent
1 = < 1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = > 10,000 km^2

Frequency
1 = < 11 events/year
2 = 11-50 events/year
3 = 51-100 events/year
4 = 101-200 events/year
5 = > 200 events/year
6 = continuous

Duration
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Reversibility (population level)
R = Reversible
I = Irreversible

Ecological/Socio-Cultural and Economic Context
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative anthropogenic effects

[a] Effects on individuals irreversible but any population effects are reversible

Geographic extent differed between summer and winter for each scenario but both were always within the same category.

Table 8.28. Significance of Predicted Residual Effects of Accidental Events on Marine Bird VEC.

Valued Environmental Component: Marine Birds				
Accidental Event Scenario	**Significance of Predicted Residual Environmental Effects**		**Likelihood[a]**	
	Significance Rating	**Level of Confidence**	**Probability of Occurrence**	**Scientific Certainty**
Subsea Blowout 7 Day	S	3	1	1
Subsea Blowout 45 Day	S	3	1	1
Above-surface Blowout 7 Day	S	3	1	1
Batch Spill 800 m^3	S	3	1	1
Batch Spill 10,000 m^3	S	3	1	1
Batch Spill 30,000 m^3	S	3	1	1

Significance Rating (significance is defined as a medium or high magnitude (2 or 3 rating) and duration > 1 year (≥ 3 rating) and geographic extent > 100 km^2 (≥ 4 rating)
NS = Not significant negative environmental effect
S = Significant negative environmental effect
NS = Not significant negative environmental effect
P = Positive environmental effect

Level of Confidence (professional judgement)
1 = Low level of confidence
2 = Medium level of confidence
3 = High level of confidence

Probability of Occurrence (professional judgement)
1 = Low probability of occurrence
2 = Medium probability of occurrence
3 = High probability of occurrence

Level of Scientific Certainty (based on scientific information and statistical analysis or professional judgement)
1 = Low level of scientific certainty
2 = Medium level of scientific certainty
3 = High level of scientific certainty

[a] Only considered in the event of significant (S) residual effect

The potential effects on seabirds are confounded by the physical properties of White Rose type crude oil. The waxy nature of the oil slows evaporation and dispersion, causing the oil to maintain its volume and persist on the surface of the water. The oil may last for several weeks or even months before the particles and patches diffuse and dilute to levels that would not affect seabirds. On the other hand, the waxy oil particles become semi-solid within a short period of time after release and may not wet birds' feathers in the same way as conventional, non-waxy oils. Major changes in the oil's spreading behaviour and its ability to wet birds' feathers will certainly reduce the potential effect of spills on birds. However, until the potential effects of White Rose type oil on seabirds are better understood, it is precautionary to assume that the risks to birds are similar to those from conventional oil.

Distribution and density data for seabirds are limited in the Project Area, especially for the areas where spilled oil is likely to occur, so no attempt was made to quantify potential bird mortalities. Large numbers of seabirds could be killed by an accidental release of hydrocarbons at the drilling sites. Oil spills have the greatest effects on marine bird populations if the spill occurs at a time and place where birds are concentrated, such as near feeding/staging/moulting aggregation areas or nesting colonies.

It is extremely unlikely that crude oil accidentally spilled at the drilling sites will reach any seabird colonies in the Study Area. None of the individual model runs for the White Rose assessment predicted oil onshore.

The oil spill trajectory models indicate that small areas near the spill site have a high probability that oil will occur there. Seabirds are known to associate with offshore structures and these birds are at increased risk to exposure in the unlikely event of an accidental release of oil. During summer, shearwaters, gulls, storm-petrels, and Northern Fulmars would be the species most likely exposed to oil near the release point. These species are vulnerable to contacting oil because individuals have frequent contact with the water's surface. Alcids are at an even greater risk to oiling, especially in winter, but it is uncertain whether this group associates with offshore structures to the same degree as shearwaters, gulls, storm-petrels, and Northern Fulmars.

The oil spill countermeasures described in the contingency plan would likely reduce the number of oiled seabirds, but *significant* negative effects are still likely even after countermeasures are imposed. Any effects of oil exposure on individual seabirds would be irreversible and any rehabilitation attempts would likely be unsuccessful. It is likely that any effects at the population level would be reversible over time. Therefore, because the significant negative effect is reversible, in the unlikely event that is occurs, the population of marine birds, which is a renewable resource, will be able to meet future needs of resource users.

8.7.5.8 Summary of Effects on Marine Birds

Depending on the time of year, location of seabirds within the Study Area, and type of oil spill or blowout, the magnitude of effects on marine birds would be *negligible to high* (Table 8.27). Geographic extent for all blowout scenarios is *greater than 10,000* km^2 while for all spill scenarios it is *1,001 to 10,000* km^2 based on the White Rose modeling. The estimates for ‘geographic extent’ are conservative because a slick will not cover a continuous area by the end of the 30-day modeling period but rather, a large number of small mats, particles, and “wax” balls interspersed with areas where there is no oil. Predicted frequency of large spills is much *less than 1 event/yr*, duration is *1 to 12 months*. Although the effects on individual birds are likely *irreversible*, the effects on marine birds at the population level are deemed *reversible* in all scenarios.

Nonetheless, effects of exposure to oil spills and blowouts on marine birds would be *significant* (Table 8.28). Similar predictions were made in the Hibernia and Terra Nova EISs and the White Rose, Jeanne d’Arc Basin, Lewis Hill and Orphan Basin EAs regarding spills or blowouts at those sites (Mobil 1985; Petro-Canada 1996; Husky 2000; LGL 2002, 2003 2005ab, 2006ab).

Because the *significant* negative effect is reversible at the population level, in the unlikely event of an oil spill or blowout, the population of marine birds, which is a renewable resource, will be able to meet future needs of resource users.

8.7.6 Marine Mammals

Most marine mammals, with the exception of fur seals, polar bears, and sea otters, are not very susceptible to deleterious effects of oil. However, newborn seal pups, and weak or highly stressed individuals, may be vulnerable to oiling. Other marine mammals exposed to oil are generally not at risk because they rely on a layer of blubber for insulation and oiling of the external surface does not appear to have any adverse thermoregulatory effects (Kooyman et al. 1976; 1977; Geraci 1990; St. Aubin 1990). Population-level effects are unlikely, as no significant long-term and lethal effects from external exposure, ingestion, or bioaccumulation of oil have been demonstrated.

8.7.6.1 Cetaceans

There is no clear evidence that implicates oil spills, including the much studied *Santa Barbara* and *Exxon Valdez* spills, with mortality of cetaceans (Geraci 1990). Migrating gray whales were apparently not adversely affected by the *Santa Barbara* spill. There appeared to be no relationship between the spill and mortality of marine mammals. The higher than usual counts of dead marine mammals recorded after the spill was a result of increased survey effort related to the spill (Geraci 1990). The conclusion was that whales were either able to detect the oil and avoid it or were unaffected by it (Geraci 1990).

There was a significant decrease in the size of a killer whale pod resident in the area of the *Exxon Valdez* spill, but no clear cause and effect relationship between the spill and the decline could be established (Dahlheim and Matkin 1994). There were no evident effects on humpback whales in Prince William Sound after the *Exxon Valdez* spill (von Ziegesar et al. 1994). There was some temporary displacement of humpback whales out of Prince William Sound, but oil contamination, boat and aircraft disturbance, or displacement of food sources may have caused this displacement.

8.7.6.1.1 Avoidance and Behavioural Effects

Studies of both captive and wild cetaceans indicate that they can detect oil spills. Captive bottlenose dolphins (*Tursiops truncatus*) avoided most oil conditions during daylight and darkness, but had difficulty detecting a thin sheen of oil (St. Aubin et al. 1985). Wild bottlenose dolphins exposed to the *Mega Borg* oil spill in 1990 appeared to detect, but did not consistently avoid contact with, most oil types (Smultea and Würsig 1995). This is consistent with other cetaceans behaving normally in the presence of oil (Harvey and Dahlheim 1994; Matkin et al. 1994). It is possible that cetaceans swim through oil because of an overriding behavioural motivation (for example, feeding). Some evidence exists that indicates dolphins attempt to minimize contact with surface oil by decreasing their respiration rate and increasing dive duration (Smultea and Würsig 1995).

8.7.6.1.2 Oiling of External Surfaces

Whales rely on a layer of blubber for insulation and oil has little if any effect on thermoregulation. Effects of oiling on cetacean skin appear to be minor and of little significance to the animal's health (Geraci 1990). It can be assumed that if oil contacted the eyes, effects would be similar to that observed in ringed seals (conjunctivitis, corneal abrasion, and swollen nictitating membranes) and that continued exposure to eyes could cause permanent damage (St. Aubin 1990).

8.7.6.1.3 Ingestion and Inhalation of Oil

Whales could ingest oil with water, contaminated food, or oil could be absorbed through the respiratory tract. Species like the humpback whale, right whale, beluga (*Delphinapterus leucas*), and harbour porpoise that feed in restricted areas (for example, bays) may be at greater risk of ingesting oil (Würsig 1990). Some of the ingested oil is voided in vomit or feces but some is absorbed and could cause toxic effects (Geraci 1990). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt 1978; 1982). Whales exposed to an oil spill are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin 1980; 1982). Only small traces of oil were found in the blubber of a gray whale and liver of a killer whale exposed to *Exxon Valdez* oil (Bence and Burns 1995).

Cetaceans may inhale vapours from volatile fractions of oil from a spill and blowout. The most likely effects of inhalation of these vapours would be irritation of respiratory membranes and absorption of hydrocarbons into the bloodstream (Geraci 1990). Stressed individuals that could not escape a contaminated area would be most at risk.

8.7.6.1.4 Fouling of Baleen

In baleen whales, crude oil could coat the baleen and reduce filtration efficiency. However, effects are minimal and reversible. Baleen experimentally fouled with oil did not change enough to alter its filtration efficiency (St. Aubin et al. 1984) and most adherent oil was removed within 30 min after fouling (Geraci and St. Aubin 1985 *in* Geraci 1990). The effects of oiling of baleen on feeding efficiency appear to be only minor (Geraci 1990).

8.7.6.1.5 Summary of Effects on Cetaceans

Whales may interact with spilled oil (Table 8.29) but are not considered to be at high risk to the effects of oil exposure. There is no clear evidence that implicates oil spills with cetacean mortality. Both toothed and baleen whales present in the affected area could experience sublethal effects, through oiling of mucous membranes or the eyes if they swim through a slick. As discussed above, these effects are reversible and would not cause permanent damage to the animals. There is a possibility that the baleen of whales could be contaminated with oil, thereby reducing filtration efficiency. However, effects would be minimal and reversible. Based on available marine mammal data for the Jeanne d'Arc Basin area and the biology of marine mammals known to occur in the area, the area is not likely an important feeding or breeding area. Some species are likely present in the Jeanne d'Arc Basin area year round, but most species likely just occur there during summer months. However, there are limited available data for winter time. For marine mammals, it is likely that only small proportions of populations are at risk at any time.

Table 8.29. Accidental Spill-Environmental Interaction Matrix for Marine Mammal and Sea Turtle VECs.

Valued Environmental Component: Marine Mammals, Sea Turtles		
Accidental Event Scenario	**Marine Mammals**	**Sea Turtles**
Subsea Blowout 7 Day	x	x
Subsea Blowout 45 Day	x	x
Above-surface Blowout 7 Day	x	x
Batch Spill 800 m^3	x	x
Batch Spill 10,000 m^3	x	x
Batch Spill 30,000 m^3	x	x

Depending on the time of year, location of toothed and baleen whales within the affected area, and type of oil spill or blowout, the effects of an offshore oil release on the health of cetaceans is predicted to range from a *negligible to low* magnitude over varying geographic extents. A geographic extent of >10,000 km^2 is predicted for all subsea and above-surface blowout scenarios which were modelled. A geographic extent of 1001-10,000 km^2 is predicted for all modelled batch spill releases. As indicated above, this estimate is quite conservative and any effects on cetaceans will likely occur over a much smaller area. For all spill scenarios considered, the duration is predicted to be 1-12 months and effects are considered reversible (Table 8.30). It is predicted that there will be *no significant* negative effect on cetaceans from an accidental release of oil at the exploratory drilling sites at Jeanne d'Arc Basin (Table 8.31).

The oil spill countermeasures contained in Husky's contingency plan and the associated disturbance would likely reduce the number of whales exposed to oil.

8.7.6.2 Seals

Reports of the effects of oil spills and blowouts have shown that some mortality of hair seals may have occurred as a result of oil fouling; however, large scale mortality has never been observed (St. Aubin 1990). The largest effect of a spill was on young hair seals in cold water (St. Aubin 1990).

Table 8.30. Accidental Spill/Blowout Effects Assessment for Marine Mammal and Sea Turtle VECs.

Valued Environmental Component: Marine Mammals, Sea Turtles										
Accidental Offshore Oil Spill or Blowout										
				Evaluation Criteria for Assessing Environmental Effects						
VEC and Spill Scenario[a]	**Potential Positive (P) or Negative (N) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Subsea blowout 7 days	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1
Subsea blowout 45 days	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1
Above-surface blowout 7 days	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1
Batch spill 800 m^3	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1
Batch spill 10,000 m^3	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1
Batch spill 30,000 m^3	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1

Key:

Magnitude:	Geographic Extent:	Frequency:	Duration:	Reversibility:
0 = negligible	1 = <1 km^2	1 = < 11 events/yr	1 = < 1 month	R = Reversible
1 = Low	2 = 1-10 km^2	2 = 11-50 events/yr	2 = 1-12 months	I = Irreversible
2 = Medium	3 = 11-100 km^2	3 = 51-100 events/yr	3 = 13-36 months	
3 = High	4 = 101-1000 km^2	4 = 101-200 events/yr	4 = 37-72 months	
	5 = 1001-10,000 km^2	5 = >200 events/yr	5 = > 72 months	
	6 = >10,000 km^2	6 = continuous		

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not negatively affected by human activity.
2 = Evidence of existing negative effects.

[a] Geographic Extent differed during summer & winter but always fell within the same category of Geographic Extent.

Table 8.31. Significance of Predicted Residual Environmental Effects on Marine Mammal and Sea Turtle VECs in the Unlikely Event of an Accidental Offshore Oil Spill or Blowout.

Valued Environmental Component: Marine Mammals, Sea Turtles				
Accidental Event Scenario	Significance of Predicted Residual Environmental Effects		Likelihood[a]	
	Significance Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Subsea Blowout 7 Day	NS	3	-	-
Subsea Blowout 45 Day	NS	3	-	-
Above-surface Blowout 7 Day	NS	3	-	-
Batch Spill 800 m^3	NS	3	-	-
Batch Spill 10,000 m^3	NS	3	-	-
Batch Spill 30,000 m^3	NS	3	-	-

Significance Rating (significance is defined as a medium or high magnitude (2 or 3 rating) and duration > 1 year (≥ 3 rating) and geographic extent > 100 km^2 (≥ 4 rating)
NS = Not significant negative environmental effect
S = Significant negative environmental effect
NS = Not significant negative environmental effect
P = Positive environmental effect

Level of Confidence (professional judgement)
1 = Low level of confidence
2 = Medium level of confidence
3 = High level of confidence

Probability of Occurrence (professional judgement)
1 = Low probability of occurrence
2 = Medium probability of occurrence
3 = High probability of occurrence

Level of Scientific Certainty (based on scientific information and statistical analysis or professional judgement)
1 = Low level of scientific certainty
2 = Medium level of scientific certainty
3 = High level of scientific certainty

[a] Only considered in the event of significant (S) residual effect

Effects on seals have not been well studied at most spills because of lack of baseline data and/or the brevity of the post-spill surveys. There is little information about the mortality rate of harp seals exposed to oil from a ruptured storage tank in New Brunswick in 1969. It is believed that 10,000 to 15,000 harp seals were coated with oil but the exact number of dead seals recovered is unknown (Sergeant 1991). The release of fuel oil from the *Arrow* into Chedabucto Bay, Nova Scotia in 1970 resulted in the fouling of 500 seals within the bay and 50 to 60 harbour and 200 grey seals on Sable Island (200 km south of the spill). Twenty-four seals were found dead and some had oil in their mouths and stomachs (Anon. 1970; 1971 *in* St. Aubin 1990). Oiled grey and harbour seals were found on the coast of Nova Scotia and Sable Island again in 1979 when the oil tanker *Kurdistan* sank in Cabot Strait. No causal relationship between oiling and death was determined (Parsons et al. 1980 *in* St. Aubin 1990). No mortalities were reported after a well blowout near Sable Island in 1984 and only two oiled grey seals were observed (St. Aubin 1990).

Intensive and long-term studies were conducted after the *Exxon Valdez* spill in Alaska. There may have been a long-term decline of 36% in numbers of moulting harbour seals at oiled haul-out sites in Prince William Sound, following the *Exxon Valdez* spill (Frost et al. 1994). Harbour seal pup mortality at oiled beaches was 23 to 26%, which may have been higher than natural mortality (Frost et al. 1994). However, attributing cause to the decreasing trend in harbour seal numbers since the spill (4.6% per year) is complicated because seal populations were declining prior to the spill (Frost et al. 1999). Further analyses of harbour seal population trends and movements in Prince William Sound does not support high mortality, but indicates that seals moved away from some oiled haul-out sites (Hoover-Miller et al. 2001).

8.7.6.2.1 Avoidance and Behavioural Effects

There is conflicting evidence on whether seals detect and avoid spilled oil. Some oiled seals hauled out on land are reluctant to enter the water, even when disturbances from intense cleanup activities occur nearby (St. Aubin 1990; Lowry et al. 1994). In contrast, several thousand grey and harbour seals apparently left Chedabucto Bay, Nova Scotia, after the grounding of the *Arrow* (Mansfield 1970 *in* St. Aubin 1990), although this movement may have been caused by the increased human disturbance during cleanup activities rather than by the presence of oil (St. Aubin 1990). Harbour seals observed immediately after oiling appeared lethargic and disoriented, which may be attributed to lesions observed in the thalamus of the brain (Spraker et al. 1994). Other seals have been observed swimming in the midst of oil spills (St. Aubin 1990). Oiling of both mother and pups does not appear to interfere with nursing (Lowry et al. 1994).

8.7.6.2.2 Oiling of External Surfaces

Adult and juvenile hair seals (includes harbour, grey, harp and hooded seals) are at virtually no risk of thermal regulatory effects from oil fouling because their blubber, not their fur, provides insulation (Kooyman et al. 1976; 1977; St. Aubin 1990). It is questionable whether young seal pups, which rely on their birth coat and brown fat stores, could survive the deleterious effects of oiling (St. Aubin 1990). Contact with oil on the external surfaces can cause increased stress and can irritate the eyes of ringed seals (Geraci and Smith 1976; St. Aubin 1990). Harbour seals oiled during the *Exxon Valdez* spill had difficulty keeping their eyes open and experienced conjunctivitis (Spraker et al. 1994). These effects seem to be temporary and reversible, but continued exposure of oil to eyes could cause permanent damage (St. Aubin 1990). Damage to a seal's visual system would likely limit foraging abilities, as vision is an important sensory modality used to locate and capture prey (Levenson and Schusterman 1997). Mucous membranes that line the oral cavity, respiratory surfaces, and anal and urogenital orifices are also sensitive to oil exposure (St. Aubin 1990). Seals fouled externally with heavy oil may also encounter problems with locomotion. The flippers of young harp seals and grey seal pups were impeded by a heavy coating of oil that became stuck to their sides (Davis and Anderson 1976; Sergeant 1991). This led to the drowning of the grey seal pups. The coating of seals and their subsequent deaths were also observed in seals exposed to heavy bunker oil during the *Arrow* and *Kurdistan* spills (Engelhardt 1987 *in* Lowry et al. 1994).

8.7.6.2.3 Oil Ingestion and Inhalation

Seals can ingest oil if their food is contaminated or by nursing contaminated milk. Oil can also be absorbed through the respiratory tract (Geraci and Smith 1976; Engelhardt et al. 1977). Some ingested oil is voided in vomit/feces or metabolized at rates that prevent significant bioaccumulation (Neff 1985 *in* Hartung 1995) but some is absorbed and can cause toxic effects (Engelhardt 1981). These effects may include minor kidney, liver and brain lesions (Geraci and Smith 1976; Spraker et al. 1994). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt 1978; 1982; 1985). Seals exposed to an oil spill and especially a blowout are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin 1980; 1982) and any effects are probably reversible (Spraker et al. 1994). There were no significant quantities of oil in the tissues (liver, blubber, kidney and skeletal muscles) of harbour seals exposed during the *Exxon Valdez* spill (Bence and Burns 1995).

Seals are also at risk from hydrocarbons and other chemicals that evaporate from spills and blowout areas. Seals generally keep their nostrils close to the water surface when breathing, so they are likely to inhale vapours if they surface in a contaminated area. Grey seals that presumably inhaled volatile hydrocarbons from the *Braer* oil spill exhibited a discharge of nasal mucous, but no causal relationship with the oil was determined (Hall et al. 1996). Laboratory studies of ringed seals indicate that the inhalation of hydrocarbons may cause more serious effects like kidney and liver damage (St. Aubin 1990). However, exposure conditions were much higher than would be expected in a natural setting.

8.7.6.2.4 Factors Affecting the Severity of Oil Exposure

Seals that are under some type of natural stress, such as lack of food or a heavy infestation by parasites, could die as a result of the additional stress of oiling (Geraci and Smith 1976; St. Aubin 1990). Seals that are not under natural stress would most likely survive oiling.

Seals exposed to heavy doses of oil for prolonged periods of time could die. Harbour seals may be particularly at risk because they exhibit site fidelity (Boulva and McLaren 1979; Yochem et al. 1987). Prolonged exposure from oil at a preferred haul-out site could cause the death of some seals. However, Jenssen (1996) reported that oil has produced little visible disturbance to grey seal behaviour and there has been little mortality despite the fact that approximately 50 percent of grey seal pups at Norway's largest breeding colony are polluted each year by oil. Based on the 14,600 slicks modeled (White Rose model), none of the slicks reached the shores of Newfoundland and Labrador. Also, it is unlikely that oil released during accidental spills or blowouts in the Jeanne d'Arc Basin would reach harp seals occurring on the Front during the breeding season given that most spill trajectories occur to the east and northeast of the modeled release sites in the Project Area.

8.7.6.2.5 Summary of Effects on Seals

Seals may interact with spilled oil (Table 8.29) but are not considered to be at high risk from the effects of oil exposure, but some evidence implicates oil spills with seal mortality, particularly young seals. As previously discussed, seals are present on or near Jeanne d'Arc Basin for at least part of the year. The majority of the Project Area falls outside of the area were pack ice typically occurs (see Section 4.5). The pack ice that occurs in the proposed drilling area is distant from the primary harp seal breeding area known as the Front. The oil spill trajectory models indicate that after the oil moves away from the release point, it will likely be found east and northeast of the modelled release point. Therefore, it is unlikely that oil accidentally released at proposed drilling sites will reach the pack ice where harp seals breed. There is a possibility that aged oil could contact the southern edge of loose pack ice for a few weeks during years of very heavy ice conditions, but seals are much less common on the deteriorating southern extremities of the pack ice than they are farther north. Few seals are expected to be exposed to oil from an accidental release at the drilling and production sites and most seals do not exhibit large behavioural or physiological reactions to limited surface oiling, incidental exposure to contaminated food, or ingestion of oil.

Depending on the time of year and type of oil spill or blowout, the effects of an offshore oil release on seals could range from a *negligible* to *low* magnitude over varying geographic extents. For subsea and above-surface blowouts, it is estimated that the geographic extent is >10,000 km^2. A geographic extent of 1001-10,000 km^2 is predicted for all modelled batch spill scenarios. As indicated previously, this estimate is quite conservative and any effects on seals will likely occur over a much smaller area. It is unlikely that oil from a blowout or spill will reach the Front were harp seals congregate to pup and breed given that oil spill trajectories are to the east and northeast. For all spill scenarios considered, the duration is predicted to be 1-12 months and effects are considered reversible (Table 8.30). It is predicted that there will be *no significant* negative effect on seals from an accidental release of oil at the exploratory drilling sites at Jeanne d'Arc Basin (Table 8.31). Similar predictions were made in the Hibernia, Terra Nova EIS and White Rose EA regarding spills or blowouts at those sites (Mobil 1985; Petro-Canada 1996a,b; Husky 2000).

The oil spill countermeasures contained in Husky's contingency plan and the associated disturbance would likely reduce the number of seals exposed to oil.

8.7.7 Sea Turtles

It is not known whether sea turtles can detect and avoid oil slicks. Gramentz (1988) reported that sea turtles did not avoid oil at sea, while sea turtles exposed to oil under experimental conditions had a limited ability to avoid oil (Vargo et al. 1986).

Loggerhead sea turtles experimentally exposed to oil had marked gross and histologic lesions present in the skin. Most effects were reversed by the tenth day following cessation of oil exposure (Bossart et al. 1995). Other effects of oil on sea turtles include reduced lung diffusion capacity, decreased oxygen consumption, decreased digestion efficiency, and damaged nasal and eyelid tissue (Lutz et al. 1989).

There are few field observations of sea turtles exposed to oil. After the Ixtoc 1 oil well blowout in 1979, seven live and three dead sea turtles were recovered (Hall et al. 1983). Two of the three carcasses had oil in the gut but no lesions. There was no evidence of aspirated oil in the lungs but hydrocarbon residues were found in kidney, liver, and muscle tissue of all three dead turtles. The authors suggested prolonged exposure to oil may have disrupted the feeding behaviour and weakened the turtles.

8.7.7.1 Summary of Effects on Sea Turtles

Sea turtles are likely rare on the Grand Banks and are even less likely to occur in the proposed drilling and production area. There is a very low likelihood that sea turtles will be exposed to oil from an accidental release near the proposed drilling and production area. Effects of oil on sea turtles will be reversible, but there is a possibility that foraging abilities may be inhibited by exposure to oil.

Depending on the time of year and type of oil spill or blowout, the effects of an offshore oil release on sea turtles could range from a *negligible* to *low* magnitude over varying geographic extents. For subsea and above-surface blowouts, it is estimated that the geographic extent is >10,000 km^2. A geographic extent of 1001-10,000 km^2 is predicted for all modelled batch spill scenarios. As indicated previously, this estimate is quite conservative and any effects on sea turtles will likely occur over a much smaller area. Also, it is unlikely that many sea turtles will occur in Jeanne d'Arc Basin. For all spill scenarios considered, the duration is predicted to be 1-12 months and effects are considered reversible (Table 8.30). It is predicted that there will be *no significant* negative effect on sea turtles from an accidental release of oil at the exploratory drilling sites at Jeanne d'Arc Basin (Table 8.31).

The oil spill countermeasures contained in Husky's contingency plan and the associated disturbance may reduce the number of sea turtles exposed to oil.

8.7.8 Species at Risk

The details of potential effects of accidental spills associated with the proposed drill centre development and production Project on relevant marine animal species listed as endangered, threatened or of special concern on Schedules 1, 2 or 3 of *SARA* (Table 5.1) have been discussed in previous sections on the effects on various VECs. Summary statements for the relevant *SARA* species are as follow:

The effects of accidental spills associated with the proposed drill centre Project on *SARA*-listed wolffishes and Atlantic cod, and their respective habitats, are *not significant* (Table 8.25).

The effects of accidental spills associated with the proposed drill centre Project on the *SARA*-listed Ivory Gull may be *significant* (Table 8.28). However, it is likely that any effects at the population level would be reversible over time. Therefore, because the significant negative effect is reversible and the occurrence of an accidental spill is unlikely, the population of the Ivory Gull will be able to meet future needs of resource users.

The effects of accidental spills associated with the proposed drill centre Project on *SARA*-listed marine mammals including blue whales, North Atlantic right whales, harbour porpoises, and Sowerby's beaked whales are *not significant* (Table 8.31).

The effects of accidental spills associated with the proposed drill centre Project on the *SARA*-listed leatherback sea turtle are *not significant* (Table 8.31).