SCREENING REPORT

Hibernia Drill Centres Construction and Operations Program

Hibernia Management and Development Company (HMDC)

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REPORT TO	**HMDC** **Suite 1000, 100 New Gower Street** **St. John's, NL**
FOR	**Hibernia Drill Centres Construction and Operations Program**
ON	**Screening Report**

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EXECUTIVE SUMMARY

Hibernia Management and Development Company Ltd. (HMDC), and the associated offshore land licence owners, are proposing the construction, installation, operation, maintenance, modification, decommissioning and abandonment of up to six drill centres within glory holes that contain the equipment necessary to support the extraction of petroleum resources. This includes subsea flowlines and associated infrastructure to enable flow to and from the existing gravity based structure (GBS). The six subsea developments and associated glory holes may be located at any point within Production Licence Areas (PLs) 1001 and 1005, Exploration Licence Areas (ELs) 1092 and 1093, and Significant Discovery Licence Areas (SDLs) 1001, 1002, 1003, 1004, 1005 and 1041 at any point in time over the life of the field which could be extended as new reserves are identified (Figure 1.1). Some of these developments remain subject to the identification of economically recoverable reserves, as well as commercial and contractual agreements between Hibernia's owners and the area license holders.

The existing Hibernia project has been subject to a full environmental assessment (EA). However, with respect to the proposed drill centre developments, the C-NLOPB has advised HMDC that the proposed drill centre developments are outside the scope of the original project that was previously assessed and the location of the drill centre(s) may be outside the original project area which was defined as the Hibernia Significant Discovery Area (Mobil Oil Canada 1985). The C-NLOPB has determined, in accordance with paragraph 3(1)(a) of the *Regulations Respecting the Coordination by Federal Authorities of Environmental Assessment Procedures and Requirements* (FCR), that an EA of the Project under section 5 of the *CEA Act* is required.

As per the *Canadian Environmental Assessment Act (CEA Act)*, the Proponent (HMDC) is required to conduct a screening level assessment of this Project. This document is intended to meet the requirements for the *CEA Act* screening level assessment, and is in accordance with the Project Scoping Document issued by the C-NLOPB to HMDC in a letter dated October 7, 2008 (Appendix A).

Project Description

The conceptual scope of the six drill centres includes up to 11 wells each originating from one or more subsea templates or manifolds which are connected to the GBS via subsea flowlines. Subsea wellheads will be located in glory holes to protect them from iceberg impacts. The location and layout of subsea equipment will provide ease of access for inspection, testing, repair, replacement, or removal. The exact configuration of the wells in each of the six drill centres is not presently known and will likely vary between drill centres.

Glory holes will be excavated using proven construction methods for the Grand Banks. Subject to confirmation of soil conditions by a geotechnical survey, a trailing suction hopper dredge (TSHD), or acceptable alternate dredging technology, will be used to excavate the glory hole. Each glory hole will be excavated to a sufficient depth (approximately 10 m) to ensure protection of subsea equipment from iceberg impacts. The estimated volume of material to be disposed at an approved disposal location within the Project Area, from a single glory hole (70 m x 70 m x 10 m), is 159,300 m^3. Smaller glory holes (30m x 30m x 10m) are possible.

Five wells are expected to be drilled over approximately two years at the Hibernia Southern Extension (HSE), the first drill centre to be constructed. Each well is expected to take 128 days on average. There are no anticipated requirements or plans for flaring during drilling, but flaring is possible. A drilling contractor will operate a mobile offshore drilling unit (MODU) to drill the subsea wells associated with this Project. More than one drill rig may be required to operate simultaneously over the course of the Project, but it is highly unlikely.

Well site or geohazard surveys may be used to identify and avoid geotechnically unstable areas (e.g., shallow gas deposits) or hazards (e.g., shipwrecks) prior to drilling. The well site survey may use a combination of video and a small acoustic array and/or sonar over the well location. Vertical seismic profiling (VSP) may be also conducted as part of the drilling and production activities using an airgun array. The VSP is used to assist in further defining a petroleum resource.

Subsea facilities to support the new drill centre(s) will include all equipment necessary for the safe and efficient operation and control of the subsea wells and transportation of production and injection fluids. The subsea equipment installation will use proven methods from other projects proposed and in operation on the Grand Banks (i.e., flowlines, umbilicals, and subsea manifolds with control system components).

All production from the new drill centre will be processed through the Hibernia facility. Some platform systems are currently utilized below their maximum capacity and this Project may partially or completely fill that available capacity. There are no plans to increase platform capacity. Emission and discharge rates will therefore not substantially change as a result. However given the life of the facility is extended, the total mass of emissions and discharges released over the project life will increase. Operations and maintenance procedures currently in place for the Hibernia project will also apply to the drill centres (modified as necessary for the new infrastructure). The GBS will not require substantial upgrades as such for this Project.

HMDC's existing fleet of supply/standby vessels will be used to support the offshore construction and installation operations associated with this Project. However, depending on the type of drill rig used, the number and type of vessels required may necessitate identifying external vessel resources.

At the end of the production life of the Hibernia oilfield, HMDC will decommission and abandon the site according to C-NLOPB requirements and any other applicable laws.

The construction and installation schedule for the HSE is tentatively planned for 2010 to 2012, with the life of the Project extending to 2036 and possibly longer. There are no definitive schedules for the other five drill centres at this time.

Effects Assessment

The assessment considered biophysical and socio-economic issues, focusing on valued environmental components (VECs) identified by the responsible authorities (RAs) in the Scoping Document (Appendix A). Six VECs were selected for this assessment and were evaluated with respect to potential Project-related effects:

- Marine Fish Habitat;
- Marine Fish and Shellfish;
- Commercial Fisheries;

- Marine Mammals;
- Marine Birds; and
- Species at Risk.

Interactions of the Project with the identified VECs relate to the routine discharge of drill wastes; dredging and disposal for the glory holes; the presence of the MODU and other vessels; well site surveys and VSPs; abandonment; and accidental spills and blowouts.

Drill Waste Discharges

Discharges of water-based mud (WBM) and associated cuttings and synthetic-based mud (SBM) cuttings are expected to occur. Potential effects of drill waste discharge during drilling include:

- Change in character of the benthic habitat (e.g., sediment size distribution and the chemical nature of the sediments) in the immediate vicinity of the well site;
- Smothering of the marine benthic community in the immediate vicinity of the well site;
- Potential contamination of organisms either directly (e.g., marine benthos) or indirectly through their food sources (e.g., marine fish, bird, mammal and turtle species at risk); and
- Change in biodiversity from organic enrichment or toxicity in the immediate vicinity of the well site.

Cuttings piles are anticipated to be limited to a radius of 50 m from the well site, and having a typical thickness ranging between 1.5 cm and 1.5 m. It is generally accepted that the biological zone of influence from cuttings deposition is confined to within 500 m of the well (Hurley and Ellis 2004; Neff 2005). Following dissipation of the cuttings pile, the benthic community is expected to recover within two to three years. Thus effects will be short-term and reversible and the marine benthos will not be significantly affected.

The affected area is not known to be a spawning area for any marine species at risk. The discharge of drill wastes around the well site is not predicted to have direct effects on marine fish species at risk. Project discharges are not likely to affect spawning behaviour, and the effect of dispersed WBM on fish eggs, larvae and juveniles is likely to be non significant due to the low concentrations in the water column.

Marine mammals, turtles and birds are also unlikely to be directly affected by drill waste discharges from the rig. There is no toxicity information on the effects of muds and cuttings or other effluents on marine mammals, turtles and sea birds. Significant impacts have not been associated with these animals as they are highly mobile and capable of avoiding such effluents and their ranges far exceed the zone of influences of the Project discharges. Therefore, potential for contact with drilling discharges is low.

Dredging and Disposal

Suspended sediments will resettle on the seabed after disturbance. The rate and location of this process is dependent upon the sediment grain size and the water currents in the area. Fines (silt/mud) will drift longer distances in the water column. Observed sediments within the area to be dredged are comprised predominantly of sands and gravels with limited fine material. Given this substrate composition, any re-suspended sediments would be expected to settle through the water column relatively quickly. The sediment chemistry at the glory hole is considered to be at background levels for the Project Area so there is little risk of contamination during disposal within the Project Area.

The effects of glory hole construction on the marine fish habitat are primarily associated with burial effects associated with the deposition of the dredged material on the seasbed. Upon completion of the glory hole construction, the disturbed area will begin the recovery process. The placement of dredge spoils may result in smothering, death and/or may startle marine fish and shellfish in the vicinity of the disposal piles. Suspended solids may have lethal, sublethal or behavioural effects on finfish. Eggs and larvae of finfish and shellfish are generally more prone to physical damage from increased levels of suspended sediment because they are passive drifters and cannot avoid the affected area like the post-settlement life stages. Concentrations of this magnitude would likely be localized to the immediate site of seabed disturbance and within the area fish are expected to avoid due to construction activity.

The effects are expected to be short term (assuming all 6 glory holes are constructed, a total of 9 months of dredging and disposal materials would occur over the 25 years). Effects on marine mammals, birds and turtles from this activity (including species at risk) are not predicted to be significant. Marine mammals and turtles may avoid the area of dredging or disposal, due to noise or if the habitat quality becomes unsuitable due to turbidity.

Transit and Presence of the MODU, Helicopters and Support Vessels

The presence of the MODU and support vessels during the drilling program has the potential to change the behaviour of species in the area. Noise from the MODU and vessels can cause attraction or avoidance depending on the species. Noise levels from drilling activities and vessel traffic for this Project are predicted to be less than the limits that cause physical effects. The level of support vessel traffic is expected to result in temporary, localized disturbance to some marine mammals, primarily baleen whales. The most likely effect on sea turtles is that they will temporarily avoid an area due to noise. The spatial extent of any such temporary disturbance from an approaching vessel will likely be small.

Fixed and moored structures typically tend to result in stimulation of biological (marine) productivity, which further attracts marine life (i.e., reef effect). It is unclear whether the presence of the MODU attracts marine mammal species, although they have been observed feeding close to offshore platforms. The MODU may attract birds, however, HMDC and all sub-contractors will obtain the necessary permits for handling stranded seabirds from the Canadian Wildlife Service.

The main concern with regard to vessel presence is the increased likelihood of a collision with a marine mammal or turtle species at risk. The likelihood of collision will be decreased significantly by vessels maintaining constant speed and course while in transit to and from the MODU (Thomson *et al*. 2000).

Safety zones of 500 m radius will be established around the MODUs and subsea infrastructure. This will prevent potential collisions between fishing and research vessels, and Project vessels. As the current level of fishing within the Project Area is minimal, these safety zones are not anticipated to result in any adverse effects on commercial fishing. HMDC will ensure the fishing industry and offshore research scientists are informed of the location and scheduling of construction and drilling activities and other potential hazards through Notice to Mariners and direct communication as required.

Well Site Surveys and VSPs

High intensity noise discharges from well site surveys and VSPs may possibly lead to the following effects:

- Direct physical effects associated with seismic noise (e.g., auditory damage, egg and larval mortality);
- Behavioural effects associated with seismic noise (e.g., avoidance, changes in migration, reproduction and feeding); and
- Temporary communication masking by seismic noise in fish and mammals (e.g., during spawning/mating, feeding, etc.).

Direct physical effects are likely to be restricted to very short ranges and limited to animals that are unable to move from within 1 to 2 m of the energy source. There are no documented cases of fish, marine mammal or turtle mortality upon exposure to seismic sound under field conditions (DFO 2004a). Rise times for seismic noise are too slow and peak pressures too low to cause serious injury outside this extremely localized zone (Turnpenny and Nedwell 1994). Extended periods of moderate noise levels underwater can affect hearing (TTS) in some marine organisms, however, hearing sensitivity is generally restored quickly after the sound dissipates. Planktonic species and life stages of fish and invertebrates in the immediate vicinity (1-2 m) of seismic air sleeves are probably the most vulnerable to direct physical effects simply because they are unable to move away from the source. However, the level of resulting mortality for any particular species will be limited to within 1-2 m metres of the array and since the eggs and larvae of these species are dispersed to low densities, the resulting mortality will not be distinguishable from the higher rates of natural mortality.

The effects of noise on whales and other marine fauna may potentially induce behavioural changes (*i.e*. feeding, breeding and migratory regimes). These will vary by species and even by individuals of the same species. The observed behavioural reactions include moving away from feeding areas or changing migration routes. A change in migration route is believed to have little biological significance since the whale’s course can be corrected once it is outside the area of influence (C-NLOPB 2005). Whales are opportunistic feeders and have adapted to the variability in prey abundance, so usually are not reliant on any single location for food.

Some fish exposed to seismic sounds could become startled resulting in a change in swimming pattern and/or a change in vertical distribution. Because of this change in behaviour, seismic surveys could result in reduced trawl and longline catches as the fish temporarily move from the area. However, if encountered, these effects are expected to be short term and non significant (DFO 2004a). As well, as stated above, commercial fishing levels within the Project Area are negligible.

Communication masking is a potential effect that is of greatest concern with respect to marine mammals. It is presently uncertain whether mammal exposure to seismic sound results in reduced communication efficiency (DFO 2004a). There have been no direct studies on the potential for seismic sound to reduce the efficiency of echolocation in marine mammals, or the potential to hamper passive acoustic detection of prey or predators by marine mammals (DFO 2004a). There is a concern that mammals exposed to seismic sounds can have a reduced ability to avoid anthropogenic threats, such as ship strikes and fishing net entanglements, but the threat has not been demonstrated (DFO 2004a). HMDC will adhere to *The Statement of Canadian Practice for Mitigation of Seismic Noise in the Marine Environment*.

Abandonment

Abandonment of the Project would result in short term and localized noise and disturbance related to vessel and equipment required to support abandonment activities. Effects would be similar to those described above for presence of support vessels and are therefore not anticipated to result in significant impacts for any of the VECs included within this assessment.

Accidental Spills and Blowouts

The likelihood of a blowout or major spill occurring over the life of the Project is low. However, if a spill or blowout does occur, the released hydrocarbons may affect organisms that come in contact with it, especially marine birds. Hibernia crude is a medium to light oil which rapidly disperses when released to form very thin layers on the water having a thickness similar to that of sheens.

Any interaction with the benthos in the event of spill or blowout would be limited near the area of release; the benthic environment would receive hydrocarbons that adhere to suspended material and settle to the seafloor. However, the resulting hydrocarbon concentration in the seafloor would be minimal, would degrade and disperse and will not affect marine benthos.

Adult fish, juveniles, larvae and eggs will be affected to different degrees by an accidental spill of hydrocarbons in the water, depending on the size and characteristics of the spill and the developmental stage of the fish. No conclusive evidence in the literature exists to suggest that oiled sites pose a long-term hazard to fish embryo or larval survival, however, a blowout can be lethal to juvenile and adult fish, as fish gills can be coated with oil, and oil can disrupt physiological processes.

Effects on commercial fisheries can include fouling and damage of gear and tainting (or perceived taint) of fish resources. Given the limited commercial fishing levels within the Project Area, these effects would be limited.

Marine mammal and turtle species at risk can be affected by an oil spill if they come in direct contact with oil. Dermal lesions and eye irritation are likely to occur with prolonged contact. Respiratory tract and digestive tract irritation may occur if oil is taken in through breathing or eating of contaminated forage species. Marine mammals may avoid oil slicks and no long-term effects on cetaceans from external exposure, ingestion, or bio-accumulation have ever been demonstrated from an oil spill (Thomson *et al.* 2000). It is, thus, unlikely that any of the marine mammal or turtle species at risk will be significantly affected and there are unlikely to be any significant adverse affects on leatherback turtles.

Contamination of surface water due to a hydrocarbon spill could also present a risk of oiling to marine birds; birds are affected by direct contact with oil and most birds that are exposed to an oil spill subsequently die (Frink and White 1990; Fry 1990). There is no clear correlation between the size of an oil spill and numbers of seabirds killed (Burger 1993). Timing and spill location, not spill volume, are the primary factors that influence bird mortality rates (Wiese et al. 2001). The density of birds in a spill area, wind velocity and direction, wave action and distance to shore may also have a greater bearing on bird mortality than size of the spill (Burger 1993). Accidental release of oil for any of the drill centres producing hydrocarbons and other drill centres as well as other offshore oil and gas activities within the Study Area are not expected to reach the coastline of Newfoundland and Labrador. Based on the above, if marine birds are within the zone of influence of a large persistent oil spill, the environmental effect of an accidental oil spill on pelagic birds could be considerable. The environmental effect of an accidental oil spill on marine birds is therefore assessed as potentially significant.

The potential effects of an accidental event on species at risk are the same as those outlined above for those species not at risk, except for the Ivory Gull, where an accidental event is not considered significant due to the expected rarity of the species within the Project Area.

Mitigation for spills and blowouts relate mainly to preventing such accidental events from occurring. Such preventative measures include the implementation of spill prevention strategies, quality control/assurance programs, proper well design, frequent equipment testing, and training of personnel. HMDC's Emergency Response Plan, which includes oil spill response, is intended to reduce the potential effects on VECs in the unlikely event of an accidental spill. Seabird and marine mammal monitoring will be conducted in the event of a large spill or blowout.

Summary of Effects Assessment

A potential significant adverse residual effect has only been predicted for Marine Birds from an accidental large oil spill that persists over time on the sea surface. A significant effect occurring is considered unlikely as a large spill would have to occur at a time when there were high concentrations of birds in the affected area; however, under worst case conditions, a significant adverse effect could result. The predicted residual adverse environmental effect for all other VECs for all other Project phases is not significant.

Cumulative Effects

The main projects and activities that may interact cumulatively with the Project on identified VECs include oil and gas activities, commercial traffic, and commercial fishing. Implementation of the mitigation measures contained in this EA and adherence to applicable legislation and guidelines reduce the potential for adverse environmental effects associated with this Project. Temporal and spatial overlap with other projects is limited. As a result, the Project is unlikely to interact cumulatively with past, present and likely future projects and activities to create significant adverse effects.

Mitigation and Follow-Up

Mitigation and follow-up (including monitoring) have been proposed to reduce the potential for adverse effects. Some of the standard mitigation to be used includes:

- use of water-based drilling muds wherever possible;
- use of non-toxic or low toxicity chemicals and muds, and treating any synthetic oil-contaminated cuttings as per the Offshore Waste Treatment Guidelines (OWTG);
- all wastewater discharges to comply with the OWTG and ship operations will adhere to Annex I of the *International Convention for the Prevention of Pollution from Ships* (MARPOL 73/78);
- use of the Offshore Chemical Management System (OCMS) to screen chemicals for the Project;
- solid waste transported to shore and recycled where possible;
- compliance with DFO's Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment; and
- all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently.

Proposed monitoring and follow-up programs are as follows:

- The current Hibernia environmental effects monitoring (EEM) program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate;
- Pursuant to the OWTG, compliance monitoring of all effluent discharges will be conducted;
- A fish habitat compensation monitoring program will also be implemented as required to ensure no net loss of productive capacity in fish habitat as a result of this Project.

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APPENDIX A Hibernia Drill Centres Construction and Operations Program Scoping Document
APPENDIX B Physical Environment at Hibernia Southern Extension – Oceans Ltd. 2008

1.0 INTRODUCTION

Hibernia Management and Development Company Ltd. (HMDC), and the associated offshore land licence owners, are proposing the construction, installation, operation, maintenance, modification, decommissioning and abandonment of up to six drill centres within glory holes that contain the equipment necessary to support the extraction of petroleum resources. This includes subsea flowlines and associated infrastructure to enable flow to and from the existing gravity based structure (GBS) (the Project). The Project is officially referred to as the Hibernia Drill Centre(s) Construction and Operations Program. The complete scope of the Project to be assessed is included in Section 2.0.

As per the *Canadian Environmental Assessment Act (CEA Act)*, the Proponent (HMDC) is required to conduct a screening level assessment of this Project. This document is intended to meet the requirements of the *CEA Act* screening level assessment and is in accordance with the Project Scoping Document issued by the C-NLOPB to HMDC in a letter dated October 7, 2008 (Appendix A).

1.1 Background

The Hibernia oil field was first discovered in 1979. In 1986, the Hibernia Development Project received Development Plan approval from the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB). The Hibernia Development Project was subject to a panel review under the former Environmental Assessment and Review Process (EARP) and it was determined that the project was not likely to cause significant adverse environmental affects. The completed GBS platform was towed to the Hibernia field and positioned on the seafloor in June 1997 and first oil was produced on November 17, 1997.

The Hibernia platform is located approximately 315 km east-southeast of St. John's, Newfoundland and Labrador, near the northeast corner of the Grand Banks in approximately 80 m of water. It is located approximately 35 km northwest of the Terra Nova oilfield and approximately 50 km west-northwest of the White Rose oilfield.

Hibernia crude is shipped from the platform to the IMTT Transshipment Terminal at Whiffen Head, Placentia Bay, NL, by the purpose-built shuttle-tankers Kometik, Mattea and the Vinland. The tankers and the transshipment terminal are completely independent of the Hibernia drilling and production operation.

The Project, as outlined in this document, will extend production operations in time and space beyond what was originally assessed and approved by regulators.

1.2 Project Rationale

HMDC currently uses a single fixed GBS platform to complete drilling of oil production, water injection and gas injection wells through a total of 64 drill well slots. Drilling complexities associated with some of the extended reach wells, as well as the lack of available drill slots within the GBS, negates full resource recovery using wells drilled from the GBS alone. While well slot recovery strategies (i.e. casing milling) have been identified and implemented and will alleviate this constraint to some degree, slot recovery strategies alone will not be sufficient to enable timely and efficient development of the resource. There is potential for a number of additional wells to be drilled over the remaining life of the project, therefore, the subsea development option must be considered.

The conceptual scope of the six drill centres includes up to 11 wells each originating from one or more subsea templates or manifolds which are connected to the GBS via subsea flowlines. To mitigate the risk of equipment damage and spills, subsea equipment will be located in glory holes to prevent impacts with icebergs. The location and layout of subsea equipment will provide ease of access for inspection, testing, repair, replacement, or removal. The exact configuration of the wells in each of the six drill centres is not presently known and will likely vary between drill centres.

The six subsea developments and associated glory holes may be located at any point within Production Licence Areas (PLs) 1001 and 1005, Exploration Licence Areas (ELs) 1092 and 1093, and Significant Discovery Licence Areas (SDLs) 1001, 1002, 1003, 1004, 1005 and 1041 at any point in time over the life of the field which could be extended as new reserves are identified (Figure 1.1). Some of these developments remain subject to the identification of economically recoverable reserves, as well as commercial and contractual agreements between Hibernia's owners and the area license holders.

The first planned subsea development is the Hibernia South Extension (HSE) development, which will be located just south of PL1001 and inside of PL1005 as shown in (Figure 1.2). Project activities are scheduled to commence in 2009. The HSE development will be led by HMDC and the license holders of PL1001, PL1005, and EL 1093.

1.3 Proponent Information

Created in 1988, HMDC is the operating company that manages the operation of the Hibernia offshore oil field development (Hibernia) on behalf of the project owners. Ownership of Hibernia is shared among ExxonMobil Canada Limited, Chevron Canada Resources, Petro-Canada, Canada Hibernia Holding Corporation, Murphy Oil and Statoil-Hydro Canada Ltd.

For the purposes of this screening report, the contact at HMDC is:

Robert A. Dunphy
Senior Environment Advisor
Hibernia Management and Development Company Ltd.
Suite 1000, Cabot Place
100 New Gower Street
St. John's, NL

Figure 1.1 Project Area

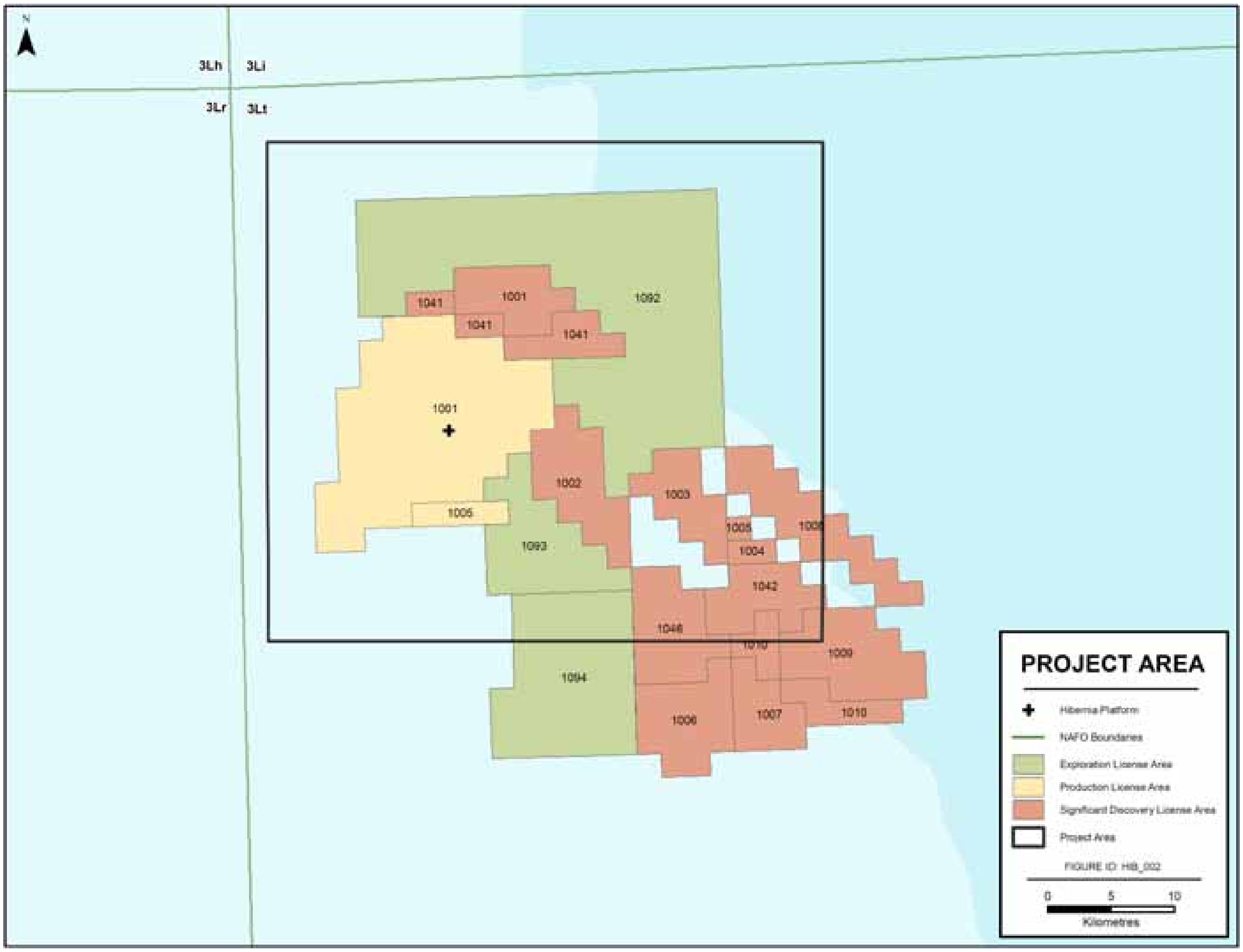
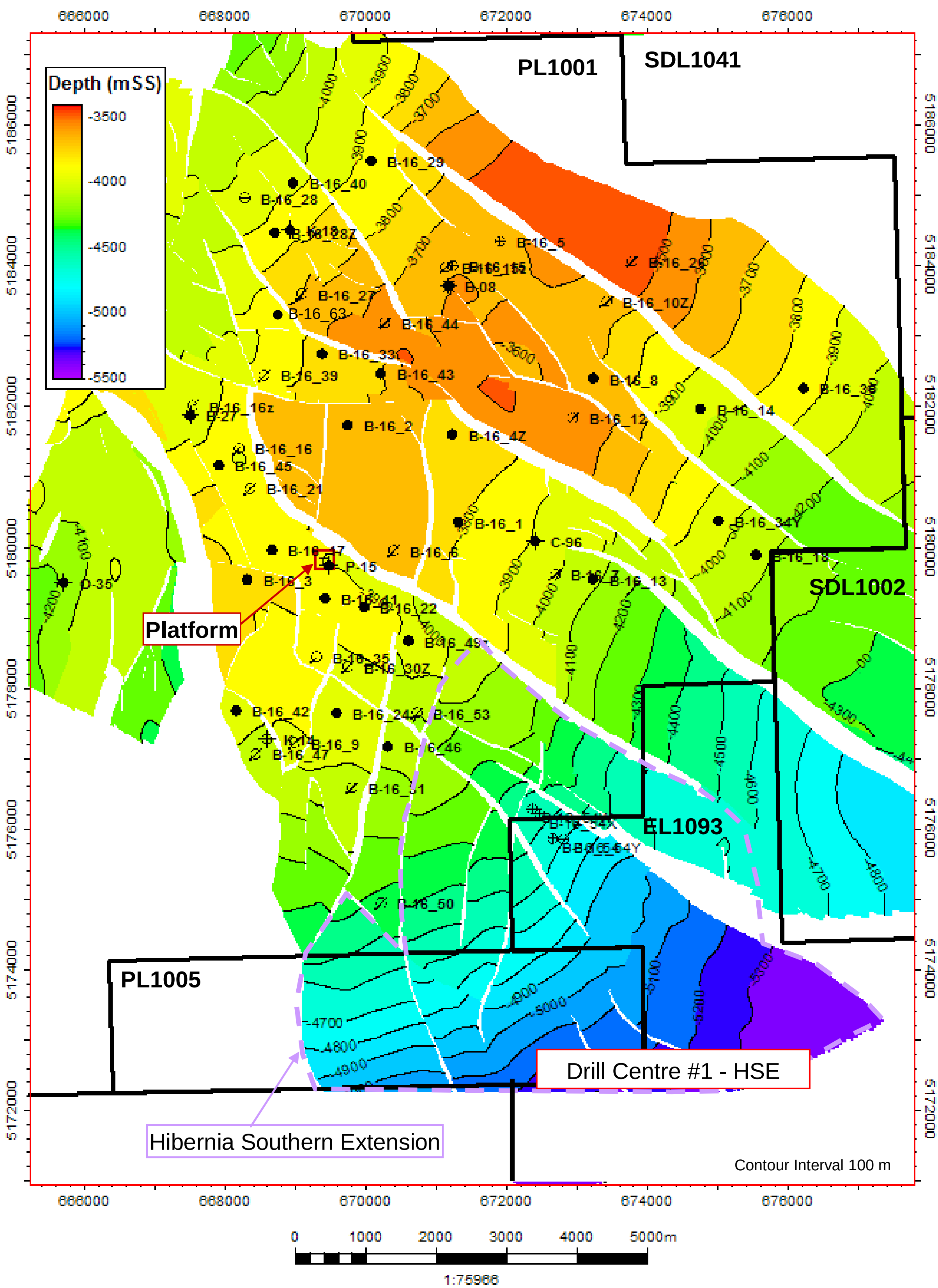


Figure 1.2 Base Hibernia Reservoir Depth Structure Map Indicating HSE and HSE Drill Centre



1.4 Regulatory Context

The C-NLOPB regulates oil and gas activities in the Newfoundland and Labrador offshore area pursuant to the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Act* and the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act* (Accord Acts). Authorizations for this Project will be required pursuant to Section 138 (1)(b) of the *Canada-Newfoundland Atlantic Accord Implementation Act* and Section 134(1)(a) of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act.*

The C-NLOPB is designated as a Federal Authority under the *CEA Act*. As reflected in the *CEA Act* Law List Regulations, projects requiring authorizations under Section 138 (1)(b) of the *Canada-Newfoundland Atlantic Accord Implementation Act* are subject to environmental assessment.

Other authorizations required for the Project and which are reflected in the *Law List Regulations* are issued by Environment Canada and the Department of Fisheries and Oceans (DFO). Environment Canada has indicated that the proposed project will require a Disposal at Sea permit pursuant to Section 127(1) of the *Canadian Environmental Protection Act* (CEPA). DFO has indicated that an authorization pursuant to Section 35(2) of the *Fisheries Act* will be required. Furthermore, drilling and production programs are specifically referenced in Section 19.9 of the *CEA Act* Inclusion List Regulations. Pursuant to Section 5(1)(d) of the *CEA Act*, the C-NLOPB, Environment Canada, and DFO are Responsible Authorities (RAs) and must undertake an EA of the Project.

As noted previously, the existing Hibernia project has been subject to a full environmental assessment. However, with respect to the proposed drill centre developments, the C-NLOPB has advised HMDC that the drill centre developments as proposed are outside the scope of the original project that was previously assessed and approved by regulators, and the location of the drill centre(s) maybe outside the original project area which is defined as the Hibernia Significant Discovery Area (Mobil Oil Canada 1985). The C-NLOPB has determined, in accordance with paragraph 3(1)(a) of the *Regulations Respecting the Coordination by Federal Authorities of Environmental Assessment Procedures and Requirements* (FCR), that an environmental assessment (EA) of the Project under Section 5 of the *CEA Act* is required. As the proposed Project is not described within the *Comprehensive Study List Regulations,* it will require a screening level assessment.

Pursuant to Section 12.2 (2) of the *CEA Act*, the C-NLOPB will be assuming the role of the Federal Environmental Assessment Coordinator (FEAC) for this EA and will be responsible for coordinating the review activities of the RAs and the expert government departments and agencies that participate in the review. In addition to their role as RA, Environment Canada is responsible for the protection of migratory birds under the *Migratory Birds Convention Act,* and for federally protected species under the *Species at Risk Act (SARA)*, and discharges to the marine environment under Section 36 of the *Fisheries Act*. DFO is also responsible for marine protected species under *SARA,* and for marine fish and fish habitat. Transport Canada would serve as an expert department as it is responsible for provision of safe navigation (under the *Navigable Waters Protection Act*) and discharge of pollutants at sea (under the *Canada Shipping Act* and Regulations such as the *Pollutant Discharge Reporting Regulations*, 1995) and Guidelines (such as the Guidelines for the Control of Ballast Water Discharge from Ships in Waters under Canadian Jurisdiction).

A Scoping Document was issued by the C-NLOPB on October 7, 2008 (Appendix A). Through this Scoping Document, the RAs, pursuant to Section 17(1) of the *CEA Act*, have formally delegated responsibility for preparation of an acceptable screening level environmental assessment to HMDC. The RAs will prepare the Screening Report, which will include the determination of significance.

1.5 Alternative Means to the Project and within the Project

The alternative of not recovering the oil within the Hibernia field is contrary to the fundamental interests of HMDC, the Province of Newfoundland and Labrador and the federal government through its ownership in Hibernia and therefore this is not considered an acceptable alternative.

As explained in Section 1.1., due to the lack of available drill well slots within the GBS, oil recovery using platform drilled wells has become substantially constrained with almost 100% of slots in use. In 2005-2007 Hibernia conducted a feasibility study on the addition of new drill well slots within the GBS. A sufficient number of new drill well slots would have alleviated the need for subsea drill centres. However, the study clearly demonstrated with a high degree of certainty that the required modifications were highly complex and the associated technical risks were unacceptably high. Thus the only method of further resource recovery is via subsea drill centres.

As portions of the reservoir become depleted and the associated wells are no longer economic to produce, the well slot becomes a candidate for reuse. Drill well slot reuse strategies have already been identified and implemented on the platform however, this strategy alone is not sufficient to address current production constraints.

Risks associated with icebergs have in the past been managed by the placement of the trees, manifolds, and subsea control equipment in recessed areas (glory holes) on the seabed. This approach provides protection against icebergs large enough to be a threat to the seabed equipment, thus enhancing overall Project safety.

Alternatives techniques used in the Newfoundland and Labrador offshore region for dredging a new glory hole include the use of a suction hopper versus a clamshell dredging system. Both techniques will be considered.

Alternatives for drilling include a semi-submersible and a drill ship neither of which pose significant advantages or disadvantages from an environmental risk perspective. The EA fully assesses both of these alternatives as both are viable and could be used throughout the life of the Project.

1.6 Organization of Report

The purpose of the environmental assessment is to describe the proposed Project, identify its potential environmental effects, identify and propose measures to mitigate these effects, and outline the significance of the remaining residual environmental effects.

This environmental assessment report was prepared on behalf of HMDC by Jacques Whitford Limited (JW), in association with Oceans Ltd. with support from Fugro Jacques Geosurveys, the Canadian Wildlife Service and DFO.

Section 1 identifies the Proponent and the proposed Project, outlines the purpose and need for the Project and the regulatory approvals processes to which it is subject, describes Project alternatives, discusses the purpose of the environmental assessment, and presents the organization of the document.

Section 2 provides a thorough description of the proposed Project components and activities, including a schedule for the proposed activities. Project-related emissions and discharges are also discussed.

Section 3 describes the Physical Environment in the Study Area and Project Area including climate, oceanography, sea ice and icebergs, bathymetry and geology.

Section 4 describes the Biological Environment in the Study Area and Project Area including fish and fish habitat, commercial fisheries, marine mammals, marine birds and species at risk.

Section 5 describes the scope of the Project and scope of factors to be considered in the EA as determined by the RAs in the Project-specific Scoping Document (Appendix A) and the EA methods used in this assessment including issues scoping, selection of VECs and organization of the effects assessment.

Section 6 provides the environmental effects analyses for each of the VECs under consideration. Each VEC is discussed in a separate section, which includes a discussion of: boundaries; potential interactions, issues, and concerns; mitigation measures; potential environmental effects and their significance; and any proposed follow-up and monitoring initiatives.

Section 7 is the cumulative effects assessment and provides a description of the other projects and activities that are included within the assessment. Each VEC is assessed separately and significance determinations are provided for the predicted adverse cumulative effects. The requirement for any mitigation and monitoring/follow-up programs is also identified.

Section 8 is the assessment of potential accidental events and/or malfunctions that could occur as a result of the Project. As the main malfunction that could occur and result in adverse effects on the environment is a hydrocarbon spill, this section focuses on the likelihood and fate and behavior of any spills from the Project Area. An assessment is provided for each VEC, along with the requirement for any mitigation and monitoring/follow-up programs.

Section 9 considers the potential effects of the environment on the Project, including, but not limited to: climate change; extreme wind and wave conditions; and sea ice and icebergs.

Section 10 presents a summary of the assessment and its main conclusions and includes a table summarizing, by VEC, the proposed mitigation and follow-up initiatives recommended throughout the environmental assessment report.

Section 11 provides references, including personal communications and the literature cited in the report.

The **appendices** provide supporting material.

2.0 PROJECT DESCRIPTION

The following Project Description fully describes those activities and components that are included within the scope of this environmental assessment. It describes Project construction, operations and maintenance, production and abandonment activities, as well as the overall Project schedule. It also describes and quantifies (where possible) likely wastes and emissions associated with the various Project phases, as well as waste management procedures.

2.1 Construction

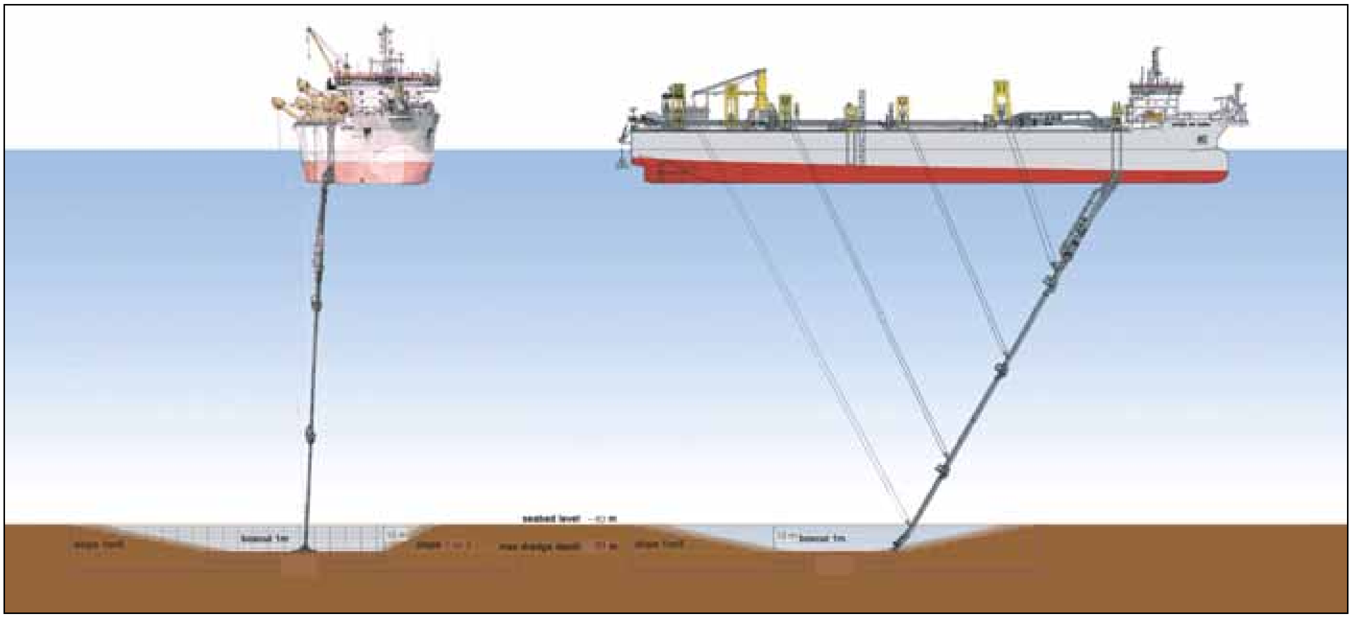
The current priority for HMDC is development of the HSE located just south of the Hibernia field in PL1005 (Figure 1.2). Once planned preconstruction geohazards surveys are completed, Project construction activities will likely begin with glory hole excavation at the HSE during the 2011 construction season. Drilling and subsea construction operations and tie-ins to the Hibernia GBS may then follow beginning in 2012. However, the preceding schedule could vary based on Project approval timing and dredging vessel availability. Other glory hole installations are not in active planning stages at this time, and remain subject to the identification of economically recoverable reserves, as well as, commercial and contractual agreements between Hibernia's owners and the area licence holders. The overall Project schedule is presented in Section 2.6.

2.1.1 Glory Hole Construction

Glory holes will be excavated using proven construction methods for the Grand Banks. Subject to confirmation of soil conditions by a geotechnical survey, a trailing suction hopper dredge (TSHD), or acceptable alternate dredging technology (e.g., clam dredge), will be used to excavate the glory hole. Based on past experience, glory holes for this Project will likely be dredged using a TSHD vessel (Figure 2.1). This type of dredge is a self-propelled ship that fills its hold or hopper during dredging while following a pre-set track. They are equipped with either single or twin (one on each side) trailing suction pipes. Material is lifted through the trailing pipes by one or more pumps and discharged into a hopper contained within the hull of the dredge. When the hoppers are full, the TSHD vessel sails to an approved disposal area and either releases the material through doors in the hull or pumps the material out of the hoppers. Currently, the largest hopper dredges in the world are Jan De Nul's Vasco Da Gama (33,000 m^3 hopper, 37,060 kW total installed power) and Boskalis WD FAIRWAY (35,000 m^3 hopper).

The TSHD vessel lowers the suction pipe to within 10 m of the seabed. A heading parallel to the longest dimension of excavation is maintained, and at the start of the depression the suction head is lowered and the seabed excavated as the vessel moves forward. The suction head is lifted at the far end of the glory hole. The number of passes required to excavate to any specific depth depends on the consistency of seabed material. Subsequent passes overlap to ensure layers are excavated correctly. Slopes at the edge of the depression are achieved by creating consecutive narrower cuts over the layer being removed. A graded feed-in ramp will be constructed to allow the pipelines and umbilical to enter the glory hole.

Figure 2.1 Dredge Vessel Schematic



Each glory hole will be excavated to a sufficient depth (approximately 10 m) to ensure protection of subsea equipment from iceberg impacts. Conceptually, the length and width are nominally 30 m and 30 m, respectively, but may be larger (up to a nominal size of 70 m x 70 m) if two manifolds are required. Estimated duration would be approximately 30 working days for 30 x 30 m, and 45 working days for 70 x 70 m glory hole.

The estimated volume of material to be disposed at an approved disposal location from a single glory hole (70 m x 70 m x 10 m), is 159,300 m^3. The dredging vessel hold is expected to be filled to capacity every second day. The initial glory hole and disposal area locations are provided in Table 2.1 and illustrated in Figure 2.2.

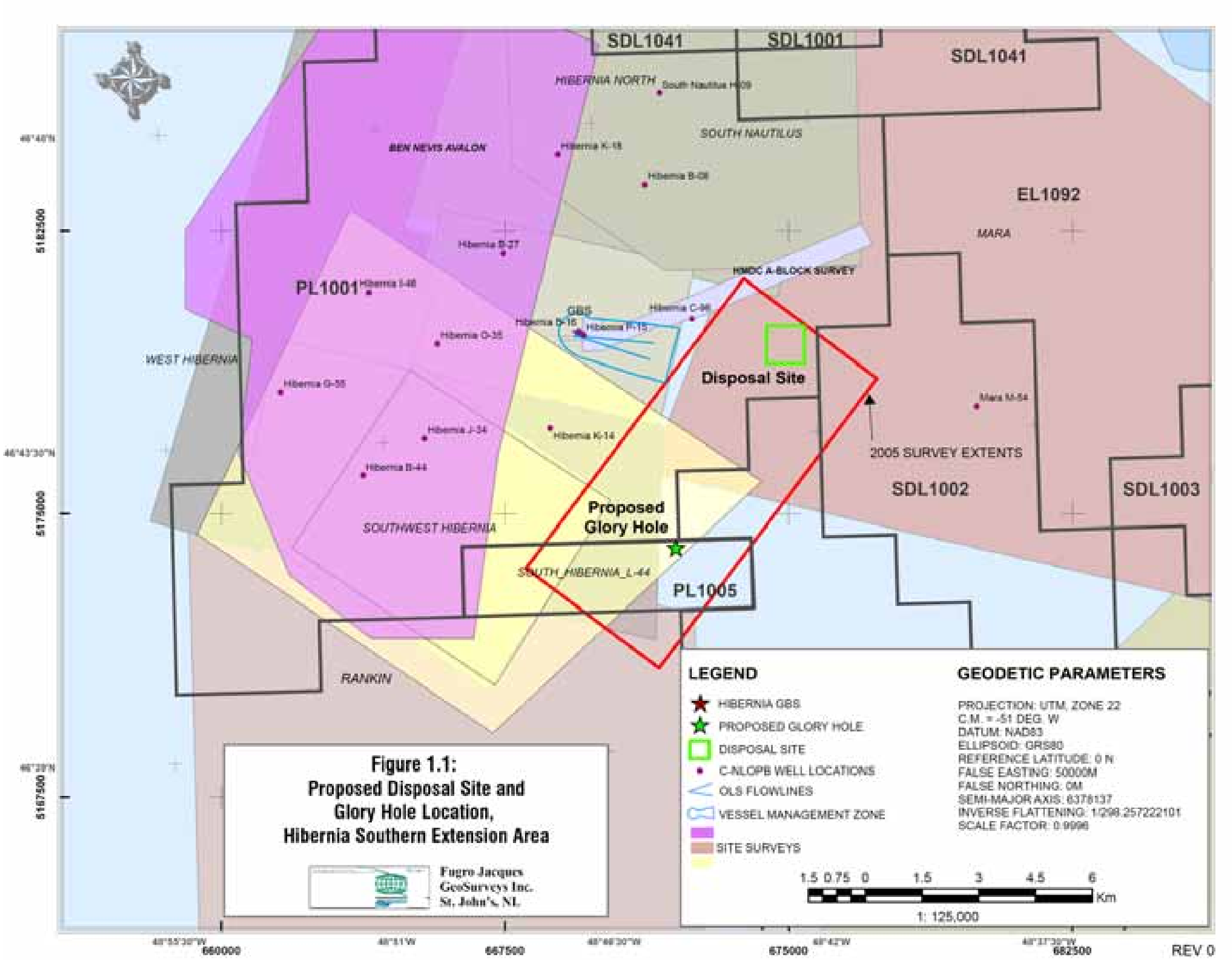
Table 2.1 Glory Hole Centre and Disposal Site Corner Positions (UTM Zone 22, NAD 83 datum)

Location	Easting	Northing
Glory Hole Centre	672020	5174100
SW corner – Disposal Site	674415	5178984
SE corner – Disposal Site	675415	5178984
NW corner – Disposal Site	674415	5179984
NE corner – Disposal Site	675415	5179984

As per Schedule 1, Part 1, Paragraph 3, Section 127 (1) of the *CEPA*, HMDC will submit an application for an Ocean Disposal Permit for the HSE Glory Hole construction early in 2009. Construction of glory holes will result in HADD and will therefore require a Section 35 (2) *Fisheries Act* Authorization prior to the beginning of construction. HMDC is in the process of developing a fish habitat compensation strategy.

Additional disposal sites may be required pending the location of subsequent glory holes. Additional Ocean Disposal Permit applications and *Fisheries Act* Authorization amendments will be submitted in consultation with regulators.

Figure 2.2 Ocean Disposal Location



2.1.2 Drilling

The number of wells to be drilled in each glory hole has yet to be determined. For planning purposes, it is assumed that the potential six drill centres could support up to 11 wells each. Five wells are expected to be drilled over approximately two years at HSE. Each well is expected to take 128 days on average. There are no anticipated requirements or plans for flaring during drilling, but flaring may occur.

A drilling contractor will operate a semi-submersible or drill ship MODU to drill the subsea wells associated with this Project. More than one drill rig may be required to operate simultaneously over the course of the Project, but it is highly unlikely. All drill rigs to be considered for this Project will have been constructed to have capability for drilling in the applicable water depths and environment and the functional specifications of the well design. The rig will have a valid Certificate of Fitness for Canadian waters issued by a Certifying Authority and a Transport Canada Marine Safety Inspection will be conducted as part of the requirements for a Letter of Compliance issued by that agency.

The *GSF Grand Banks*, is an example of a typical MODU that has been used on the East Coast. The *GSF Grand Banks* is a rectangular, twin hull, column stabilized, MODU, constructed to an Aker #3.2 design. There are two 29.5 ft. (9.0 m) diameter corner stability columns plus two 24.3 ft. (7.4 m) diameter intermediate stability columns rising from each hull to support the main deck. The deck is arranged with the drilling mast in the centre and modules on the perimeters, housing the living quarters, equipment, storage area and workshops. The GSF Grand Banks or a comparable MODU will be used to execute the proposed Project. A description of potential drilling waste discharges is provided in Section 2.7.

The Temporary Guide Base (TGB) is, in principle, a standard drilling technology used for individual wells and in multi-well manifold configurations for the purpose of providing a precise location to begin a well and re-enter a well. TGBs are generally used only for the spudding and surface casing portion of the well. As the wellhead system is “built up”, a permanent guide base (PGB) is located above the TGB and becomes the new well entry point

2.1.3 Geohazard and Vertical Seismic Profile Surveys

Well site or geohazard surveys may be used to identify and avoid geotechnically unstable areas (e.g., shallow gas deposits) or hazards (e.g., shipwrecks) prior to drilling. The well site survey may use a combination of video and a small acoustic array and/or sonar over the well location. Although a variety of seismic sources may be used for such a wellsite/geohazard survey, a typical source is a 160 cu. in. four-gun ladder array of sleeveguns with an estimated source level of 238 dB re 1μPa @ 1m (zero to peak) towed at a depth of 3 m. This equates to 244 dB re 1μPa @ 1m (peak to peak).

Vertical seismic profiling (VSP) may be also conducted as part of the drilling and production activities using an airgun array. VSPs are a collection of well bore measurements (seismograms) recorded by geophones inside the wellbore using sound sources at the surface near the well. A VSP is used to correlate well data with surface seismic data, to obtain images of higher resolution than surface seismic images, and to collect data ahead of the drill bit. The array is similar to that employed by 2-D or 3-D seismic surveys, but is typically smaller and deployed in a smaller area over a shorter time period, often only 12 to 36 hours, but occasionally up to several days. An airgun similar to that employed for surface seismic collection is used as the seismic source.

An imaging toolstring is run in the wellbore and is anchored at successive points as required to cover the entire recording depth. With a zero-offset VSP, a seismic source array is deployed over the side of the drilling platform. The source is activated (typically three to five times) to create a sonic wave that is picked up by geophones in the toolstring.

Typically, only one zero-offset VSP is conducted on each well when total depth has been reached. An operator may elect to conduct two zero-offset VSPs per well, when the intermediate and lower hole sections have been drilled. An operator may also elect to conduct a walkaway VSP concurrent to the intermediate hole section zero-offset VSP. A walkaway VSP is a type of VSP in which the source is moved to progressively farther offset at the surface and receivers are held in a fixed location, effectively providing a mini 2-D seismic line that can be of higher resolution than surface seismic data and provides more continuous coverage than an offset VSP. 3-D walkaways, using a surface grid of source positions, provide 3-D images in areas where the surface seismic data do not provide an adequate image due to near-surface effects or surface obstructions. If a walkaway VSP is used, the two source arrays would not be activated concurrently.

While the exact specifications of sources to be employed in this project are still unknown, typical source arrays used in similar operating environments include:

- four 150-cu. in. airguns;
- four 40-cu. in. airguns; and
- calibrated peak vertical amplitude of 13.4 bar @ 1m (242.5 dB).

During any VSP surveys, the Operator will follow the mitigations outlined in the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2008a) and implement a 500 m marine mammal monitoring zone.

2.1.4 Subsea Equipment Installation

The subsea equipment installation will use proven methods from other projects proposed and in operation on the Grand Banks (i.e., flowlines, umbilicals, and subsea manifolds with control system components).

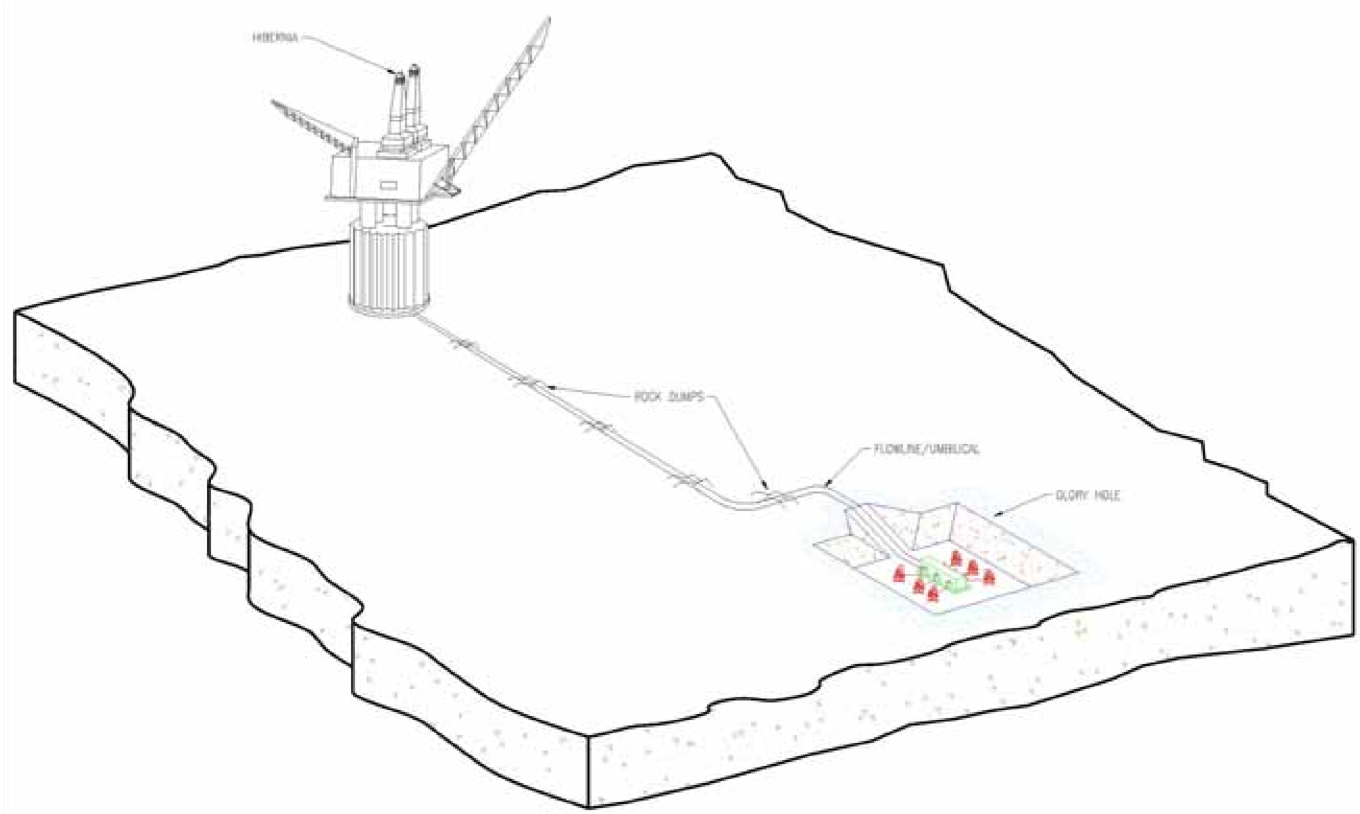
Subsea facilities will include all equipment necessary for the safe and efficient operation and control of the subsea wells and the transportation of production and injection fluids. The following equipment will be installed in the new drill centres:

- wellheads and xmas trees (production and water injection);
- production and water injection manifolds;
- subsea distribution units;
- subsea umbilical termination unit;
- flowlines (gas lift, stimulation, production, injection);
- jumpers; and
- rigid spools (to production and water injection xmas trees).

Iceberg protection measures applied to the current Hibernia project will also be applied to this Project, including placement of wellheads, xmas trees and manifolds in glory holes, with the top of the equipment a minimum of 2 to 3 m below the seabed level and use of flowline weak link technology. A typical subsea layout is shown in Figure 2.3.

The conceptual design for each drill centre may include both water injection and production flowlines running from the platform outlet possibly along with a high pressure stimulation line and umbilical to the drill centres. Both injection and production flowlines may be installed by either reel-lay or S-lay vessel with the high pressure (HP) stimulation line in a piggy-back installation arrangement. The main umbilical may be laid away from the platform in the same manner. Both ends of the flowlines and umbilical will have weak links or break away connectors as a contingency for icebergs or other threats. Flowlines may be rigid or flexible and will be chosen when considering the project installation methodology. The flowlines will be laid on the seafloor with stitch rock dumping or concrete mattresses for stability. Dropped object protection will be put in place for the flowlines near the GBS within the crane lifting zone and may be installed by DSV or another vessel of opportunity.

Figure 2.3 Typical Subsea Concept Layout



Similar to that in place for the offshore loading system, Hibernia's Ice Management Plan will be amended as required to reflect operational procedures that are implemented in the event of an iceberg threat to the new subsea flowlines. Additional flowline protection measures will be evaluated and those deemed necessary will be implemented. Depending on the configuration of drill centres, flowlines may or may not be interconnected between drill centres however existing compatible flowlines will be used whenever possible in subsequent drill centre installations.

Risers will be installed inside an existing J-tubes in the GBS. Tie-ins may involve rigid spool pieces installed between the riser and pipeline by a diving support vessel (DSV) and may be connected by divers. Well tie-ins may be performed by either a semisubmersible or DSV during the subsea construction program. Trees, templates, and manifolds may be installed by mobile offshore drilling unit (MODU), whereas pipeline-to-manifold tie-ins may be made by divers. Hydraulic/electric flying leads may be connected by remotely operated vehicle (ROV).

Subsea equipment, while standard in design, must be installed quite accurately relative to the seabed and other equipment components. Two types of specialty vessels are required for installation of the subsea equipment; a subsea construction vessel (SCV) and a subsea DSV.

The SCV work will generally consist of large equipment lifts that require precise placement on the seabed. This work is generally supported by ROV rather than diving operations and may involve several structures such as foundations, piles, manifolds. The flowlines and umbilicals may be installed by a DSV. The lines will be transported on large reels on a heavy lift vessel (HLV) and handled onto the DSV or in a carousel (on the DSV while at the factory). The lines are precisely laid on the seabed, inspected and mapped by ROV. The lines are then connected by divers, displaced to water, pigged and tested.

A conceptual subsea design has been developed for the first planned drill centre, the HSE development. Components of the proposed HSE subsea development include:

- A glory hole of up to 70 m X 70 m X 10 m in dimension;
- A water injection flowline of between 12” to 16” for a distance of approximately 8 km (with umbilical and 3” stimulation line) with weak links;
- A drilling centre with up to an 11-well capacity manifold(s), umbilical termination assembly, control pods, jumpers and flying leads. A template or cluster arrangement may be employed;
- A flowline tie-in to the water injection manifold; and
- Seven oil producers and two water injectors drilled from the platform.

Specifics of the conceptual design may change as designs are finalized. Well configurations and flowline characteristics for subsequent subsea developments may differ from the HSE development described above, but can be generally inferred from the details provided herein. Subsea installations for HSE are expected to require 30 to 40 days.

The approximate HSE glory hole location (within a 500 m radius) in relation to the GBS is illustrated in Figure 2.4, with the detail of the flowlines exiting the GBS provided in Figure 2.5. Final locations will be adjusted based on geotechnical and geohazard surveys.

2.2 Production

The Hibernia facility has been operational on the Grand Banks since November 1997. It contains the necessary equipment to produce, process and store crude oil and to subsequently transfer the crude to shuttle tankers. All production from the new drill centre(s) will be processed through the Hibernia facility, however production rates will not substantially increase as result. The platform is currently producing below its maximum capacity and this Project may use the available capacity.

The GBS and topsides will not require significant upgrades for this Project. Tie-ins to the water and gas injection systems may be required to supply water or gas to the injection flowlines and/or stimulation flowlines. Skids will be installed to supply controls and utilities to the sub-sea hardware. These may include a master control station, topsides umbilical termination assembly, hydraulic power unit, electrical power unit, chemical injection skid and methanol injection skid. This Project will be controlled/operated/maintained from the Hibernia platform.

Air emission and wastewater (including produced water) discharge rates are not anticipated to be greatly affected by this Project. A maximum daily discharge rate for produced water has been set by the C-NLOPB and approval will be required to exceed that rate. However, the Project will extend the life of the field and therefore the total mass of air emissions and wastewater released over the life of the field will increase.

Figure 2.4 Flowline/Umbilical Routing to Glory Hole

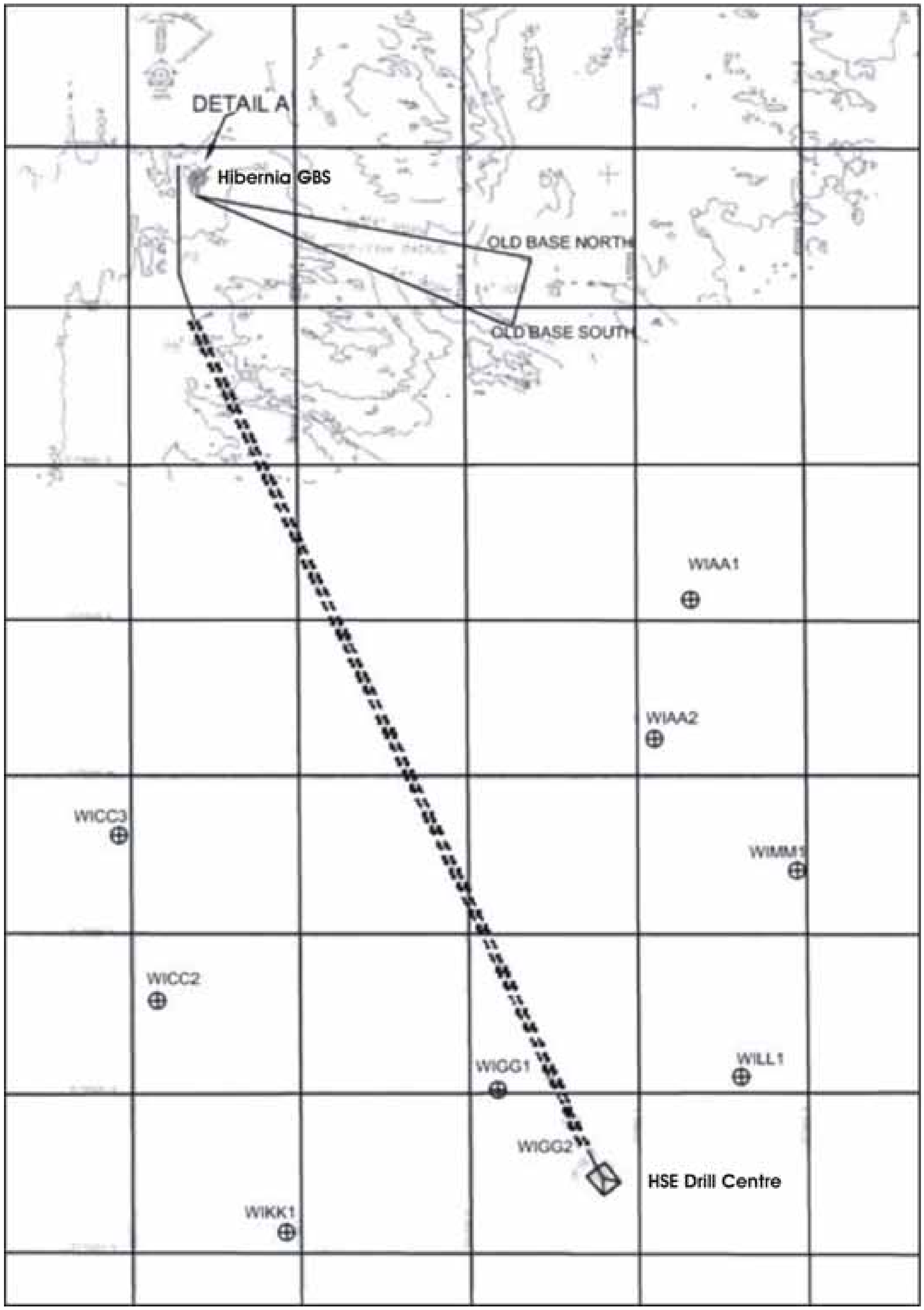
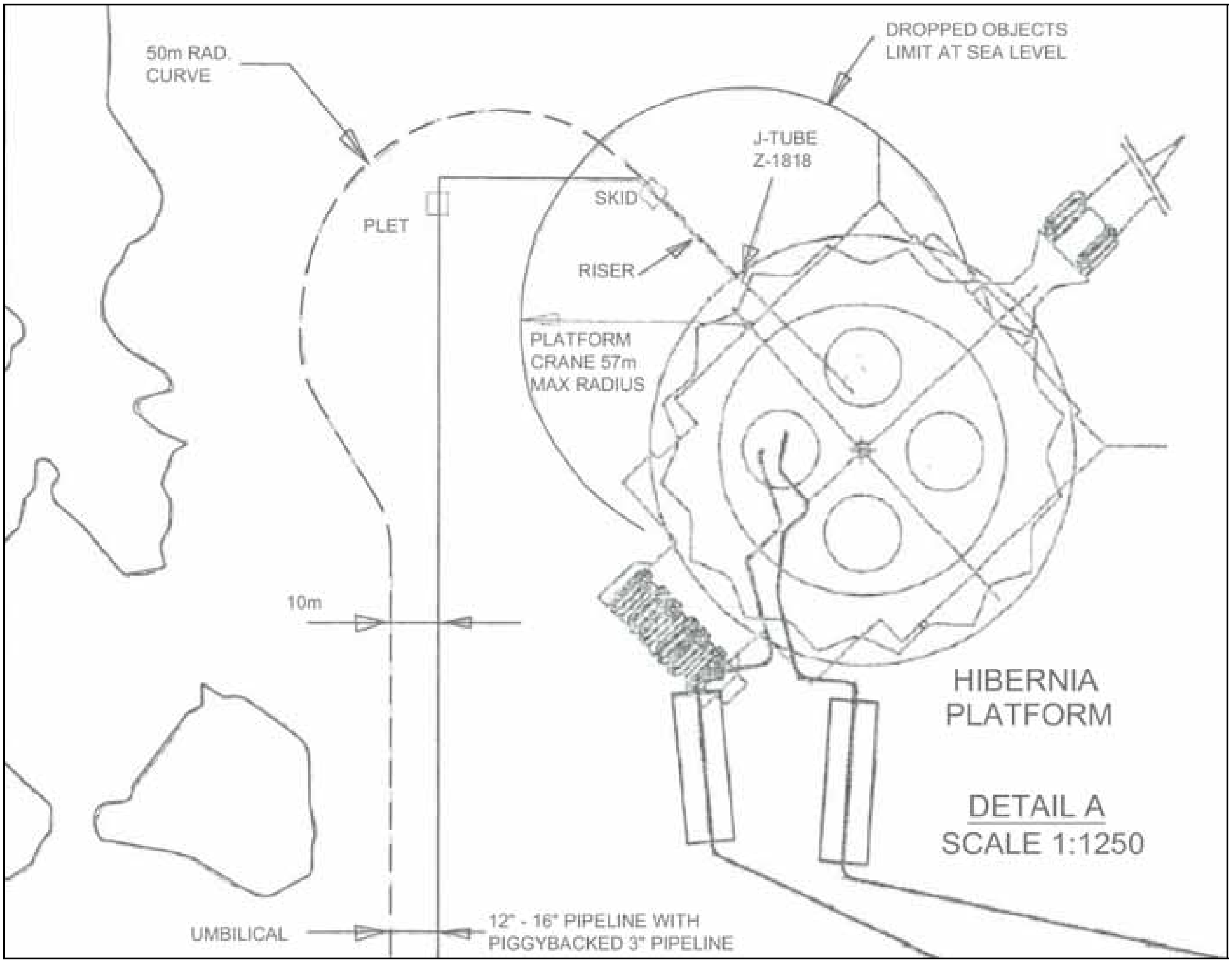


Figure 2.5 Detail of HSE Flowline from the GBS



2.2.1 Operations and Maintenance Procedures

Operations and maintenance procedures have been prepared specifically for the Hibernia facility. This documentation is intended to ensure the facility is operated safely, to minimize risk to the environment and to ensure compliance with regulatory requirements. Personnel working at the facility receive the necessary training and testing to ensure they are competent in their respective areas of responsibility. This includes a sound understanding of the applicable operating and maintenance procedures.

Operating and maintenance records and associated data are retained and documented in accordance with HMDC requirements and where applicable, regulatory requirements. The same data records and document management system will be used for the development of the new drill centre(s).

Hibernia's Operations Plan contains both the Safety Plan and Environmental Protection Plan for both drilling and production operations. The Environmental Protection Plan describes compliance monitoring requirements, waste management, chemical management, oil spill prevention and response, environmental effects monitoring and internal/external reporting processes. These procedures will also apply to the construction and operation of the new drill centre(s).

As with existing HMDC operations, the maintenance program for new equipment will be extensively supported by computerized systems, providing detailed information on each item of equipment, including maintenance requirements and frequency, maintenance history and spares to be kept in inventory. The system may also be linked to an inventory control system as needed. The required features of monitoring, inspection, and maintenance and repair, will be recognized in the program.

The Hibernia Operations Manual – Safety Plan deals with the safe and efficient operation of the Hibernia facility for all facets of production, drilling, aviation and marine-related activities. It describes in detail how the following activities are carried out or managed:

- process start-up and shutdown;
- routine production;
- operation limits;
- adverse weather conditions;
- crude storage and shipment;
- ice management;
- aviation; and
- marine activities.

The Hibernia Operations Plan will apply to all activities associated with the construction and operation of the new drill centre(s). When required, existing procedures will be updated and new procedures will be developed to support the drill centre project.

2.3 Logistics

As with the current HMDC project, personnel movements between St. John's and the field will normally be carried out by helicopter. During construction of the new drill centre(s), some additional helicopter flights may be required to transfer personnel from drilling rigs. During operations, the current helicopter requirements will remain the same as it is anticipated that no additional personnel will be required on the Hibernia platform.

A helicopter contractor will be used to provide helicopter support for the proposed development. The contractor will provide all auxiliary flight services including First Response Equipment and technicians.

HMDC’s existing fleet of supply/standby vessels will be used to support the offshore construction and installation operations associated with this Project. However, depending on the type of drill rig used, the number and type of vessels required may necessitate identifying external vessel resources. In addition to the dredge and pipe laying vessel, approximately three to four supply boat transits will occur every week during construction and one supply vessel will remain at the drilling location on standby.

Vessels will be continuously available in the field for standby duty in accordance with regulatory requirements. Supply vessels will convey materials, consumables and equipment to and from the offshore facilities.

Warehouse facilities will be provided by a contracted warehouse provider and Project contractors as required and will consist primarily of storage for tubular goods and the rig contractor(s) equipment.

During operations of the proposed Project, no additional warehousing and storage yard space will be required above that used for the current HMDC operations.

2.3.1 Communications

Communication requirements related to the construction and operation of the new drill centre(s) will be similar to and may be integrated as needed into the system currently used for the Hibernia project. The Hibernia system includes communications linkages between all of HMDC's facilities both onshore and offshore. Primary and back-up systems will continue to be used to ensure continuous communications capability amongst all facilities in all environmental conditions. Communication system elements available to the GBS MODU and vessels include the following:

- Main satellite communications link;
- INMARSAT (alternate / backup satellite system);
- Facility / Vessel Telephone System;
- Local Area Network (LAN);
- Ship Radio System (Global Marine Distress Signalling System);
- Facilty Air/Ground/Marine VHF Base Station;
- Air/Ground/Marine Hand-held Radios (UHF);
- HF Radio on the GBS;
- Marine and Aeronautical Radio System (VHF)
- Navigation aids including Non-directional Beacon for Aircraft Approach;
- Onshore Base Radio Station Services and:
- Onshore marine vessel tracking and flight following.

Operations and coordination of voice and data communication services from offshore installations and vessels may be provided from a central communications facility in St. John's. The primary communications link between the offshore installation(s) and the project operations office in St. John's may be via a dedicated satellite service.

2.4 Abandonment

2.4.1 Approval Process

At the end of the production life of the Hibernia oilfield, HMDC will decommission and abandon the site according to C-NLOPB requirements and *Newfoundland Offshore Petroleum Production and Conservation Regulations* and any other applicable laws and industry practices.

2.4.2 Abandonment Methods

2.4.2.1 Production and Injection Wells

HMDC intends to abandon wells in accordance with the *Newfoundland Offshore Petroleum Drilling Regulations.*

2.4.2.2 Topsides, GBS and Subsea Equipment

The original Hibernia EIS stated that abandonment of a GBS production platform would involve removal of equipment which could be economically used elsewhere and a plan for the abandonment of the structure itself would be developed in compliance with all government regulations at the time (Mobil Oil 1985; Volume II Chapter 8).

In the March 1990 Development Plan Update, Mobil Oil reiterated this commitment in stating that when the reserves of the Hibernia field have been recovered, decommissioning and site restoration will be carried out in accordance with applicable regulations in effect at that time. In addition, Mobil Oil committed to remove all abandoned subsea well equipment above the seafloor and to design the GBS platform for eventual refloating.

The C-NLOPB in its Decision Report 86.01 addressed facility abandonment in Condition 10. Condition 10 of the Decision Report required:

> *That the Proponent design all subsea facilities such that, upon termination of production, they will be capable of being covered or removed so that the area is returned to a fishable condition, and design the GBS so that it could be removed if the Authorities at that time so require.*

The ultimate disposition of the GBS will depend upon its condition at the end of the production life of the Hibernia field and upon the options available for further use.

2.5 Schedule of Activities

As previously indicated, among the six drill centres, only the HSE development is presently in the active planning stages. A notional schedule for the HSE development is presented in Table 2.2. While the installation of the five additional drill centres is subject to a number of factors, the notional schedule for HSE can be considered generally applicable to all subsequent developments with respect to sequence of events, duration and time of year.

Table 2.2 Proposed HSE Project Schedule

Project Activity	Timing
Geotechnical & Geophysical Investigations	Summer – Fall 2009 to commence and complete.
Glory Hole Excavation	Summer – Fall 2011 to commence and complete
Subsea Equipment Installation	Summer – Fall 2012 to commence and complete
Drilling	Summer 2012 – Fall 2014 to commence. Drilling to be completed year round over several years.
Production Operations	Fall 2012 to commence. Current depletion of HSE estimated in 2036 but may be extended.
VSP/ Checkshot surveys	May occur any time of the year during drilling and production phases (workovers)
Abandonment	After 2036

The construction and installation schedule for the HSE is tentatively planned for 2010 to 2012; although the start/finish dates for the program can vary by one year (i.e. earlier and later) due to a number of factors such as vessel and equipment availability. Geotechnical and geophysical investigations for site selection is tentatively planned to occur in 2009.

An indication of duration and frequency of each Project activity is provided in Table 2.3. Construction activities, which have the most potential for interactions with the environment, will be intermittent over the life of the field.

Table 2.3 Frequency and Duration of Project Activities

Project Phase/Activity	Frequency /Duration Base Case[A]	Maximum Number of Events	Cumulative Maximum Total Duration until 2036 (months)
Glory Hole Excavation			
Dredge operation	45 days	6 glory holes	9
Presence of structures	45 days	6 glory holes	9
Safety zone	45 days	6 glory holes	9
Lights	45 nights	6 glory holes	9
Deck drainage, bilge water, and ballast water	Periodic daily	6 glory holes	9
Sanitary or domestic waste water	45 days	6 glory holes	9
Routine air emissions Dredge boats, helicopters	45 days	6 glory holes	9
Marine vessels	periodic	6 glory holes	<1
Helicopter flights	periodic	6 glory holes	<1
Drilling			
Presence of structures	128 days	66 wells	281
Safety zone	128 days	66 wells	281
Lights	128 nights	66 wells	140
Flaring	Periodic during testing	66 wells	<1
Mud operations	128 days	66 wells	281
Cement	1	66 wells	2
BOP discharge[B]	Periodic	66 wells	<1
Cooling water	128 days	66 wells	281
Deck drainage, bilge water, ballast water, valve control fluid etc.	Periodic daily	66 wells	<1

Project Phase/Activity	Frequency /Duration Base Case[A]	Maximum Number of Events	Cumulative Maximum Total Duration until 2036 (months)
Sanitary or domestic waste water	128 days	66 wells	281
Produced water	periodic	66 wells	<1
Supply boat transits	18 trips	66 wells	<1
Supply boat on standby	365 days/year	66 wells	281
Helicopter flights	54 flights	66 wells	<1
Rig operation	1 rig	66 wells	48
Air emissions (testing)	periodic	66 wells	20
Routine air emissions (Rig, vessels, helicopters)	128 days	66 wells	281
VSP	2 days	66 wells	4
Subsea Production Equipment Installation			
Presence of structures	30 days	6 glory holes	6
Safety zone	30 days	6 glory holes	6
Lights	30 nights	6 glory holes	3
Production Operation[C]			
Presence of structures	365 days/year	24 years	288
Safety zone	365 days/year	24 years	288
Lights	365 days/year	24 years	288
Flaring	365 days/year	24 years	288
Cooling water	365 days/year	24 years	288
Deck drainage, bilge water, ballast water, valve control fluid etc.	Periodic daily	24 years	288
Sanitary or domestic waste water	365 days/year	24 years	288
Produced water	365 days/year	24 years	288
Supply boat transits	3/week	24 years	250
Supply boat on standby	365 days/year	24 years	288
Helicopter flights	6/week	24 years	124
GBS operation	365 days/year	24 years	288
Routine air emissions GBS, vessels, helicopters	365 days/year	24 years	288
Abandonment			
Presence of structures	30 days	6 glory holes	6
Safety zone	30 days	6 glory holes	6
Lights	30 nights	6 glory holes	3
Sanitary or domestic waste water	30 days	6 glory holes	6
Routine air emissions Vessels, helicopters	30 days	6 glory holes	6
Marine vessels	30 days	6 glory holes	6
Helicopter flights	30 days	6 glory holes	6

[A] Based on one event (i.e., single glory hole or well)
[B] As per regulation
[C] Note that all of the production activities fall within the range of the original Hibernia environmental assessment (and subsequent produced water environmental assessment). They are included here to allow for “within Project” cumulative environmental assessment.

2.6 Discharges and Emissions

The disposal of drilling waste (spent drilling mud and drill cuttings) is considered the primary environmental concern during exploration and development drilling operations (Cranford et al. 2001, Royal Society 1990). Waste discharges during the development may also include produced water, grey and black water, ballast water, bilge water, deck drainage, discharges from machinery spaces, cement, blowout preventer (BOP) fluid, and air emissions. All discharges will be in compliance with C-NLOPB approved Environmental Protection Plans (EPP) which generally reflect requirements outlined in the OWTG. Substances not discussed below or specifically addressed in the OWTG will not be discharged without prior notification and approval of the C-NLOPB as required in section 2.17 of the OWTG.

Waste discharges from the dredging and supply vessels would include air emissions, grey and black water and bilge water, which are regulated under the *Canada Shipping Act*.

2.6.1 Drilling Muds and Cuttings

Drilling mud is a solution of suspended solids and dissolved materials in a carrier liquid such as synthetic oil (SBMs) or water (WBMs). Drilling muds are re-conditioned and recycled to minimize waste discharges and cost and to maximize operational efficiencies. Drill cuttings and solids are formation particles that are typically discharged to the marine environment after treatment, in accordance with the Operators EPP and the OWTG.

WBMs will be used where possible, which is usually during the first sections of each well. Typically the first three (surface, conductor and first intermediate) sections of a well are drilled with WBMs. SBMs may then be used thereafter to drill the majority of each well. All drilling cuttings and fluid discharges will be in accordance with the Operators EPP which generally reflects requirements outlined in the OWTG and are subject to approval by C-NLOPB.

The first part of the hole (i.e., the conductor and surface casing) is drilled without the riser in place and thus the WBM and associated cuttings are discharged directly to the seafloor. WBM used for these two sections typically consist of just seawater and bentonite (clay) and/or barite only. Approximately 250 m^3 of water based cuttings may be discharged per well during this stage of the drilling. Once the riser is installed, the first intermediate hole section is drilled with a water based mud system. For this section and any other section that may be drilled with WBM additives may include glycol ,potassium chloride, caustic soda, soda ash, viscosifiers, filtration-control additives and shale inhibitors which are added to control mud properties. WBM cuttings generated in the drilling of this hole section are discharged overboard. Chemicals used in the drilling process are screened through the C-NLOPB chemical selection guidelines. The process enables identification of the more toxic chemicals and either restricts or prohibits usage. The discharge of WBM may increase total metal concentrations in sediments such as barium, arsenic, cadmium, copper, mercury, lead and zinc. A large portion of each metal is not bioavailable and is not bioaccumulated. WBMs are virtually free of hydrocarbons.

When SBMs are used, formation cuttings, fines from the centrifuges and SBM are returned to the MODU at surface and processed through the mud recovery system. After passing through the solids control system, the cleaned cuttings are then discharged overboard through a cuttings chute. Sampling and analysis of the cuttings is required to ensure the synthetic oil on cuttings (SOC) levels are within acceptable limits.

In terms of waste generated by the Project, the largest contributors to waste volumes are spent muds and cuttings. Mud systems are very expensive and whenever possible drilling related waste is minimized through mud recovery, reconditioning and reuse. SBM will be recycled and reused where possible, and will be brought to shore for disposal when spent. Release of spent SBM to the sea is prohibited. Opportunities to reduce the amount of cuttings generated are limited with the exception of the glory hole site selection process. Glory holes are located to minimize the overall amount of drilling distance required.

Prior to making a decision to proceed with a subsea development, reusing well slots in the GBS will be first considered. Such is the case with the HSE development which consists of a combination of GBS and MODU drilled wells. This strategy minimizes environmental impacts overall in that the number of MODU drilled wells will be minimized; SBM cuttings from GBS drilled wells will be reinjected; and the size of glory holes and associated disposal requirements will be minimized.

SBMs (on cuttings) have the potential to biodegrade relatively rapidly, require less mud (compared to WBM) for the same distance drilled and tend to disperse less than WBMs (CNLOPB 2008b). The SBM for this Project will use ParaDrill IA as the base fluid. ParaDrill has an aromatic content of <0.01 percent and a PAH content of <0.001 ppm. ParaDrill received a Group E classification by the Offshore Chemical Notification System (OCNS) in the United Kingdom. Group E classification is the best rating achievable under OCNS and is assigned to chemicals that have low toxicity and/or do not bioaccumulate or readily biodegrade. This drilling fluid is used by many operators on the East Coast and has been demonstrated to be not acutely or chronically toxic through operator testing or through government testing (Payne et al. 2001a, 2001b; Andrews et al. 2004). The other additives are primarily the same as WBMs, mostly barite (weighting agent) with other additives.

2.6.1.1 Drill Mud and Cuttings Dispersion

Prior to riser installation, cuttings from the initial two sections of the well will be discharged directly to the seafloor. The material is forced up the annulus of the hole during drilling operations. Cuttings are expected to be primarily composed of particles a few centimetres in size, with some smaller, sand-sized portion. Representative fall velocities for this large spectrum of particle sizes range from 0.3 to 0.03 m/s. The characteristics of the eject plume will depend on pump rate and annulus size. These in turn depend on stratigraphy, bit type, rate of penetration and weight on bit. Cuttings must be elevated out of the hole to enable drilling to proceed uninterrupted. This can be accomplished with intermittent sweeps of viscous fluids or, depending on a number of factors, the hole may be cleared continuously by the pumped drill fluid. Pump rates of the order of 1,000 gpm are typical of bit clearing but larger flow rates may be used. Until the hole is started, the exact conditions to be encountered are difficult to determine and hence the exact drilling parameters required are not known. Cuttings under these conditions have been described as fine silt to gravel. The eject plume is assumed to reach a height of 10 m with a width of approximately 5 m. Settling times will range from 30 to 300 s. Bottom releases of mud during jetting/drilling of the upper hole sections result initially in small clouds of fine particles in the benthic boundary layer. These clouds will continue to be diluted by turbulence and will be dispersed to the southwest as they are advected by the mean current.

Once the riser is installed mud returns will be processed through solids control equipment. WBM is used for the 1st intermediate hole section and SBM is used for the remaining sections of the wellbore. Cuttings are discharged overboard. Due to processing, the bulk of the SBM cuttings have a size of approximately 1 to 2 cm, depending on the bit size and characteristics of the geology and requirements for reconditioned mud (i.e. if a heavier mud is required centrifuges may not be used and mainly large diameter cuttings will be separated via the shakers). Such material is expected to settle at rates between 0.4 to 0.6 m/s. Because the discharge rate is low, there will be no initial plume and the main consideration is the convective descent of individual particles.

The fate of drill muds and cuttings from drilling projects in the Jeanne d'Arc Basin has been modelled and reported in the original Hibernia Development Project EIS (Mobil Oil 1985; Sections 4.2.3.2 and 4.2.3.3), the White Rose Oilfield Comprehensive Study (Husky Oil 2000, Section 4.3.1.4); the Statoil Hydro drilling program (LGL 2008b; Section 7.2.1.5), and the SDL 1040 Delineation Drilling Screening (Husky Energy and Norsk Hydro Canada 2006; Section 2.4.1). The results of these modelling exercises have been used here to predict the fate and behavior of drill mud and cuttings for this Project since all these projects operate within similar physical and biological environments and because previous modeling results have reached similar conclusions.

Results of the White Rose modelling of cuttings deposition indicated that the biological 'zone of influence' (ZOI) is generally confined within approximately 500 m of the drilling area. Similar conclusions have been drawn in several recent review papers (Buchanan et al. 2003; Hurley and Ellis 2004; Neff 2005). Canadian EEM data and scientific literature suggest that biological effects were generally detected within 1,000 m of drill sites for benthic community change. However, some habitats (i.e., hard substrates) and more sensitive species (i.e., bivalves) may be affected over greater scales along the axis of predominant currents (Hurley and Ellis 2004). Recent EAs (White Rose, Jeanne d'Arc Basin, and South Whale Basin) have predicted a total area of impact of less than 1 km^2 from multi-well drilling based on modelling and published literature.

Similar to the approach taken in the StatoilHydro Drilling EA (LGL 2008b), the above noted modeling results are considered applicable to this Project EA and it is therefore reasonable to conclude that WBM and cuttings will cover an area of the seabed of about 0.8 km^2 to a thickness of at least 1 cm per well. For this Project, several wells may be drilled within a 70 m x 70 m drill centre, but the area of smothering is not predicted to increase incrementally with each well, as most of the depositional footprint will be re-covered with each subsequent well (i.e., the ZOIs will overlap). SBM-associated cuttings tend to disperse less and fall closer to the drilling rig, and therefore will not extend beyond the 0.8 km^2 area affected predicted from WBM and cuttings.

Using depth average currents as given by the DFO data sets and the WebTide model, Norsk Hydro also estimated the distribution of these WBM cutting on the seafloor (Husky Energy and Norsk Hydro Canada 2006). Each current profile was depth averaged and used to determine the offset of particles settling under those conditions. The deposition model used a spatial resolution of 5 m. Composite distributions based on the hourly currents were determined and a settling rate of 0.5 m/s was used.

It was assumed that all of the WBM material (227 m^3) is composed of coarse particles (0.3 m/s fall velocity). Initial model results showed a build-up of 2.5 m within a radius of approximately 10 m. This pile would slump to an angle of repose of, at most, approximately 30 degrees (B. Taylor, pers. comm.). Therefore, for the fastest settling rate it was expected that slumping would limit the height of the pile. Assuming realistic proportions of coarse material (i.e., 20 percent), the maximum deposition thickness was shown to be approximately 1 to 2 m.

Approximately 270 m^3 of SBM cuttings and residual mud may be released from the surface. The results of the Norsk Hydro model indicate that the SBM cuttings would be deposited on the seafloor within approximately 40 m of the drilling platform (Table 2.4). The maximum thickness of the SBM cutting deposit was approximately 25 cm; this pile would slump to an angle of repose of, at most, approximately 30 degrees.

Table 2.4 Summary of Drill Mud and Cuttings Discharge Scenarios

Scenario	Estimated Volume (m^3)	Affected Benthos			Settling Time (s)
		Radius (m)	Area (m^2)	Thickness[1] (cm)	
Seafloor Return of WBM Cuttings	227	50	8,000	2 to 150	30 to 300
Seafloor Release of WBM	680	7.5[2]	200	100[3]	No settling[4]
Surface Release of SBM[5] Associated Cuttings[6]	270	40	5,000	0.05 to 0.5	200

1 Average thickness calculated over the specified radius. Outside this radius the thickness is <1 cm (seafloor return of WBM cuttings) or <0.1 cm (surface release of SBM cuttings).
2 Initial radius of a hypothetical collapsed cloud - see text.
3 Typical deep ocean boundary layer thickness.
4 Mud particles are assumed to remain in the water column.
5 Cuttings contain residual SBM.
6 Two options of surface release of cuttings (either WBM or SBM) are presented.
Source: Husky and Norsk Hydro 2006

2.6.2 Produced Water

If hydrocarbons are present and testing is conducted, then small amounts of produced water may be discharged by atomizing with hydrocarbons and flared. Together with the produced water discharged from the Hibernia platform, the potential incremental increase in produced water resulting from this Project will be within the amount assessed in the Hibernia Produced Water EA (HMDC 2006). Produced hydrocarbons will be separated from produced water on the MODU. Small volumes of oil (approximately 0.14 L) are typically released in 30 bbl (approximately 4,800 L) of produced water. If well testing occurs, the amount of produced water generated would be a relatively small volume released over a short period of time.

As per the Hibernia Produced Water EA (HMDC 2006), produced water separated from the gas, oil and condensate will be treated on site to meet the limits prescribed in the OWTG; a 24-hour limit of 60 mg/l based on an arithmetic average of two consecutive 12 hour samples and a 30 day volume weighted rolling average limit of 30 mg/L or less. Minimal, if any, produced water will be discharged during development drilling.

A maximum daily discharge rate for produced water has been set by the C-NLOPB and approval will be required to exceed that rate.

Compliance monitoring of produced water will be conducted as per the HMDC Environmental Compliance Monitoring Plan (ECMP).

2.6.3 Cement

After riserless drilling of the upper hole sections, casing is placed in the hole and cement is pumped between the outside of the casing wall and the formation. Cemented casing functions to stabilize the hole to allow further drilling as well as to isolate the deeper higher pressure sections of the reservoir. Similar to drilling mud, cement is pumped down the drill stem and is forced back toward the surface along the outside of the casing wall. Approximately 26.4 m^3 of cement (per well) or more may be released to the seafloor as excess cement is pumped in to ensure a complete and safe cement job. The amount of cement made up for a cement job is always in excess of the calculated volume required to ensure sufficient amount of cement is available in the event of an emergency like unexpected losses downhole or errors in volume calculations. The excess amount on hand however is limited to only that amount required to ensure a complete and safe cement job. Dispersion of the cement is not expected, and the risk of contamination from cement is low.

2.6.4 Grey and Black Water

Grey and black water produced on the drilling rig and the Hibernia Platform is treated as per the OWTG. Black water or sewage will be macerated to 6 mm particle size or less prior to discharge. The original Hibernia Development Project EA (Mobil Oil 1985) estimated that grey water discharge (e.g., showers, dishwashing, deck drains) associated with an offshore drilling rig accommodating approximately 100 persons would be 40 m^3/day, while black water discharge (sanitary waste) would be 19 m^3/day. This represents a fair estimate of potential discharge for the Project, since the number of persons on the drilling rig is likely to be between 85 and 120.

2.6.5 Bilge Water

Bilge water often contains oil and grease that originate in the engine room and machinery spaces. Prior to discharge, bilge water will be treated to less than the 15 mg/L oil in water limit specified in the OWTG. Oil concentrations exceeding 15 mg/L are considered to have exceeded normal operating practice and will be reported to the C-NLOPB within 24-h.

2.6.6 Deck Drainage

Typically deck drainage would be collected and treated to 15 mg/L oil content or less and discharged as per the OWTG. Water collecting on walkways and pipe storage areas that are open to the weather is not considered to originate in oily areas so is not treated prior to discharge through open marine gutters and scuppers. Any oil that is found in these areas is immediately cleaned up to minimize the risk of oil loss to the environment.

2.6.7 Ballast Water

On floating drill rigs and supply boats, ballast water is stored in dedicated ballast tanks. Oil is not expected to be present in the discharged ballast water. However, if oil is detected in ballast water, it will be treated to ensure that oil concentrations in the discharge do not exceed 15 mg/L, as required by the OWTG.

2.6.8 Cooling Water

Seawater is used for cooling equipment such as mud pump line-cooling systems and main engines. Seawater is pumped through heat exchangers and discharged overboard without additives or treatment except chlorine for anti-fouling purposes. The seawater or cooling water return is treated with chlorine and is monitored pursuant to the OWTG. Proposals for the use of biocides other than chlorine will be submitted to the C-NLOPB as per the current OWTG.

2.6.9 Solid Hazardous and Non Hazardous Waste

All trash and garbage, including organic waste from galleys, will be containerized and transported to shore for disposal in approved landfills. Combustible waste such as oil rags and paint cans will be managed as hazardous waste and transported to shore as per the Transportation of Dangerous Goods requirements. All hazardous waste is shipped out of province for disposal at approved hazardous waste disposal facilities.

2.6.10 Glycol and Other Chemicals

When drilling with semi-submersibles, BOP test fluid (glycol/water) is released at intervals (typically three pressure and three function tests per 40 days of drilling). About 1.0 m^3 is released per test.

Similar to the operation of the BOP, the actuation of subsea valves during production operations will result in water-based biodegradable control fluid being vented to sea. The fluid will consist of approximately 5-10% control fluid concentrate and 40-50% glycol. Subsea valves may require adjustments as a result of;

- Subsea Injection System Shut-down;
- Platform Injection System Shut-down;
- Subsea Injection System Valve Integrity Tests;
- Tree Choke Valve Adjustments;
- Misc. Valve Actuations, and
- SCM Solenoid Valve By-pass / Leakage.

Based on typical valve adjustment frequencies for the various operations noted above and typical release volumes (based on valve size), the annual release to sea is estimated to be up to 0.44 m^3 per well. Therefore, a glory hole containing eleven wells can be expected to result in a cumulative annual release of up to 5 m^3.

All chemicals having potential to be released to the sea will be screened in accordance with the C-NLOPB offshore chemical selection guidelines.

2.6.11 Air Emissions

Within Canada, Transport Canada and Environment Canada have regulatory authority concerning marine vessels. Transport Canada instituted the air pollution regulations in the *Canada Shipping Act* (Communications Research Centre Canada, Vol. XV, c. 1404) that addresses fuel usage standards. This section of the *Canada Shipping Act* categorizes the smoke produced from marine vessels according to different levels of smoke density, specific constituents are not regulated. Environment Canada has authority to regulate emissions from marine diesel engines of less than 37 kW and addresses the import, production and sale of fuel in *CEPA* 1999, Part 7: Controlling Pollution and Managing Waste, Div. 4. Therefore, there are no Canadian regulations and/or guidelines that are directly applicable to quantifying air contaminant emissions produced by a marine vessel such as a semi-submersible.

In comparison to production operations, drilling operations emit a relatively small amount of greenhouse gases (GHG). The quantity of GHG emissions from the Hibernia project is estimated annually and submitted to the C-NLOPB as per the OWTG and is also reported to Environment Canada via Statistics Canada.

Well testing is critical to the determination of the reservoir and fluid conditions in production wells. Each test will produce up to or greater than 1,000 m^3 of mixed hydrocarbon liquids (oil and gas). Hydrocarbons and some completion fluids produced by the well testing and some completion fluid will be burned with burner booms. Flaring activities will be kept to a minimum reflecting only those tests absolutely necessary to obtain essential reservoir data. If flaring must be carried out, the resulting greenhouse gas emissions are estimated to be in the order of 1,650 tonnes CO_2e per test.

Emissions associated with the Project consist primarily of combustion gases from drilling operations. Project-related emissions were calculated using estimated fuel consumption and published emission factors. It is estimated that the drilling rig will consume approximately 110 barrels of marine diesel per day, (1 bbl equals approximately 159 L). Marine diesel was assumed to have a fuel sulphur content 0.5 percent and one US gallon of diesel fuel produces approximately 139 MMBTU of energy.

Emissions estimates provided are based on US EPA AP-42 emission factors (Fifth Edition, Volume 1, Chapter 3.4: Large Stationary Diesel and All Stationary Dual-fuel Engines). Evaporative losses are nominal in diesel engines due to low volatility of diesel fuel therefore only air exhaust emissions were considered.

The emissions factors as prescribed by AP-42 for large stationary diesel internal combustion sources are shown in Table 2.5.

Table 2.5 Gaseous Emissions Factors for Large Stationary Diesel Internal Combustion Sources

Air Contaminant	Emission Factor (fuel input) (lb/MMBtu)
NO_x	3.2
CO	0.85
SO_x[A]	$1.01S_1$
CO_2	165
PM	0.1

[A] Assumes that all sulphur in the fuel is converted to SO_2. S_1 = % sulphur in fuel oil. Therefore, for this estimate, with a sulphur fuel content of 0.5%, results in an emission factor of 0.505. Actual sulphur analysis values should be used when available.

Daily air contaminant emissions assuming consumption of 110 bbl/d of fuel were evaluated and are shown in Table 2.6. Whereas a formal analysis has not been conducted on air emissions from a semi-submersible, the resultant emissions would be slightly higher due to greater fuel consumption required for activities such as station-keeping. These emissions are comparable to emissions from a single large container ship of the type commonly present in the area. As shown in Table 2.6, drilling operations by comparison to production operations emit much lower amounts of criteria air contaminants and GHG.

Table 2.6 Daily Criteria Air Contaminant Emissions for the Project Drilling Rig

Air Contaminant	Diesel Fuel (# bbl/day)	# US Gallons/ day	Energy Produced Per Day (MMBtus)[A]	Emission Factors (fuel input) (lb/MMBtu)	Air Contaminant Emissions (lbs/day)	Air Contaminant Emissions (tonnes/day)
NO_x	110	4,620	642	3.2	2,055	0.93
CO	110	4,620	642	0.85	546	0.25
SO_x*	110	4,620	642	0.505	324	0.15
CO_2	110	4,620	642	165	105,960	48
PM	110	4,620	642	0.1	64	0.03
[A] MMBtu = 1,000,000 Btu.						

Emissions resulting from Project activities will disperse rather quickly because of the strong average winds at the site. Emissions from the Project will also be temporary in nature. There will be negligible adverse environmental effects to air quality beyond the exclusion zone. The large distance to the nearest non-related emissions sources makes the potential for cumulative environmental effects very low.

Emissions released to the atmosphere will cause very localized atmospheric temperature elevations, and locally elevated levels of emission gases and particulate matter in the form of soot and fugitive dust. Given the small amounts of the material involved, the location of Hibernia in the open ocean well away from land, and the exchange and dispersion characteristics at the Hibernia site, no significant physical or chemical environmental changes will result (Mobil Oil 1985).

The fuel handling and combustion systems on marine vessels and MODU's are designed to ensure the quality of the air used by workers is not impacted to the extent that unacceptable human health risks develop. However, if air quality is in question, occupational air quality monitoring may be conducted to properly assess risks to human health and corrective measures implemented when deemed necessary.

Mitigation for air contaminant emissions will include the use of modern equipment, maintained according to the manufacturer's specifications to ensure efficient operation. Due to the limited amount of air contaminant emissions and the relative isolation of the site, air quality monitoring is not thought to be necessary.

2.6.11.1 Noise

Noise may be generated by drilling, dredging, pipe laying, geohazard survey, VSP survey, supply and support vessels and helicopters. Each activity, except supply vessels and personnel flights will likely occur in sequence with little chance for more than one activity at a time. Noise generated during the removal of the wellhead and other infrastructure will be of short duration and localized. It is unlikely that explosives will be required to remove the wellhead. Estimated ambient sound levels and sound levels from Project activities are listed in Table 2.7.

Table 2.7 Comparison of Natural and Potential Project-related Noise Levels

Source	Broadband Sound Level (dB re 1 μPa[1])	Sound Level at Dominant Frequencies	
		Frequency (Hz)	Level (dB re 1 μPa[1])
Ambient Noise			
Wind < 1.8 km/h	-	100	60
Wind 20.4 to 29.7 km/h	-	100	97
Wind 40.8 to 50.0 km/h	-	100	102
Heavy Shipping	-	50	105
Light Shipping	-	50	86
Remote Shipping	-	50	81
TNT Explosion			
0.5 kg at 60 m	267	21	-
Seismic Airguns	216-259	50-100	-
VSP Array			
Peak source level	233	-	-
Depth Sounder	180+	12,000+	-
Semi-submersible Drill Rig	154	7-14, 29, 70	-
Drillship	174-185	to 600	-
Supply Boats			
Reduction with propeller nozzles	-10	-	-
Increase with bow thrusters operating	+11	-	-
Large Tanker	186	100+, 125	177
Supertanker	190-205	70	175
Dredge Vessel	187	10-100	175
Pipe lay Barge	169	to 1000	105
Supper Puma Helicopter at 300 m asl			
Received level at sea surface	-	20, 50	105-110
Received levels at 3 to 18 m depth	-	-	65-70
[1] 3rd octave band level			
Source: adapted from LGL 2008 (adapted from Richardson et al. 1995)			

2.7 Environmental Management System

HMDC is committed to conducting business in a manner that is compatible with the environmental and economic needs of the communities in which we operate, and that protects the safety, health and security of our employees, those involved in our operations, our customers and the public. These commitments are documented in our Safety, Health, Environmental, Product Safety and Security policies. These policies are put into practice through a disciplined management framework called Operations Integrity Management System (OIMS).

HMDC's OIMS framework establishes expectations for controlling operations integrity risks inherent in its business. Operations integrity addresses all aspects of Hibernia's operations including security, which can impact safety, health and environmental performance.

The overall structure and scope of OIMS have been established through the Operations Integrity Management System Framework, which is composed of 11 Elements and 64 Expectations, plus the characteristics of, and processes for, evaluating and implementing management systems. OIMS management system 6-5 in Environmental Management, provides a framework for environmental management that is fully integrated with HMDC's business planning process.

Within OIMS System 6-5 is HMDC's Environmental Protection Plan which contains the environmental compliance monitoring plan and the environmental effects monitoring plan as well as other key plans and procedures. The HMDC Management System will apply to all activities related to construction and operation of the new drill centre(s). The following sections describe some of the specific plans/environmental protection procedures to be applied to the proposed Project.

2.7.1 Offshore Chemical Management System

All chemicals used in the offshore having the potential to be discharged to the marine environment must be assessed or screened in accordance with the C-NLOPB Offshore Chemical Selection Guidelines. The process enables identification of the more toxic chemicals and either restricts or prohibits their use and discharge. Where chemicals are deemed to have unacceptable toxicity ratings, a substitution for that chemical is sought. Hibernia's existing chemical management system will be applied to all products subject to release to the sea.

2.7.2 Waste Management Plan

Hibernia will ensure that hazardous and nonhazardous waste generated by development of the new drill centres will be managed in a manner which is aligned with the Waste Management Plan currently implemented for the Hibernia project. The drilling contractor will be required to have in place the necessary procedures which identify the waste types, waste containers are properly labelled, and also ensure compliance with the Transportation of Dangerous Goods Regulations. Waste disposal facilities will undergo facility assessments to verify their operations meet the minimum required expectations. Drill rig contractors will be required to have recycling programs in place for those materials that are able to be recycled locally.

2.7.3 Ice Management Plan

HMDC has an existing Ice Management Plan in place for its operations on the Grand Banks to manage ice and iceberg threats to the GBS as well as the offshore loading system.

The document provides guidance to Hibernia operations and ice management contractor personnel pertaining to any hazardous situation arising due to the presence or motion of sea ice or icebergs. The primary functions of the document are:

- to define appropriate actions in responding to ice related hazards;
- to provide important supporting information, particularly with respect to ice conditions and ice operations procedures.

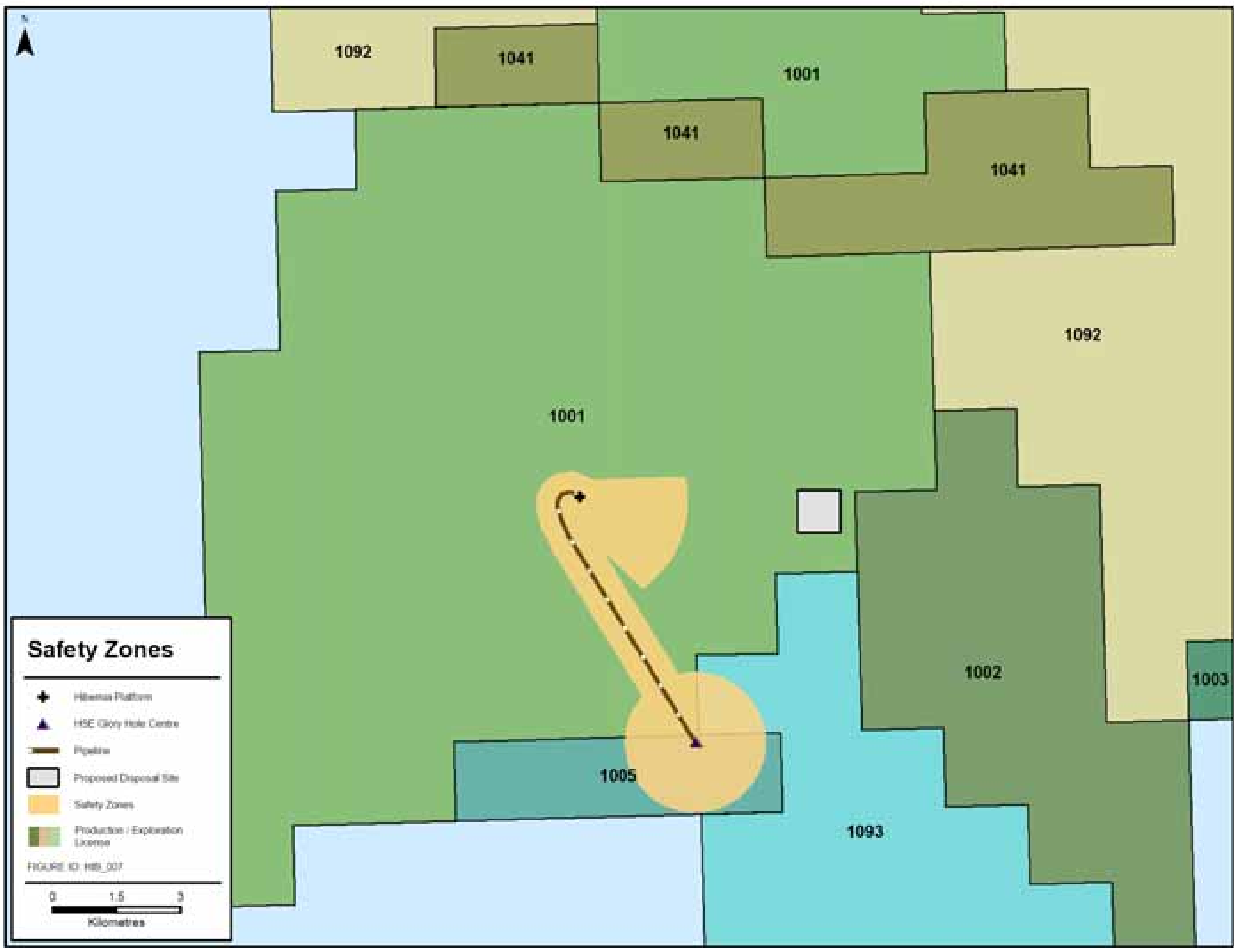
This plan is intended to be non-prescriptive in that specific actions shall be determined in the field in consideration of the level of risk presented to the Hibernia operations and facilities as well as to the environment. HMDC will update the Ice Management Plan to ensure all subsea equipment is properly protected from the threat of sea ice and icebergs.

Ice management is now coordinated among the offshore operators. To the extent it is safe and practical to do so, the existing ice management program may be sufficient to provide the information necessary for the MODU to properly manage risks associated with ice and icebergs. When this is not possible or practical one or more observers may be stationed on the MODU to assist Drilling Operations personnel in strategic and tactical planning along with recording and reporting the weather and oceanographic duties.

2.7.4 Safety Zones

During Project construction, a temporary safety zone would extend approximately 500 m from a drill ship and approximately 1.25 or 1.65 km from the drill centre for a semi-submersible rig, depending on the anchor arrangement. Thus, the safety zone could range from <1 km^2 for a drill ship to 5 or 8.2 km^2 for a semi-submersible in total area, per drill centre. A safety zone of 500 m would be required on either side of all flowlines which run from the GBS to the drill centre(s). The current safety zone around the Hibernia GBS and OLS would continue. An illustration of the commercial fisheries safety zone for the Hibernia Southern Extension development is provided in Figure 2.6.

Figure 2.6 Commercial Fisheries Safety Zone Schematic



2.7.5 Environmental Monitoring

Compliance monitoring for this Project will be addressed as per the HMDC Environmental Compliance Monitoring Plan (ECMP). Any requirement for Environmental Effects Monitoring (EEM) will also be addressed through the existing HMDC EEM program (with review and adjustment as required).

Whenever it is safe and practical to do so, monitoring of the physical environment will be conducted by the weather observer on the Hibernia GBS. In some cases, this may not be appropriate and a dedicated weather observer will be stationed on the MODU.

2.7.6 Operational Limits

Operational limits, such as sea states or wind speed, are put in place to ensure activities are conducted under environmental conditions that allow the activity to proceed in a manner which is safe and does not pose unacceptable risks to the environment. The following activities are subject to such operational limits:

- diving operations;
- cargo handling / crane operations;
- personnel working outside;
- helicopter flying; and
- tanker loading.

Appropriate operational limits will be put in place for all aspects of the drill centres(s) development.

2.7.7 Emergency Procedures

Hibernia is committed to ensuring the safety of all people associated with its operations onshore and offshore. During an emergency, maintaining the safety of those initially unaffected; ensuring the safety of those responding to the incident; and rescuing those who may have been injured are the prime responsibilities of responders and those in command. Hibernia's Emergency Response Plan aims to ensure the safety of people, to reduce the potential for environmental impacts and to reduce the potential for loss or damage of physical assets. Appendix A of the Emergency Response contains the Hibernia Oil Spill Response Plan.

The Operation Integrity Management System 10-2, Emergency Preparedness and Response, outlines the requirements for development of plans and procedures for emergency response. This plan was developed from the results of risk assessments and regulatory requirements. Updating of plans and procedures are based on learnings from drills and exercises, and actual events.

All personnel involved in emergency response, including oil spills, contribute to the development and improvement of this and other emergency response documentation, and are trained to act in compliance with this plan during any emergency situation.

Furthermore, the Operational Plan, along with this Emergency Response Plan, is available to all employees, both onshore and offshore. This includes crews on standby vessels, tankers and aircraft that service the offshore production installation. Updates are redistributed both electronically and in a paper format to Hibernia's Emergency Response team members.

The HMDC Emergency Operations Centre will also be supported by the ExxonMobil Emergency Support Group (ESG). It is through the ExxonMobil ESG that Hibernia is able to access the resources available globally to ExxonMobil. The response to an incident will be based on the PEAR principles, protection of people, minimize impact on the environment; minimize impact on assets and protection of Corporate reputation.

Once emergencies are brought under control and personnel and the facility impacted made safe, investigations are carried out according to Procedure No. HS-O-O-X-A00-PH-0901.001 Incident Investigation and Reporting.

3.0 PHYSICAL ENVIRONMENT

Detailed descriptions of the physical environment within the Jeanne d'Arc Basin have been presented in numerous EAs and scientific papers. Since the original EA for the Hibernia Development Project (Mobil Oil 1985 and component studies), several EAs have provided summaries of more recent data and physical environment models for this area. Specifically:

- StatoilHydro Canada Jeanne d'Arc Basin Area Seismic and Geohazard Program, 2008-2016 and Exploration and Appraisal/Delineation Drilling Program for Offshore Newfoundland, 2008-2016 (LGL 2008 a, b);
- Husky exploratory drilling EAs and updates (LGL 2002, 2003, 2005a, 2006b, 2007b); and
- SDL 1040 Delineation Drilling Screening (Husky and Norsk Hydro 2006).

Presented here is a summary of the physical environment for the region as well as sections from the Physical Environment at Hibernia South report (Oceans Ltd. 2008) for the Project Area. The entire Oceans report is attached as Appendix B.

3.1 Climate

The climate of the Grand Banks is very dynamic, being largely governed by the passage of high and low pressure circulation systems. These circulation systems are embedded in, and steered by, the prevailing westerly flow that typifies the upper levels of the atmosphere in the mid-latitudes, which arises because of the normal tropical to polar temperature gradient. The mean strength of the westerly flow is a function of the intensity of this gradient, and as a consequence is considerably stronger in the winter months than during the summer months, due to an increase in the south to north temperature gradient. (Meteorological convention defines seasons by quarters; e.g., winter is December, January, February, etc.).

During the winter months, an upper level trough tends to lie over Central Canada and an upper ridge over the North Atlantic resulting in three main storm tracks affecting the Grand Banks: one from the Great Lakes Basin, one from Cape Hatteras, North Carolina and one from the Gulf of Mexico. These storm tracks, on average, bring eight low pressure systems per month over the area.

Frequently, intense low pressure systems become 'captured' and slow down or stall off the coast of Newfoundland and Labrador. This may result in an extended period of little change in conditions that may range, depending on the position, overall intensity and size of the system, from the relatively benign to heavy weather conditions.

Rapidly deepening storms are a problem south of Newfoundland in the vicinity of the warm water of the Gulf Stream. Sometimes these explosively deepening oceanic cyclones develop into a "weather bomb"; defined as a storm that undergoes central pressure falls greater than 24 mb over 24 hours. Hurricane force winds near the center, the outbreak of convective clouds to the north and east of the center during the explosive stage, and the presence of a clear area near the center in its mature stage (Rogers and Bosart, 1986) are typical of weather bombs. After development, these systems will either move across Newfoundland or near the southeast coast producing gale to storm force winds from the southwest to south over the Project Area.

There is a general warming of the atmosphere during spring due to increasing heat from the sun. This spring warming results in a decrease in the north-south temperature gradient. Due to this weaker temperature gradient during the summer, storms tend to be weaker and not as frequent. Furthermore, the weaker tropical-to-polar temperature gradient in the summer results in the storm tracks moving further north. With the low pressure systems passing to the north of the region, the prevailing wind direction during the summer months is from the southwest to south. As a result, the incidences of gale or storm force winds are relatively infrequent over Newfoundland during the summer.

3.1.1 Precipitation

The frequency of precipitation type (Table 3.1) shows that annually, precipitation occurs 23.9% of the time. Winter has the highest frequency of precipitation with 37.6% of the observations reporting precipitation. Snow accounts for the majority of precipitation during the winter months, accounting for 58.0% of the occurrences of winter precipitation. Summer has the lowest frequency of precipitation with a total frequency of occurrence of 14.3%. Snow has been reported in each month from October to May.

Table 3.1 Percentage Frequency (%) Distribution of Precipitation.

	Rain / Drizzle	Freezing Rain/ Drizzle	Rain / Snow Mixed	Snow	Hail	Total
January	14.9	0.4	0.7	26.6	0.2	42.7
February	10.3	1.2	0.4	25.2	0.1	37.1
March	11.6	1.4	0.4	13.7	0.0	27.1
April	12.3	0.2	0.1	5.8	0.1	18.5
May	16.3	0.0	0.0	0.8	0.0	17.2
June	15.4	0.0	0.0	0.0	0.0	15.4
July	12.9	0.0	0.0	0.0	0.0	12.9
August	14.7	0.0	0.0	0.0	0.0	14.7
September	18.8	0.0	0.0	0.0	0.0	18.8
October	23.2	0.0	0.0	1.1	0.2	24.5
November	22.5	0.0	0.4	5.0	0.2	28.2
December	17.2	0.1	1.0	14.8	0.3	33.4
Winter	14.3	0.5	0.7	21.8	0.2	37.6
Spring	13.6	0.5	0.2	6.3	0.0	20.6
Summer	14.3	0.0	0.0	0.0	0.0	14.3
Autumn	21.7	0.0	0.1	2.2	0.1	24.2

3.1.2 Air and Water Temperature

The moderating influence of the ocean serves to limit both the diurnal and the annual temperature variation on the Grand Banks. Diurnal temperature variations due to the day/night cycles are very small. Short-term, random temperature changes are due mainly to a change of air mass following a warm or cold frontal passage. In general, air mass temperature contrasts across frontal zones are greater during the winter than during the summer season.

Air and sea surface temperatures for the Project area were extracted from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). A subset of global marine surface observations from ships, drilling rigs, and buoys for the area 46.5°N to 47.0°N; 48.5°W to 49.0°W covering the period from January 1950 to December 2006 was used in this report. A monthly plot of air temperature versus sea surface temperature is presented in Figure 3.1. Temperature statistics presented in Table 3.2 show that the atmosphere is coldest in February with a mean temperature of –0.6°C, and warmest in August with a mean temperature of 14.1°C. The sea surface temperature is warmest in August with a mean temperature of 14.0°C and coldest in February and March with a mean temperature of 0.5°C. The mean sea surface temperature is in the range of 0.1 to 1.5°C colder than the mean air temperature from March to August, with the greatest difference occurring in the month of July. From September to February, sea surface temperatures are in the range of 0.0 to 1.1°C warmer than the mean air temperature. The colder sea surface temperatures from March to August have a cooling effect on the atmosphere, while relatively warmer sea surface temperatures from September to February tends to warm the overlying atmosphere.

Figure 3.1 Monthly Mean Air and Sea Surface Temperature

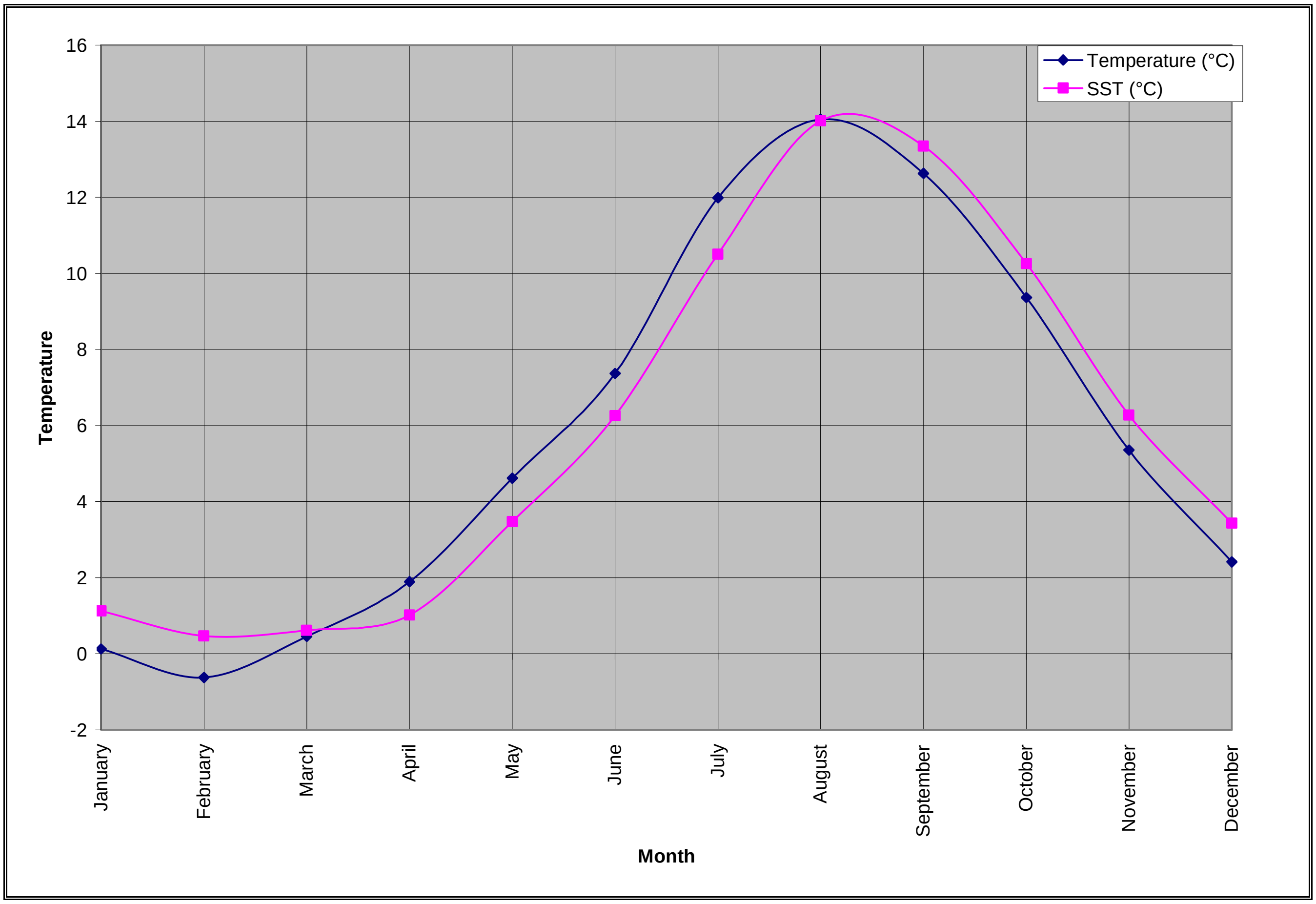


Table 3.2 Air and Sea Surface Temperature Statistics

	Air Temperature (°C)			Sea Surface Temperature (°C)		
	Mean	**Maximum**	**Minimum**	**Mean**	**Maximum**	**Minimum**
January	0.1	10.4	-9.4	1.1	9.0	-1.9
February	-0.6	10.4	-10.5	0.5	9.0	-2.2
March	0.5	11.1	-8.2	0.6	9.0	-2.2
April	1.9	10.7	-5.0	1.0	9.2	-2.8
May	4.6	13.4	-2.2	3.5	11.4	-2.2
June	7.4	16.6	-0.1	6.3	14.4	0.0
July	12.0	20.3	3.8	10.5	18.3	4.0
August	14.1	20.2	7.0	14.0	19.0	7.8
September	12.6	20.0	4.9	13.4	19.1	7.0
October	9.4	18.3	0.6	10.3	16.1	2.0
November	5.4	15.6	-3.3	6.3	15.0	0.0
December	2.4	13.0	-7.2	3.4	12.0	-1.8
Winter	0.6	11.3	-9.0	1.7	10.0	-2.0
Spring	2.3	11.7	-5.1	1.7	9.9	-2.4
Summer	11.1	19.0	3.6	10.3	17.2	3.9
Autumn	9.1	18.0	0.7	10.0	16.7	3.0

3.1.3 Visibility

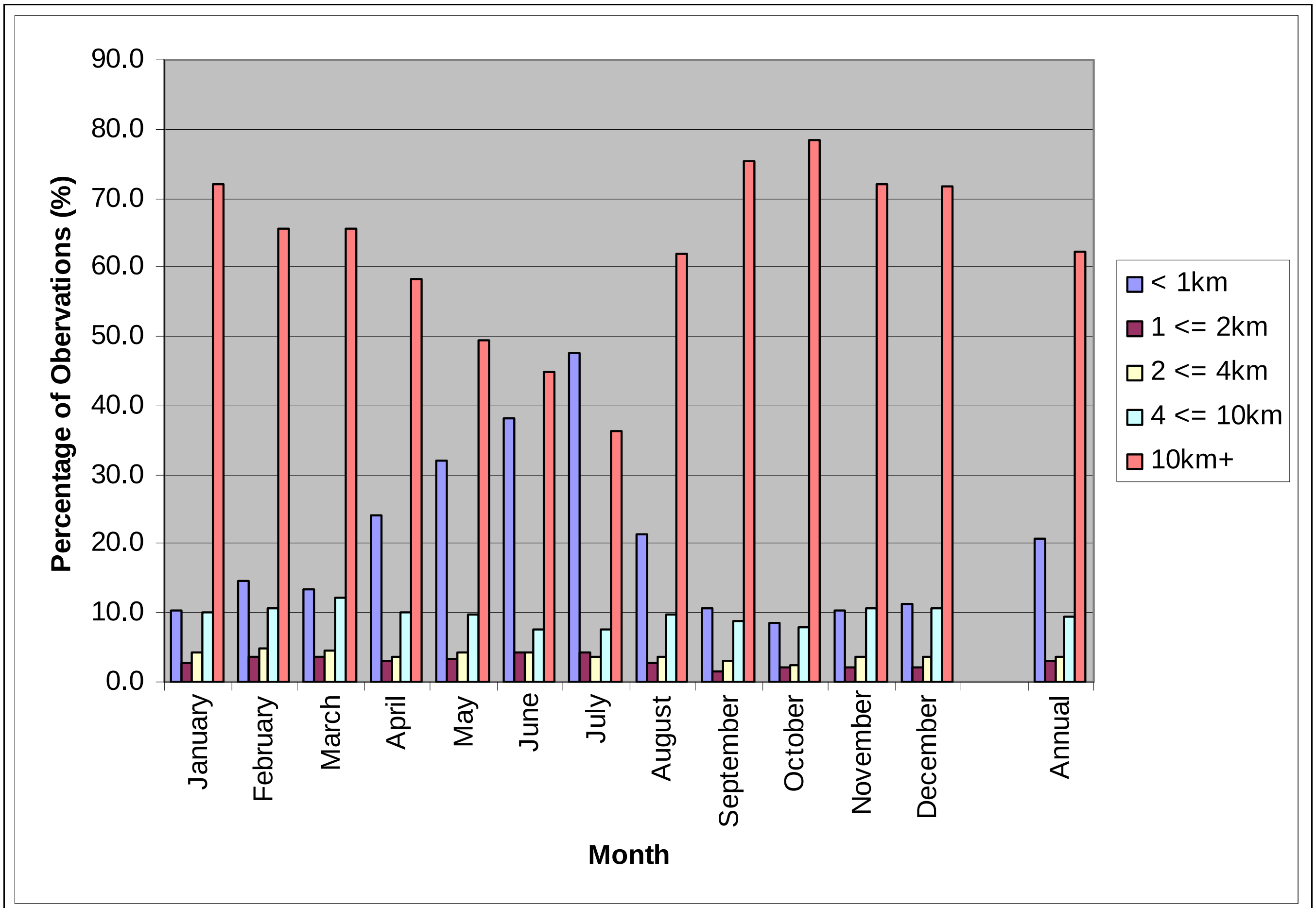
Visibility is defined as the greatest distance at which objects of suitable dimensions can be seen and identified. Horizontal visibility may be reduced by any of the following phenomena, either alone or in combination:

- fog;
- mist;
- haze;
- smoke;
- liquid precipitation (e.g., drizzle);
- freezing precipitation (e.g., freezing rain);
- frozen precipitation (e.g., snow); and
- blowing snow.

A plot of the frequency distribution of visibility from the ICOADS data set is presented in Figure 3.2. Obstructions to vision can occur in any month. Annually, 37.9% of the recorded observations had reduced visibilities. During the winter months, the main obstruction is snow; however, mist and fog may also reduce visibilities at times. As spring approaches, the amount of visibility reduction attributed to snow decreases. As the air temperature increases, so does the occurrence of advection fog. Advection fog forms when warm moist air moves over the cooler waters of the Labrador Current. By March, the sea surface temperature on the Grand Banks is cooler than the surrounding air. As warm moist air moves over the colder sea surface, the air cools and its ability to hold moisture decreases. The air will continue to cool until it becomes saturated and the moisture condenses to form fog. The presence of advection fog increases from April through July.

The month of July has the highest percentage (63.8%) of obscuration to visibility, most of which is in the form of advection fog, although frontal fog can also contribute to the reduction in visibility. On average, fog reduces visibility below 1 kilometre 47.6% of the time in July. In August, the temperature difference between the air and the sea begins to narrow and by September, the air temperature begins to fall below the sea surface temperature. As the air temperature drops, the occurrence of fog decreases. Reduction in visibility during autumn and winter is relatively low and is mainly attributed to the passage of low-pressure systems. Fog is mainly the cause of the reduced visibilities in autumn and snow is the cause of reduced visibilities in the winter. October has the lowest occurrence of reduced visibility (21.7%) since the air temperature has, on average, decreased below the sea surface temperature and it is not yet cold enough for snow.

Figure 3.2 Monthly and Annual Percentage Occurrence of Visibility



Source: ICOADS Data set (1950-2006)

3.1.4 Wind Climatology

The Grand Banks experiences predominately southwest to west flow throughout the year. West to northwest winds which are prevalent during the winter months begin to shift counter-clockwise during March and April resulting in a predominant southwest wind by the summer months. As autumn approaches, the tropical-to-polar temperature gradient strengthens and the winds shift slightly, becoming predominately westerly again by late fall and into winter.

Low pressure systems crossing the area are more intense during the winter months. As a result, mean wind speeds tend to peak during this season. Mean wind speeds at grid point 11028, the ICOADS data set and the Hibernia MANMAR dataset peak during the month of January (Table 3.3). Grid Point 11028 is located at 46.7°N; 48.7°W and considered to be most representative of conditions within the Project Area. Grid 11028 had January and February mean wind speeds of 10.9 m/s, while the ICOADS dataset recorded the highest mean wind speed of 14.1 m/s for January. The Hibernia platform also had its highest mean wind speeds of 15.9 m/s during the month of January. Wind speeds from all three data sets are not directly comparable to each other due to their sampling period and the heights at which they were measured. Winds from the Hibernia dataset were 10-minute means, measured from an anemometer located 139 metres above sea level.

The wind speed is dependent on height since the wind speed increases at increasing heights above sea level. Methods to reduce wind speeds from anemometer level to 10 metres have proven ineffective due to atmospheric stability issues. As a result, wind speed data from the Hibernia platform is presented in its original form and not reduced to the reference 10 m height. Winds in the ICOADS data set were either estimated or measured by anemometers at various heights above sea level. Also, winds speeds from each of the data sources have different averaging periods. The MSC50 winds are 1-hour averages, while the ICOADS winds are 10-minute average winds. The adjustment factor to convert from 1-hour mean values to 10-minute mean values is usually taken as 1.06 (U.S. Geological Survey, 1979).

Table 3.3 Mean Wind Speed (m/s) Statistics

	MSC50 Grid Point 11028		ICOADS		Hibernia MANMAR	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
January	10.9	4.6	14.1	6.7	15.9	7.6
February	10.9	4.5	13.8	6.3	15.3	7.4
March	9.9	4.3	12.4	5.9	14.4	6.7
April	8.4	3.9	11.2	5.6	13.4	6.8
May	7.0	3.5	10.1	4.7	11.8	5.9
June	6.5	3.1	9.7	4.8	11.5	5.6
July	6.1	2.9	9.8	4.6	11.1	5.9
August	6.4	3.0	9.1	4.3	10.5	5.6
September	7.5	3.6	9.9	4.9	11.2	5.9
October	8.8	3.9	11.8	5.3	13.0	6.4
November	9.5	4.2	12.3	5.9	13.3	6.8
December	10.6	4.5	13.3	6.1	15.2	7.3

A wind rose of the annual wind speed and histogram of the wind speed frequency from grid point 11028 is presented in Figure 3.3 and Figure 3.4. Monthly wind roses along with histograms of the frequency distributions of wind speeds for Grid Point 11028 can be found in Appendix B. There is a marked increase in the occurrence of winds from the west to northwest in the winter months as opposed to the summer months, which is consistent with the wind climatology of the area. The percentage exceedance of wind speeds at grid point 11028 is presented in Figure 3.5.

Figure 3.3 Annual Wind Rose for MSC50 Grid Point 11028 located near 46.7°N; 48.7°W. 1954 – 2005

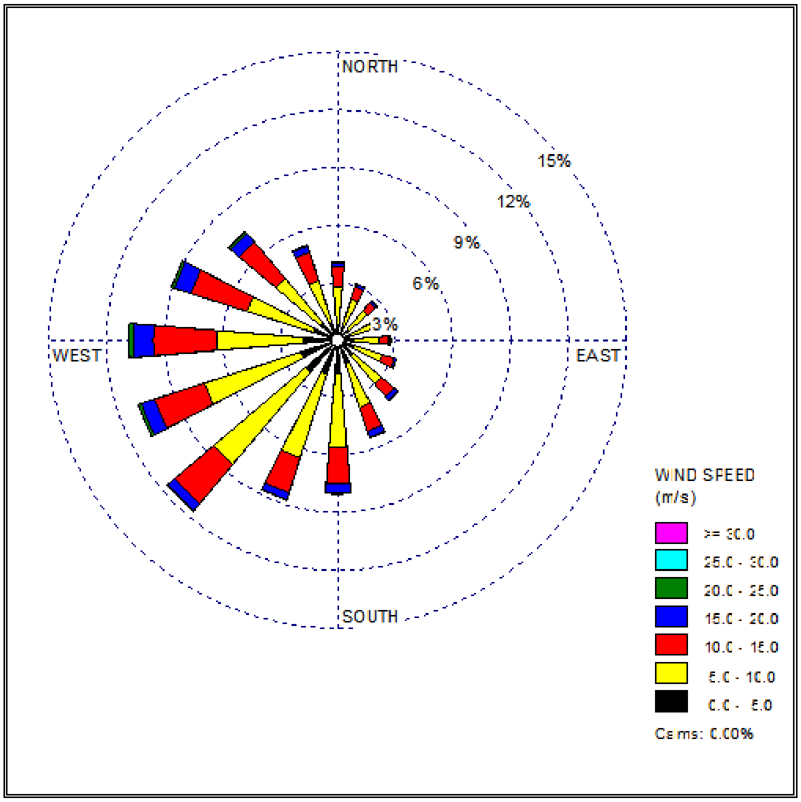


Figure 3.4 Annual Percentage Frequency of Wind Speeds for MSC50 Grid Point 11028 located near 46.7°N, 48.7°W; 1954 – 2005

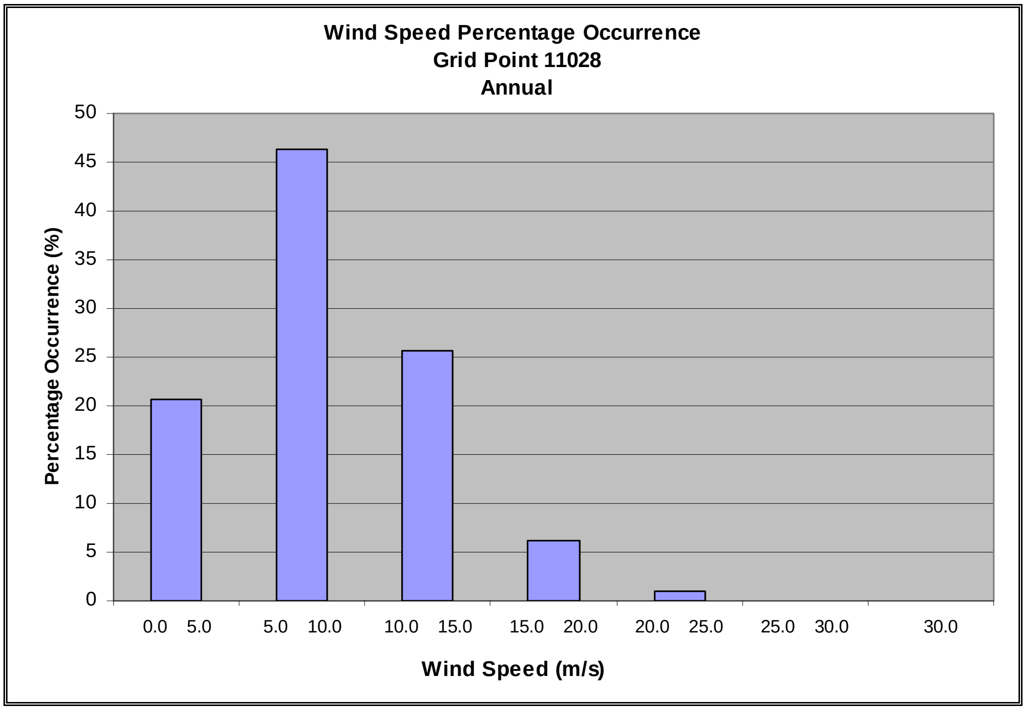
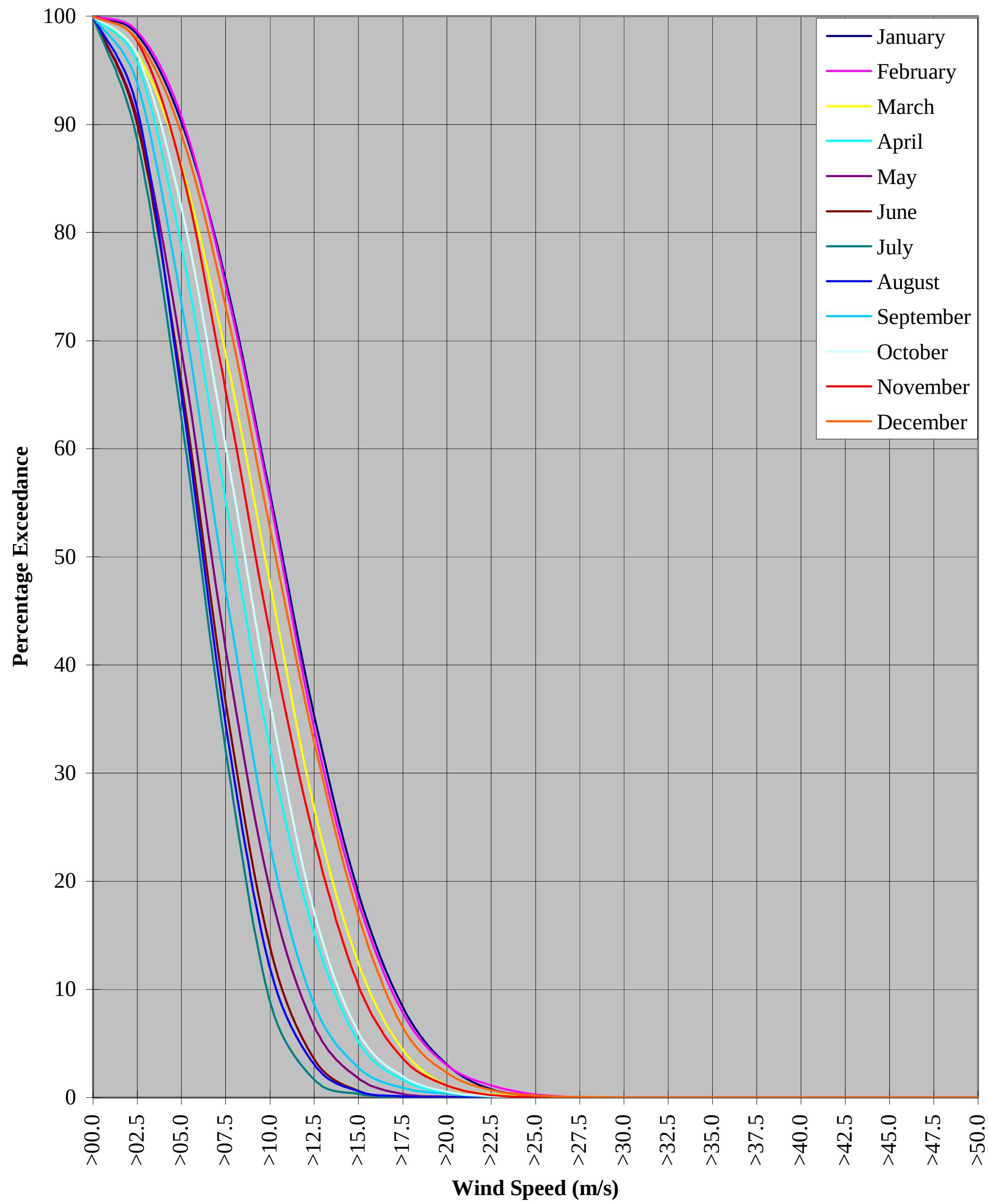


Figure 3.5 Annual Percentage Exceedance of 10-metre Wind Speed at Grid Point 11028



Source: MSC50 Grid Point 11028 Lat: 46.7°N Lon: 48.7°W, 1954 to 2005.

Intense mid-latitude low pressure systems occur frequently from early autumn to late spring. In addition, remnants of tropical systems have passed near Newfoundland between spring and late fall. Therefore, while mean wind speeds tend to peak during the winter months, maximum wind speeds may occur at anytime during the year. A table of monthly maximum wind speeds for each of the data sets is presented in Table 3.4.

Table 3.4 Maximum Wind Speeds (m/s) Statistics

	MSC50 Grid Point 11028	ICOADS	MANMAR
January	27.0	35.0	43.2
February	30.2	38.1	49.4
March	27.4	36.5	37.6
April	24.2	28.3	32.9
May	21.9	24.7	30.9
June	23.0	23.2	31.4
July	18.1	22.1	29.8
August	27.0	23.2	36.0
September	25.4	25.7	37.6
October	27.2	30.9	41.2
November	27.2	34.0	38.1
December	29.9	32.9	39.1

Rapidly deepening storm systems known as weather bombs frequently cross the Grand Banks. These storm systems typically develop in the warm waters of Cape Hatteras and move northeast across the Grand Banks. On February 11, 2003 wind speeds at Grid Point 11028 peaked at 29.9 m/s. Wind speeds of 49.4 m/s from the southwest were recorded at 18Z by the Hibernia Platform anemometer as this system passed. During this storm, a low pressure developing off Cape Hatteras on February 10th rapidly deepened to 949 mb as it tracked northeast across the Avalon Peninsula around 18Z on February 11th.

Another intense storm which developed south of the region passed east of the area on December 16, 1961. This storm resulted in wind speeds similar to that produced during the February 11th storm. During this event, grid point 11028 had wind speeds of 29.9 m/s. There were no observations from the ICOADS dataset recorded during this storm.

While mid-latitude low pressure systems account for the majority of the peak wind events on the Grand Banks, storms of tropical origin can also on occasion pass over the region. On August 22, 1995, the remnants of Category 4 Hurricane Felix passed approximately 60 nm west of the region as a tropical storm with maximum sustained 1-minute wind speeds of 25.7 m/s and a central pressure of 985 mb. During this event, the 1-hour average wind speeds in the MSC50 data set peaked at 27.0 m/s from the south-southwest. No observations were recorded within the ICOADS dataset during this event.

3.1.5 Wave Climatology

The main parameters for describing wave conditions are the significant wave height, the maximum wave height, the peak spectral period, and the characteristic period. The significant wave height is defined as the average height of the 1/3 highest waves, and its value roughly approximates the characteristic height observed visually. The maximum height is the greatest vertical distance between a wave crest and adjacent trough. The spectral peak period is the period of the waves with the largest energy levels, and the characteristic period is the period of the 1/3 highest waves. The characteristic period is the wave period reported in ship observations, and the spectral period is reported in the MSC50 data set.

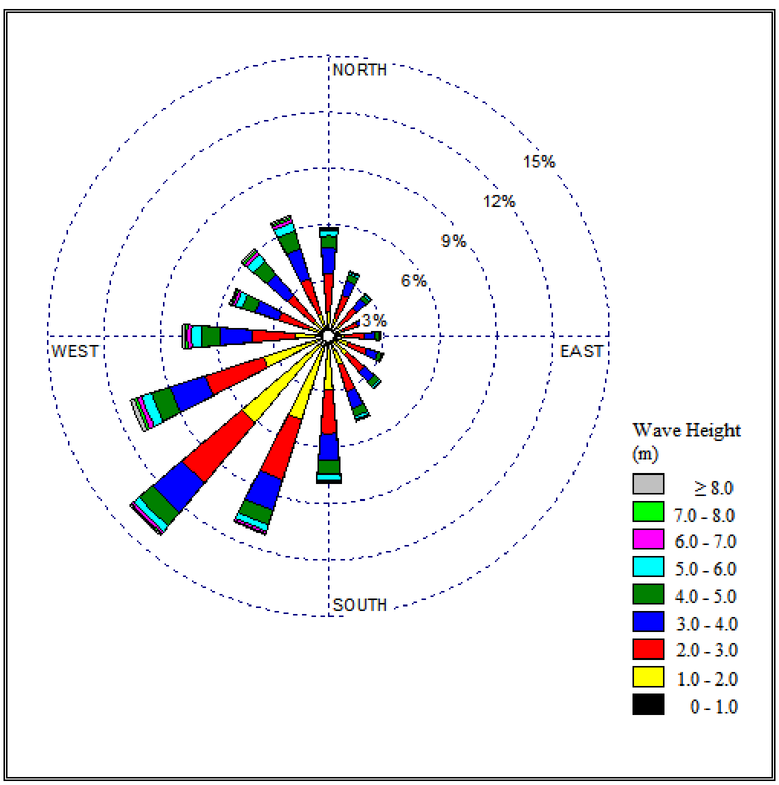
A sea state may be composed of the wind wave alone, swell alone, or the wind wave in combination with one or more swell groups. A swell is a wave system not produced by the local wind blowing at the time of observation and may have been generated within the local weather system, or from within distant weather systems. The former situation typically arises when a front, trough, or ridge crosses the point of concern, resulting in a marked shift in wind direction. Swells generated in this manner are usually of low period. Swells generated by distant weather systems may propagate in the direction of the winds that originally formed to the vicinity of the observation area. These swells may travel for thousands of miles before dying away. As the swell advances, its crest becomes rounded and its surface smooth. As a result of the latter process, swell energy may propagate through a point from more than one direction at a particular time.

The wave climate of the Grand Banks is dominated by extra-tropical storms, primarily during October through March, however severe storms may, on occasion, occur outside these months. Storms of tropical origin may occur during the early summer and early winter, but most often from late August through October. Hurricanes are usually reduced to tropical storm strength or evolve into extra-tropical storms by the time they reach the area, however they are still capable of producing storm force winds and high waves.

Mean monthly ice statistics were used when calculating the wave heights in the MSC50 data. As a result, if the mean monthly ice coverage for a particular grid point is greater than 50% for a particular month, the whole month (from the 1st to the 31st) gets "iced out"; meaning that no forecast wave data has been generated for that month. This sometimes results in gaps in the wave data.

The annual wave rose from the MSC50 data for grid point 11028 is presented in Figure 3.6. The wave rose show that the majority of wave energy comes from the west-southwest to south-southwest, and accounts for 36.2% of the wave energy at grid point 11028. Waves were "iced out" for 1.31% of the time over the 50-year record; this value may be somewhat high since monthly ice files were used when generating the waves.

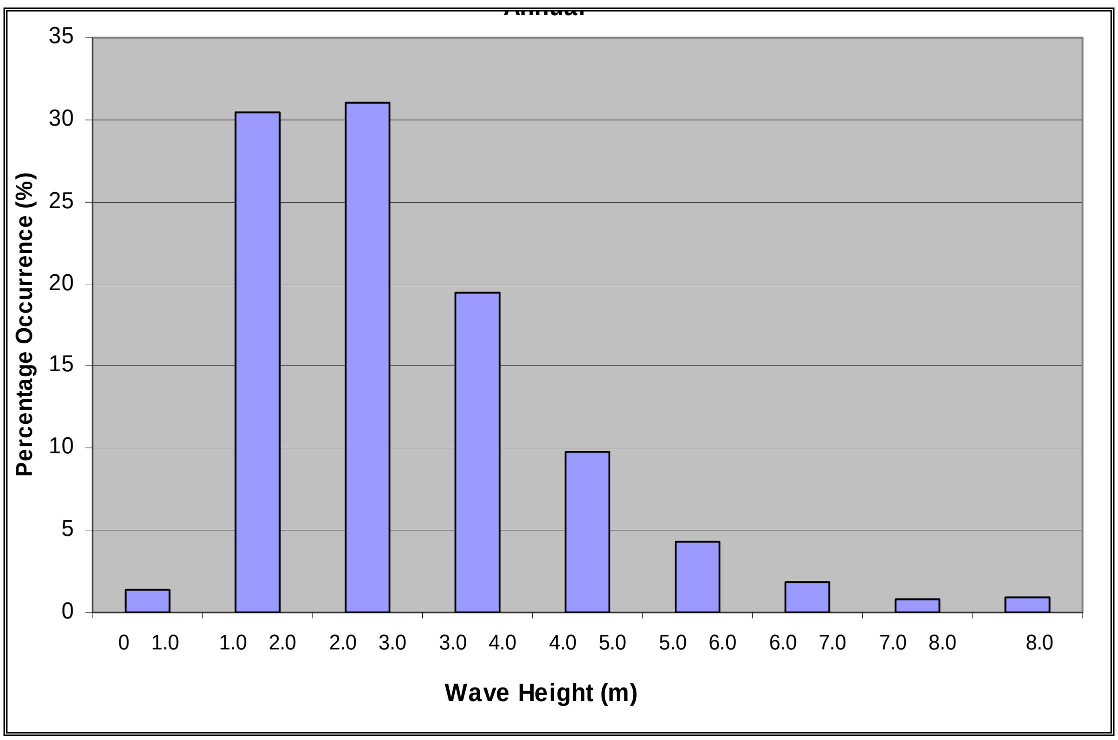
Figure 3.6 Annual Wave Rose for MSC50 Grid Point 11028 located near 46.7°N; 48.7°W



During autumn and winter, the dominate direction of the combined significant wave height is from the west. This corresponds with a higher frequency of occurrence of the wind wave during these months, suggesting that during the late fall and winter, the wind wave is the main contributor to the combined significant wave height. During the months of March and April, the wind wave remains predominately westerly, while the swell begins to back to southerly, resulting in the vector mean direction of the combined significant wave heights backing to southwesterly. A mean southwesterly direction for the combined significant wave heights during the summer months is a result of a mainly southwesterly wind wave and a southwesterly swell. As winter approaches again, during the months of September and October, the wind wave will veer to the westerly and become the more dominant component of the combined significant wave height. This will result in the frequency of occurrence of the combined significant wave heights veering to westerly once again.

The annual percentage frequency of significant wave height is presented in Figure 3.7. This histogram shows that the majority of significant wave heights are between 1.0 m and 5.0 m on the Grand Banks. There is a gradual decrease in frequency of wave heights above 4.0 m and only a small percentage of the wave heights exceed 8.0 m. Monthly wave roses along with histograms of the frequency distributions of wave heights for Grid Point 11028 can be found in Appendix B.

Figure 3.7 Annual Percentage Frequency of Wave Height for MSC50 Grid Point 11028 located near 46.7°N; 48.7°W. 1954 – 2005



Significant wave heights on the Grand Banks peak during the winter months with Grid Point 11028 having a mean monthly significant wave height of 3.9 metres. The lowest significant wave heights occur in the summer with July having a mean monthly significant wave height of only 1.7 m (Table 3.5).

Table 3.5 Combined Significant Wave Height Statistics (m) for the MSC50 data set

	Mean	Standard Deviation	Maximum
January	3.9	1.7	12.6
February	3.7	1.7	13.6
March	3.1	1.6	10.8
April	2.6	1.3	10.6
May	2.2	0.9	9.9
June	1.9	0.7	9.7
July	1.7	0.6	6.2
August	1.8	0.7	8.5
September	2.4	1.0	10.6
October	2.9	1.2	11.4
November	3.3	1.4	11.2
December	3.9	1.5	13.0

Combined significant wave heights of 10.5 metres or more occurred in each month between September and April, with the highest waves occurring during the month of February. The highest combined significant wave heights of 13.6 m occurred during the February 11, 2003 storm as discussed earlier. While maximum significant wave heights tend to peak during the winter months, a tropical system could pass through the area and produce wave heights during any month.

Figure 3.8 shows percentage exceedance curves of significant wave heights for grid point 11028. For the months of January through April the percentage exceedance curves do not reach 100% because of the presence of ice on the Grand Banks during these months.

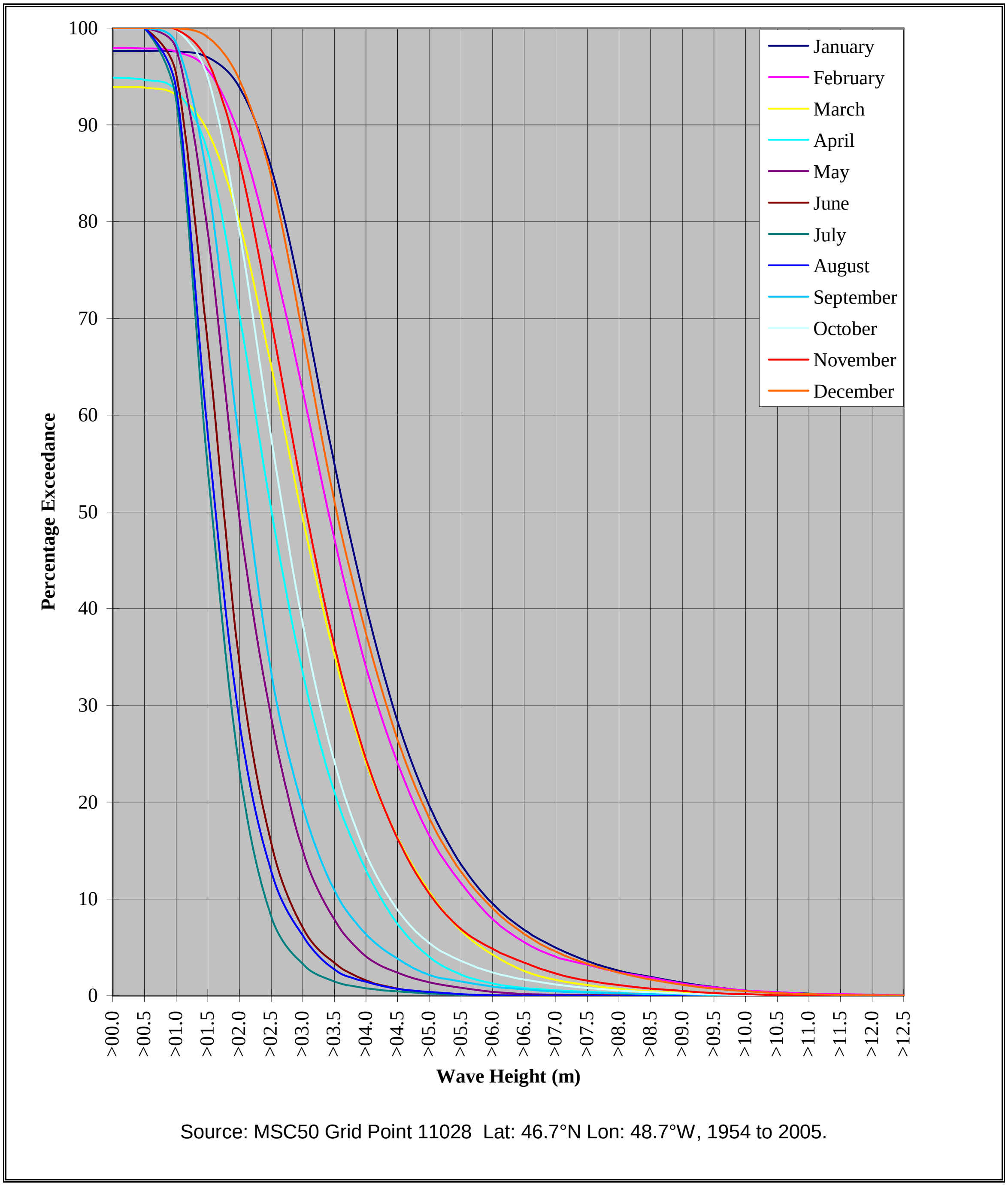
3.1.6 Wind and Wave Extremes

An analysis of extreme wind and waves was performed using the MSC50 data set. This data set was determined to be the most representative of the available datasets, as it provides a continuous 52-year period of 1 hourly data for the Regional Area. The extreme value analysis for wind speeds was carried out using the peak-over-threshold method. For the extreme wave analysis, two methods were used; the peak-over-threshold method and the joint probability method.

After considering four different distributions, the Gumbel distribution was chosen to be the most representative for the peak-over-threshold method as it provided the best fit to the data. Since extreme values can vary, depending on how well the data fits the distribution, a sensitivity analysis was carried out to determine how many storms to use in the analysis.

Grid Point 11028 located at 46.7°N; 48.7°W was deemed to give the most accurate depiction of conditions within the region and was used in this analysis. Since extreme values can vary depending on how well the data fits the distribution, a sensitivity analysis was carried out to determine the number of storms to use. The sensitivity analysis showed that the best fits occurs using 258 storms for winds and 270 storms for waves. This represented storms of 8 m waves and above and winds of 21.5 m/s and above. The 61 storms used in the monthly analysis corresponded to similar storm conditions during the winter months.

Figure 3.8 Annual Percentage Exceedance of Significant Wave Height at Grid Point 11028



3.1.6.1 Wind Extremes

The extreme value estimates for wind were calculated using Oceanweather's Osmosis software program for the return periods of 1-year, 10-years, 25-years, 50-years and 100-years. The calculated annual and monthly values for 1-hour, 10-minutes and 1-minute are presented in Tables 3.6, 3.7 and 3.8. The analysis used hourly mean wind values for the reference height of 10-metres above sea level. These values were converted to 10-minute and 1-minute wind values using a constant ration of 1.06 and 1.22, respectively (U.S. Geological Survey 1979). The annual 100-year extreme 1-hour wind speed was determined to be 31.4 m/s for grid point 11028. The highest extreme winds are expected to occur during February.

Table 3.6 1-hr Extreme Wind Speed Estimates (m/s) for Return Periods of 1, 10, 25, 50 and 100 Years

Month	Grid Point #11028				
	1	10	25	50	100
January	22.1	25.7	26.8	27.6	28.4
February	21.8	27.0	28.6	29.7	30.9
March	19.8	24.8	26.3	27.5	28.6
April	17.8	22.2	23.5	24.5	25.5
May	15.2	19.3	20.6	21.5	22.5
June	14.1	18.0	19.2	20.1	21.0
July	13.0	16.8	18.0	18.8	19.7
August	13.5	19.7	21.6	23.0	24.4
September	16.4	22.3	24.2	25.5	26.9
October	17.6	23.7	25.5	26.9	28.3
November	19.5	24.4	26.0	27.1	28.2
December	21.2	26.2	27.8	28.9	30.0
Annual	24.8	28.2	29.4	30.4	31.4

Table 3.7 10-minute Extreme Wind Speed (m/s) Estimates for Return Periods of 1, 10, 25, 50 and 100 Years

	Grid Point #11028				
Month	1	10	25	50	100
January	23.4	27.2	28.4	29.2	30.1
February	23.1	28.6	30.3	31.5	32.8
March	21.0	26.3	27.9	29.1	30.3
April	18.9	23.5	24.9	26.0	27.0
May	16.1	20.5	21.8	22.8	23.8
June	14.9	19.1	20.4	21.3	22.3
July	13.8	17.8	19.0	19.9	20.9
August	14.3	20.9	22.9	24.4	25.9
September	17.4	23.7	25.6	27.1	28.5
October	18.6	25.1	27.1	28.5	30.0
November	20.7	25.9	27.5	28.7	29.9
December	22.5	27.8	29.4	30.6	31.8
Annual	26.3	29.8	31.2	32.2	33.2

Table 3.8 1-minute Extreme Wind Speed (m/s) Estimates for Return Periods of 1, 10, 25, 50 and 100 Years

Month	Grid Point #11028				
	1	10	25	50	100
January	26.9	31.3	32.6	33.6	34.6
February	26.6	32.9	34.8	36.3	37.7
March	24.2	30.2	32.1	33.5	34.9
April	21.8	27.0	28.7	29.9	31.1
May	18.5	23.6	25.1	26.3	27.4
June	17.2	22.0	23.4	24.5	25.6
July	15.9	20.5	21.9	22.9	24.0
August	16.5	24.0	26.4	28.1	29.8
September	20.0	27.3	29.5	31.1	32.8
October	21.4	28.9	31.2	32.9	34.5
November	23.8	29.8	31.7	33.0	34.4
December	25.9	32.0	33.9	35.3	36.6
Annual	30.3	34.4	35.9	37.1	38.3

A comparison of these values, with actual values measured by platforms on the Grand Banks was not possible. Logarithmic profiles for adjusting wind speeds from anemometer height to the surface are valid only in neutral or unstable conditions. Observations from platforms on the Grand Banks over the past ten years frequently show stable conditions in which the surface layer wind speed profiles are not valid. Using a logarithmic profile to adjust wind speeds between the 10-metre and anemometer level would therefore introduce an unnecessary source of error in the results.

3.1.6.2 Wave Extremes

The annual and monthly extreme value estimates for significant wave height for return periods of 1-year, 10-years, 25-years, 50-years and 100-years are given in Table 3.9. The annual 100-year extreme significant wave height was 14.5 metres at grid point 11028. This significant wave height corresponds with a significant wave height of 14.66 metres recorded over a 20-minute interval by a waverider buoy in the area on February 11, 2003. A storm with a return period of 100 years means that the calculated significant wave height will occur once every 100 years, averaged over a long period of time. The value recorded on February 11, 2003 was the highest recorded significant wave height in a near continuous waverider data set extending back to early 1999. The previous highest recorded value in this data set was 12.47 metres, which occurred on January 25, 2003. The maximum significant wave heights measured during the “Ocean Ranger” storm of 1982 was approximately 12 m. If more occurrences of an event of this magnitude were observed, the calculated statistics would consequently begin to increase.

Table 3.9 Extreme Significant Wave Height Estimates for Return Periods of 1, 10, 25, 50 and 100 Years

	Grid Point #11028				
Month	**1**	**10**	**25**	**50**	**100**
January	8.6	11.4	12.3	13.0	13.6
February	8.0	11.7	12.9	13.7	14.6
March	6.8	9.8	10.7	11.4	12.1
April	5.4	8.4	9.4	10.0	10.7
May	4.4	7.0	7.8	8.4	9.0
June	3.6	5.9	6.6	7.1	7.6
July	3.3	5.3	5.9	6.4	6.8
August	3.6	6.1	6.8	7.4	8.0
September	4.9	8.7	9.9	10.7	11.6
October	6.1	9.5	10.6	11.5	12.3
November	7.2	10.1	11.0	11.7	12.4
December	8.4	11.2	12.1	12.7	13.4
Annual	10.3	12.5	13.3	13.9	14.5

The maximum individual wave heights were calculated within Oceanweather's OSMOSIS software by evaluating the Borgman integral (Borgman 1973), which was derived from a Raleigh distribution function. The maximum individual wave heights and extreme associated peak periods are presented in Table 3.10 and Table 3.11. Maximum individual wave heights and the extreme associated peak periods peak during the month of February.

During a storm event on January 08, 2007 a maximum individual wave height of 22.63 metres was recorded by a waverider in the Terra Nova field. This is similar to the 25-year return period estimate of 22.7 metres. The significant wave height during this event was 9.72 metres.

Table 3.10 Extreme Maximum Wave Height Estimates for Return Periods of 1, 10, 25, 50 and 100 Years

	Grid Point #11028				
Month	**1**	**10**	**25**	**50**	**100**
January	15.8	21.1	22.7	23.9	25.1
February	15.0	21.6	23.6	25.2	26.7
March	12.6	18.1	19.8	21.1	22.4
April	10.2	15.5	17.2	18.4	19.6
May	8.1	14.1	16.0	17.4	18.7
June	6.9	10.8	12.0	12.9	13.8
July	6.3	9.9	11.0	11.9	12.7
August	6.8	10.9	12.2	13.1	14.1
September	9.4	15.9	17.9	19.4	20.8
October	11.7	17.6	19.6	21.1	22.6
November	13.4	18.8	20.5	21.7	23.0
December	15.5	20.8	22.4	23.6	24.8
Annual	19.1	23.0	24.6	25.7	26.8

Table 3.11 Extreme Associated Peak Period Estimates for Return Periods of 1, 10, 25, 50 and 100 Years

	Grid Point #11028				
Month	**1**	**10**	**25**	**50**	**100**
January	12.4	14.1	14.6	15.0	15.3
February	12.0	14.1	14.7	15.1	15.5
March	11.5	13.1	13.5	13.8	14.1
April	10.5	12.1	12.5	12.8	13.1
May	10.0	11.7	12.1	12.4	12.7
June	8.5	10.7	11.2	11.7	12.0
July	8.2	10.7	11.3	11.8	12.3
August	8.6	11.5	12.2	12.8	13.3
September	10.4	12.9	13.5	14.0	14.4
October	11.3	13.1	13.6	13.9	14.3
November	11.8	13.3	13.7	14.0	14.2
December	12.5	14.0	14.4	14.7	14.9
Annual	13.5	14.7	15.1	15.4	15.7

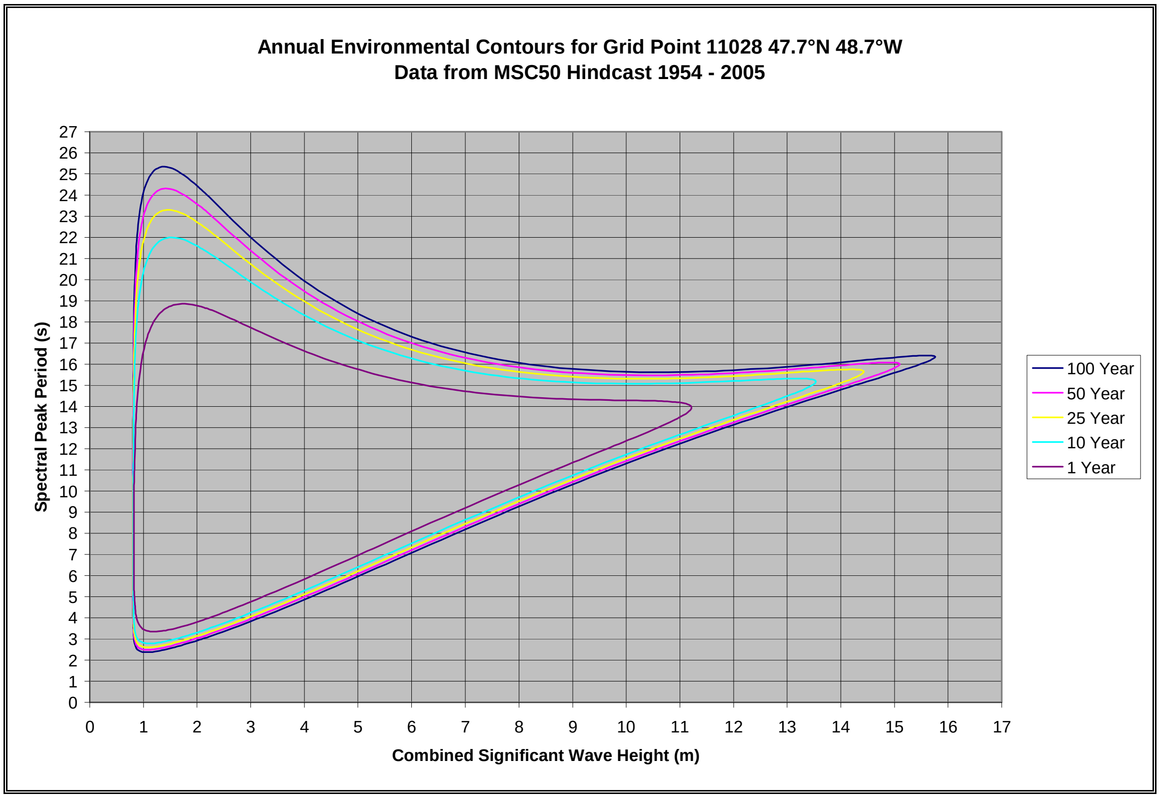
In order to examine the period ranges of storm events, an environmental contour plot was produced showing the probability of the joint occurrence of significant wave heights and the spectral peak periods using the methodology of Winterstein et al. (1993). The wave heights were fitted to a Weibull Distribution and the peak periods to a lognormal distribution using data for every 3 hours over a 51 year period. The wave data was divided into bins of 1 metre for significant wave heights and 1 second for peak periods. Since the lower wave values were having too much of an impact on the wave extremes, the wave heights below 2 m were modeled separately in a Weibull Distribution. The two Weibull curves were combined near 2 m, the point where both functions had the same probability.

A lognormal distribution was fitted to the spectral peak periods in each wave height bin. The coefficient of the lognormal distribution was calculated. Using the coefficients and the two distribution functions, the joint wave height and period combinations were calculated for the various return periods. A contour plot depicting these values for return periods of 1-year, 10-years, 25-years, 50-years and 100-years is presented in Figure 3.9. The annual values for the significant wave height estimates and the associated spectral peak periods are given in Table 3.12. The extreme wave height for all return periods, were higher using the Weibull Distribution when compared to the Gumbel Distribution. The 100-year extreme significant wave height was 16.3 metres using the Weibull Distribution as compared to 14.5 metres using the Gumbel Distribution. A 14.5 m wave corresponds to a 25-year return period using the Weibull Distribution.

Table 3.12 Annual Extreme Significant Wave Estimates and Spectral Peak Periods for Return Periods of 1, 10, 25, 50 and 100 Years

Return Period (years)	Combined Significant Wave Height (m)	Spectral Peak Period Median Value (s)
1	11.2	13.9
10	13.5	15.2
25	14.4	15.6
50	15.1	16.0
100	15.8	16.3

Figure 3.9 Annual Environmental Contour Plot for Grid Point 11028 (46.7°N 48.7°W)

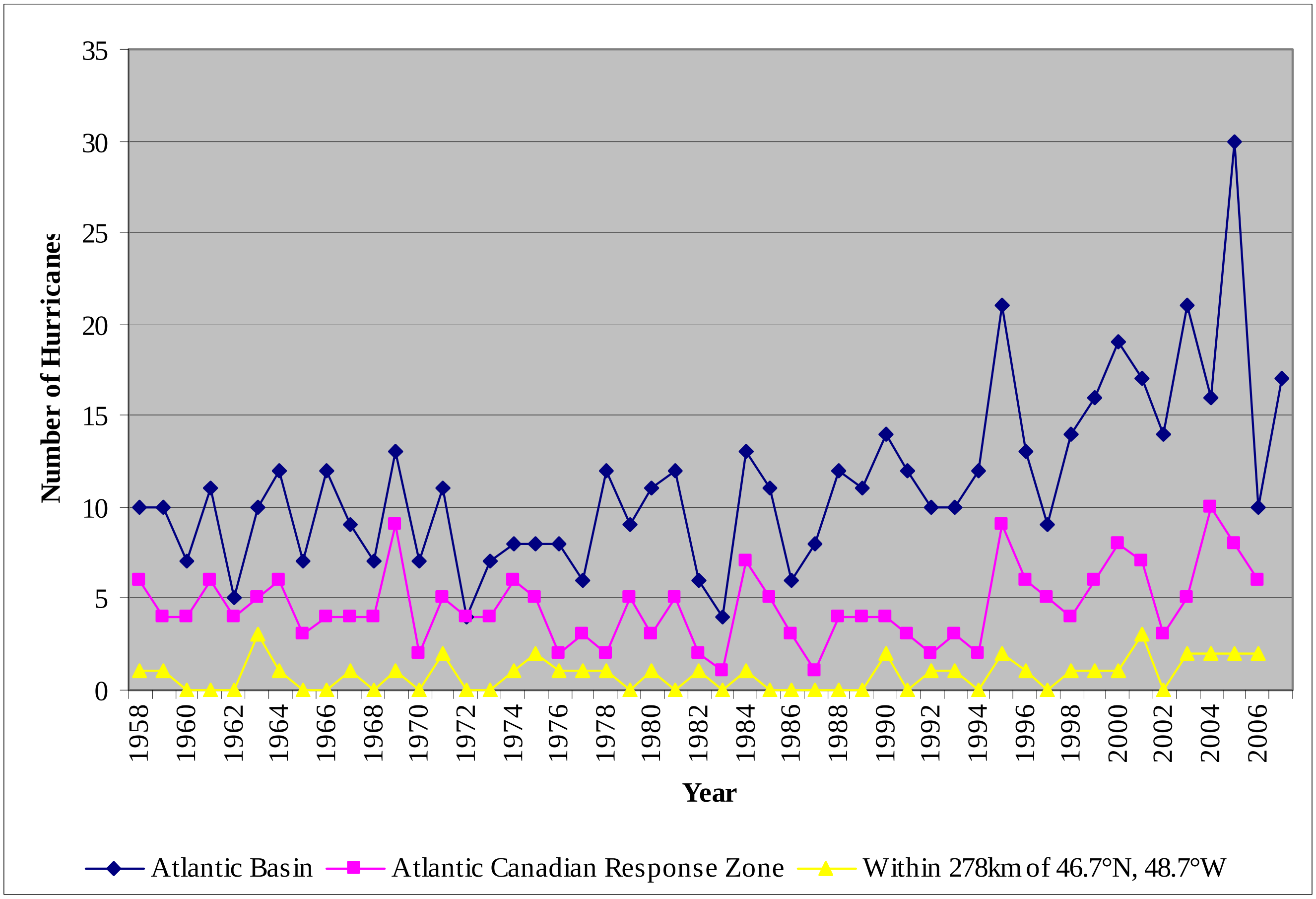


3.1.7 Tropical Systems

The hurricane season in the North Atlantic basin normally extends from June through November, although tropical storm systems occasionally occur outside this period. While the strongest winds typically occur during the winter months and are associated with mid-latitude low pressure systems, storm force winds may occur at any time of the year as a result of tropical systems. Once formed, a tropical storm or hurricane will maintain its energy as long as a sufficient supply of warm, moist air is available. Tropical storms and hurricanes obtain their energy from the latent heat of vapourization that is released during the condensation process. These systems typically move east to west over the warm water of the tropics, however, some of these systems turn northward and make their way towards Newfoundland and the Grand Banks. Since the capacity of the air to hold water vapour is dependent on temperature, as the hurricanes move northward over the colder ocean waters, they begin to lose their tropical characteristics. By the time these weakening cyclones reach Newfoundland, they are usually embedded into a mid-latitude low and their tropical characteristics are usually lost.

Since 1995 the number of hurricanes that have developed within the Atlantic Basin has been increasing as shown in Figure 3.10. This increase in activity has been attributed to naturally occurring cycles in tropical climate patterns near the equator called the tropical multi-decadal signal and typically lasts 20 to 30 years (Bell, 2006). As a result of the increase in tropical activity in the Atlantic Basin, there has also been an increase in tropical storms or their remnants entering the Canadian Hurricane Centre Response zone, and consequently, a slight increase in the number of tropical storms entering the Regional Area. It should be noted that the number of storms in 2006 and 2007 have shown a decrease with only 10 tropical storms developing in the Atlantic Basin in 2006 and 17 tropical storms in 2007. This time period is not of sufficient length however to determine whether this decrease will continue.

Figure 3.10 Frequency of Tropical Storm Development in the Atlantic Basin 1958 – 2007



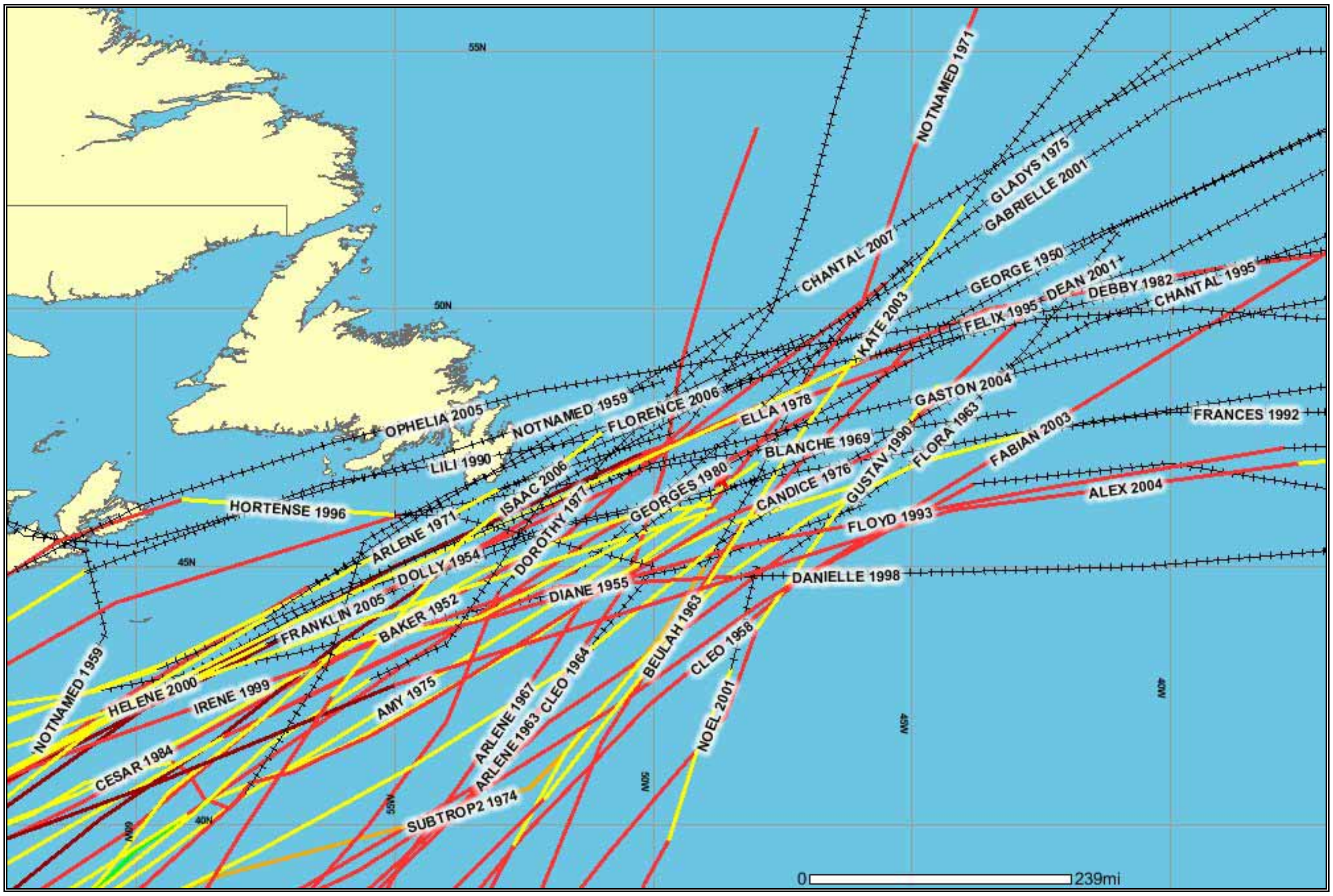
Since 1950, 46 tropical systems have passed within 278 km of 46.7°N; 48.7°W. The names are given in Table 3.13 and the tracks over the Grand Banks are shown in Figure 3.11. It must be noted that the values in the table are the maximum 1-minute mean winds speeds occurring within the tropical system at the 10-metre reference level as it passed within 278 km of the location.

On occasion, these systems still maintain their tropical characteristics when they reach Newfoundland. On October 02, 1975, Hurricane Gladys, a Category 4 hurricane as it passed east of Cape Hatteras tracked northeast towards the Grand Banks. Gladys, still a Category 2 hurricane with 43.7 m/s winds and a central pressure of 960 mb on October 03 moved northeast across the Grand Banks and maintained hurricane strength until it moved north of 50° latitude when it weakened to a post-tropical storm. As this system passed over the region, the MSC50 data set has peak winds speeds of 26.7 m/s and wave heights of 7.5 m.

Table 3.13 Tropical Systems Passing within 278 km of 46.7°N; 48.7°W, 1950 to 2006

Year	Month	Day	Hour	Name	Lat	Long	Wind (m/s)	Pressure (mb)	Category
1950	10	5	1200Z	Georges	47.0	-51.9	30.9	N/A	Post-Tropical
1952	9	8	1200Z	Baker	47.8	-49.3	30.9	N/A	Post-Tropical
1954	9	3	1200Z	Dolly	46.8	-47.4	25.7	N/A	Post-Tropical
1955	8	21	1200Z	Diane	45.0	-49.3	18.0	N/A	Post-Tropical
1958	8	20	0000Z	Cleo	44.8	-47.1	38.6	N/A	Category 1 Hurricane
1959	6	21	1200Z	NotNamed	47.3	-53.7	23.1	N/A	Post-Tropical
1963	8	11	0000Z	Arlene	42.5	-52.0	33.4	N/A	Post-Tropical
1963	8	28	0000Z	Beulah	45.8	-48.3	36.0	N/A	Category 1 Hurricane
1963	10	12	1800Z	Flora	45.2	-47.5	38.6	N/A	Post-Tropical
1964	9	4	1800Z	Cleo	46.9	-49.8	36.0	N/A	Category 1 Hurricane
1967	9	4	0600Z	Arlene	45.8	-48.6	30.9	N/A	Tropical Storm
1969	8	13	0000Z	Blance	47.1	-49.0	25.7	N/A	Post-Tropical
1971	7	7	1800Z	Arlene	46.5	-53.0	23.1	N/A	Post-Tropical
1971	8	6	1200Z	NotNamed	46.0	-49.0	38.6	974	Category 1 Hurricane
1974	7	20	0600Z	SubTropical	46.7	-48.0	20.6	N/A	Post-Tropical
1975	7	4	0600Z	Amy	44.5	-51.6	25.7	986	Tropical Storm
1975	10	3	1200Z	Gladys	46.6	-50.6	43.7	960	Category 2 Hurricane
1976	8	24	0000Z	Candice	45.9	-48.7	41.2	N/A	Category 1 Hurricane
1977	9	30	0000Z	Dorothy	47.0	-51.0	25.7	995	Post-Tropical
1978	9	5	0600Z	Ella	47.2	-50.2	41.2	975	Category 1 Hurricane
1980	9	8	1200Z	Georges	45.6	-51.1	35.0	993	Category 1 Hurricane
1982	9	19	0600Z	Debby	47.0	-50.5	38.6	979	Category 1 Hurricane
1984	9	2	1200Z	Cesar	46.0	-50.4	25.7	994	Tropical Storm
1990	9	3	0000Z	Gustav	46.0	-46.5	28.3	993	Tropical Storm
1990	10	15	0600Z	Lili	46.6	-56.4	20.6	994	Post-Tropical
1992	10	26	1800Z	Frances	46.0	-46.9	28.3	988	Tropical Storm
1993	9	10	0600Z	Floyd	45.4	-48.3	33.4	990	Category 1 Hurricane
1995	7	20	1800Z	Chantal	45.4	-48.8	25.7	1000	Post-Tropical
1995	8	22	1200Z	Felix	46.8	-50.8	25.7	985	Tropical Storm
1996	9	16	0000Z	Hortense	46.0	-54.0	20.6	998	Post-Tropical
1998	9	4	0000Z	Danielle	44.8	-48.5	33.4	975	Post-Tropical
1999	10	19	1200Z	Irene	48.0	-48.0	41.2	968	Post-Tropical
2000	9	25	1200Z	Helene	44.0	-55.5	28.3	988	Tropical Storm
2001	8	29	0000Z	Dean	47.0	-48.5	23.1	999	Post-Tropical
2001	9	20	0000Z	Gabrielle	48.5	-48.5	30.9	988	Post-Tropical
2001	11	6	1200Z	Noel	43.0	-48.5	25.7	996	Post-Tropical
2003	9	8	0000Z	Fabian	44.3	-47.9	36.0	975	Category 1 Hurricane
2003	10	7	1800Z	Kate	47.5	-47.2	30.9	980	Tropical Storm
2004	8	6	0000Z	Alex	44.5	-49.3	38.6	978	Category 1 Hurricane
2004	9	2	0000Z	Gaston	47.0	-50.0	23.1	997	Post-Tropical
2005	7	30	1800Z	Franklin	46.4	-48.8	20.6	1006	Post-Tropical
2005	9	19	0600Z	Ophelia	49.0	-48.8	23.1	1001	Post-Tropical
2006	9	14	0000Z	Florence	47.6	-51.3	33.4	965	Post-Tropical
2006	10	3	0000Z	Isaac	47.6	-51.0	28.3	996	Post-Tropical
2007	8	1	1800Z	Chantal	49.0	-49.5	30.9	988	Post-Tropical

Figure 3.11 Storm Tracks of Tropical Systems Passing within 278 km of 46.7°N; 48.7°W, 1950 to 2006



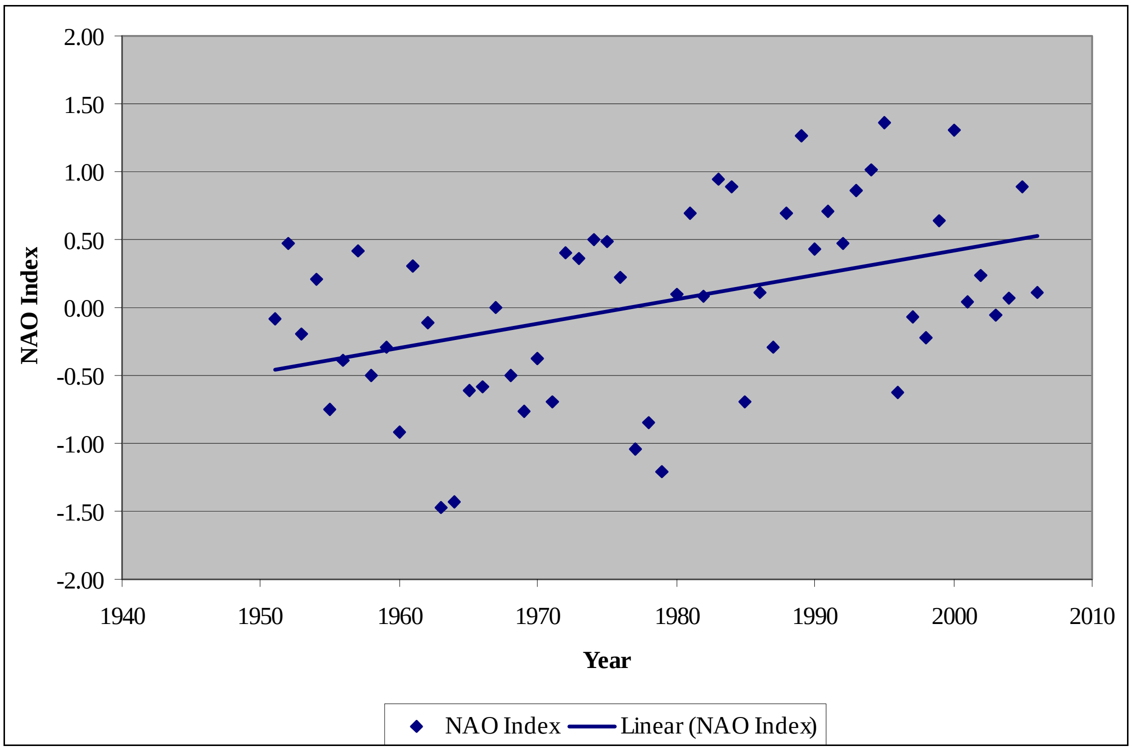
3.1.8 Climate Variability

Climate is naturally variable and can change over a range of time scales from the very short term, to seasonally, and to longer time periods in response to small and large-scale changes of atmospheric circulation patterns. Short-term meteorological variations are largely a consequence of the passage of synoptic scale weather systems: low pressure systems, high pressure systems, troughs and ridges. The energetics of these features varies seasonally in accordance with the changes in the strength of the mean tropical - polar temperature gradient. Long-term changes occur in response to small and large-scale changes of atmospheric circulation patterns and in the past in the Northern Hemisphere were mainly the result of changes in the North Atlantic Oscillation (NAO). While the NAO still has an effect on climate patterns, there is a general consensus amongst the scientific community that greenhouse gas (GHG) emissions have played a significant role in the climate during the last 50 years. However, the high degree of natural variation in climate makes it difficult to identify, with any degree of certainty, trends that are a direct result of climate change (Environment Canada 1997).

The dominate features of the mean sea level pressure pattern in the North Atlantic Ocean are the semi-permanent area of relatively low pressure in the vicinity of Iceland and the sub-tropical high pressure region near the Azores. The relative strengths of these two systems control the strength and direction of westerly winds and storm tracks in the North Atlantic and therefore play a significant role in the climate of the North Atlantic. The fluctuating pressure difference between these two features is known as the NAO.

A measure of the North Atlantic Oscillation is the NAO Index, which is the normalized difference in pressure between the Icelandic low and the Azores high. A large difference in pressure results in a positive NAO Index and can be the result of a stronger than normal subtropical high, a deeper than normal sub-polar low, or a combination of both. A time-series of the Winter (DJF) North Atlantic Oscillation Index is presented in Figure 3.12 and shows that during the period of 1950 – 2006 there is a general trend towards increasing NAO Index indicating that in recent years either the Icelandic low is deeper or the Azores high is stronger than on average. This trend is also present in the Summer North Atlantic Oscillation index, albeit significantly weaker.

Figure 3.12 Winter North Atlantic Oscillation Index (1950 - 2006)

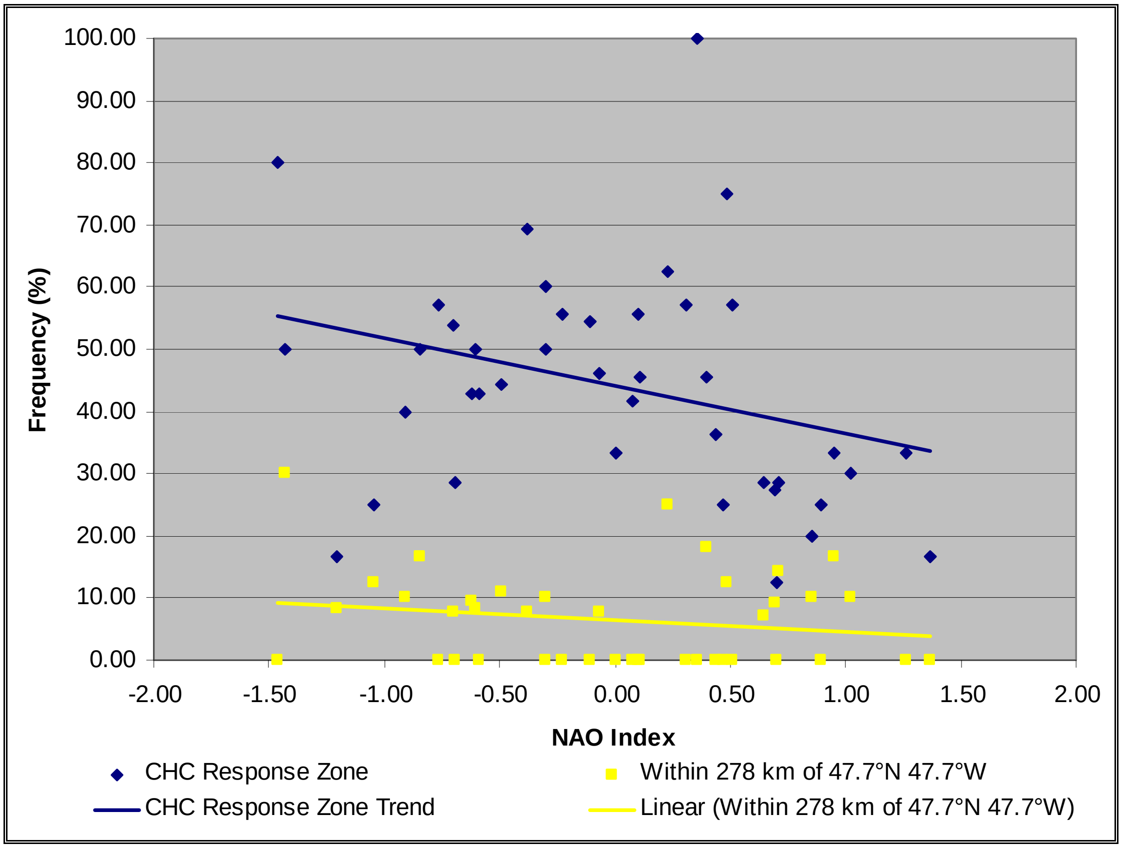


In general, over the Northwest Atlantic during the winter season, a positive NAO index brings with it an increase in frequency and strength of westerly winds in the upper atmosphere, which tends to steer storm systems in a more west to east direction. As a result, a positive NAO index results in an increase in storm systems coming off of the continent resulting in colder temperatures, increased precipitation, and relatively stronger winds. Due to the weaker trend in NAO index and other atmospheric patterns, conclusions could not be drawn about correlations between summer NAO indices and temperature, precipitation and winds during the summer months.

During the summer months, the NAO index has a less direct effect on the climate of Eastern Canada; however studies have shown that the NAO has an effect on the track of hurricanes in the North Atlantic. During seasons with a negative NAO index, hurricanes tend to favour a track that parallels lines of latitude often ending up in the Gulf of Mexico and the Caribbean (Elsner, 2003), while during seasons with a positive NAO index, hurricanes tend to curve northward (Elsner & Bosak 2004) along the United States Eastern Seaboard. An analysis of the number of tropical storms entering the Canadian

Hurricane Centre Response Zone however shows that tropical storm frequency decreases with increasing summer NAO index (Figure 3.13). Likewise, the number of tropical storms coming within 278 km of the Project Area also decreases during summers with positive NAO index.

Figure 3.13 Frequency of Atlantic Basin Storms entering the Canadian Hurricane Centre Response Zone against Summer NAO Index

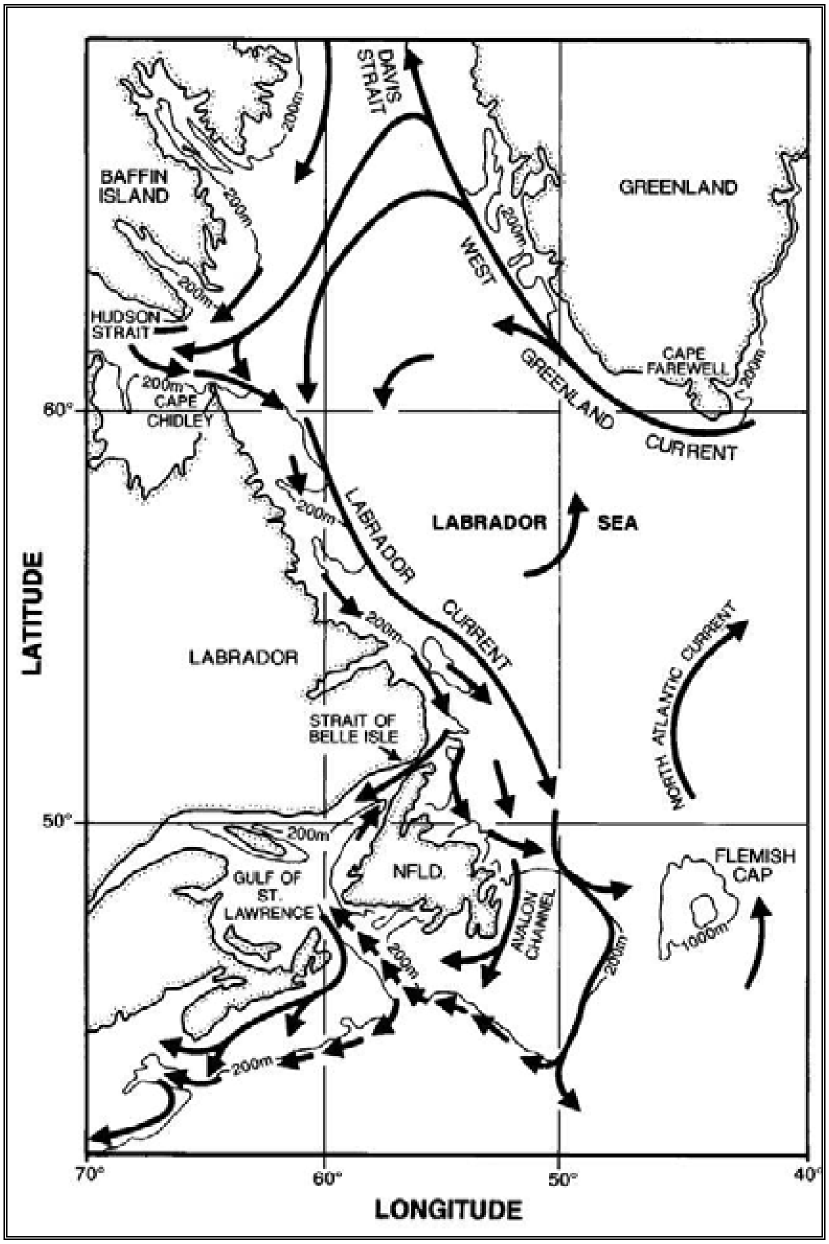


3.2 Oceanography

3.2.1 General Description of the Major Currents

The large scale circulation offshore Newfoundland and Labrador is dominated by well established currents that flow along the margins of the Continental Shelf. The main circulatory feature near the Project is the Labrador Current, which transports sub-polar water to lower latitudes along the Continental Shelf of eastern Canada (Figure 3.14). Oceanographic studies show a strong western boundary current following the shelf break with relative low variability compared to the mean flow. Over the Grand Banks a weaker current system is observed where the variability often exceeds that of the mean flow (Colbourne 2000).

Figure 3.14 Mayor Ocean Circulation Features in the Northwest Atlantic



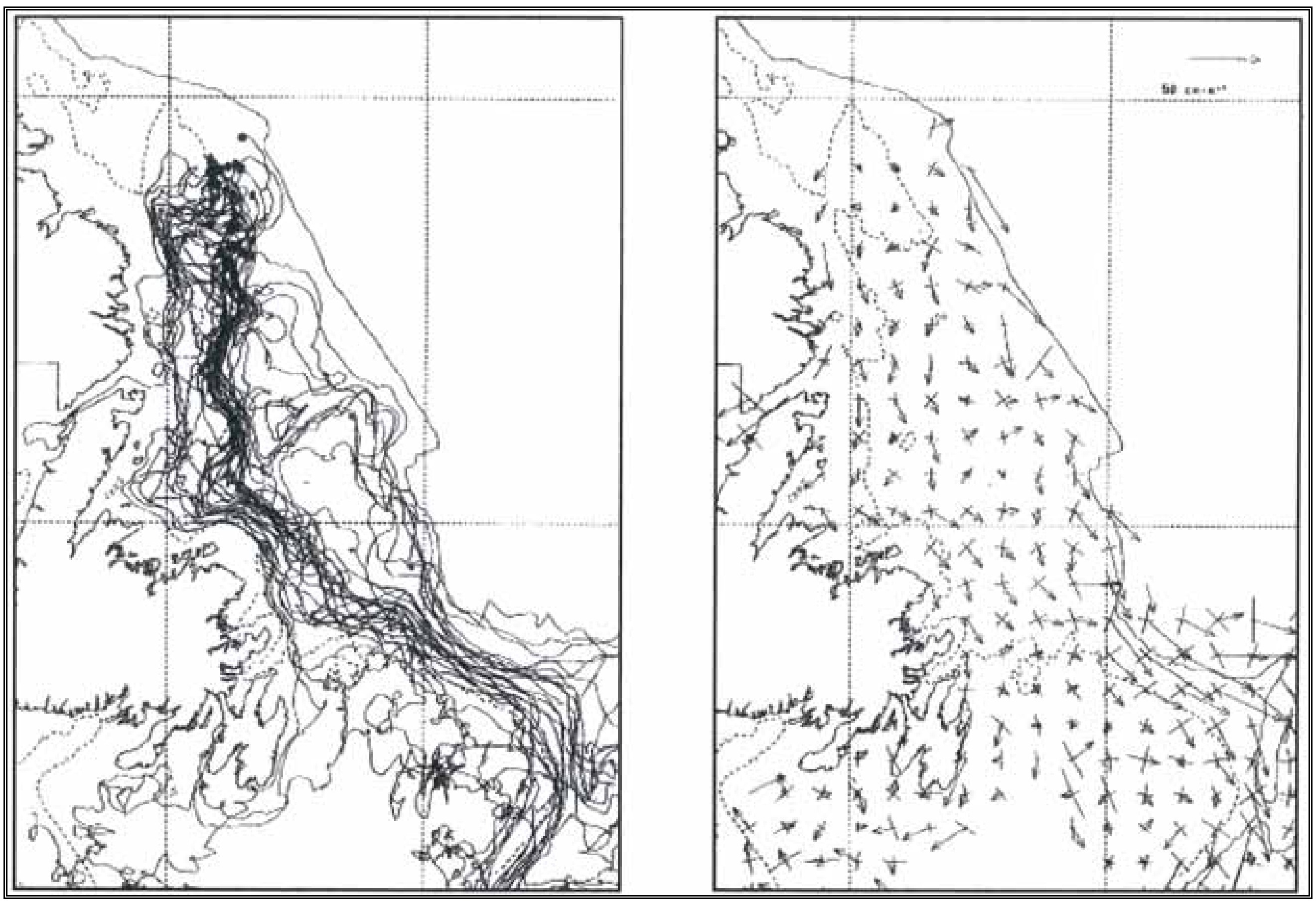
Source: Colbourne et al., 1997

The Labrador Current consists of two major branches. The inshore branch is located on the inner part of the shelf and its core is steered by the local underwater topography through the Avalon Channel. The stronger offshore branch flows along the shelf break over the upper portion of the Continental Slope. Lauzier and Wright (1993) found that the offshore branch of the Labrador Current offshore Labrador was located in a 50 km wide band between the 400 m and 1200 m isobaths. This branch of the Labrador Current divides between 48°W and 50°W, resulting in one sub-branch flowing to the east around the Flemish Cap and the other flowing south around the eastern edge of the Grand Banks and through the Flemish Pass. Characteristic current speeds on the Slope are in the order of 30 cm/sec to 50 cm/sec (Colbourne 2000), while those in the central part of the Grand Banks are generally much lower, averaging between 5-15 cm/sec.

The outer branch of the Labrador Current exhibits a distinct seasonal variation in flow speeds (Lazier and Wright 1993), in which the mean flows is a maximum in October and a minimum in March and April. This annual cycle is reported to be the result of the large annual variation in the steric height over the continental shelf in relation to the much less variable internal density characteristic of the adjoining deep waters. The additional freshwater in spring and summer is largely confined to the waters over the shelf. In summer, the difference in sea level between the shelf and open ocean is 0.09 m greater than in winter (Lazier and Wright 1993). This difference produces a greater horizontal surface pressure gradient and hence stronger mean flows.

Figure 3.15 shows the trajectories and mean current velocities calculated by Pepin and Helbig (1997) of 41 satellite tracked drifting buoys that were placed in the Labrador Current near Hamilton Bank during 1992 and 1994. This figure illustrates the general pattern of the spatial distribution of the surface currents in the northeast sector of the Newfoundland Shelf.

Figure 3.15 Currents on the Northeast Newfoundland Shelf as Inferred from 149 Drifting Buoys by Pepin and Helbig (1997)



Left Panel: Low-pass-filtered drifting buoys tracks. Drop locations are indicated by circles and terminal positions by asterisks.
Right Panel: Mean surface currents derived from spatial averages of all drifting buoy tracks. The principal axes of variation are indicated by crosses.

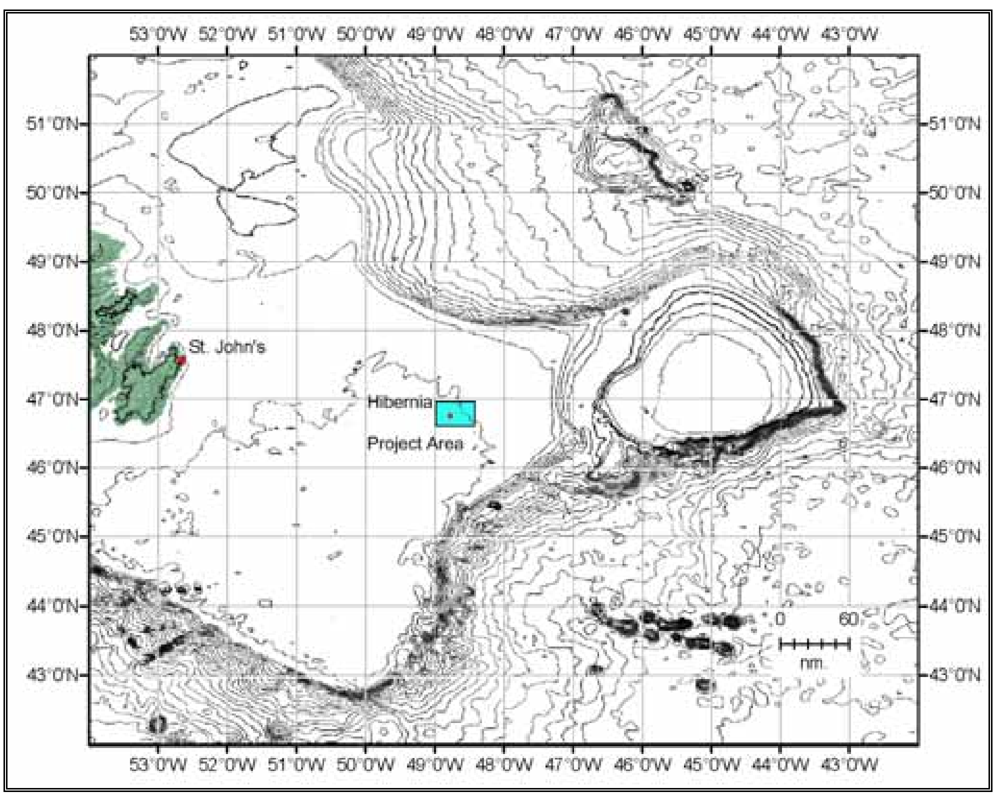
Another major current system is situated to the south of the Grand Banks. In the area of the Southeast Newfoundland Rise, the Gulf Stream branches into two streams. The southern branch continues east at approximately 40°N. The northern branch, known as the North Atlantic Current, turns north and flows along the Continental Slope southeast of the Grand Banks and continues north-eastward along the east side of Flemish Cap.

Wind stress is an important driving force for the currents on the Continental Shelf, with a distinct annual cycle of comparatively strong winds in winter and weaker, more variable winds in summer. The analysis of an array of current meter data collected from January to May 1992 by De Tracey et al. (1996) shows that near-surface currents and local wind are highly coherent in the interior of the shallow region of the Grand Banks, which suggests that the currents have a strong wind driven component. In this area the currents are weak (a few centimetres per second) with a variability much larger (5 to 15 cm/s) than the mean velocities. Near the 200 m contour on the Northeast Newfoundland Shelf, the coherence between wind stress and the barotropic current was insignificant suggesting that local wind was not a major source contributing to the current flow. De Tracey et al. (1996) suggested that currents over the shelf edge are generated by mechanisms other than direct wind forcing and postulates that the major causes of the observed low-frequency currents may be meandering of the Labrador Current, eddy formation, and shelf wave propagations.

3.2.2 Currents in the Project Area

Hibernia and the Project Area are located on the shallow section of the Grand Banks where the water depth is less than 100 m (Figure 3.16). The majority of the moored current meter data at Hibernia was collected from 1980 to 1984 during exploration drilling. Five additional data sets obtained from the archive at the Bedford Institute of Oceanography (BIO) were included. Surface currents are continuously measured at the Hibernia platform by a MIROS Directional Wave and Currents Radar. Information on surface currents for years 2003 to 2007 are included in this report.

Figure 3.16 Location of Project Area



Tides play a major role in the currents on the Grand Banks. The semi-diurnal tidal currents rotate through 360° twice per day in a clockwise direction. The diurnal tidal ellipses at Terra Nova are almost circular showing no preferred direction, and the semidiurnal tidal ellipses are slightly elongated in a northwest/southeast direction. Overall, the tidal currents at Terra Nova are responsible for about 30% of the variability near the surface and at mid-depth, and for 20% of the variability near the bottom.

Wind stress is another important driving force for the currents on the Grand Banks, with a distinct annual cycle of comparatively strong winds in winter and weaker more variable winds in summer.

The low frequency components are the most important contributor to the overall flow. The strongest currents have been observed to always occur during the passage of low pressure systems. Some of the flow can be attributed to direct effects of the wind stress upon the sea surface as indicated by an inertial period signal showing up in spectral analysis of the data. Spectral analysis shows that the low frequency components are in the period range of 4 to 7 days. The barotropic component appears to be the largest component of the strong flows.

Tables 3.14 to 3.16 present current values at Hibernia measured 20 m below the surface, at mid-depth, and at 10 m above the bottom. Tables 3.14 to 3.16 present mean speeds, mean velocities, and maximum speeds and directions for each month. The mean current speed varied between 13.5 cm/s to 21.3 cm/s near the surface, between 10.9 cm/s to 20.2 cm/s at mid-depth, and between 11.0 cm/s to 15.3 cm/s near bottom. The magnitude of the mean velocity was very low at all depths due to the high degree of variability. The mean velocity tends to be directed in a southerly direction between south and southwest at all depths. The maximum current speeds reached 127 cm/s in September in near surface waters, 119 cm/s in November at mid-depth, and 72 cm/s in November near the bottom.

Table 3.14 Near-surface (20 m) Currents at Hibernia (1980-1984)

Month	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction (°T)	Max Speed (cm/s)	Direction (°T)
January	21.05	6.16	SSW	67.00	193
February	18.05	4.76	SSW	59.00	179;199
March	14.63	0.62	SSW	47.00	312
April	14.55	0.67	NE	114.00	264
May	13.54	2.37	S	44.00	182
June	13.90	4.73	S	59.00	134
July	13.78	5.53	S	50.00	118
August	15.36	4.97	S	74.00	347
September	15.91	3.83	SSW	127.00	204
October	18.58	4.19	SSW	68.00	233;292
November	21.33	5.58	SSW	74.00	216
December	20.28	7.92	SSW	59.00	154;182

Table 3.15 Mid-depth Currents at Hibernia (1980-1984)

Month	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction (°T)	Max Speed (cm/s)	Direction (°T)
January	18.04	4.99	SSW	48.00	199
February	15.75	3.94	SSW	61.00	314
March	13.17	0.97	SSW	54.00	220
April	13.59	1.19	NE	54.00	172
May	11.89	1.50	SSW	38.00	181
June	10.91	3.09	SSW	75.00	151
July	12.80	5.56	SW	44.00	237
August	12.66	3.44	SW	40.00	221
September	14.83	3.03	SW	59.00	217
October	16.54	3.67	SSW	57.00	213
November	19.01	4.71	SW	119.00	88
December	20.24	7.59	SSW	78.00	219;238

Table 3.16 Near-bottom Currents at Hibernia (1960-1984)

Month	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction (°T)	Max Speed (cm/s)	Direction (°T)
January	14.17	4.12	SSW	39.00	222
February	14.33	3.66	SSW	57.00	181;315
March	12.79	0.73	SSW	46.00	265
April	11.88	0.11	SW	30.00	37
May	11.02	1.76	SW	32.00	229
June	11.32	3.46	SW	36.00	248
July	11.12	4.60	SW	36.00	240
August	11.00	3.35	SW	33.00	239
September	11.65	2.33	SW	56.00	307
October	13.06	2.35	SW	36.00	350
November	15.25	3.80	SW	72.00	199
December	15.18	5.98	SSW	57.00	137

3.2.3 Water Properties in the Project Area

Temperatures and salinity data for the Project Area was acquired from BIO and used to produce statistics, T-S diagrams and contour plots. Tables 3.17 and 3.18 show the mean, minimum and maximum values for temperature and salinity, respectively, on a monthly basis for the surface waters and for depths of 50 m and 100 m. The majority of the data is for months of April to July and October to December. There is no data for January, February, and March and only a few observations for August and September.

The data in Table 3.17 shows that the warmest temperatures near the surface are between July and September with mean temperatures ranging between 10.3°C to 11.7°C. The coldest temperatures are normally in March on the Grand Banks. The mean salinities ranged between 31.9 psu in September and 32.8 psu in April.

At a depth of 50 m, the mean temperatures ranged between -0.6°C to 2.1°C in August. At a depth of 100 m, the mean temperatures were always negative ranging between -1.4°C in September to -0.3°C in July. The mean salinities varied between 32.7 psu in December to 32.9 psu in April and October at a depth of 50 m, and between 33.1 psu in May to 33.4 psu in December at a depth of 100 m.

Table 3.17 Temperature Statistics for the Surface and Depths of 50 m and 100 m

Month	Depth (m)	No. of observations	Minimum (°C)	Maximum (°C)	Mean (°C)
January	-	-	-	-	-
February	-	-	-	-	-
March	-	-	-	-	-
April	0	58	-0.69	3.13	0.40
	50	144	-1.67	1.07	-0.23
	100	52	-1.58	0.84	-0.34
May	0	26	0.41	3.59	2.00
	50	286	-1.63	2.84	1.53
	100	42	-1.52	-0.02	-0.84
June	0	277	2.90	8.10	5.60
	50	810	-0.85	3.65	0.87
	100	59	-1.34	0.40	-0.34
July	0	192	5.05	14.21	10.26
	50	402	-1.47	3.95	0.61
	100	208	-1.44	0.37	-0.28
August	0	2	11.63	11.84	11.73
	50	11	-0.67	3.88	2.08
	100	6	-0.85	-0.45	-0.74
September	0	13	9.11	11.53	10.51
	50	17	-1.46	0.76	-0.61
	100	5	-1.49	-1.34	-1.39
October	0	15	6.83	11.77	8.64
	50	240	-1.10	2.19	-0.50
	100	14	-1.33	-1.10	-1.16
November	0	48	3.35	9.80	6.05
	50	108	-1.21	6.39	1.05
	100	75	-1.06	0.51	-0.47
December	0	30	1.27	4.06	2.46
	50	67	-0.93	4.97	1.54
	100	26	-0.99	0.32	-0.33

Table 3.18 Salinity Statistics for the Surface and Depth of 50 m and 100m

	Depth (m)	No. of observations	Minimum (psu)	Maximum (psu)	Mean (psu)
January	-	-	-	-	-
February	-	-	-	-	-
March	-	-	-	-	-
April	0	58	32.23	33.02	32.83
	50	144	32.71	33.28	32.90
	100	52	32.92	33.66	33.25
May	0	26	31.87	32.77	32.52
	50	286	32.66	33.97	32.77
	100	42	32.91	33.24	33.11
June	0	277	30.11	33.68	32.57
	50	810	32.50	33.89	32.82
	100	59	32.84	33.44	33.21
July	0	192	31.89	32.67	32.43
	50	402	32.46	33.93	32.89
	100	208	32.93	33.42	33.22

	Depth (m)	No. of observations	Minimum (psu)	Maximum (psu)	Mean (psu)
August	0	2	32.04	32.09	32.07
	50	11	32.62	32.99	32.71
	100	6	33.03	33.31	33.13
September	0	13	31.70	32.09	31.90
	50	17	32.60	33.12	32.87
	100	5	33.04	33.42	33.27
October	0	15	30.28	32.40	31.93
	50	240	32.55	33.06	32.90
	100	14	33.03	33.24	33.17
November	0	48	31.67	32.52	32.16
	50	108	32.11	33.35	32.84
	100	75	32.95	33.81	33.27
December	0	30	32.13	32.91	32.44
	50	67	32.02	33.33	32.70
	100	26	33.16	33.62	33.43

Contour plots of the mean temperature and salinity with depth are shown in Figures 3.17 and 3.18 for months of April to December.

In summer and fall the water is stratified to a depth of 50 m. Below 50 m the water is less stratified and shows negative temperatures at 100 m, within the core of the Cold Intermediate Layer. In winter and spring, the water between the surface and 50 m is less stratified than during summer and fall. Between 50 m and 100 m the water is more stratified during winter than during the other seasons.

Figure 3.17 Contour Plot of Monthly Temperature Data at Hibernia

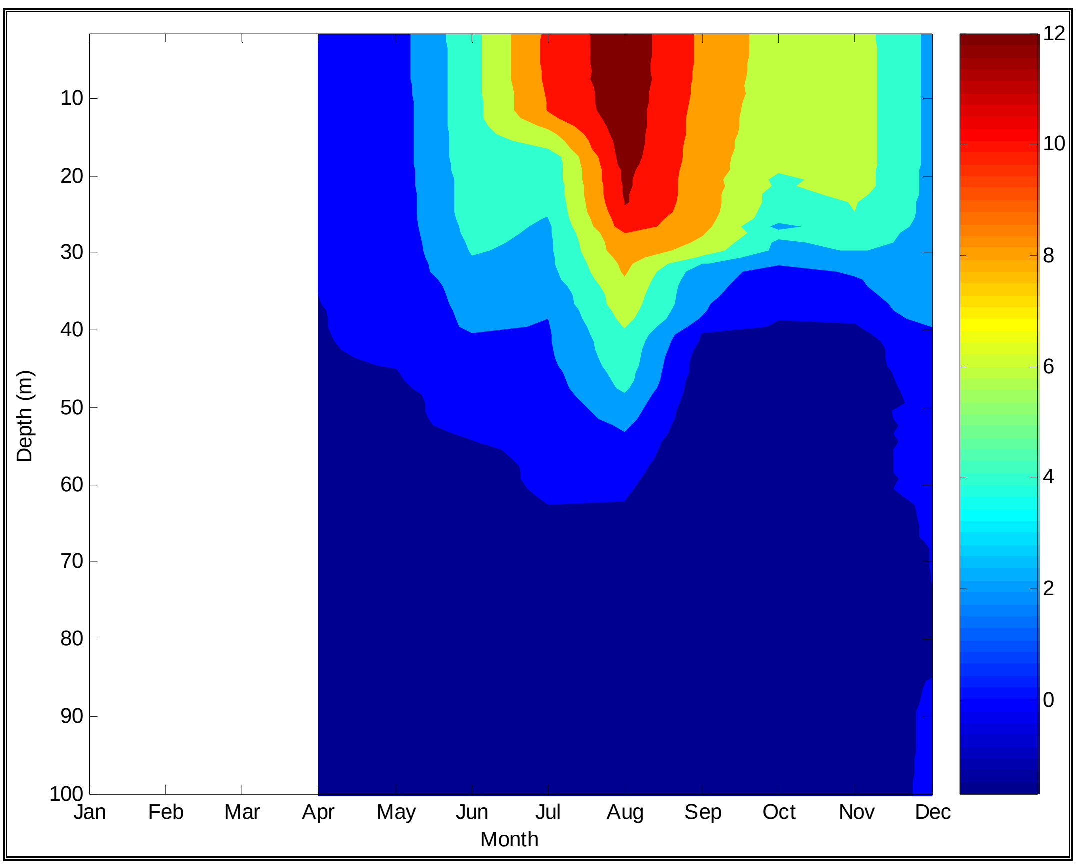
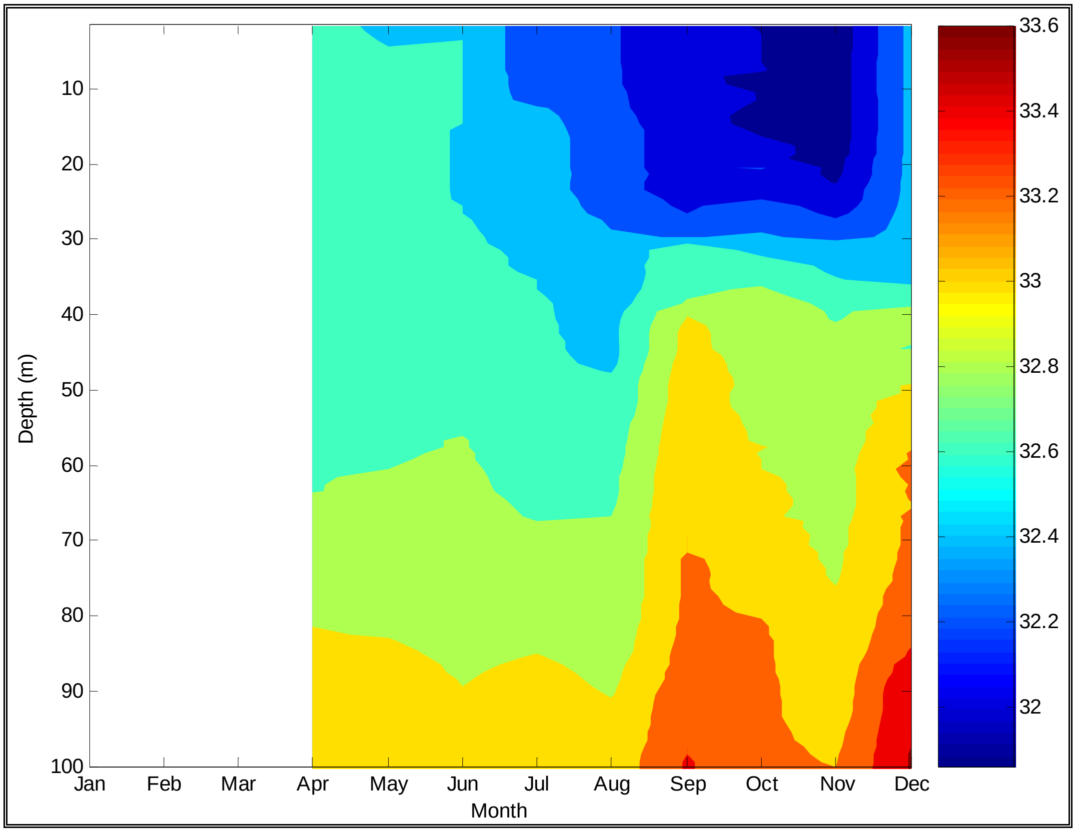


Figure 3.18 Contour Plot of Monthly Salinity Data



3.2.3.1 Water Mass Structure

The water structure on the Grand Banks of Newfoundland is characterized by the presence of several identifiable features. The first identifiable feature is the surface layer which is exposed to interaction with the atmosphere, and experiences temperature variations from sub zero values in January and February to above 15°C in summer and early fall. Salinity at this layer is strongly impacted by wave action and local precipitations. Considering that a water mass is a body of water which retains its well defined physical properties, over a long time period, the surface layer of variable temperature and salinity is usually left out of a water mass analysis for a particular region. During the summer, the stratified surface layer can extend to a depth of 40 m or more. In winter, the stratification in the surface layer disappears and becomes well mixed due to atmospheric cooling and intense mixing processes from wave action.

A second element of the thermohaline structure on the Grand Banks is the Cold Intermediate Layer (Petrie et al., 1988). In areas where the water is deep enough, this layer of cold water is trapped during summer between the seasonally heated upper layer and warmer slope water near the seabed (Colbourne, 2002). Its temperatures range from less than -1.5°C to 0°C (Petrie and al., 1988; Colbourne et al., 1996) and salinities vary within 32 and 33 psu. It can reach a maximum vertical extent of over 200 m (Colbourne, 2004). The Cold Intermediate Layer is the residual cold layer that occurs from late spring to fall and is composed of cold waters formed during the previous winter season. It becomes isolated from the sea surface by the formation of the warm surface layer during summer, and disappears again during late fall and winter due to the intense mixing processes that take place in the surface layer from strong winds, high waves and atmospheric cooling. In winter the two layer structure is replaced by a mixed cold body of water which occupies the entire water column.

3.2.3.2 Water Chemistry

A water column chemistry component was added to the Hibernia EEM in 2004 and 2007 to sample locations potentially affected by the discharge of produced water. The 2004 and 2007 water chemistry program validated dilution ratios that were predicted to occur within 50 m of the discharge point as per produced water modelling (Lorax Environmental 2004). The observed elevated parameters are localized adjacent to the produced water discharge area (essentially within 50 m from the discharge point). This finding is in agreement with results of other international produced water monitoring programs.

In 2007, concentrations of arsenic, copper, and iron were detected in all 52 water column samples collected from both the Hibernia and the reference stations. Chromium was detected in some samples from Hibernia and the reference locations. Manganese, nickel, zinc and mercury were not detected in all samples from Hibernia. When detected, the concentrations of these metals were generally low and did not vary considerably when compared to concentrations at the reference locations. None of the measured metal concentrations in sea water samples collected from either Hibernia or reference locations exceeded the CCME marine water guidelines of Environment Canada (CCME 2003), with the exception of mercury. Sampling stations located 22 to 33 m from the platform did have mercury concentrations of 0.02 µg/L which is marginally above the CCME guideline of 0.016 µg/L.

Water column samples near Hibernia contained mostly the lighter fraction of hydrocarbons (i.e., benzene, toluene, ethylbenzene and xylenes (BTEX)), and C6-C10 hydrocarbon range (less BTEX). Fuel range hydrocarbons (C10-C21) were detected in 5 out of the 52 water column samples at Hibernia, marginally above the detectable limit of 0.05 mg/L. Lube range hydrocarbons (C21-C32) were detected in only one water column sample from Hibernia, at the detection limit of 0.1 mg/L. Hydrocarbons were not reported in water samples from stations at 100 m and 200 m from the GBS, nor from the reference locations.

Some concentrations of PAHs were detectable in water column samples from Hibernia, most notably phenanthrene, at very low concentrations (mean of 0.03 µg/L compared to the RDL of 0.01 µg/L). The measured concentrations of phenanthrene were in the range of 0.01 to 0.09 µg/L (parts per trillion range). It is worth noting that this PAH was also detected in the water column in one of the reference location samples, at a similar average concentration of 0.03 µg/L. Other PAHs detected in some samples at very low levels near Hibernia were 1-methylnaphthalene, 2-methylnaphthalene, acenaphthene, fluorene, and naphthalene.

The reported range for suspended particulate matter in the Grand Banks water column is 0.01 to 2.77 mg/L and is within ranges reported for other ocean environments (MacKnight et al. 1981 in Mobil Oil 1985). Water samples collected at the Terra Nova oilfield indicate that total suspended solids is homogeneous throughout the water column, with a mean value of 1.79 ± 0.37 mg/L at the surface, 1.9 ± 0.46 mg/L at mid-depth and 1.93 ± 0.65 mg/L near the bottom (Petro-Canada 2003).

3.3 Sea Ice and Icebergs

The mean annual number of icebergs within the ice monitoring zone around the Hibernia platform is 54 based on the past 26 years of data and 45 icebergs per year since the GBS was installed in 1997. However, there are large seasonal variations in the numbers of icebergs each year. There have been several years where no icebergs were recorded within the ice monitoring zone. On average, 1 in every 4 years are iceberg free (P. Rudkin, pers. comm.).

Pack ice incursions into the ice monitoring zone around Hibernia have been recorded in two years (2003 and 2008) since the installation of the Platform (P. Rudkin, pers. comm.).

Icebergs can have drafts larger than 150 m in off-shelf areas, but while in on-shelf areas, icebergs drafts are restricted to 20 to 100 m because of water depth. For water depths less than 100 m the mean iceberg mass was 125,000 tonnes (LGL 2008b). Iceberg drift speeds in the area show a correlation with sub-surface currents. Iceberg drift speeds measured from various drilling operations on the Grand Banks show speeds ranging from 0 to 1.3m/s, with a mean drift speed equal to 0.3 m/s (LGL 2008b).

Iceberg scours are continuous or interrupted gouges and pits along the sea floor created when icebergs whose drafts exceed water depth. Icebergs often become grounded in the seabed when this occurs.

3.3.1 2008 Ice Season

In 2008, the pack ice reached the White Rose oil field on the 1st of April and remained until April 26th. The pack consisted of 20% - 80% ice cover of thin and medium first-year ice with thickness up to 150 cm.

The iceberg distribution over the 2008 season was heavy. The first iceberg of the 2008 season was tracked on March 22, 2008 and the last iceberg was tracked on April 28, 2008. The ice season was officially closed on June 27th, 2008. During that time, 82 icebergs were tracked, of those, 28 required management operations.

Management operations were split between the iceberg net (34%) and single vessel rope tows (34%). The water cannon were used on 21% of the management operations while prop-washing accounted for the remaining 11 percent.

Due to the amount of pack ice and icebergs in the vicinity of the White Rose field, the Sea Rose FPSO experienced some periods of production shut in related to risk mitigation and focusing on icebergs embedded in the pack ice. The GSF Grand Banks was moved off location on account of approaching pack ice.

Hibernia and Terra Nova recorded no downtime related to ice over the 2008 ice season. Hibernia has never had to interrupt operations due to iceberg threats. All icebergs that were identified and required activation of the Hibernia Ice Management Plan were able to be managed (i.e. deflected) without having to implement emergency response procedures (i.e., OLS system flushing and/or shut-in of production and drilling).

During the 2008 ice season 59 ice reconnaissance flights by Provincial Aerospace were flown totaling over 300 hours. In addition, the Ice Centre also received data from 18 ice reconnaissance missions flown by the International Ice Patrol, 22 missions flown by Canadian Ice Services and 5 synergistic surveillance missions flown by the Fisheries and Oceans Canada, Canadian Coast Guard, and the Department of Defense.

3.3.2 Recent Past Ice Seasons

The pack ice cover over the 2004/05 season was light, although not as light as the 2003/04 season. The maximum southerly extent of the pack occurred on March 14th, which is typical of the maximum extent of pack ice over the past thirty years. The pack ice was 51 miles northwest of Hibernia and consisted of only 40 percent ice cover. The 2005 season opened February 28th as the pack encroached on the top of the Banks and closed with the last iceberg being dropped from the tracking system 07 April 2005. Over those 38 days a total of 1 iceberg was tracked, its course did not require any management operations.

In 2006, the season did not officially open, as no ice (of any form) crossed south of 48° N. While this is an unusual situation, it is not without equal. The 1966 ice season also saw no ice recorded south of 48N and again in 1999 and 2005 only one iceberg was recorded below 48N. Based on the icebergs recorded, the 2006 iceberg season equals the lightest year on record and active ice management operations were not required.

The pack ice cover over the 2007 season was typical when compared to previous years. The maximum southerly extent of the pack was reached on March 14th when it was 82 miles northwest of Hibernia and consisting of 50 percent ice cover. The iceberg distribution over the 2007 season was moderate. The season was opened on the 23rd of February and closed July 27, 2007. Over the course of the 155 day season, a total of 11 icebergs were tracked, of those, 7 required management operations. The most common management operation (82%) was either an iceberg net or a single vessel tow. The water cannon was used on two operations during this season, which is equivalent to 12% of the total operations. Ice management operations were successful with no downtime related to ice.

Tables 3.19 and 3.20 summarize the size of icebergs encountered and the management methods used in recent years.

Table 3.19 Iceberg Size Distribution 2006, 2007 and 2008

Category	Number Tracked			Percentage of Total		
	2008	2007	2006	2008	2007	2006
Large	4	1	0	5%	9%	N/A
Medium	11	0	0	13%	0%	N/A
Small	51	8	0	62%	73%	N/A
Bergy Bit / Growler	8	2	0	10%	18%	N/A
Not Reported	8	0	0	10%	0%	N/A

Table 3.20 Management Method Summary 2006, 2007 and 2008

Tow Method	Number Managed			Percent of Total		
	2008	2007	2006	2008	2007	2006
Rope Tows	13	7	0	34%	41%	N/A
Water Cannon Deflections	8	3	0	21%	18%	N/A
Prop-Washing	4	0	0	11%	0%	N/A
Two Vessel Rope Tow	0	0	0	0%	0%	N/A
Net	13	7	0	34%	41%	N/A

The 2003 ice season tracked and managed the most icebergs of the previous seven years with 261 icebergs tracked and 68 icebergs requiring management operations (Table 3.21). Some icebergs may require more than one type of management operation. For example, if the water cannon management operation is not successful in deflecting the iceberg, the iceberg may have to be towed by a support vessel using an iceberg net or tow rope.

Table 3.21 Number of Icebergs Tracked and Managed from 2002 to 2008

Year	Number of Icebergs Tracked	Number of Management Operations	Number of Icebergs Requiring Management
2008	82	38	28
2007	11	17	7
2006	0	0	0
2005	1	0	0
2004	18	10	5
2003	261	106	68
2002	100	37	21

For more detail on ice and icebergs within the Jeanne d'Arc Basin, please see Section 4.4 of the Statoil Drilling EA (LGL 2008b).

3.4 Bathymetry

Water depths within the Project Area range from approximately 75 m to over 100 m Lower Low Water Large Tide (LLWLT). The seabed slopes gently to the east-northeast to an average of 0.05 degrees (FJG 2006).

3.5 Geology

The Hibernia development is situated within the Jeanne d'Arc Basin, one of the major (Mesozoic) sedimentary basins within the eastern Canadian offshore. The Hibernia Field is a structural play associated with a major roll-over anticline at the western margin of the Jeanne d"Arc Basin ("the Hibernia Anticline") (FJG 2006). The Jeanne d'Arc Basin evolved through a series of rift-drift episodes associated with the early opening of the Atlantic (Enachescu 1987; Sinclair 1988; Keen et al. 1987; Tankard and Welsink 1987; Grant and McAlpine 1990). The succession consists predominantly of distal marine claystones and shales of the Banquereau Formation, which overlie thinly bedded Cretaceous shales, chalks, marls and sandstones of the Dawson Canyon, Ben Navis and Avalon Formations (FJG 2006).

The surficial and shallow geology of the banks reflect episodes of Pleistocene glaciations, relative sea level change, and marine shelf sedimentation.

More detail on the geology of the Project Area is available in the Hibernia EIS (Vol. IIIa Section 3.1.4), the White Rose Comprehensive Study (Section 2.6) and Supplemental Report (Section 5.2).

3.5.1 Seabed Morphology

The seabed characteristics within the Project Area are consistent with the inferred glacial and post-glacial history of the region (FJG 2006). The seabed displays a gentle undulating morphology related to the presence of discontinuous, low relief (< 1 m) sand waves and ridges. Sand waves are response features lasting several years.

The seabed within areas of the proposed HSE drill centre location consists of predominately gravel substrate with a discontinuous veneer of surficial sand (Figure 3.19). There are isolated seabed boulders possible.

The surficial sediments of the proposed dredge spoil disposal location is comprised of predominantly sand substrates (66 percent) and areas that are predominantly gravel/cobbles/boulders with minor sand (34 percent of the disposal area) (E. Cumming, pers. comm.). Occasional iceberg scours and pits are evident in places approximately 1 m deep and 25 m to 50 m wide (Figure 3.20).

Figure 3.19 Side Scan Sonar Mosaic – Proposed Glory Hole

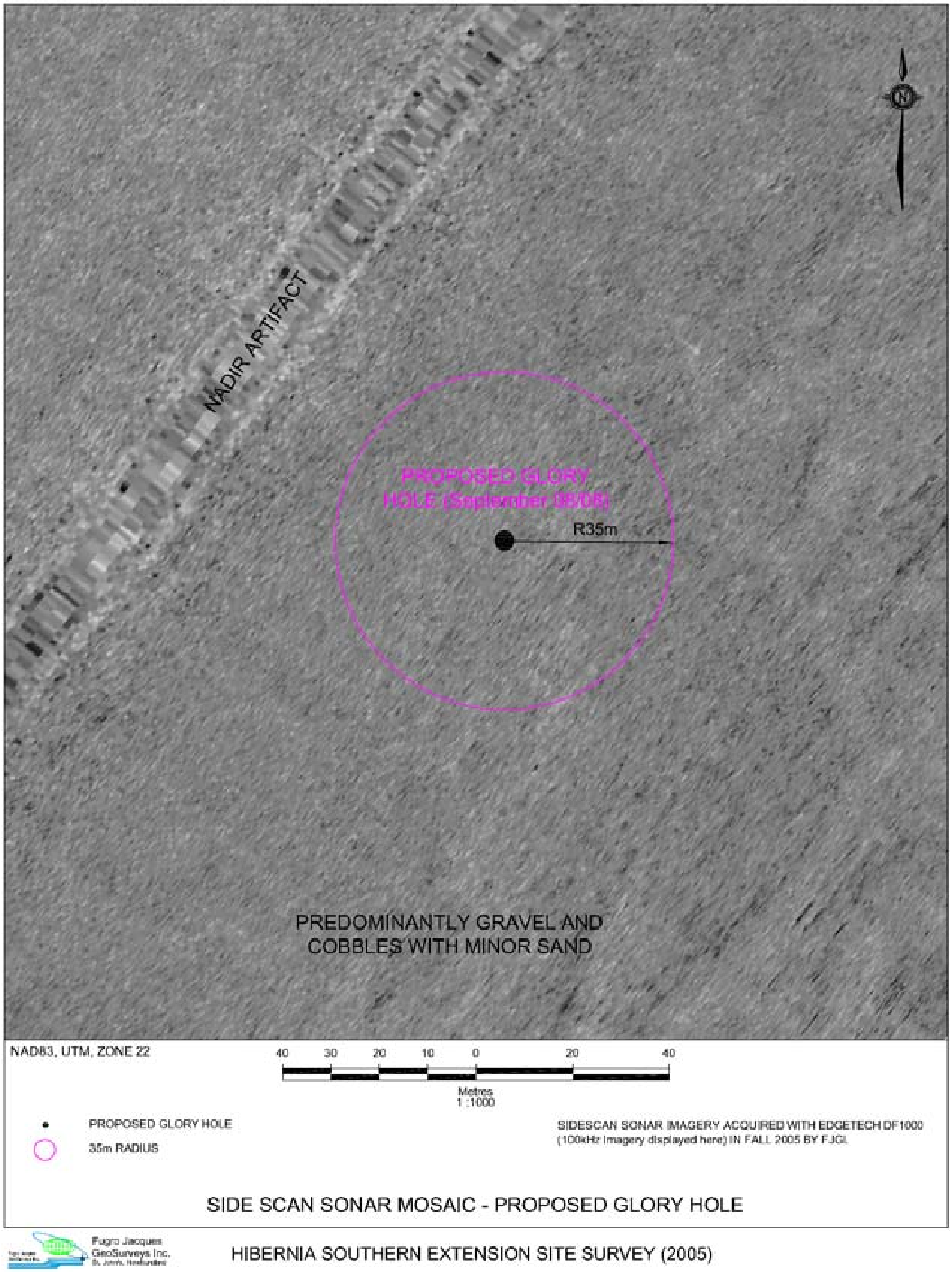
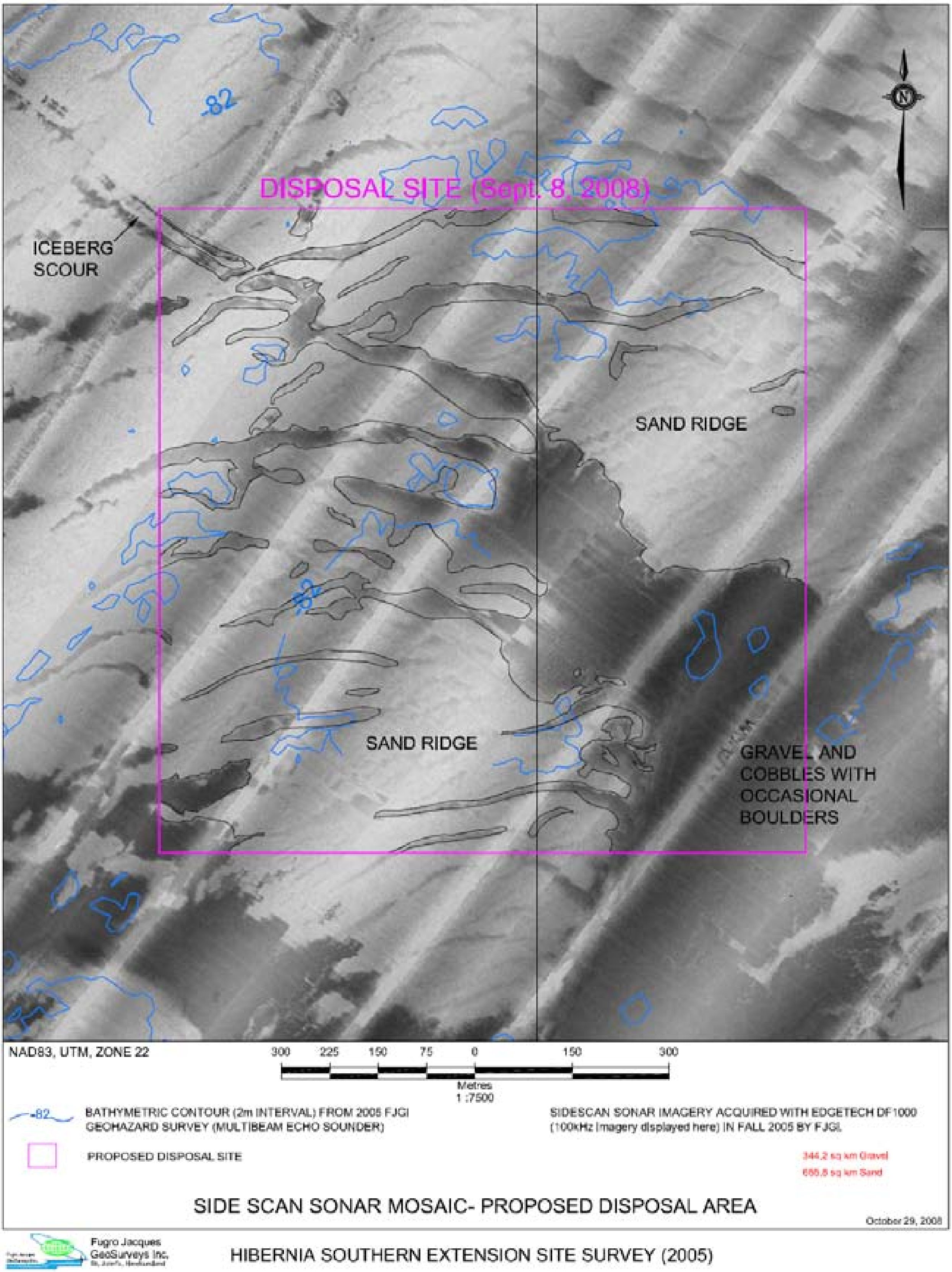


Figure 3.20 Side Scan Sonar Mosaic – Proposed Disposal Area



3.5.2 Sediment Chemistry

The results of the 2007 Hibernia EEM program found improvements in sediment chemistry compared to previous EEM programs (Table 3.22). The 2007 hydrocarbon concentrations in sediment have decreased to concentrations comparable to the 1998 data (one year post operation) or 1994 baseline data. The 2007 barium concentrations have decreased to near the 1999 barium concentrations. The improvement in sediment contaminant concentrations is attributed to operational changes on the Hibernia platform. Partial re-injection of SBM drilling wastes commenced in March 2000 with greater than 95 percent re-injection since September 2002.

Table 3.22 Hibernia EEM Sediment Chemistry Summary

EEM Program	Distance from Source (m)	TPH (mg/kg)	Barium (mg/kg)
2000 (Hydrocarbons as TEH)	250 500 2,000	472 to 1086 26 to 90 5 to 13	728 to 1,700 177 to 447 133 to 423
2002 (Hydrocarbon as TPH)	250 500 2,000	< 3 to 798 < 3 to 58.9 < 3 to 22.7	150 to 1,300 130 to 540 110 to 590
2004 (Hydrocarbons as TPH)	250 500 2,000	14.4 to 134 < 3 to 29.8 < 3 to 25.7	250 to 780 150 to 390 120 to 420
2007 (Hydrocarbons as TPH)	250 500 2,000	10.7 – 80.6 0.3 – 16.0 <0.3 – 19.4	210 – 600 91 – 300 120 - 510

All Hibernia sediment chemistry concentrations from 2007 are lower than both the probable effects levels (PEL) and the Interim Sediment Quality Guideline (ISQG). The PEL is the concentration of a chemical above which adverse biological effects are expected to occur frequently (CCME 2003). Sediment chemical concentrations below the ISQGs are not expected to be associated with any adverse biological effects. Therefore, no adverse biological effects from the chemicals listed in Table 3.23 are expected to be associated with Hibernia sediment.

Table 3.23 Comparison of Hibernia EEM Sediment Chemistry with Marine Sediment Quality Guideline

Parameter	Hibernia Sediment Chemistry Ranges (mg/kg)	Canadian Interim Sediment Quality Guidelines*	
		ISQG (mg/kg) PAH's in μg/kg	PEL (mg/kg) PAH's in μg/kg
Metals			
Arsenic	<2 – 3	7.24	41.6
Cadmium	<0.15 - 0.2	0.7	4.2
Chromium	<2 – 9.7	52.3	160
Copper	<2 – 5.4	18.7	108
Lead	<0.5 - 4.8	30.2	112
Zinc	<5 - 13	124	271
Mercury	<0.01-0.01	0.13	0.70
PAHs			
Acenaphthene	<0.05	6.71	88.9
Acenaphthylene	<0.05	5.87	128
Anthracene	<0.05	46.9	245
Benz(a)anthracene	<0.05	74.8	693
Benzo(a)pyrene	<0.05	88.8	763

Parameter	Hibernia Sediment Chemistry Ranges (mg/kg)	Canadian Interim Sediment Quality Guidelines*	
		ISQG (mg/kg) PAH's in µg/kg	PEL (mg/kg) PAH's in µg/kg
Chrysene	<0.05	108	846
Dibenz(a,h)anthracene	<0.05	6.22	135
Fluoranthene	<0.05	113	1,494
Fluorene	<0.05	21.2	144
2-Methylnaphthalene	<0.05	20.2	201
Naphthalene	<0.05	34.6	391
Phenathrene	<0.05	86.7	544
Pyrene	<0.05	153	1,398
Source: CCME 2003.			

Sediment chemistry samples were also collected from the proposed HSE glory hole location and the dredge spoils disposal site in September 2008 (Tables 3.24 and 3.25). Most available metal concentrations were below the reportable detection limit, so all metals were well below the Ocean Disposal Guidelines.

Table 3.24 Available Metal Chemistry at the Proposed Disposal Area

Parameter	Units	RDL	Sample Identification and Date				Ocean Disposal Guideline
			DA1	DA2	DA3	DA4	
			2008/09/21				
Metals							
Aluminum	mg/kg	10	<10	<10	<10	<10	-
Antimony	mg/kg	2	<2	<2	<2	<2	-
Arsenic	mg/kg	2	<2	<2	<2	<2	-
Barium	mg/kg	5	<5	<5	<5	<5	-
Beryllium	mg/kg	2	<2	<2	<2	<2	-
Boron	mg/kg	5	<5	<5	<5	<5	-
Cadmium	mg/kg	0.3	<0.3	<0.3	<0.3	<0.3	0.6
Chromium	mg/kg	2	<2	<2	<2	<2	-
Cobalt	mg/kg	1	<1	<1	<1	<1	-
Copper	mg/kg	2	<2	<2	<2	<2	81
Iron	mg/kg	50	<50	<50	<50	<50	-
Lead	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	66
Manganese	mg/kg	2	<2	<2	<2	<2	-
Molybdenum	mg/kg	2	<2	<2	<2	<2	-
Nickel	mg/kg	2	<2	<2	<2	<2	-
Selenium	mg/kg	2	<2	<2	<2	<2	-
Silver	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	-
Strontium	mg/kg	5	<5	<5	33	<5	-
Thallium	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	-
Uranium	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	-
Vanadium	mg/kg	2	<2	<2	<2	<2	-
Zinc	mg/kg	5	<5	<5	<5	<5	160

RDL = Reportable Detection Limit

Table 3.25 Available Metal Chemistry at the Proposed HSE Glory Hole

Parameter	Units	RDL	Sample Identification and Date						Ocean Disposal Guideline
			GH1	GH2	GH3	GH4	GH5	GH6	
			2008/09/21						
Metals									
Aluminum	mg/kg	10	<10	<10	<10	<10	<10	<10	-
Antimony	mg/kg	2	<2	<2	<2	<2	<2	<2	-
Arsenic	mg/kg	2	<2	<2	<2	<2	<2	<2	-
Barium	mg/kg	5	<5	<5	<5	<5	5	<5	-
Beryllium	mg/kg	2	<2	<2	<2	<2	<2	<2	-
Boron	mg/kg	5	<5	<5	<5	<5	<5	<5	-
Cadmium	mg/kg	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	0.6
Chromium	mg/kg	2	<2	<2	<2	<2	<2	<2	-
Cobalt	mg/kg	1	<1	<1	<1	<1	<1	<1	-
Copper	mg/kg	2	<2	<2	<2	<2	<2	<2	81
Iron	mg/kg	50	<50	<50	<50	<50	<50	<50	-
Lead	mg/kg	0.5	0.5	<0.5	1.7	<0.5	<0.5	<0.5	66
Manganese	mg/kg	2	<2	<2	<2	<2	<2	<2	-
Molybdenum	mg/kg	2	<2	<2	<2	<2	<2	<2	-
Nickel	mg/kg	2	<2	<2	<2	<2	<2	<2	-
Selenium	mg/kg	2	<2	<2	<2	<2	<2	<2	-
Silver	mg/kg	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	-
Strontium	mg/kg	5	270	270	260	250	240	250	-
Thallium	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Uranium	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	-
Vanadium	mg/kg	2	<2	<2	<2	<2	<2	<2	-
Zinc	mg/kg	5	<5	<5	<5	<5	<5	<5	160

RDL = Reportable Detection Limit

PAHs, BTEX (benzene, toluene and ethylbenzene) and PCBs were not detected in any sample. Trace levels (0.4 mg/kg) of fuel range (C_{10}-C_{21}) and lube range (C_{21}-C_{32}) hydrocarbons were detected in two of four samples from the disposal area. One of six samples from the HSE glory hole site contained fuel range hydrocarbons reported at the RDL of 0.3 mg/kg and five of the six samples contained lube range hydrocarbons at concentrations from 0.4 to 1.3 mg/kg. Low concentrations of hydrocarbons are expected where there has been any drilling within the Project Area.

4.0 BIOLOGICAL ENVIRONMENT

4.1 Fish and Fish Habitat

The focus of this section is on commercially and ecologically important fish species and their habitats. Here, we describe the biological components of fish and fish habitat. The physical (Seabed Morphology – Section 3.6.1) and chemical (Sediment Chemistry - Section 3.6.2 and Water Chemistry - Section 3.3.3.2) components of fish habitat are described elsewhere. Fish species considered at risk by COSEWIC or under the *Species at Risk Act* are profiled in Section 4.5.

Historically, Atlantic cod and American plaice were the most abundant commercial species on the Grand Banks. In more recent years these species have become rare on the northern portion of the Grand Banks and in the Newfoundland region generally. Increasingly, the ground fish fisheries have been replaced by snow crab (*Chionoecetes opilio)* and northern shrimp (*Pandalus borealis*) fisheries. More than 99 percent of the commercial landings reported from NAFO Unit Area 3Lt from 2002 to 2003 were snow crab (DFO 2004a); the remainder is comprised of yellowtail flounder, Atlantic halibut (*Hippoglossus hippoglossus*), turbot, American plaice and Atlantic cod.

Pelagic, schooling species common to the Grand Banks are capelin, Arctic cod (*Boreogadus saida*) and sand lance. These species are all ecologically important as a food supply for larger pelagic fish species, whales, seals and seabirds.

A detailed analysis of the distribution of demersal fish species on the Grand Banks indicates that the Hibernia area in general, does not support a high biomass of demersal fish relative to other areas on the Grand Banks (Kulka et al. 2003).

4.1.1 Phytoplankton

Phytoplankton convert water and carbon dioxide into organic matter by the use of sunlight and as such, are the primary producers of the marine ecosystem. The resulting biomass supports the entire marine food web. The seasonal cycle of phytoplankton is characterized by two peaks (blooms) one in spring (April/May) and a smaller one in late fall/early winter (October to January). Phytoplankton on the Grand Banks is normally found in the upper 30 to 50 m of the water column.

The diatoms species *Chaetoceros decipiens* and *Thalassiosira* spp. are the most dominant phytoplankton species during the spring and fall blooms (Bundy et al. 2000). Diatoms and other species like dinoflagellate phytoplankton of the genus *Ceratium* are critical to primary production on the Grand Banks, but other species have also become abundant in more recent years (Maillet and Pepin 2005). During a bloom, phytoplankton densities are on the order of 1×10^4 to $>3 \times 10^4$ cells per m^3.

The Atlantic Zone Monitoring Program (AZMP) reported some indications of an increase in the magnitude of the spring phytoplankton bloom in 2007 compared to previous years and the duration was the longest on record (AZMP Bulletin PMZA 2008). Other than during the spring bloom, phytoplankton abundance was generally lower than average throughout the remainder of the year. Evidence of subsurface phytoplankton blooms were detected during the summer (July–August), but there was little evidence of an autumn bloom at Station 27 in 2007 compared to previous years.

4.1.2 Zooplankton

Zooplankton play a key role in the marine food web by providing a link between the primary producers (phytoplankton) and other species. Herbivorous zooplankton, such as copepods, feed on phytoplankton and are then in turn fed upon by invertebrates, fish, birds and marine mammals. Zooplankton are also a major source of detritus for the benthic community, which serves as a critical pathway for nutrient generation.

Zooplankton are most abundant on the northern Grand Banks during late spring and summer, with copepods representing over 80 percent of the zooplankton. The most abundant species of copepods throughout the 1990s were *Oithona similis*, *Pseudocalanus* sp., *Calanus finmarchius*, *Temora longicornis* and *Centropages hamatus*. In terms of biomass, *C. finmarchius* was the most dominant due to relatively large individuals (Dalley et al. 2001).

During the 1990s, fish larvae (ichthyoplankton) have been found to be most abundant to the north of the Grand Banks on the northeast Newfoundland Shelf, while the lowest densities were reported on the eastern part of the Grand Banks (Dalley et al. 2000). On the northeast Grand Banks, during late summer and early fall, the ichthyoplankton may include Atlantic cod, American plaice, sand lance, redfish (*Sebastes* spp.), jellyfish, squid (*Illex illecebrosus*), lanternfish (*Myctophum* spp.), alligatorfish (*Aspidophoroides monopterygius*), sculpins (unidentified), blennies, seasnails, white hake (*Urophycis tenuis*), haddock (*Melanogrammus aeglefinus*), wolffish (unidentified), witch flounder (*Glyptocephalus cynoglossus*), yellowtail flounder (*Limanda ferruginea*) and Greenland halibut (*Reinhardtius hippoglossoides*) (Dalley et al. 2000).

Capelin, sand lance and redfish are the most abundant ichthyoplankton species in the area during August and September (Anderson et al. 1999).

4.1.3 Benthos

Benthos refers to the community of plants and animals living in or on the seafloor. The group is very diverse and includes attached micro- and macro-algae, and invertebrates such as polychaete worms, molluscs and crustaceans. Benthic invertebrates living on the seafloor form an important link to higher trophic levels such as fish, seabirds and marine mammals.

The dynamic physical environment of the Grand Banks seafloor coupled with the temporal variability in abundance of some macrofaunal species (Kenchington et al. 2001), ensures benthic communities can be highly variable, even within a small area. On a larger scale, benthic community structure is not only influenced by grain size, but also by water depth and composition of the water mass (Bundy et al. 2000). Grain size and several benthic community indices (e.g., species abundance, richness, diversity) are strongly correlated (DeBlois et al. 2005).

The infauna determined from 200 grab samples collected during a three-year trawling impact study (1993 to 1995) near the White Rose field has been described by Kenchington et al. (2001). The sediment samples contained 246 taxa, primarily composed of polychaetes, crustaceans, echinoderms and molluscs. The biomass was dominated by propeller clams (*Cyrtodaria siliqua*) and sand dollars (*Echinarachnius parma*). The brittlestar *Ophiura sarsi*, the bivalve *Macoma calcarea*, and the sea urchin (*Strongylocentrotus pallidus)* also contributed substantially to the biomass collected. Abundance was dominated by the polychaetes (*Prionospio steenstrupi)* and the mollusc *Macoma calcarea*. Other species that were relatively abundant included the polychaetes *Chaetozone setosa, Spio filicornis*, and *Nothria conchylega*, the amphipod *Priscillina armata*, and the sand dollar**.**

Video imagery from a wellsite survey conducted within the Project Area in 2002 showed epibenthic fauna including starfish, crabs, and bivalves (e.g., scallops) on coarse substrate and burrowing infauna, starfish, and sand dollars on sandy seabed (Fugro Jacques GeoSurveys Inc. 2002).

In October 2008, an ROV survey was conducted within the proposed HSE's glory hole dredge site and dredge spoils disposal location. At the disposal site, snow and toad crab were observed occasionally, but were more abundant when the dominant substrate was sand. Approximately 60 snow crab and 26 toad crab were observed during the 1 km survey. Sand dollars and clams were also observed, but again were more numerous when the dominant substrate was sand. Scallops, purple sunstars and northern red anemones were also observed but were scarce. Water depth throughout the area is about 83 meters.

At the proposed glory hole location, approximately 38 snow crab and 23 toad crab were observed during the 1 km survey. Sand dollars and clams were abundant when substrate was sandy, but scallops were scarce on the sandy substrate. Northern red anemones and purple sunstars were also scarcely observed. Barnacles were also present when substrate consisted of small boulders, rubble, and cobble. Water depth is approximately 81 meters.

Deep-water corals are common in certain areas in Atlantic Canada. They are found primarily below the 200 m depth contour along the edge of the continental slope, in canyons or in channels between banks. Some soft corals do occur in shallower areas on the continental shelf, but none are expected within the Project Area (Edinger et al. 2007).

4.1.4 Shellfish

In recent years, the vast majority of the commercial harvest within the 3Lt was comprised of northern shrimp and snow crab. Stimpsons surf clam (*Mactromeris polynyma*) and Greenland cockle (*Serripes groenlandica*) are also fished in the area.

4.1.4.1 Species Profiles

Snow Crab

Snow crab occur from Greenland to the Gulf of Maine over a depth range from 20 to >400 m. While commercial-sized snow crab (95 mm carapace width) typically occur on mud or mud/sand substrate, smaller snow crabs can be found on soft or hard substrates (DFO 2005). Snow crabs prefer water temperatures ranging between –1 and 4ºC. Snow crab mating generally occurs during the spring months. Depending on location, female snow crabs carry the fertilized eggs for one to two years prior to larval hatch. Hatching normally occurs in late spring and summer after which the larvae remain planktonic for up to three to four months before settlement (Dawe and Taylor 2003). The snow crab diet includes fish, clams, polychaetes, brittle stars, shrimp, crabs and other crustaceans. Common predators of snow crab include various ground fish, seals and snow crabs themselves (DFO 2005).

Northern Shrimp

Northern shrimp occur in the Northwest Atlantic from Davis Strait to the Gulf of Maine (DFO 2004c). Northern shrimp on the northeast Newfoundland Shelf occur in areas greater than 150 m deep over muddy substrates. Shrimp tend to congregate during the winter and spring, and disperse during the summer and early fall.

Northern shrimp spawn typically in late-June or early-July. Eggs are extruded during late summer and fall and remain attached to the female until hatching the following spring. Shrimp larvae remain pelagic for a few months, before they settle to a benthic life style. Colbourne and Orr (2004) studied the abundance of northern shrimp and temperature during spring and fall in NAFO divisions 3LNO. Catches indicated a preferred temperature in the spring from 2°C to 4°C and a preferred temperature in the fall from 1°C to 3°C. Very few shrimp were found below 0°C or above 4°C during either season.

During the day, shrimp are benthic and feed on detritus, phytoplankton, worms and small crustacean. At night, shrimp move up into the water column and feed on detritus and zooplankton (Bundy et al. 2000). Shrimp are common prey for Greenland halibut and Atlantic cod, Atlantic halibut, skates, wolffishes and harp seals.

4.1.5 Finfish

4.1.5.1 Hibernia 2007 EEM Results

As part of the Hibernia EEM program, American plaice are sampled for fish health, taint and body burden analysis at the Hibernia site and at a reference area (Figure 4.1). The bycatch of finfish and shellfish during the sampling effort is presented here as an indication of species relative abundance. In total, 16 species were caught in the seven tows conducted near the Hibernia site in 2007 (HMDC 2008; Figure 4.1). The highest overall CPUE (catch per unit effort) occurred for mailed sculpin, at 83.9 individuals per tow, ranging from 13 individuals per tow (H-07) to 280 individuals per tow (H-09). The next highest overall CPUE occurred for capelin (66.3 individuals per tow), followed by American plaice (32.8 individuals per tow), and sand lance and hookear sculpin (7.1 individuals per tow). Other species exhibited lower CPUE and a more sporadic occurrence, as evidenced by their absence from several tows.

In 2007, both the lube and fuel range hydrocarbons were detected in fish livers from Hibernia and Reference areas. There were no statistically significant differences between the Hibernia and Reference areas in the levels of lube and fuel range hydrocarbons detected in the livers. There were differences in metal concentrations detected between the Hibernia and Reference areas. It is important to note that there is no pattern to the differences in metal concentrations detected and these differences are attributed to inter-annual variations and not attributed to Hibernia platform discharges. The results of the fish health study indicated the health status of American plaice collected at the Hibernia area is similar to those collected at the Reference area. The triangle test and hedonic scaling assessments found that American plaice were not tainted at either the Hibernia or Reference areas (HMDC 2008).

Figure 4.1 Otter Trawl Transect Locations

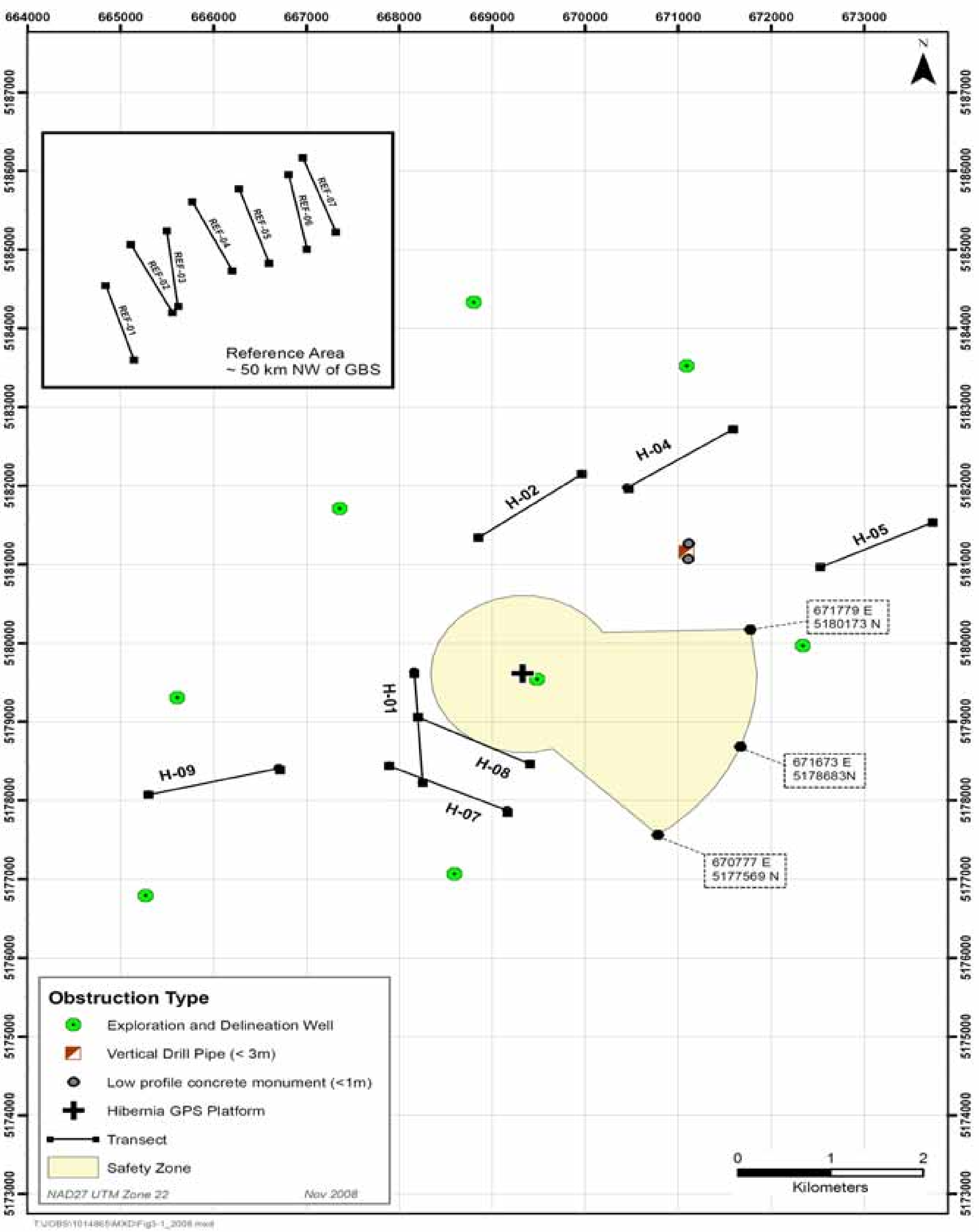
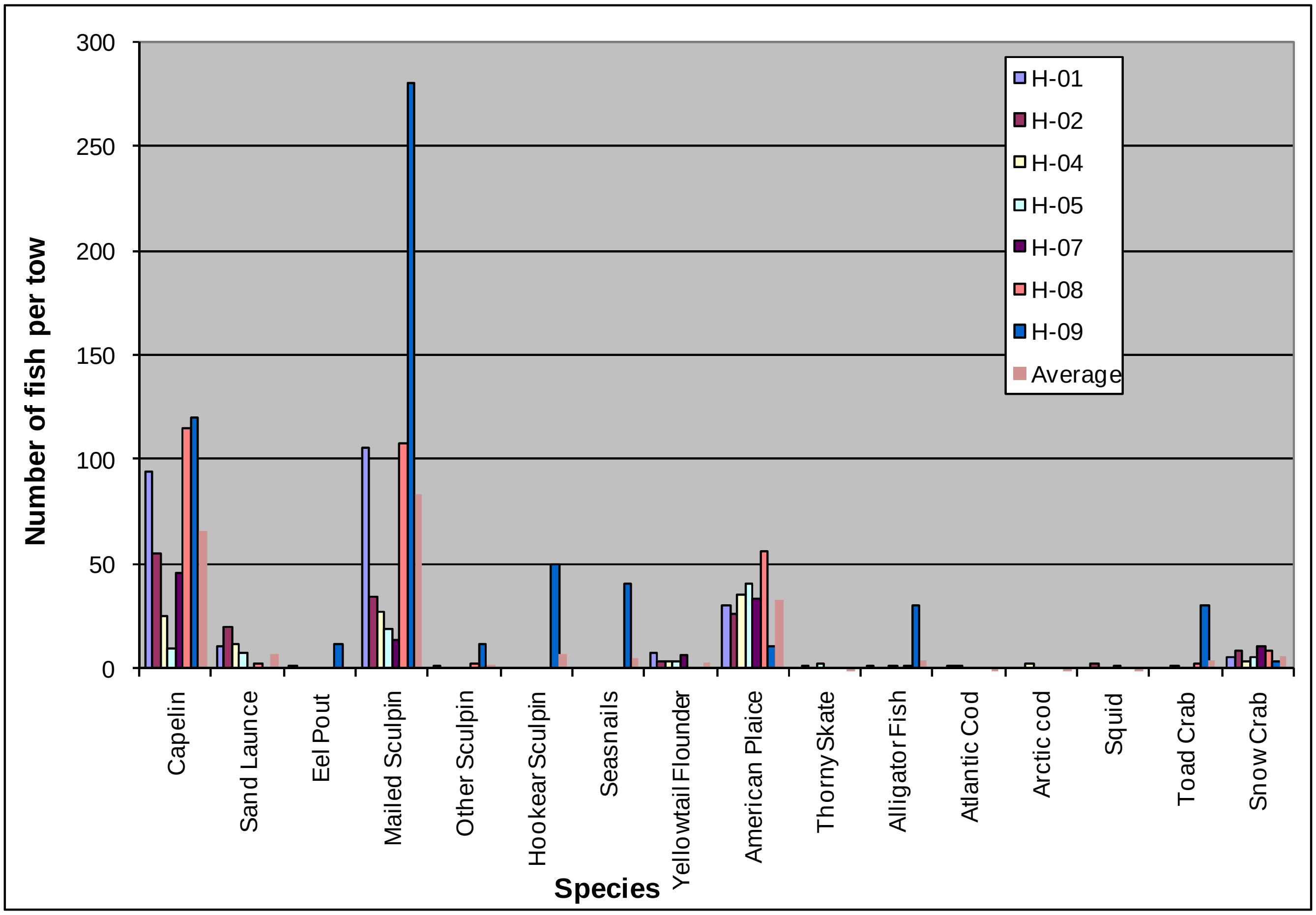


Figure 4.2 CPUE of Species per Hibernia Site Station during the Hibernia EEM 2007



4.1.5.2 Species Profiles

Atlantic Halibut

Atlantic halibut move seasonally between deep and shallow waters, apparently avoiding temperatures below 2.5ºC (Scott and Scott 1988). The spawning grounds of the Atlantic halibut are not clearly defined. Eggs and larvae are pelagic for about 3 months before the juveniles settle when they are approximately 20 mm long. As juveniles, Atlantic halibut feed mainly on invertebrates, including annelid worms, crabs, shrimps, and euphausiids. Young adults (30 to 80 cm in length) consume both invertebrates and fish, while mature adults (greater than 80 cm) feed entirely on fishes (Scott and Scott 1988).

Distribution maps based on spring and fall research vessel surveys between 1992 and 2000 indicate that Atlantic halibut occur east of the Project Area in the slope region, particularly during the fall (Kulka et al. 2003).

American Plaice

American plaice occur in the Northwest Atlantic from west Greenland to the Gulf of Maine (Scott and Scott 1988). On the Grand Banks, they are found on both the northern and southern portions at low densities. The area of highest biomass of American plaice is at the southern part of the Grand Banks straddling NAFO Unit Areas 3NO (Morgan et al. 2003). Populations have generally declined since the late 1980s and current population estimates are between 3 and 5 percent of the early 1980s level (Dwyer et al. 2003). However, there have been signs of an increase on the Tail of the Grand Banks since the mid 1990s (Kulka et al. 2003).

The American plaice typically inhabit depths ranging from 70 to 275 m, although they also occur in shallower and deeper areas, but prefer water temperatures ranging between 1 and 4ºC. The species appears to be relatively sedentary, with a home range of less than 50 km (Pitt 1969; Morgan and Brodie 1991). However, there is some evidence of a seasonal migration off the Grand Banks in the winter to warmer water along the shelf edge (Morgan and Brodie 1991).

American plaice spawning is most intensive on the northern Grand Banks and occurs primarily from April to June at depths of 50 to 200 m (Morgan 2001). During the DFO RV surveys in June of 1998 to 2002, American plaice have been collected from the Project Area in spawning condition (Ollerhead et al. 2004). American plaice larvae hatch from planktonic eggs within two weeks of spawning at temperatures of 5°C (Scott and Scott 1988). The larvae remain in the upper water column for about 3 months. Once settled, juveniles are typically found over homogenous silt or mud substrates (Walsh 1991), while adult plaice seem to prefer sand substrates over a mix of sand and gravel or gravel alone (Morgan 2000).

American plaice diet varies according to fish size, with small plaice feeding on mysiids, amphipods and echinoderms and larger plaice feeding on echinoderms and bivalves (Archambault et al. 2001).

Thorny Skate

Several species of skate may occur in the Grand Banks, with the most abundant being the thorny skate. Thorny skate occur from Greenland to South Carolina in the western Atlantic at depths ranging from 20 to >150 m and at temperatures ranging from -1.4°C to 6.0°C. In recent years, skate have been concentrating along the southwest slope and edges of the Grand Banks during the spring and occur throughout the Tail of the Grand Banks, especially over the Southeast Shoal during fall (Kulka et al. 2003). During recent years, thorny skate abundance has been seen to decline most in the northern extent of its range (Kulka et al. 2004).). It is currently estimated that approximately 80 percent of the biomass is concentrated within 20 percent of the area on the southwest edge of the Grand Banks (Kulka et al. 2004).

This skate is considered sedentary, rarely moving more than 100 km during their lifetime, but there are indications that they undergo a seasonal migration from the plateau of the Grand Banks in early winter to the edge and slope, returning in early summer (Kulka et al. 2004). Thorny skate appear to spawn in the fall and winter and may lay from six to 40 egg cases per year. Thorny skate egg cases are released by the female and hatching occurs approximately six months later. Young skates emerge from the egg case as free-swimming fish. They feed on polychaetes, crabs, whelks, sculpins, redfish, sand lance and haddock, with fish being more important prey items for larger skate (Scott and Scott 1988).

Arctic Cod

Arctic cod are circumpolar in distribution and are also found along the Labrador coast, eastern Newfoundland coast, and the northern and eastern Grand Banks. Temperatures of 0°C to 4°C are believed to be optimal for Arctic cod, but they have usually been found in waters colder than 0°C and frequently near drifting ice (DFO 2008b). Arctic cod are found close to shore among ice floes and also offshore in depths greater than 900 m.

Both male and female Arctic cod are mature when about 20 cm long and three years of age. In northern Canadian waters, spawning is thought to occur in late autumn and winter under the Arctic ice cover (DFO 2008b).

Juvenile Arctic cod, 4 to 6 cm long, feed mainly on the eggs and larvae of copepods and adult amphipods (DFO 2008b). Adults prey upon euphausiids copepods, amphipods and arrow worms and larger fish may be cannibalistic.

Yellowtail Flounder

Yellowtail flounder can be found from Labrador to Chesapeake Bay along the continental shelf at depths ranging from 10 to 100m. Juvenile and adult yellowtail are generally concentrated on the southern Grand Bank, on or near the Southeast Shoal where the substrate consists primarily of sand (Unit Area 3Nc, primarily), but there are occurrences on the slope region of Unit Areas 3Nd and 3Nf (Walsh et al. 2001; Walsh et al. 2006).

Spawning occurs between May and September on the Grand Bank and peaks during the latter part of June. Spawning tends to occur at depths less than 100m and at water temperatures exceeding 2°C. The eggs, larvae and early juvenile stages of yellowtail flounder are pelagic. This flounder is restricted in the size of prey it can consume because of its small gape. Polycheates, amphipods, shrimp, cumaceans, isopods, and small fish make up the diet of yellow flounder.

Greenland Halibut

The Greenland halibut (turbot) is a deepwater flatfish species that has a water temperature preference of 0.0 to 4.5°C, but will inhabit waters with temperatures ranging between -0.5 to 6.0°C. These fish are normally caught at depths exceeding 450 m in the northwest Atlantic off northeastern Newfoundland but reported depths of capture range from 90 to 1,600 m, with larger individuals tending to be deeper.

Fertilized eggs are benthic but the hatched juveniles move upwards in the water column and remain at about 30 m below surface until they grow to about 70 mm in length. They move downwards in the water column as they grow bigger (Scott and Scott 1988).

Greenland halibut feed on a variety of prey and are considered voracious bathypelagic predators. Capelin, Atlantic cod, polar cod, young Greenland halibut, grenadier, redfishes, sand lance, barracudinas, crustaceans, cephalopods and various benthic invertebrates make up the diet of Greenland halibut. Predators of the Greenland halibut include the Greenland shark, various whales, hooded seals, cod, salmon, and Greenland halibut (Scott and Scott 1988).

Sand Lance

The sand lance is one of the major unexploited fish resources on the Northwest Atlantic. This fish is typically found in water less than 100 m deep where substrate is predominantly comprised of sand and light gravel. Spawning typically occurs on sandy substrate in shallow water during the winter. The fertilized eggs adhere to the substrate and remain there during embryonic development. Hatched larvae rise to the surface waters where they remain for a few weeks before descending to the bottom. Sand lance move out of the substrate and up into the water column to feed, often at night. Copepods often are the prey of choice. The sand lance is a major food item for Atlantic cod, Atlantic salmon and numerous other marine fishes.

Capelin

In the Newfoundland region, there are four stocks of capelin. Capelin is a pelagic schooling species that can undergo dramatic changes in mature biomass (Nakashima 1999). The 3KL capelin stock is centered on the northern Grand Banks, but migrates to the coastal beaches of Newfoundland to spawn in June and July. After hatching, the larvae are carried out of the bays by currents to nursery areas. The 3NO stock tends to spawn offshore usually in June and July (Carscadden et al. 1989, in Carscadden et al. 2001). Juveniles live offshore and spawn at three or four years of age. Capelin feed on plankton such as copepods, euphausiids and amphipods (Carscadden et al. 2001). Capelin are preyed upon by harp seals, cod, halibut, American plaice, Atlantic salmon , seabirds and whales. Capelin is considered a keystone species of the Grand Banks food web.

Large Pelagics

Swordfish and various tuna species (*Thunnus* spp.) may feed along the slopes of the Grand Banks during the summer months. Adult swordfish are opportunistic feeders. They like to forage for their food from the surface to the bottom over a wide depth range. Swordfish and tuna species diet consists of other fish, some crustaceans and squid. Swordfish is not known to spawn in the area (Fishbase 2006). Bluefin, yellowfin, albacore and skipjack tunas are also oceanic fish and often occur in mixed schools during their feeding migrations. No tuna species spawn within the area (Fishbase, 2006).

4.1.6 Sensitive/Special Areas

In April 2003, R.G. Thibault, the Minister of Fisheries and Oceans, announced that special conservation measures are required in the Hawke Channel (off southern Labrador) and the Bonavista Corridor to protect spawning and juvenile concentrations of Atlantic cod and their habitat. These measures will include an area within the Bonavista Corridor that will be closed to otter trawling (**www.dfo-mpo.gc.ca**).

The Bonavista 'Cod Box' coordinates, as provided by DFO, are (1) 50º00' N, 50º00'W, (2) 49º18'N, 51º36'10"W, (3) 48º54'N, 51º23'50"W, and (4) 48º54'15"N, 49º54'W. This cod box is about 250 km northwest of the Project Area.

The Project Area is within an area currently being considered as part of an Integrated Management Plan for the Placentia Bay Grand Banks Large Ocean Management Area. As part of this plan, DFO has identified ecologically and biologically significant areas (EBSAs) which may require special management measures. Some EBSAs are put forward as Areas of Interest for Marine Protected Area (MPA) status and other EBSAs are considered for protection under other management tools. None of the EBSAs overlap with the Project Area. The Northeast Shelf and Slope is the EBSA nearest the Project Area and is on the northeastern Grand Bank starting at the Nose of the Bank, from 48°W to 50°W, and from the edge of the shelf (e.g. 200 m isobath) to the 1000 m isobath. The Project Area is on the shelf, in approximately 80 m of water and approximately 60 nm from the 200 m isobath. The Northeast Shelf and Slope is a low priority on the list of conservation objectives within this Large Ocean Management Area (DFO 2007). The area has been identified as an EBSA because portions of the area are known for:

- spotted wolffish aggregation;
- cetacean aggregation at Sackville Spur;

- pinniped aggregation at Sackville Spur; and
- coral concentrations north of Tobin's Point (DFO 2007).

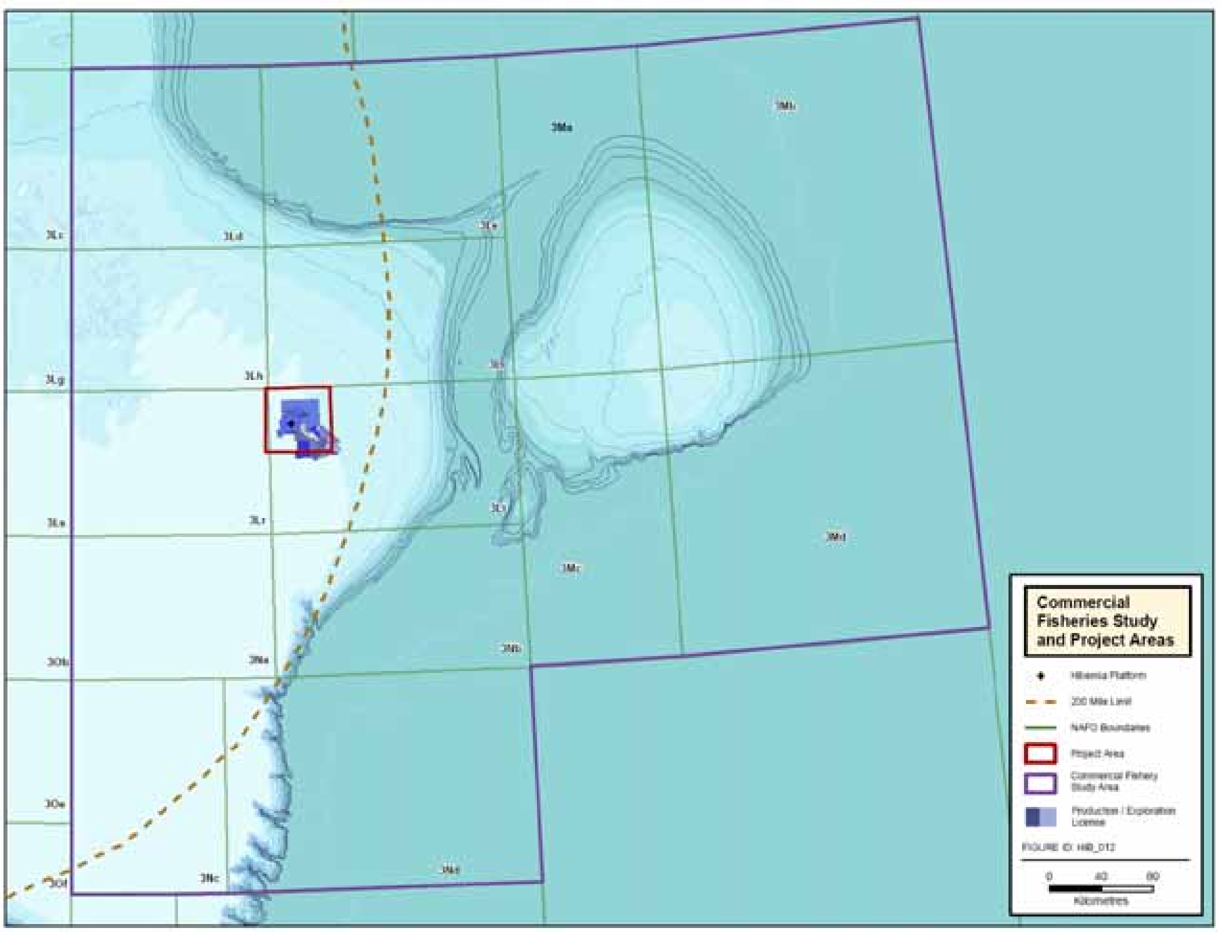
Fish, seabirds, sea turtles and marine mammals may feed within and migrate through the Project Area, but, there are no known sensitive areas (e.g., critical spawning areas) or designated Marine Protected (MPAs). In fact, there are indications that the Hibernia area may be less productive relative to other areas of the Grand Banks (Kulka et al. 2003).

Hibernia is aware of the DFO initiative to establish marine protected areas in the offshore area. Through CAPP, Hibernia and other offshore operators will keep appraised of this initiative and will participate as required.

4.2 Commercial Fisheries

This section describes the current commercial fisheries in the areas nearest the proposed Project. For the purpose of this description, the commercial fisheries Study Area is encompassed by NAFO Unit Areas (UAs), 3Lh, 3Li, 3Lr, 3Lt, 3Ld, 3Le, 3Ma, 3Mb, 3Md, 3Na, 3Nb, 3Nc and 3Nd. The Project is within the NAFO UA 3Lt (Figure 4.3). These UAs are those potentially affected by a large oil spill (see Chapter 8).

Figure 4.3 Study Area and Project Area Locations within NAFO Areas



Presented here is a summary of the most recent data available for commercial fisheries in the Study and Project Areas. An overview of historical harvesting activity within the Jeanne d'Arc Basin is also provided.

4.2.1 Data Sources

The commercial fisheries data used here for catch summaries and modeling is based on time-series data derived from DFO's Newfoundland and Labrador Region and Maritimes Region (Nova Scotia) catch and effort datasets[1]. Maritimes Region data are included because a small portion of the harvest (mainly shrimp) in 3L is landed in that region by Nova Scotia-based vessels. Foreign catches (primarily shrimp) landed outside these two regions are not included in these data. The data used in the report represent all catches landed within DFO Maritimes Region and all Newfoundland and Labrador-landed catch. The data describe the species, quantity, month and location of fish harvesting.

To best represent current and future fishing activity to the extent possible, a summary of the activity in 2005, 2006 and 2007 is provided, which is the most current fisheries data available. For a summary of older data and details of the historical fisheries datasets, please refer to the following EA reports and sections:

- Environmental Assessment of StatoilHydro's Jeanne d'Arc Basin Area Seismic and Geohazard Program, 2008-2016 (LGL 2008a): Section 4.3;
- Environmental Assessment of StatoilHydro Canada Ltd. Exploration and Appraisal/Delineation Drilling Program for Offshore Newfoundland, 2008-2016 (LGL 2008b): Section 5.3;
- Environmental Assessment of Petro-Canada's Jeanne d'Arc Basin 3-D Seismic Program: (LGL 2007c): Section 4.5; and
- Hibernia Geohazard Survey: (LGL 2005b): Section 4.5.

The DFO catch data from this area are geo-referenced, so harvesting locations are plotted in relation to the Project Area. The location in the dataset is that recorded in the vessel's fishing log, by degree and minute of latitude and longitude. The position should be accurate within approximately 0.5 nautical mile of the reported coordinates. For some gear, such as mobile gear towed over an extensive area, or for extended gear, such as longlines, the reference point does not represent the full distribution of the gear or activity on the water. However, this is of little concern for fixed gear fisheries like crab.

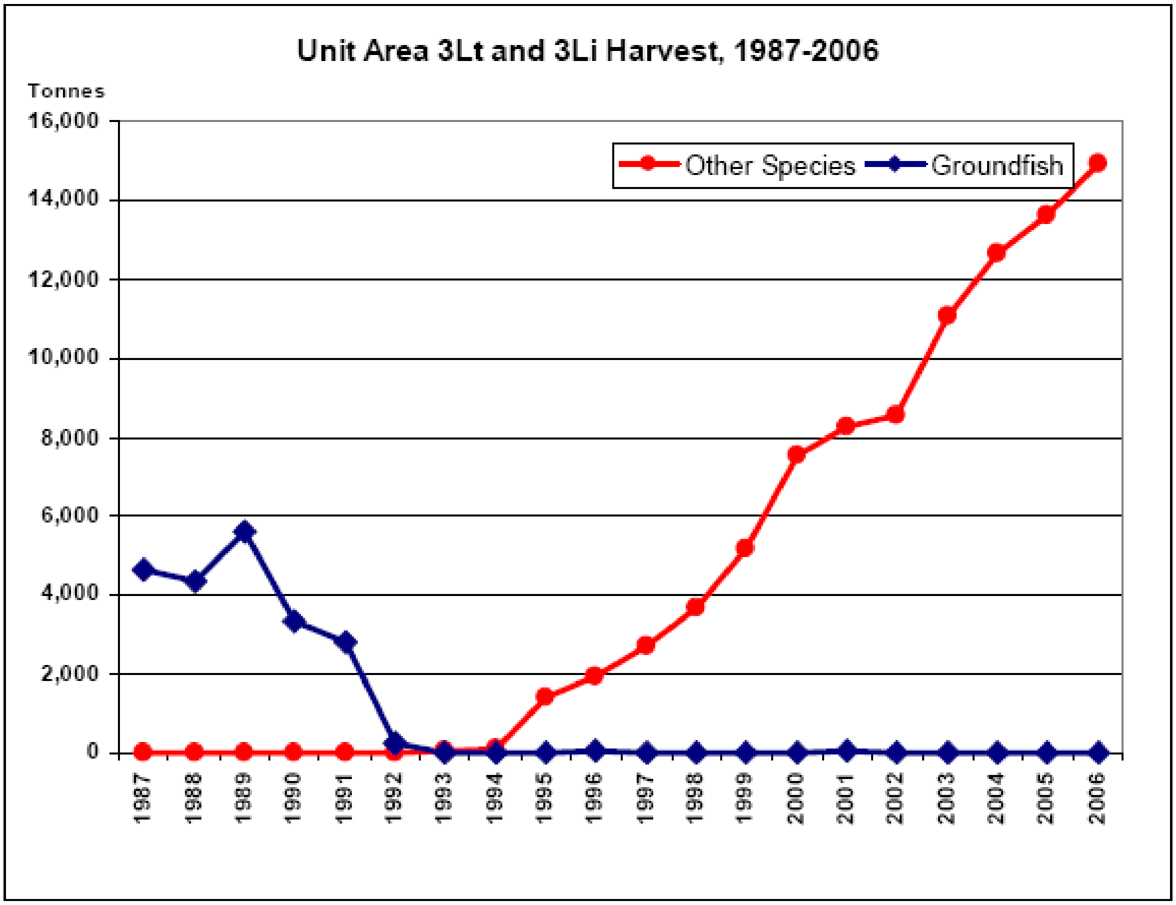
The quantity of each species harvested, rather than the product values, were used to summarize catches. Quantities are directly comparable from year to year, while values (for the same quantity of harvest) may vary annually with negotiated prices, changes in exchange rates and fluctuating market conditions. To assess the potential for interference with fisheries, it is the level of fishing effort and gear used (better represented by quantities of harvest) that is more useful.

[1] The DFO data used in the report represent all catch landed within DFO Maritimes Region and for all Newfoundland and Labrador landed catch. Foreign catches landed outside these areas are not included in the DFO data sets, but most are captured in the NAFO data.

4.2.2 Regional and Historical Overview

The fisheries in Unit Area 3Lt were dominated until the early 1990s by ground fisheries mainly using stern otter trawls and targeting primarily Atlantic cod and American plaice. Yellowtail flounder, Atlantic halibut and turbot, comprised the bulk of the remainder. In 1992, with the acknowledgement of the collapse of several groundfish stocks, a harvesting moratorium was declared and directed fisheries for Atlantic cod virtually vanished in this area (Figure 4.4).

Figure 4.4 Groundfish and Other Species Harvesting in 3Lt and 3Li, 1987 to 2006



Since the collapse of these fisheries, the formerly under used species of snow crab and northern shrimp have become the principal harvest in eastern 3L. As in many areas of the Jeanne d'Arc Basin, snow crab is particularly important in 3Lt, and since the moratorium, has been the primary species harvested in 3Lt (>99 percent by quantity). Northern shrimp, while not as important in 3Lt, is one of the main commercial species in the other unit areas of NAFO 3L.

Historically, 3Lt was not one of the more important areas within Division 3L, accounting for an average of just 1.5 percent of the overall 3L catch by total landings during the five years preceding the moratorium (1987 to 1991). However, since the groundfish closure, it has become a significant sub area because of its snow crab resources, and comprises 53.5 percent of the 3Lt, 3Lr, 3Lh and 3Li total harvest (2005 to 2007 average) by quantity.

4.2.3 Recent Commercial Fisheries within the Study Area

From 2005 to 2007, the harvest of cockles, yellowtail, snow crab, northern shrimp, and clams were the dominant species respectively by weight, accounting for 94.5 percent of the total harvest within the Study Area (UAs 3Lh, 3Li, 3Lr, 3Lt, 3Ld, 3Le, 3Ma, 3Mb, 3Md, 3Na, 3Nb, 3Nc and 3Nd) (Table 4.1).

Table 4.1 Study Area Harvest, 2005, 2006 and 2007

Species	Weight In Tonnes			Total Weight	% of Total Weight
	2005	2006	2007		
Snow/Queen Crab	4311.70	4218.60	3514.95	12045.24	19.63
Clams (sp)	2711.82	4813.70	159.17	7684.69	12.52
Cockles	4394.89	9864.11	726.93	14985.93	24.42
American Plaice	1008.28	5.51	189.10	1202.89	1.96
Yellowtail	10666.16	176.09	2053.03	12895.28	21.01
Turbot	540.26	290.44	477.02	1307.72	2.13
Grenadier	39.57	18.87	5.42	63.86	0.10
Northern Shrimp	1723.66	4667.12	4013.77	10404.55	16.95
Other Ground Fish	220.52	3.60	68.38	292.51	0.48
Tuna (sp)	7.05	0.00	0.00	7.05	0.01
Swordfish	9.08	0.00	0.00	9.08	0.01
Shark/Skate (sp)	2.44	2.60	0.88	5.92	0.01
Iceland Scallop	123.22	346.08	0.00	469.30	0.76
Total Harvest in Study Area				**61374.03**	**100.00**

The “other groundfish” category is a result of by-catch during the yellowtail and turbot fisheries. Another notable observation is the lack of scallop harvesting in these areas.

Harvesting times may change, depending on seasons and regulations set by DFO, the harvesting strategies of fishing enterprises, or on the availability of the resource itself. Within the Study Area, the majority of the harvesting occurs from April through to July, but there is activity year round (Figure 4.5). Within 3Lt, harvesting occurs almost exclusively from April to July because snow crab comprises more than 99 percent of the overall harvest (Figure 4.6).

Figure 4.5 Temporal Distribution of All Species Harvesting within the Study Area

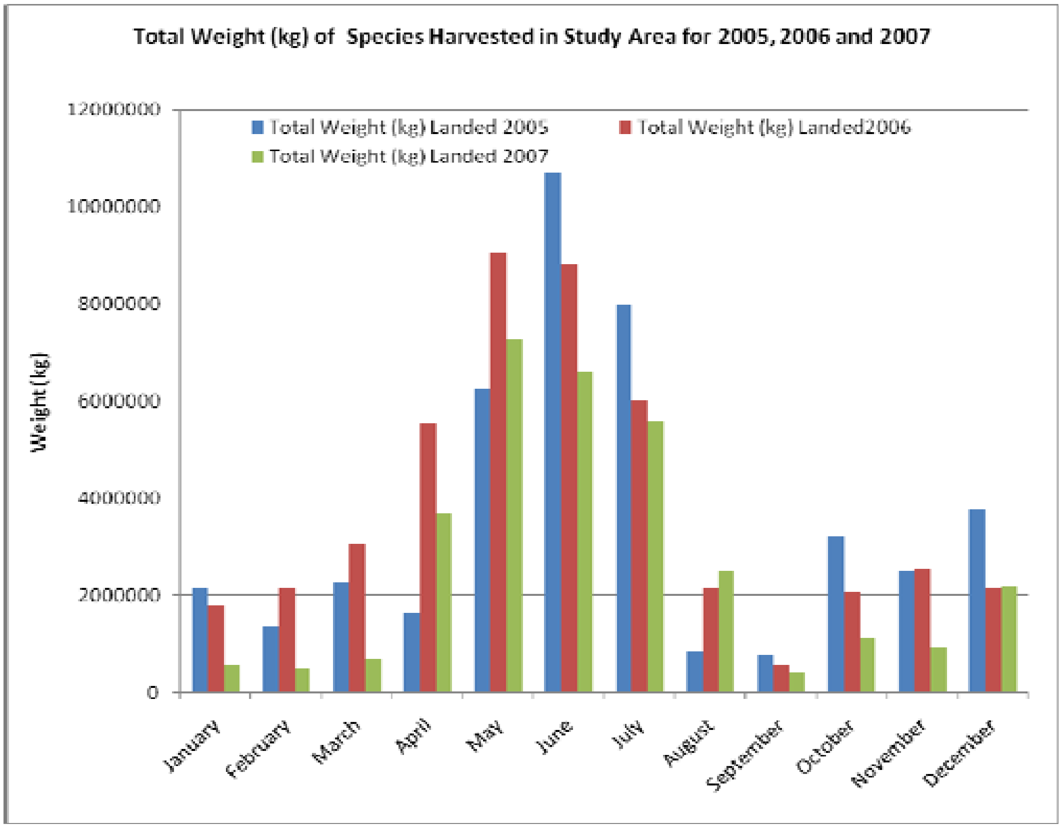
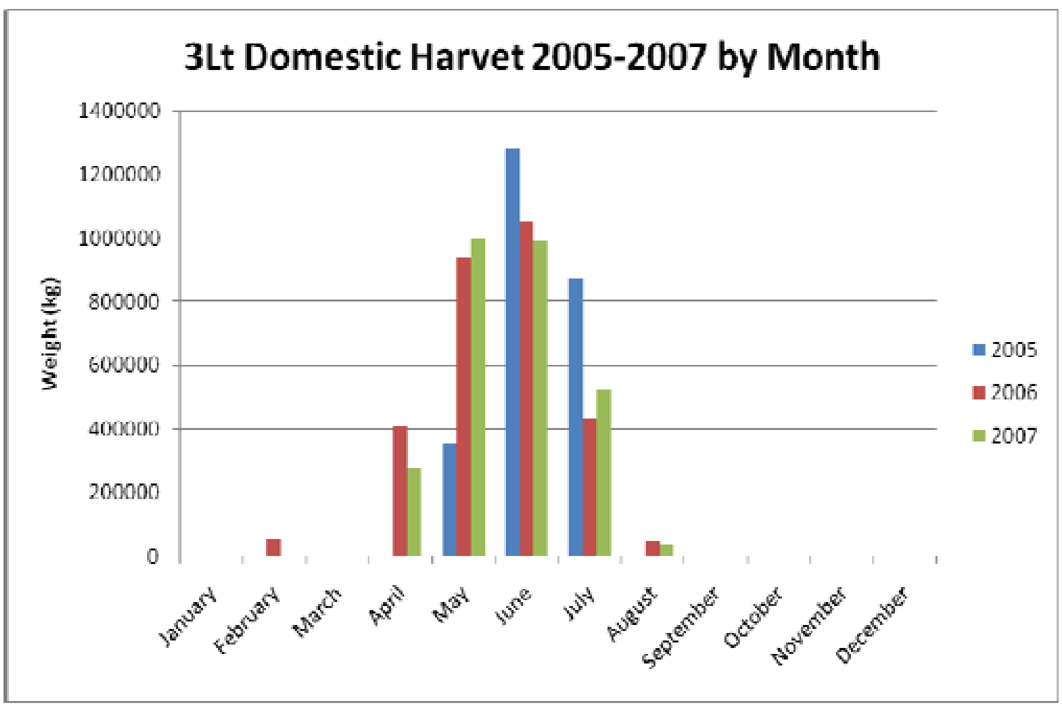
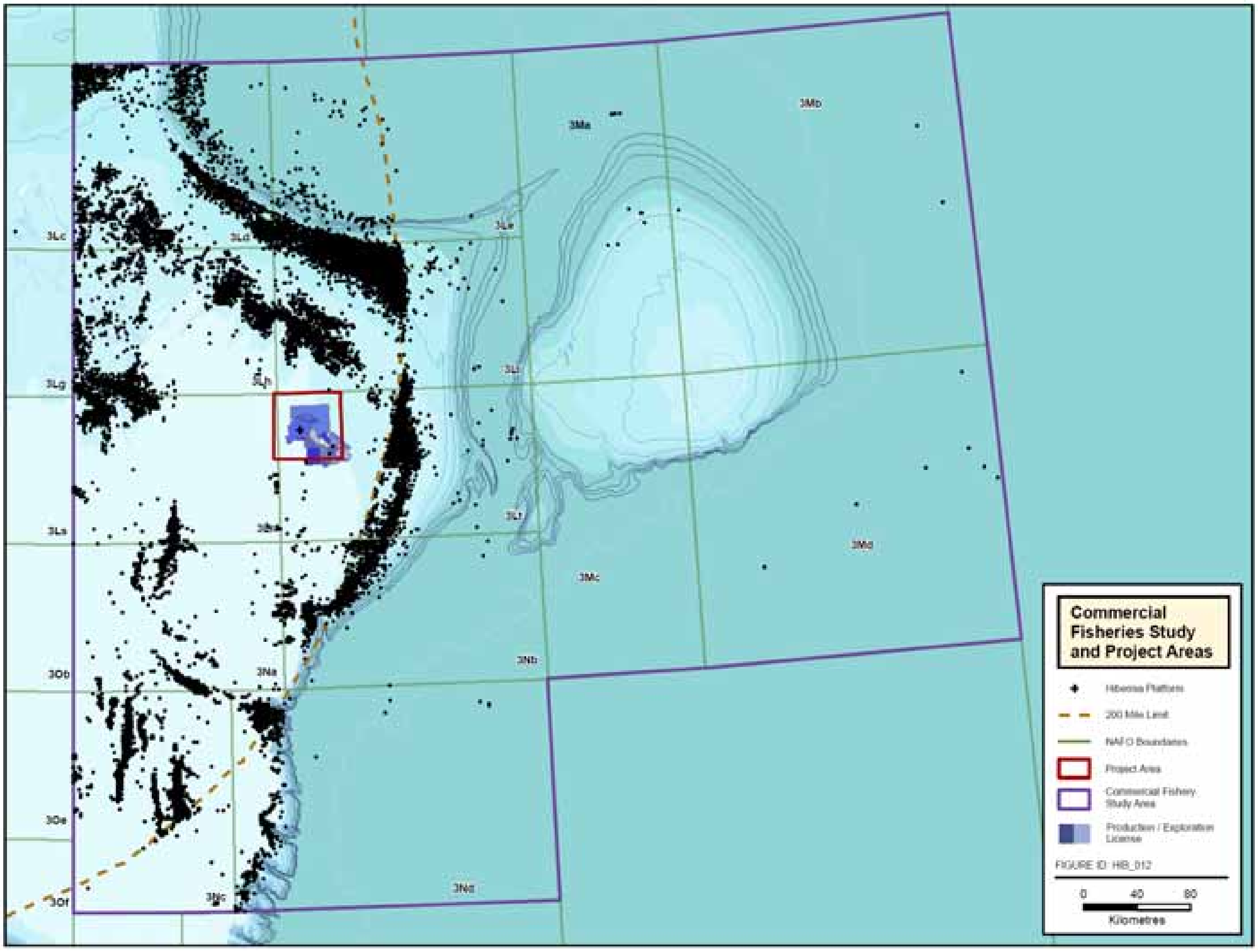


Figure 4.6 Temporal Distribution of All Species Harvesting within 3Lt



Within the Study Area, fishing effort occurs primarily outside the 100 m contour of the Grand Banks. Very little activity occurs in water less than 100 m deep (Figure 4.7). As shown in Figure 4.7, very little fishing effort occurs within the Project Area.

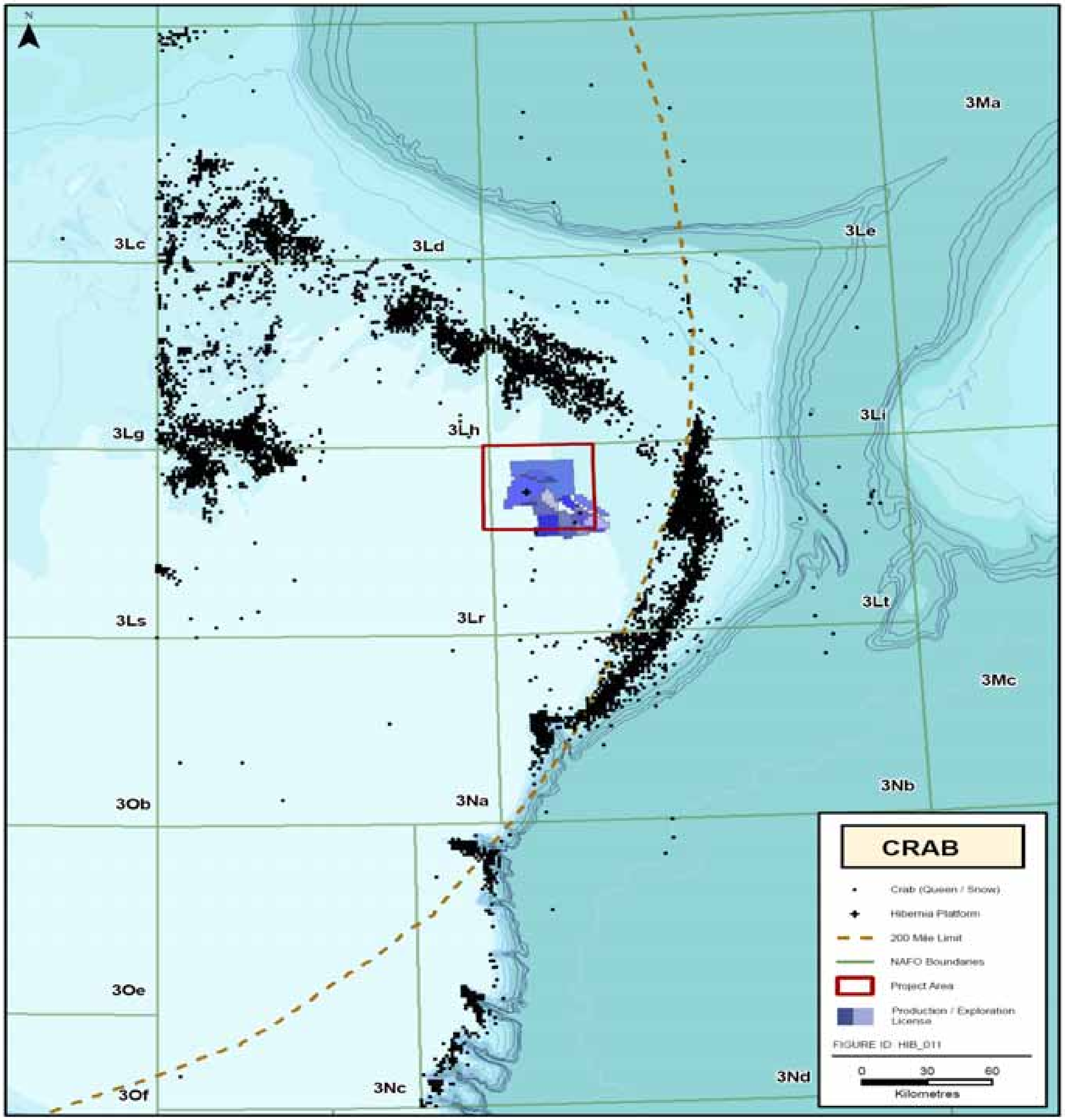
Figure 4.7 Study Area Commercial Fisheries all Species



4.2.3.1 Snow Crab

Most snow crab fishing occurs between the 100 and 200 m contours (Figure 4.8). The snow crab fishery occurs predominantly from May to July. Snow crab landings in 3L peaked at 20,800 t in 1999 and then decreased to approximately 17,900 t between 2000 and 2001 due to a reduction in the total allowable annual catch (DFO 2008a). Since 2001, landings have been increasing and reached their highest level in 2007 at 21,000 t. In 2008, DFO set a quota of 1110 t of crab with 1147 being taken. The fishery was closed on August 7, 2008. (DFO 2008a)

Figure 4.8 Snow Crab Harvesting Locations 2005, 2006 and 2007

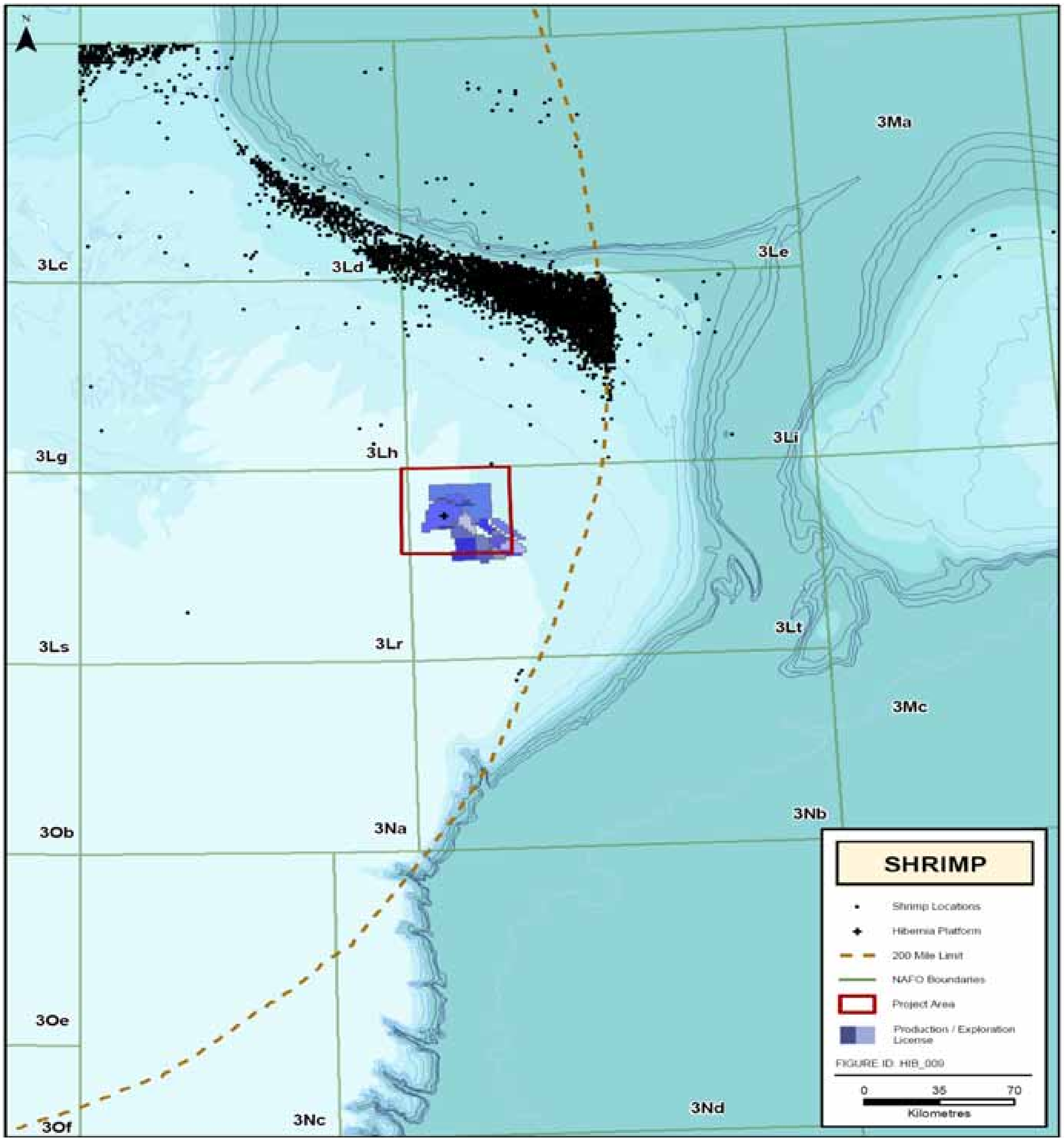


4.2.3.2 Northern Shrimp

Northern shrimp are harvested year–round. Harvesting locations for 2005, 2006 and 2007 are shown in Figure 4.9. Most harvesting during these years occurred in the northern portion of 3Li. There was no domestic shrimp harvested within 3Lt in 2005, 2006 and 2007.

DFO has not yet provided information on 3L shrimp quotas for 2008.

Figure 4.9 Northern Shrimp Harvesting Locations 2005, 2006 and 2007



4.2.3.3 Fishing Gear

Fisheries within 3Lt are conducted almost entirely using crab pots. The amount of crab gear fishers are permitted to use varies by license category, and also by the area in which a license holder may be fishing. Crab pots are set on the seabed in strings buoyed at the surface. Crab gear generally has a highflyer (radar reflector) at one end and a large buoy at the other. Some fishers use highflyers at both ends. Depending on weather, they may be left unattended several days at a time.

Fishers typically try to leave approximately 36 m on the seabed between each pot. For example, allowing slack for the anchor ropes on either end of the string to extend upwards at an angle, the distance between the typical highflyer and end-buoy of a 50- to 60-pot string of crab gear would be approximately 1.8 to 2.3 km.

4.2.3.4 Industry and DFO Surveys

DFO conducts annual spring and fall surveys in NAFO Division 3L each year. The 2008 DFO RV schedule is provided in Table 4.2. Coverage of specific areas and times are usually decided two to four weeks ahead of the surveys and other adjustments are often necessary for operational considerations during these surveys.

DFO conducted the spring survey within NAFO Division 3LNO during May and June. The fall survey is expected to occur from early October to about mid December. Surveys are conducted using the *R/Vs Templeman, Teleost*, or *Needler*.

Table 4.2 Fisheries and Oceans Canada Science Survey Schedule (2008 Final) Eastern Grand Banks

Scientist / Ship	Survey	Start Date	End Date
R/V Templeman or R/V Needler			
Brodie	Multi-species 3LNO	06-May-08	20-May-08
Brodie	Multi-species 3LNO	21-May-08	03-Jun-08
Brodie	Multi-species 3LNO	04-Jun-08	17-Jun-08
Brodie	Multi-species 3LNO	18-Jun-08	28-Jun-08
Brodie	Multi-species - 3KLNO	01-Oct-08	07-Oct-08
Brodie	Multi-species - 3KLNO	08-Oct-08	21-Oct-08
Brodie	Multi-species - 3KLNO	22-Oct-08	04-Nov-08
Brodie	Multi-species - 3KLNO	05-Nov-08	18-Nov-08
Brodie	Multi-species - 3KLNO	19-Nov-08	02-Dec-08
Brodie	Multi-species - 3KLNO	03-Dec-08	16-Dec-08
R/V Teleost			
Brodie	Multi-species 3KLMNO	03-Dec-08	16-Dec-08

4.2.4 Recent Commercial Fisheries within the Project Area

In recent years, the vast majority of the fishery in UA 3Lt is for snow crab, with a clam and cockle harvest in one of the past three years. Within the Project Area, very little fishing has occurred in the past three years, and none in 2007 (Table 4.3). Total harvest from within the Project Area accounted for 0.18 % of the landings for 3Lt from 2005 to 2007.

Table 4.3 3Lt and Project Area Harvest Summary

Area	Species	Weight In Tonnes			Total	Percent of Total
		2005	2006	2007		
3Lt Excluding Project Area	Snow/Queen Crab	2503.19	2868.84	2826.33	8198.36	98.58
	Stimpsons Surf Clams	0.00	84.73	0.00	84.73	1.02
	Cockles	0.00	18.21	0.00	18.21	0.22
	Total Harvest in 3Lt Excluding Project Area				**8301.30**	
Project Area	Snow/Queen Crab	9.16	6.02	0.00	15.18	0.18
	Total Harvest in Project Area				**15.18**	
3Lt + Project Area	Total Harvest in Project Area and 3Lt				**8316.49**	100.00

There are records of two crab fishing events within the Project Area from 2005 to 2007 (Figure 4.8). These reported catches of crab were 6021 kg and 9162 kg harvested in May 2005 and June 2006, respectfully.

4.2.4.1 Emerging Fishery Species

Atlantic hagfish (*Myxine glutinosa*) (also known as slimy eel) is an eel-like (i.e. cartilaginous, not boney) fish that typically grows to approximately 40 to 80 cm in length and lives at depths of 30 to 1,200 m. They are bottom-dwelling and reside in soft, muddy substrates (Scott and Scott 1988).

Hagfish are widely distributed in the Arctic Sea and southward along both coasts of the North Atlantic. Hagfish are distributed in the Northwest Atlantic from Greenland through the Gulf of St Lawrence, around the southern areas of Nova Scotia and New Brunswick, on the west and south coast of Newfoundland and Labrador and southward to New York and continue to Morocco and the Mediterranean Sea in the eastern Atlantic. Spawning is believed to occur anytime throughout the year (Scott and Scott 1988).

In 2006, DFO managers indicated that there was one fisher involved in experimental fishing activities within 3L. This fisher is based in Port au Grave and conducted an experimental harvest of hagfish at various locations. The fisher focused his harvest of this species along the 180-m depth contour with most of the fishing activities concentrated on suitable grounds in the northern portion of 3L.

4.3 Marine Mammals

The Study Area for Marine Mammals is defined by the boundary of the original Hibernia EIS (Mobil Oil 1985). There are at least 20 species of cetaceans (whales), and three species of phocids (seals) that may occur in the Study Area. Additional species may occur rarely. Most marine mammals are seasonal inhabitants, and come to the waters around the Grand Banks to feed. Aggregations of plankton and krill and schooling fish like capelin and squid attract several species of marine mammals. As a result, whales and dolphins are common on the Grand Banks through the spring and summer. Marine mammals are generally opportunistic feeders so they likely move around in search of food. However, there are special feeding areas, like the Southeast Shoal and along the edge of the Shelf where marine mammal prey congregate. There are no known special feeding areas or sensitive areas for marine mammals in the Project Area.

Marine mammals within and near the Study Area were described in the Hibernia EIS (Mobil 1985), updated for the Terra Nova EIS (Petro-Canada 1997), and again for the White Rose Comprehensive Study (Husky 2000). Most of the description of mammal distribution in these assessments was based on marine mammal surveys conducted for the Hibernia EIS (Parsons and Brownlie 1981), which remains the most comprehensive distribution data available.

There are more recent marine mammal sightings data available from a database DFO has been compiling. These are mostly opportunistic records from government platforms such as fisheries vessels, some sightings by fishermen, several aerial surveys by DFO, plus some data collected by oil companies as part of offshore monitoring work, including a few seismic monitoring operations (Jack Lawson, pers. comm.). These data are used here as confirmatory observations within the Project Area and as large scale indications of distribution.

Provided here is a spatial and temporal summary of the DFO marine mammal database, as well as relevant life history details, based on the information known for the Study Area. Population estimates and many of the marine mammal species that occur within the Project and Study Areas are indicated in Table 4.4. For most species of marine mammals there are no reliable population estimates for Atlantic Canada; most estimates provided in Table 4.4 are based on data collected in northeastern U.S. waters (Waring et al. 2006). Additional information on marine mammal species considered at risk by COSEWIC or under the *Species at Risk Act* is provided in Section 4.5.

Table 4.4 Population Estimates of Marine Mammals that Occur in the Study Area

Species	Northwest Atlantic Population Size Estimated Number and Coefficient of Variation (CV)	Stock Occurring in the Study Area	Estimated Number	Source of Updated Information
Baleen Whales				
Humpback Whale	5,505 (11, 570 in North Atlantic; CV=0.068)	NF/Labrador	1,700-3,200	Whitehead (1982); Katona and Beard (1990); (2003); Stevick et al. 2003
Blue Whale	308 [a] (600-1500 in North Atlantic)	NW Atlantic	Unknown	Sears and Calambokidis (2002)
Fin Whale	2,814 [b] (CV=0.21)	Can. E. Coast	Unknown	Waring et al. (2007)
Sei Whale	1,393- 2,248	Nova Scotia	Unknown	COSEWIC (2003); Waring et al. (2007)
Minke Whale	2,998 [c] (CV=0.19)	Can. E. Coast	Unknown	Waring et al. (2007)
Toothed Whales				
Sperm Whale	4,804 [d] (CV=0.38)	North Atlantic	Unknown	Reeves and Whitehead (1997); Waring et al. (2007)
Northern Bottlenose Whale	Tens of thousands	North Atlantic	Unknown	Reeves et al. (1993); Waring et al. (2007)
Sowerby's Beaked Whale	Unknown			Katona et al. (1993)
Bottlenose Dolphin (offshore stock)	81,588 [j] (CV=0.17)	NW Atlantic	Unknown	Waring et al. (2006)
Risso's Dolphin	20,479 [f] (CV=0.59)	US East Coast	Unknown	Waring et al. (2007)
Striped Dolphin	94,462 [i] (CV=0.40)	NW Atlantic	Unknown	Waring at el. (2007)
Killer Whale	Unavailable		Unknown	Lien et al. (1988); Waring et al (2007)
Long-finned Pilot Whale	31,139 [g] (CV=0.27)	NW Atlantic	4000-12,000	Nelson and Lien (1996); Waring et al. (2007); Lawson pers. comm. (2007)
Short-beaked (Common) Dolphin	120,743 [h] (CV=0.23)	NW Atlantic	Unknown	Katona et al. (1993); Waring et al. (2007)
Atlantic White-sided	51,640 [e] (CV=0.38)	NW Atlantic	Unknown	Palka at al. (1997); Waring et al.

Species	Northwest Atlantic Population Size Estimated Number and Coefficient of Variation (CV)	Stock Occurring in the Study Area	Estimated Number	Source of Updated Information
Dolphin				(2007)
White-beaked Dolphin	Unknown	NW Atlantic	Unknown	Waring et al. (2007)
Harbor Porpoise	Unknown	Newfoundland	Unknown	Wang et al. (1996); COSEWIC (2005); Waring et al. (2007)
True Seals				
Harp Seals	5.9 million	NW Atlantic	Unknown	ICES (2005)
Grey Seals	154,000	E. Canada	Unknown	Mohn and Bowen (1996)
Hooded Seals	592,000(±1878,000)	NW Atlantic	Unknown	ICES (2005)
Turtles				
Leatherback	35,000 nesting females	NW Atlantic	Unknown	DFO
Kemp's Ridley	Unknown	US East Coast	Unknown	NMFS
Loggerhead	68,000 to 90,000 nests	US East Coast	Unknown	NMFS

a Based on surveys from the Gulf of St. Lawrence. This estimate deemed unsuitable for abundance estimation.
b Based on surveys from George's Bank to the mouth of the Gulf of St. Lawrence.
[c] Based on surveys from George's Bank to the mouth of the Gulf of St. Lawrence plus a survey in the Gulf of St. Lawrence.
[d] Based on surveys from Florida to the Gulf of St. Lawrence
[e] Gulf of Marine Stock
[f,h,l,] Based on surveys from Florida to Bay of Fundy
[g] Based on surveys from Gulf of St. Lawrence to Florida. Considers both long- and short-finned pliot whales.
[j] Based on surveys from Florida to Georges Bank. Numbers in Atlantic Canada unknown.
Source LGL 2008a

A summary of the known preferred prey item for each marine mammal species is provided in Table 4.5

Table 4.5 Prey of Marine Mammals that Occur in the Study Area

Species	Prey	Source
Baleen whales		
Blue Whale	Euphausiids	
Fin Whale	Fish (predominantly capelin), euphausiids	Piatt et al. (1989)
Sei Whale	Copepods, euphausiids, some fish	
Humpback Whale	Fish(predominantly capelin), euphausiids	Piatt et al. (1989)
Minke Whale	Fish(predominantly capelin), squid, euphausiids	Piatt et al. (1989)
Toothed Whales		
Sperm Whale	Cephalopods, fish	Reeves and Whitehead (1997)
Northern Bottlenose Whale	Primarily squid, also fish	
Sowerby's Beaked Whale	Squid, some fish	Pitman (2002)
Bottlenose Whale	Squid, fish (mackerel, butterfish)	Gaskin (1992a)
Killer Whale	Herring, squid, seals, dolphins, other whales	Lien et al. (1988)
Long-finned Pilot Whale	Short-finned squid, northern cod, amphipods	Nelson and Lien (1996)
Short-beaked (common) Dolphin	Squid, fish	Katona et al. (1993)
Atlantic White-sided Dolphin	Schooling fish (sand lance, herring), hake, squid	Palka et al. (1997)
White-beaked Dolphin	Fish (cod, capelin, herring), squid	Hai et al (1996)
Risso's Dolphin	Squid	Reeves et al. (2002)
Striped Dolphin	Cephalopods, shoaling fish	Reeves et al. (2002
Harbor Porpoise	Schooling fish (capelin, cod, herring, mackerel)	
True Seals		
Harp Seal	Fish (capelin, cod, halibut, sand lance), crustaceans	Lawson and Stenson (1995); Lawson et al. (1998); Wallace and Lawson (1997); Hammill and Stenson (2000)
Hooded Seal	Fish (Greenland halibut, redfish, Arctic and Atlantic cod, herring), squid, shrimp, mollusks	Ross (1993)
Grey Seal	Fish (herring, cod, hake, Pollock), squid, shrimp	Benoit and Bowen (1990), Hammill at al. (1995)

Source: From LGL 2007c after Mobil (1985) with updates where indicated.

4.3.1 DFO Cetacean Sighting Database

The Department of Fisheries and Oceans in St. John's (J. Lawson, pers. comm.) is compiling a database of cetacean sightings in waters around Newfoundland and Labrador from opportunistic observations, DFO and industry surveys. All recorded species observations within the Marine Mammal Study Area and Project Area from 1947 to 2007 have been summarized below in Table 4-6. These data provide some indication of relative abundance and distribution, but quantitative interpretation is not possible since the database typically does not include observation effort.

Table 4.6 contains the coarse summary data pertaining to sightings from the Study Area and the Project Area. Caveats apply to both datasets. Humpback whales accounted for most sightings followed by pilot, fin, and minke whales, respectively. There are relatively few sightings of dolphins and harbour porpoise recorded in the Study Area.

Table 4.6 Cetacean Sighting Records within the Study Area and Project Area

Species	Project Area			Study Area		
	No. of Sightings	No. of Individuals	Month(s) Sighted in Project area	No. of Sightings	No. of Individuals	Month(s) Sighted in Study area
Blue Whale	0	0	N/A	55	70	May – Sept.
Fin Whale	3	5	June, July, Sept.	559	1,419	Feb. – Dec.
Sei Whale	0	0	N/A	41	144	Feb., May – Sept., Nov.
Fin/Sei Whale	0	0	N/A	2	3	July, Sept.
Humpback Whale	38	125	May, July-Oct.	2,544	8,247	Jan. – Dec.
Minke Whale	1	1	May	1,007	2,299	Jan., Mar. – Dec.
Right Whale	0	0	N/A	5	8	June, Aug., Sept.
Sperm Whale	0	0	N/A	146	313	Jan. – Dec.
Pygmy Sperm Whale	0	0	N/A	1	2	June
Northern Bottlenose Whale	0	0	N/A	23	117	Mar. – Sept.
Killer Whale	1	6	June	85	382	Jan., Mar. – Nov.
False Killer Whale	0	0	N/A	1	2	June
Long-finned Pilot Whale	2	17	Mar., Sept.	615	13,003	Jan. – Dec.
Narwhal	0	0	N/A	6	6	June, July
Atlantic White-sided Dolphin	1	7	July	223	3,259	Jan., Feb., April – Nov.
Bottlenose Dolphin	0	0	N/A	2	16	Aug., Sept.
White-beaked Dolphin	3	31	Aug.	151	1,878	Feb. – Sept., Nov.
Common Dolphin	0	0	N/A	204	3,220	Jan., Mar., April, June – Dec.

Species	Project Area			Study Area		
	No. of Sightings	**No. of Individuals**	**Month(s) Sighted in Project area**	**No. of Sightings**	**No. of Individuals**	**Month(s) Sighted in Study area**
Harbour Porpoise	0	0	N/A	209	556	Feb., Mar., May – Dec.
Risso's Dolphin	0	0	N/A	5	41	June, July
Striped Dolphin	0	0	N/A	4	162	Aug.
Unknown Cetacean	11	39	July – Oct.	1,629	15,725	Jan. – Dec.

Source: – Project and Study Area data J. Lawson, DFO Marine Mammal Research Scientist, 2008, pers. comm.) ;
*Note the following caveats associated with the tabulated data:
(1) The sighting data have not yet been completely error-checked.
(2) The quality of some of the sighting data is unknown.
(3) Most data have been gathered from platforms of opportunity that were vessel-based. The inherent problems with negative or positive reactions by cetaceans to the approach of such vessels have not been factored into the data.
(4) Sighting effort has not been quantified (i.e., the numbers cannot be used to estimate true species density or areal abundance)
(5) Both older and some more recent survey data have yet to be entered into this database. These older data will represent only a very small portion of the total data.
(6) Numbers sighted have not been verified (especially in light of the significant differences in detectability among species).
(7) For completeness, these data represent an amalgamation of sightings from a variety of years (e.g., since 1945) and seasons. Hence, they may obscure temporal or areal patterns in distribution (e.g., the number of pilot whales sighted in nearshore Newfoundland appears to have declined since 1980s but the total number sighted in the database included here suggested they are relatively common)

Pilot whales were the only marine mammal recorded in the DFO database from within the Project Area during January, February, and March. Sightings during April, May, and June included the minke, fin, killer, and humpback whales. During July, August, and September marine mammal sightings included humpback, finback, white-beaked dolphins and other unidentified whales and dolphins were recorded in the DFO database. Humpbacks were also recorded in the Project Area during the months of October, November, and December, along with other unidentified mammal species.

Marine Mammal sightings within the Study Area and Project Area are presented by quarter in Figures 4.10 to 4.13.

Figure 4.10 Marine Mammal Sightings in the Study and Project Areas (January to March)

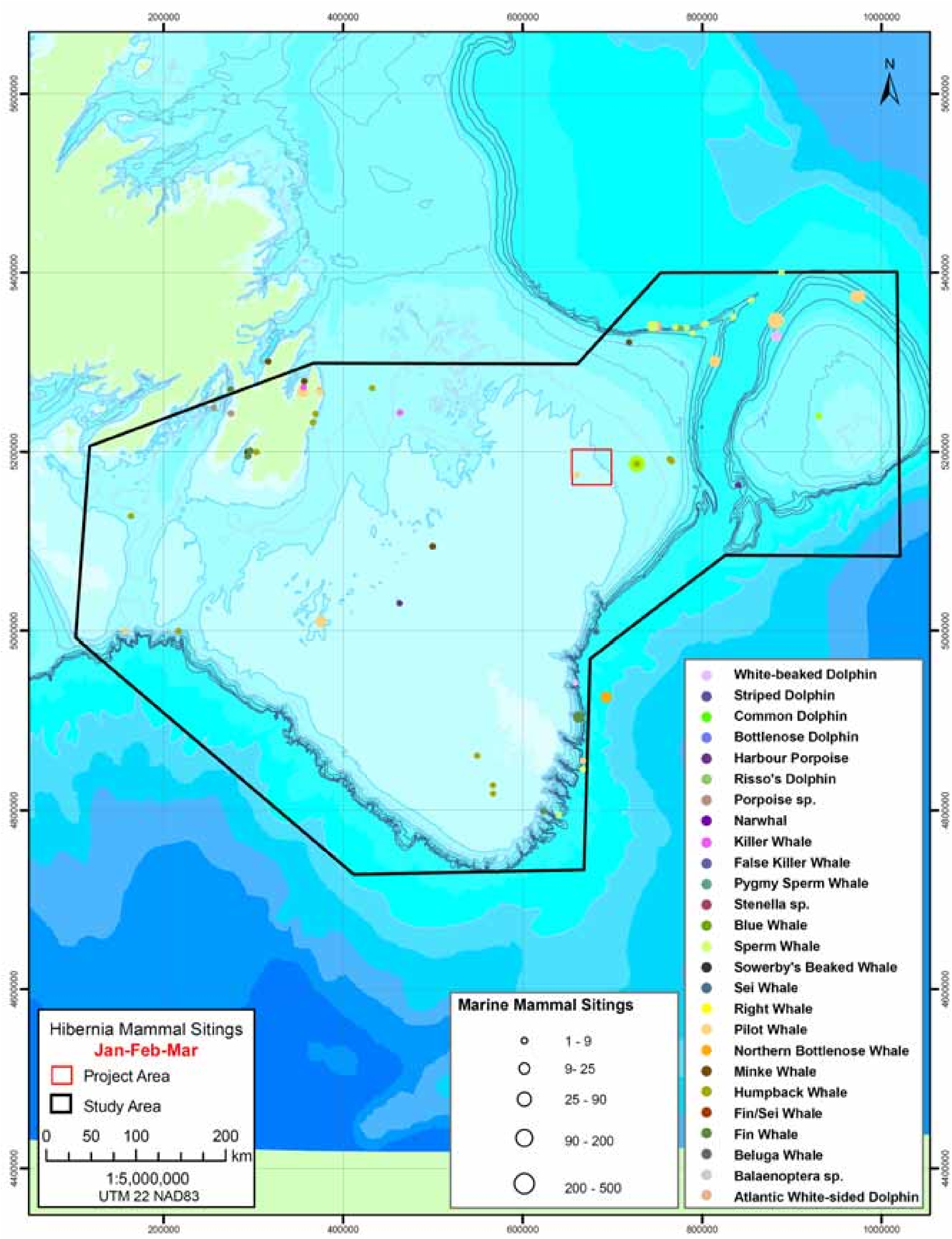


Figure 4.11 Marine Mammal Sightings within the Study and Project Areas (April to June)

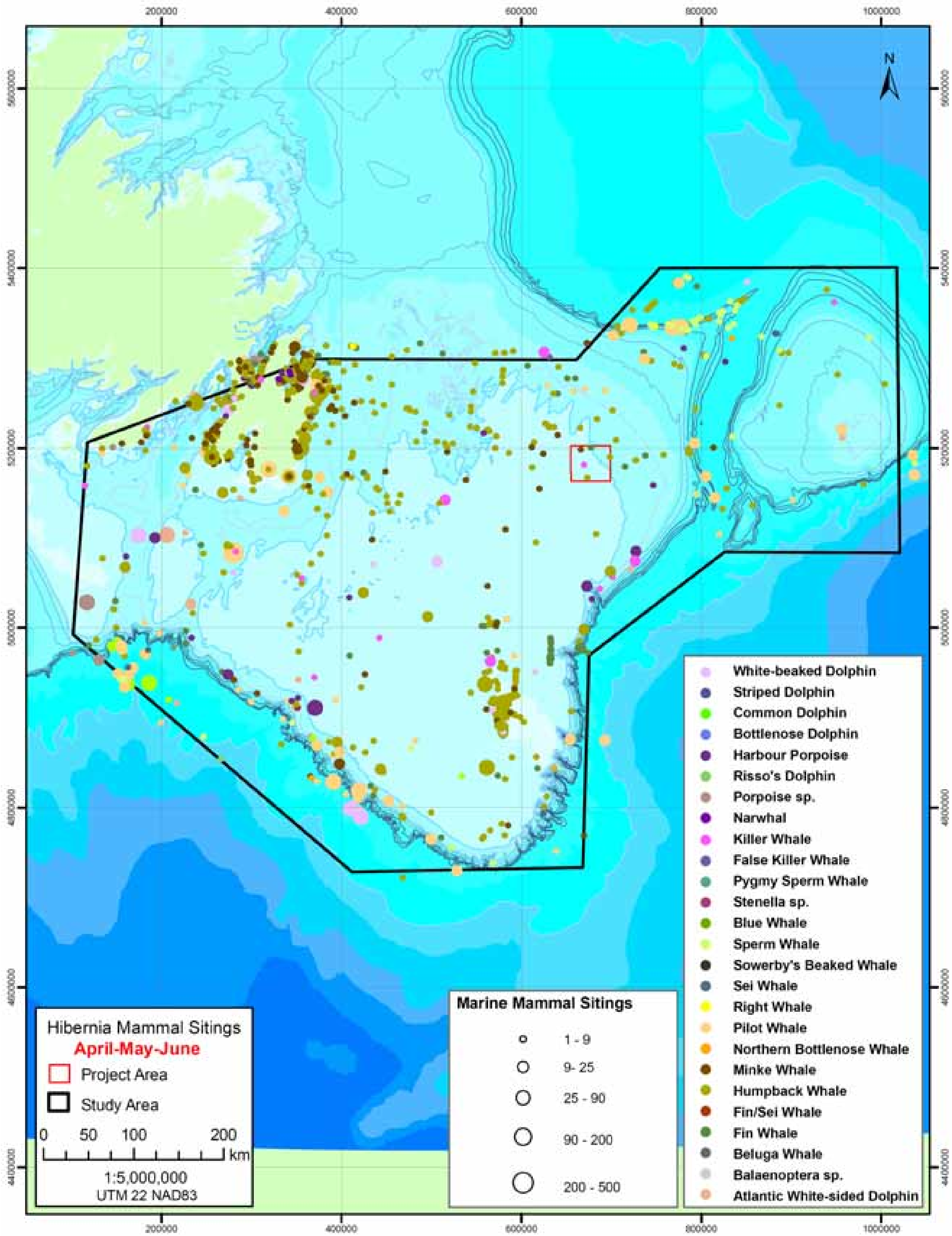


Figure 4.12 Marine Mammal Sightings within the Study and Project Areas (July to September)

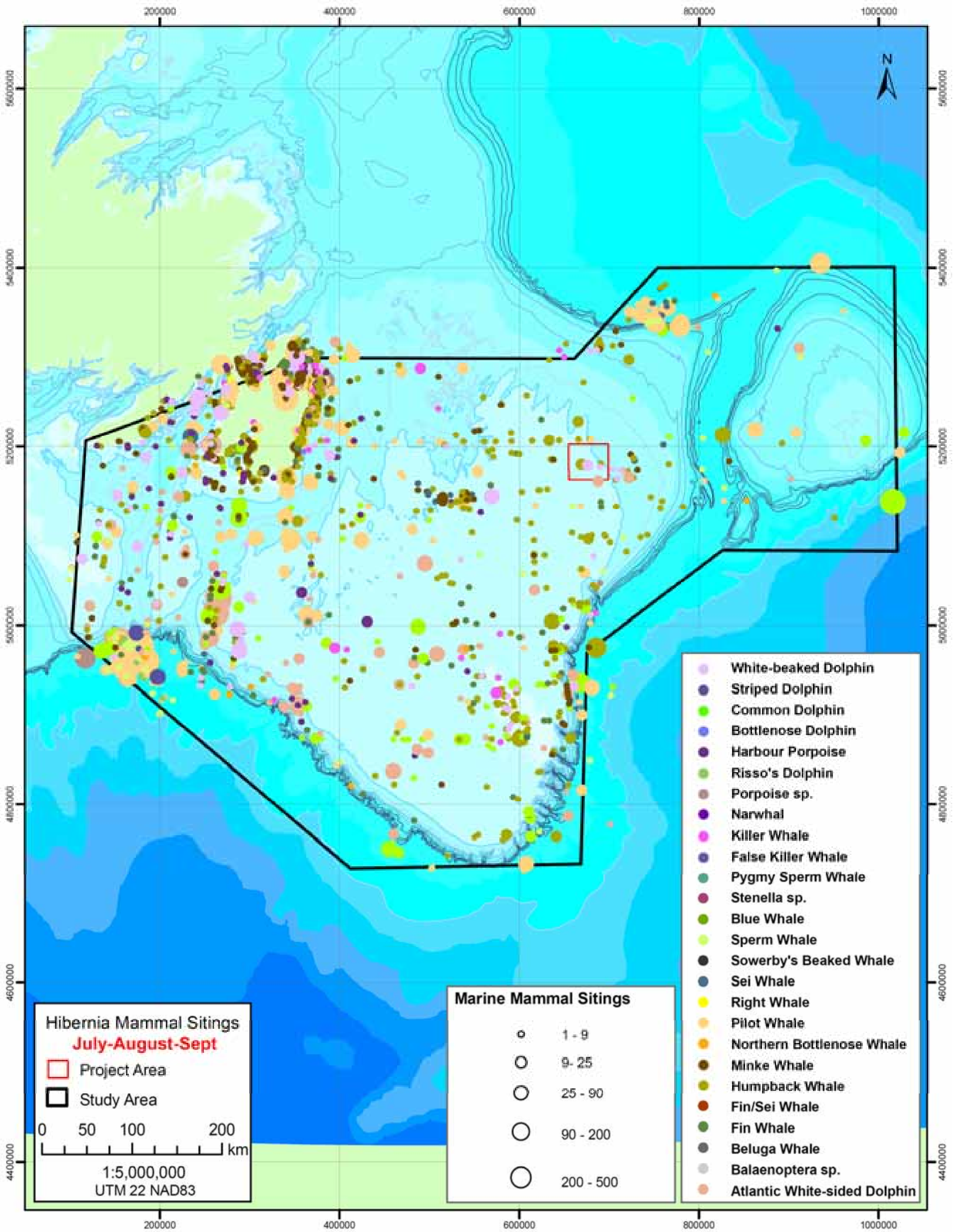
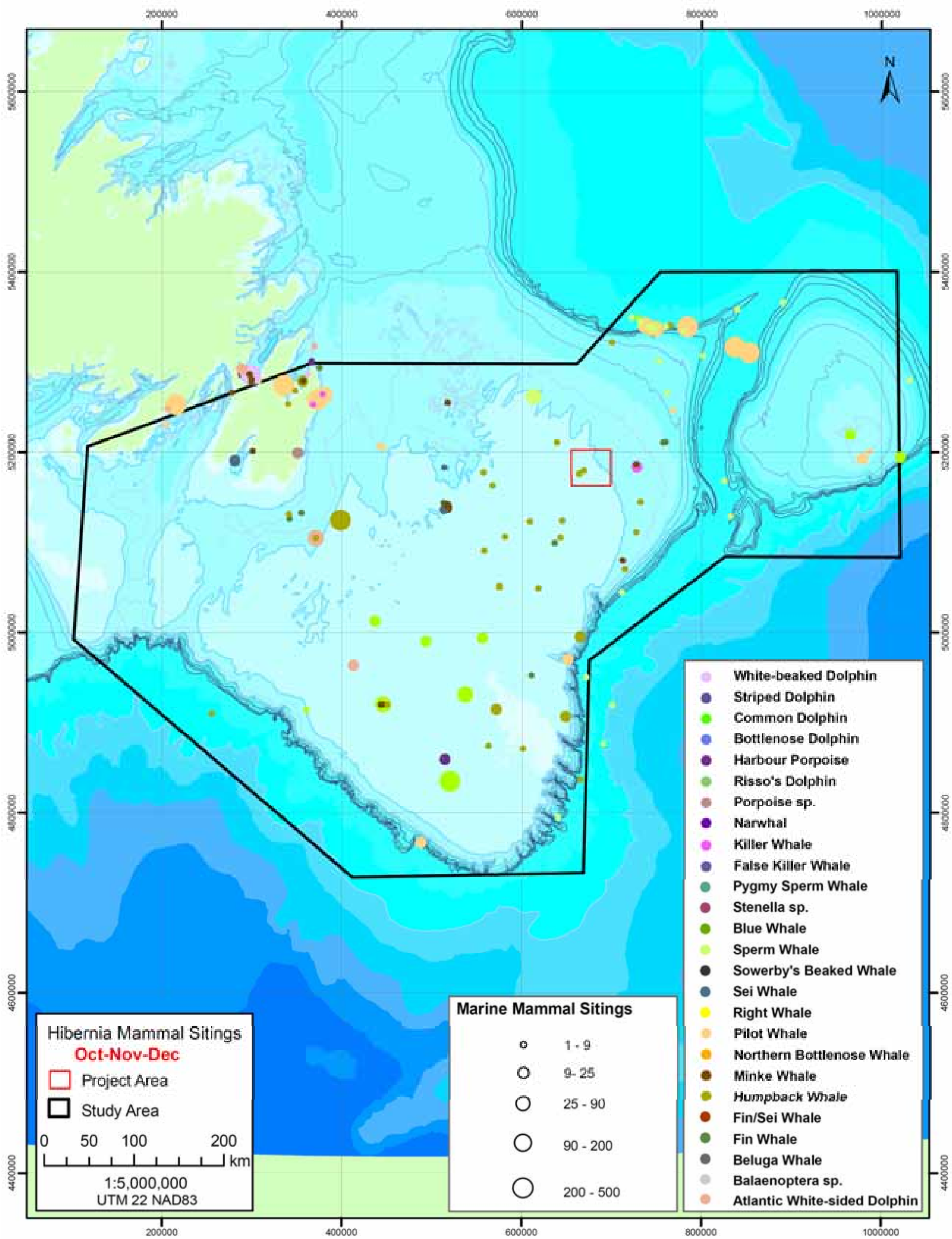


Figure 4.13 Marine Mammal Sightings within the Study and Project Areas (October to December)



4.3.2 Baleen Whales

Presented below are the species profiles of the baleen whales that have the most potential to occur near the Project Area. They include the sei (*B. borealis*), minke (B. *acutorostrata*) and humpback (*Megaptera novaeangliae*) whales. Additional species profiles for baleen whales that may occur within the Study Area are provided in Section 5.7.1.2 of (LGL 2005c) and in Section 4.7.1.2 of LGL (2007c).

4.3.2.1 Humpback Whale

The humpback whale migrates between high-latitude summering grounds and low-latitude wintering grounds (Winn and Reichley 1985). It is by far the most common baleen whale in Newfoundland waters. About 900 humpbacks are thought to use the Southeast Shoal of the Grand Banks during the summer to feed on capelin (Whitehead and Glass 1985).

The entire North Atlantic population is estimated at approximately 11,570 individuals (Baird 2003), the northwest Atlantic population at 5,505 individuals (Katona and Beard 1990) and the Newfoundland/Labrador population at 1,700 to 3,200 (Whitehead 1982).

Humpback whales would be common within the Project Area, except during winter.

4.3.2.2 Sei Whale

Sei whales are not likely as common near the Project Area compared to other baleen whale species. They are most often found in open, pelagic waters and along the continental shelf edge in the northwest Atlantic (COSEWIC 2003). Their diet in the North Atlantic consists mostly of copepods and euphausiids, but they may also feed on schooling fish and squid (see COSEWIC 2003). They migrate northward along the continental slope in July and August and return along the slope from September to November, although their occurrence may be sporadic from year to year (Mitchell 1974, Mitchell and Chapman 1977).

In Atlantic Canada, the Nova Scotia Stock is considered separate from eastern North Atlantic stock and there is possibly another separate stock found off Labrador (COSEWIC 2003). The western North Atlantic population was estimated between 1,393-2,248 animals in the late 1970, but this is still considered the most accurate information (COSEWIC 2003).

The Atlantic population of the sei whale is considered as *data deficient* by COSEWIC (COSEWIC 2007).

4.3.2.3 Minke Whale

The northwest Atlantic population of minke whales is not well known, but the best available estimate is ~3,600 individuals (Waring et al. 2006) which only includes a portion of the minke whale's range in the northwest Atlantic. Minke whales occur worldwide and are common throughout Newfoundland and Labrador during the summer. Most stay for the summer and fall, as late as October or November, but some individuals remain into the winter. Minkes are generally sighted in nearshore or in waters less than 200 m deep (Hooker et al. 1999), but they occur offshore as well. They are most commonly observed singly, but may occur in groups of two or three. Minkes feed on capelin and sand lance (Naud et al. 2003), but also eat planktonic crustaceans, herring, mackerel and, occasionally, squid.

Minke whales occur within and near the Project Area most commonly during the summer. Minke whales are considered ‘not at risk’ by COSEWIC.

4.3.3 Toothed Whales

The toothed whales that may have the most potential to occur near the Project Area include the sperm (*Physeter catadon*), killer (*Orcinus orca*), long-finned pilot (*Globicephala melaena*), northern bottlenose (*Hyperoodon ampullatus*), short-beaked (common) dolphin (*Delphinus delphis*), Atlantic white-sided (*Lagenorhynchus acutus*), and white-beaked dolphin (*L. albirostris*). Species accounts of those toothed whales listed on *SARA* or COSEWIC are presented in Section 4.5.2.

4.3.3.1 Sperm Whale

Sperm whales have an extensive worldwide distribution and are considered ‘not at risk’ by COSEWIC. The population of sperm whales in the western north Atlantic has been estimated to be about 4,800 animals. This species routinely dives to depths of hundreds of metres and may occasionally dive to more than 3,000 m. They apparently are capable of remaining submerged for longer than two hours, but most dives probably last a half-hour or less (Rice 1989). The diet of sperm whales is dominated by squids and fishes (Reeves and Whitehead 1997). Sperm whales use acoustic clicks for echolocation and communication. Measured frequencies during foraging dives have been in the range of 5-14 kHz (Madsen et al. 2002).

Sperm whales have previously been reported to be associated with areas of high plankton productivity and upwelling along the slopes of the Continental Shelf, presumably because squid are also sometimes concentrated in these areas. Sperm whales were regularly sighted in deeper waters (Orphan Basin) north of Jeanne d’Arc Basin during the summers of 2004 and 2005, but were not sighted during the 2005 Husky seismic monitoring program in the Jeanne d’Arc Basin (see LGL 2007a).

4.3.3.2 Killer Whale

Habitat of killer whales varies between populations, with broad variations in water depths, salinity and temperature preferences. The habitat of the Atlantic population is not well described. There have been no clear patterns of distribution or movement documented for this population. However, limited surveys would suggest that the killer whales are not abundant in the North Atlantic.

There were 363 sightings of over 1,710 killer whales reported in Atlantic Canada between 1864 and 2007, with most records occurring since 1950 (Lawson et al. 2007). A large portion (31.4 percent) was recorded in the last seven years during June to September with a majority of them in Newfoundland and Labrador waters (Lawson et al. 2007). They have been recorded in all areas, including Nova Scotia, Gulf of St. Lawrence, Labrador, Hudson Bay and the Canadian Arctic. There have been many suggestions that killer whales migrate seasonally, but this has yet to be documented (Mitchell and Reeves 1988, Sergeant and Fisher 1957 in Lawson et al. 2007). Orcas have been sighted most frequently in Trinity, Bonavista and St. Mary’s Bay, the Strait of Belle Isle, and just off St. John’s (Jon Lien 1985). Killer whales have been sighted in all months of the year, and for the last four years have been seen moving within the nearshore ice fields of northern Newfoundland around breeding harp seals (Lawson unpubl. data in Lawson 2007).

Killer whales feed on fish, squid, seabirds and other marine mammals. Different populations of killer whales specialize on specific prey types, either fish or mammal. The eastern Arctic whales are thought to hunt beluga whales. This primary diet category is one of the population characteristics that are used to segregate killer whale populations into transient or resident types. There are also morphological, genetic and behavioural differences between these two types of killer whale. However, there is not enough information available to segregate killer whales from the Eastern Arctic populations into resident or transient types (COSEWIC *In Press*). On a global basis, killer whales are not endangered. There are no population estimates for the northwest Atlantic. This species is considered 'data deficient' by COSEWIC (2007).

4.3.3.3 Long-finned Pilot Whale

The long-finned pilot whale is considered abundant on the Grand Banks area from July through December, but may occur year-round. Pilot whales are distributed throughout the North Atlantic with some evidence of segregation between the west and east North Atlantic populations (Bloch and Lastein 1993). The Newfoundland and Labrador population has been estimated between 4,000 and 12,000 with a world-wide abundance estimate of 750,000. Long-finned pilot whales or potheads usually travel in pods of 10 or more related individuals (Amos et al 1993; Whitehead et al. 1998). Squid is a primary prey item along with pelagic schooling fish species. The long-finned pilot whale has not been assessed by COSEWIC and is not listed under *SARA*, so is considered not at risk.

4.3.3.4 Northern Bottlenose Whale

The Project Area is within the known range of the northern bottlenose whale and there have been several sightings of this species in deep waters north and south of the Project Area.

This whale's life history is poorly known and most records from Newfoundland are based on carcasses washed ashore. The northern bottlenose whale that inhabits the Scotian Shelf is considered Endangered whereas the Davis Strait population is considered not at risk (COSEWIC 2007). It is uncertain as to which population the individuals sighted off eastern Newfoundland would belong, but available information suggests that it is unlikely that sightings of northern bottlenose whales in or near the Jeanne d'Arc Basin area would be from the Scotian Shelf population.

4.3.3.5 Atlantic White-sided Dolphin

The Atlantic white-sided dolphin is quite common in the Northwest Atlantic, with a total population of several hundred thousand (Reeves et al. 1999). Those in the western North Atlantic may be comprised of three distinct populations; Gulf of Maine, Gulf of St. Lawrence and the Labrador Sea population (Palka et al. 1997).

The Atlantic white-sided dolphin usually travels in groups numbering between 50 and 60, but sometimes number in the hundreds (Reeves et al. 1999). Their primary foods are squid and herring. They are most likely to occur near the Project Area mostly during summer and fall.

The Atlantic white-sided dolphin was declared not at risk by COSEWIC in 1991 and is not listed under *SARA.*

4.3.3.6 White-beaked Dolphin

White-beaked dolphins reside predominantly in high latitude areas. The total population in the North Atlantic could be as high as a few hundred-thousand individuals (Reeves et al. 1999). White-beaked dolphins occur on both sides of the North Atlantic, but the west and east populations are genetically distinct (Kinze 2002). The largest population is off Labrador and south western Greenland, but they are not common near the Project Area.

White-beaked dolphins commonly travel in groups of approximately 30, but groups may number in the hundreds or even thousands (Kinze 2002). They have a varied diet of squid, schooling fish and crustaceans. The white-beaked dolphin was declared not at risk by COSEWIC in 1998 and is not listed under *SARA*.

4.3.4 Seals

Three species of seals are known or suspected to occur near the Project Area including harp, hooded, and grey seals. Other seal species (ringed, harbour, and bearded) may occur rarely.

4.3.4.1 Harp Seal

Harp seals whelp during the spring in the Gulf of St. Lawrence and in an area known as the 'Front' off southern Labrador and northeastern Newfoundland (Sergeant 1991; DFO 2000). Individuals from these two areas spend the summer in the Arctic and then migrate south in the autumn. Surveys conducted during the early 1990s suggested that offshore waters on the northern edge of the Grand Banks in NAFO fishing area 3L were an important over-wintering area for these animals during those years (Stenson and Kavanagh 1994). Similarly, data from satellite transmitters deployed on harp seals suggest that the Grand Banks is an important wintering area for some seals (Stenson and Sjare 1997). It is possible that more harp seals are occurring south of this area in recent years because there has been an apparent change in their distribution. There has been a documented increase in the extralimital occurrences (south of normal range) of harp seals in the northern Gulf of Maine (McAlpine et al. 1999; Lacoste and Stenson 2000), which may also be occurring in the Grand Banks area. This southward expansion may be related to the increase in the harp seal population or the recent changes in ocean ecology that may be affecting their foraging success (McAlpine et al. 1999). The total population in 2004 was estimated at 5.9 million (ICES 2005).

The diet of harp seals foraging off Newfoundland and Labrador appears to vary considerably with age, season, year and location. On the Grand Banks and Labrador Shelf, capelin predominates, followed by sand lance, Greenland halibut and other flatfish (Wallace and Lawson 1997; Lawson et al. 1998). The diet of harp seals greater than one year old from northeast Newfoundland, indicates that there was a shift in prey from capelin in 1982 to Arctic cod in 1986 and beyond, while Atlantic cod remained relatively unimportant throughout this period. Harp seals consume less Atlantic cod than once believed as seals apparently spend more time offshore than previously thought (Hammill and Stenson 2000).

4.3.4.2 Hooded Seal

The most recent population estimate of hooded seals in the northwest Atlantic is 592,100 based upon surveys of pups in 2005 (ICES 2006). Like the harp seal, the hooded seal is a North Atlantic endemic species that reproduces on the spring pack ice of the Gulf of St. Lawrence and along the Labrador coast, and then migrates northward to the sub-Arctic and Arctic to feed during the summer (Lydersen and Kovacs 1999). Little is known regarding their winter distribution, although it is believed that the majority of seals remain offshore; they have been seen feeding off the Grand Banks in February. Surveys in the early 1990s suggested that, as was the case for harp seals, the offshore waters on the northern edge of the Grand Banks also might be an important over-wintering area for hooded seals (Stenson and Kavanagh 1994). The number of visitors to the Study Area is unknown. However, these numbers may be increasing as hooded seals are apparently expanding their southern range of occurrence (McAlpine et al. 1999; Harris et al. 2001a; Mignucci-Giannoni and Odell 2001).

Hooded seals consume a variety of prey including Greenland halibut, redfish, Arctic cod, Atlantic herring and capelin. Relatively small amounts of squid (Gonatus spp.) and Atlantic cod were also found (Ross 1993).

4.3.4.3 Grey Seal

Grey seals on the Grand Banks are likely migrants from the Sable Island and Gulf of St. Lawrence breeding populations. The Sable Island and Gulf of St. Lawrence breeding areas account for essentially all of the pup production in the northwest Atlantic, which increased exponentially between 1977 and 1989 (Stobo and Zwanenburg 1990). The eastern Canadian population of grey seals was estimated at 154,000 in 1994 (Mohn and Bowen 1996). Grey seals potentially occur near the Project Area year-round, but most likely during July and August (Stenson 1994).

The food of grey seals in the western North Atlantic includes at least 40 species including Atlantic cod, herring, and capelin (Benoit and Bowen 1990; Hammill et al. 1995).

4.4 Marine Birds

The avifauna community of the Study Area is composed mainly of true pelagic species, with over 27 marine birds species known in the area. These include species of Alcidae (Dovekie, Murres – Common and Thick-billed, Atlantic Puffin), Laridae (skuas – Great and South Polar; jaegers – Pomarine, Parasitic, and Long-tailed; gulls – Herring, Iceland, Glaucsous, Lesser Black-backed, Great Black-backed, and Ivory; Black-legged Kittiwake and Arctic Tern), Sulidae (Northern Gannet), Hydrobatidae (Wilson and Leach's Storm-Petrels); Phalaropodinae (phalarope – Red and Red-necked), and Procellariidae (Northern Fulmar, Greater, Sooty and Manx Shearwaters).

A summary of seabird biology as it pertains to the Jeanne d'Arc Basin area was recently provided in LGL 2008a (Section 5.4). Here, we provide an overview of the biology and a current summary of seabird observation data collected by CWS under an ESRF funded study to increase our knowledge on seabird distributions.

4.4.1 Prey and Foraging Strategies

Seabirds within the Study Area consume a variety of prey including small fish, crustaceans and invertebrates (Table 4.7). Gulls have an especially varied diet of aquatic and terrestrial vertebrates and invertebrates, plant matter, and the eggs and young of other birds. The Jaeger species are also generalists in their diet. The Parasitic Jaeger specializes on kleptoparasitism (i.e., stealing food from other animals) as a foraging strategy. Other species like the alcids are more specialized on diving for fish. The surface-feeding Procellariiformes roam around the Atlantic covering huge distances and only coming to land to breed (Huntington et al. 1996). They are non-breeders on the Grand Banks, foraging for fish and surface amphipods.

Methods for capturing prey vary from plunge diving to diving from the water surface and feeding at the water surface. Different species occupy different foraging niches in the marine ecosystem, both in strategy and habitat. Foraging strategies of seabirds in the Study Area include: plunge diving, using flight-like movements below the surface like shearwaters practice; pursuit diving, typical of murres;

dipping, or surface feeding (like gulls and phalaropes); kleptoparasitism such as jaegers and skuas; and surface plunging typical of terns. Most seabird species take prey within 0.5 m of the sea surface (Balance et al. 2001). Diet and foraging strategies by species group is outlined in Table 4.7. The main prey and foraging strategies of seabirds in the Study Area are also summarized in Table 4.7.

Seabirds benefit from interactions with other organisms in the ecosystem in obtaining food. Subsurface predators like cetaceans and pinnipeds frequently force prey to the surface, where seabirds can take advantage of high density prey (i.e., forage fish). Seabirds can also benefit by eating injured or disoriented prey from subsurface predators, or from the leftover scraps (Balance et al. 2001). Forage fish are important staples in the diets of most of the seabirds as shown in Table 4.7. Due to their abundance and tendency to swim in large schools they provide an easy and stable food source for many species. Forage fish are an important link in the marine food web, and fluctuations in their availability can be responsible for dramatic, within-season changes in the breeding conditions of certain bird species (Suryan et al. 2002). Capelin are especially known to be a key forage species for birds like the Atlantic Puffin and Black-legged Kittiwake (Carscadden et al. 2002).

Table 4.7 Foraging Strategy and Prey of Seabirds in the Study Area

Species	Prey	Foraging Strategy	Time with Head Under Water	Depth (m)
Procellariidae				
Northern Fulmar	Fish, cephalopods, crustaceans, zooplankton, offal	Surface Feeding	Brief	< 1
Greater Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	1-10
Sooty Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	1-10
Manx Shearwater	Fish, cephalopods, crustaceans, zooplankton, offal	Shallow plunging, surface feeding	Brief	1-10
Hydrobaridae				
Wilson's Storm-Petrel	Crustaceans, zooplankton	Surface Feeding	Brief	<0.5
Leach's Storm Petrel	Crustaceans, zooplankton	Surface Feeding	Brief	<0.5
Sulidae				
Northern Gannet	Fish, cephalopods	Deep plunge diving	Brief	10
Phalaropodinae				
Red Phalarope	Zooplankton, crustaceans	Surface Feeding	Brief	0
Red-necked Phalarope	Zooplankton, crustaceans	Surface Feeding	Brief	0
Laridae				
Great Skua	Fish, cephalopods, offal	Kleptoparasitism	Brief	<0.5
South Polar Skua	Fish, cephalopods, offal	Kleptoparasitism	Brief	<0.5
Pomarine Jaeger	Fish	Kleptoparasitism	Brief	<0.5
Parasitic Jaeger	Fish	Kleptoparasitism	Brief	<0.5
Long-tailed Jaeger	Fish, crustaceans	Kleptoparasitism , surface feeding	Brief	<0.5
Herring Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5
Iceland Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5
Glaucous Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5
Great Black-backed Gull	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5
Black-legged Kittiwake	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5
Arctic Tern	Fish, crustaceans, offal	Surface feeding, shallow plunging	Brief	<0.5

Species	Prey	Foraging Strategy	Time with Head Under Water	Depth (m)
Alcidae				
Dovekie	Crustaceans, zooplankton, fish	Pursuit diving	Prolonged	Max 30, Average is <30
Common Murre	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 100, average 20-50
Thick-billed Murre	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 100, average 20-60
Razorbill	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 120, average 25
Atlantic Puffin	Fish, crustaceans, zooplankton	Pursuit diving	Prolonged	Max 60, average <60

Sources: Cramp and Simmons (1983); Nettleship and Birkhead (1985); Lock et al. (1994); Gaston and Jones (1998).

4.4.2 Seasonal Abundance

The abundance and distribution of marine birds within the Study Area varies considerably season. For instance, the Northern Fulmar (*Fulmaris glacialis*) is common throughout the year, whereas the Greater Shearwater (*Puffinus gravis*) and Sooty Shearwater (*Puffinus griseus*) is common from June to October, and absent from January to March. Leach's Storm-Petrels (*Oceanites oceanicus*) are common from May to October. The Northern Gannet (*Morus bassanus*) may occur from May to October. Red Phalarope (*Phalaropus fulicarius*) and Red-necked Phalarope (*P. lobatus*) and Skuas (*Stercorarius* spp.*)*, may occur from May to September/October, but in low numbers. The gull species may occur during the winter months. Auks such as Dovekies (*Alle alle*) and Thick-billed Murre (*Uria lomvia*) are most numerous in Newfoundland waters during the winter and migration periods. Common Murre (*Uria aalge*) and Atlantic Puffin (*Fratercula arctica*) are abundant breeders in Newfoundland but winter mostly south of the Project Area.

Table 4.8 provides a summary of seabird abundance within the Study Area.

Table 4.8 Predicted monthly abundances of seabird species occurring in the Study Area.

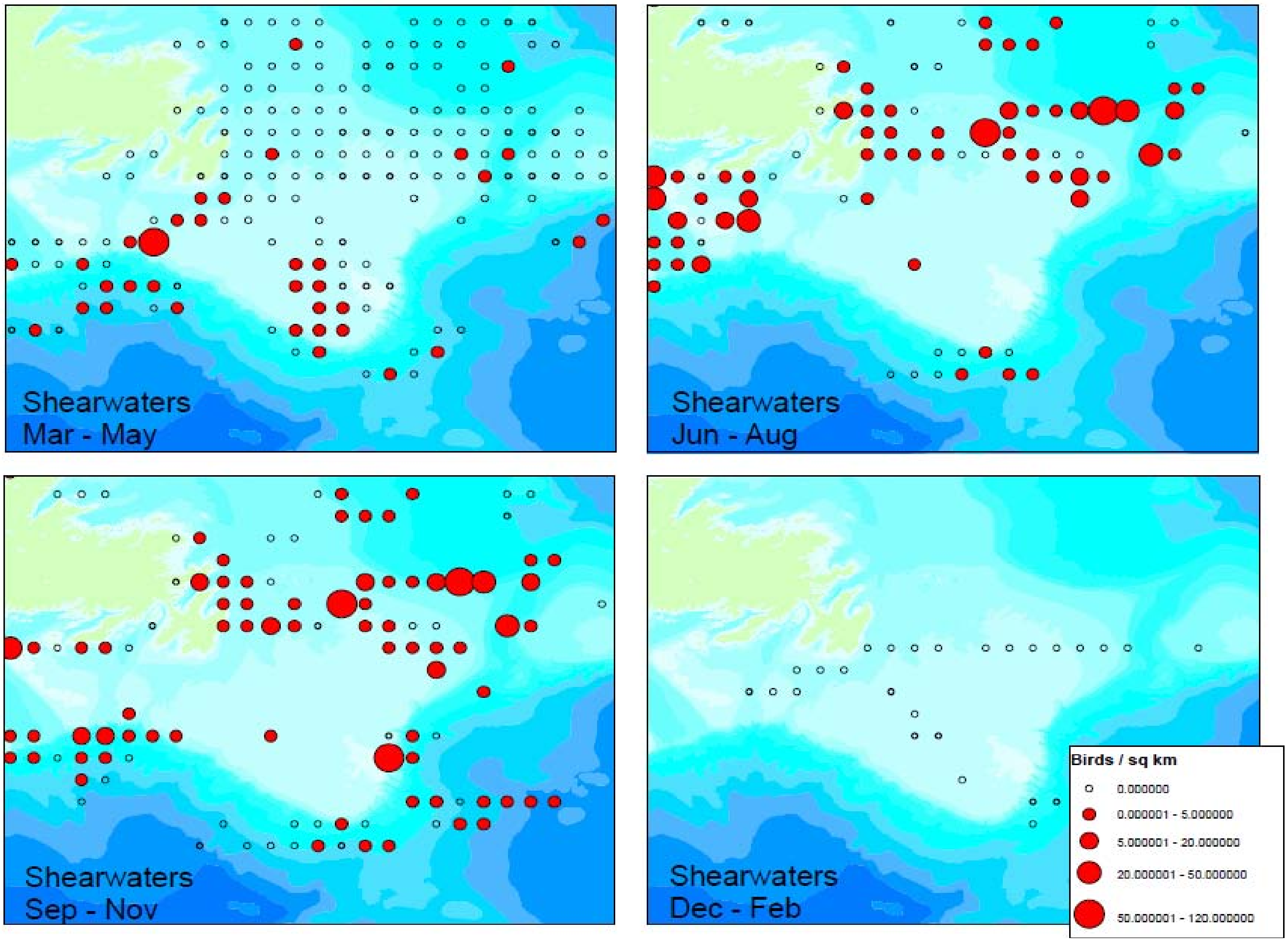
Common Name	***Scientific Name***	**Monthly Abundance**											
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Procellariidae													
Norhtern Fulmar	*Fulmarus glacialis*	C	C	C	C	C	C	C	C	C	C	C	C
Greater Shearwater	*Puffinus gyavis*					U	C	C	C	C	C	S	
Sooty Shearwater	*Puffinus gyiseus*					S	S-U	S-U	S-U	S-U	S-U	S	
Manx Shearwater	*Puffinus puffinus*					S	S	S	S	S	S		
Hydrobatidae													
Leach's Storm-Petrel	*Oceanodroma leucorhoa*				U-C	U-C	U-C	U-C	U-C	U-C	U-C	S	
Wilson's Storm-Petrel	*Oceanites oceanicus*						S	S	S	S			
Sulidae													
Northern Gannet	*Morus bassanus*				S	S	S	S	S	S	S		
Phalaropodinae													
Red Phalarope	*Phalaropus fulicarius*					S	S	S	S	S	S		
Red-necked Phalarope	*Phalaropus lobatus*					S	S	S	S	S			
Laridae													
Great Skua	*Stercorarius skua*					S	S	S	S	S	S		
South Polar Skua	*Stercorarius Maccormichi*					S	S	S	S	S	S		
Pomarine Jaeger	*Stercorarius pomarinus*					S	S	S	S	S	S		
Parasitic Jaeger	*Stercorarius parasiticus*					S	S	S	S	S			
Long-tailed Jaeger	*Stercorarius longicaudus*					S	S	S	S	S	S		
Herring Gull	*Larus argentatus*	S	S	VS	VS	VS	VS	VS	VS	S	S	S	S
Iceland Gull	*Larus glaucoides*	S	S	S	S							S	S
Lesser Blk-backed Gull	*Larus fuscus*					VS	VS	VS	VS	VS	VS	VS	VS
Glaucous Gull	*Larus hyperboreus*	S	S	S	S						S	S	S
Great Black-backed Gull	*Larus marinus*	U	U	VS	VS	VS	VS	VS	U	U	U	U	U
Ivory Gull	*Pagophila eburnea*	VS?	VS?	VS?	VS?								
Black-legged Kittiwake	*Rissa tridactyla*	C	C	C	C	C	S	S	S	U	C	C	C
Arctic Tern	*Sterna paradisaea*					S	S	S	S	S			
Alcidae													
Dovekie	*Alle alle*	U-C	U-C	U-C	U-C	S	VS	VS	VS	S	C	C	U-C
Common Murre	*Uria aalge*	S-U	S-U	S-U	S-U	S-U	S	S	S	S	S-U	S-U	S-U
Thick-billed Murre	*Uria lomvia*	U-C	U-C	U-C	U-C	VS-S	VS-S	VS-S	VS-S	VS-S	U-C	U-C	U-C
Razorbill	*Alca torda*				S	S	S	S	S	S	S	S	
Atlantic Puffin	*Fratercula arctica*				S-U	S-U	S-U	S-U	S-U	S-U	U	U	

Source: Brown (1986); Lock et al. (1994); Baillie et al. (2005); Lang et al. (2006). Abgrail et al (in prep. a) and Lang (2007).

Notes: C =Common, occurring daily in moderate to high numbers, U = Uncommon, occurring regularly in small numbers, S = Scarce, a few individuals occurring and VS = Very Scarce, very few individuals. Blank cells indicate that the species is not expected to occur.

As indicated by at-sea data collected since 2005 by CWS, Shearwater observations in the Study Area are the greatest during summer and fall (June to August and September to November) with highest concentrations on the northeast slope of the Grand Banks. There were modest observations during the spring (March to May) and they are scarce during the winter months (Figure 4.14).

Figure 4.14 Shearwater Abundance and Distribution within the Study Area

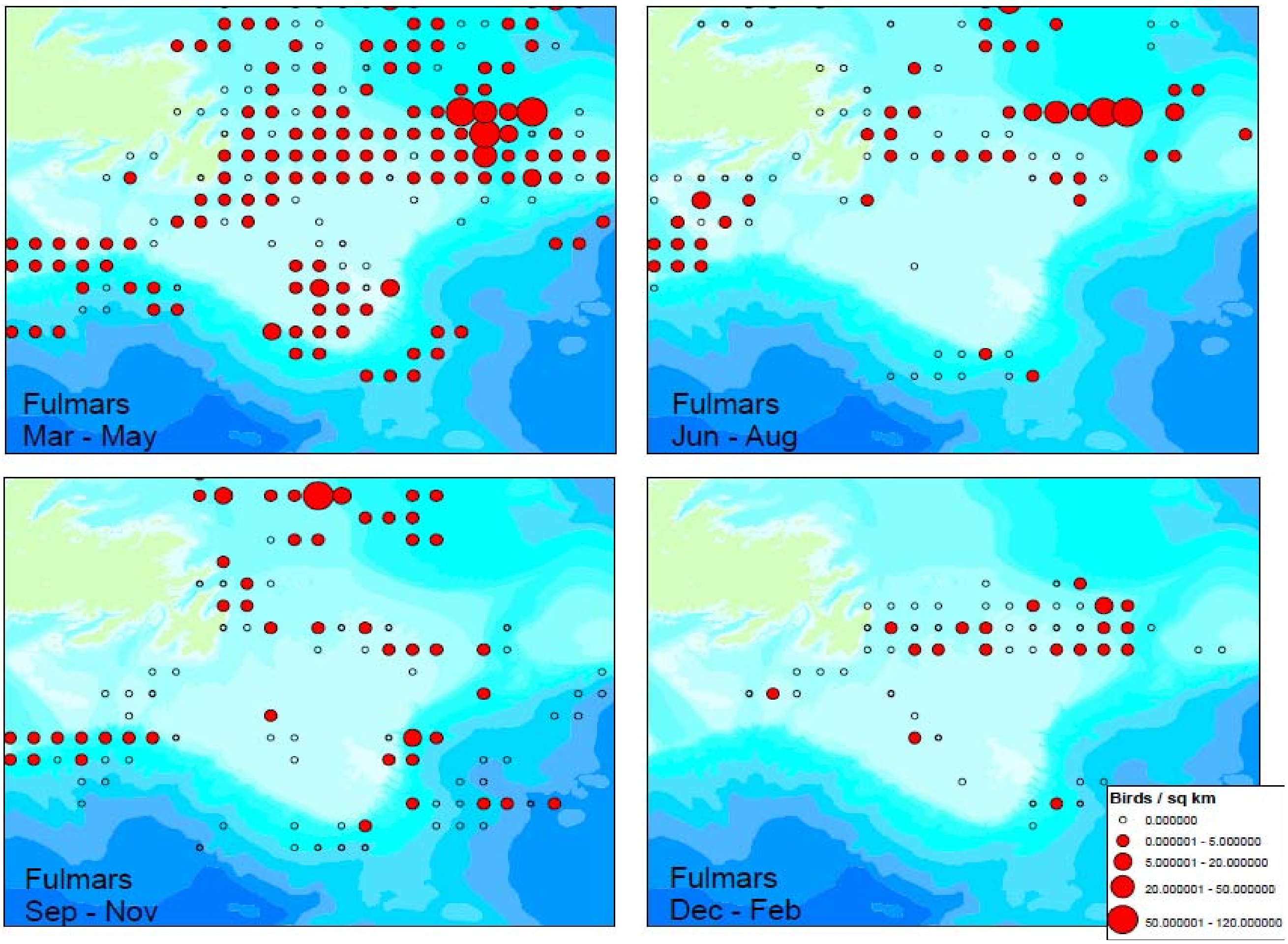


Source: CWS Pelagic Seabird Database 2008

The Manx Shearwater is a scarce breeder in North America and is expected to be scarce from April to November within the Study Area. Most of the world's population of Greater Shearwater is thought to migrate from South Atlantic breeding colonies to the Grand Banks and eastern Newfoundland to moult and feed during summer months after completion of nesting (Lock et al. 1994 in LGL 2008a). This species is expected to be common in the Study Area from May to early November, whereas Sooty Shearwater is expected to be uncommon from May to October (Brown 1986; Baillie et al. 2005 in LGL 2008b).

Northern Fulmars were most abundant on the northeast slope of the Grand Banks and Flemish Pass area during from March to May. Observations during the summer and fall months are modest and observations during the winter months were low by comparison (Figure 4.15). In October, large numbers of Arctic breeding Northern Fulmars arrive in eastern Newfoundland waters, including the Grand Banks, to spend the winter.

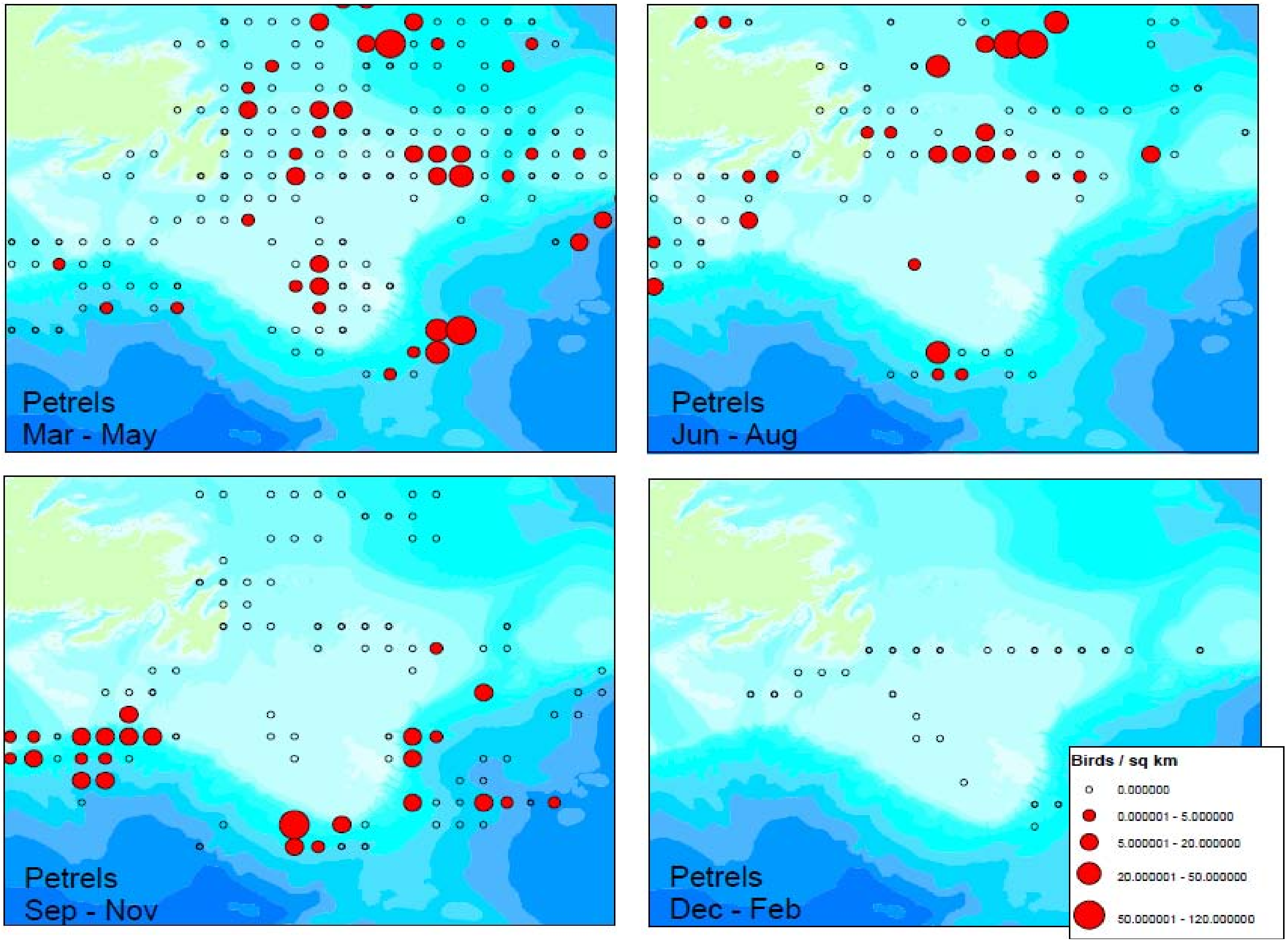
Figure 4.15 Fulmar Abundance and Distribution within the Study Area



Source: CWS Pelagic Seabird Database 2008

Petrels are congregated in large numbers on the northern Grand Banks and the northeast Newfoundland Shelf during spring and summer. Their distribution appears to move off the shelf to deeper waters throughout the fall and winter (Figure 4.16). Concentrations of petrels were observed along the slope of the Grand Banks in all months except winter. Leach's Storm-Petrel is an abundant breeder in eastern Newfoundland (Cairns et al. 1989) and nesting birds can range far from colonies on foraging trips. Wilson's Storm-Petrel migrate from Southern Atlantic colonies to the Grand Banks.

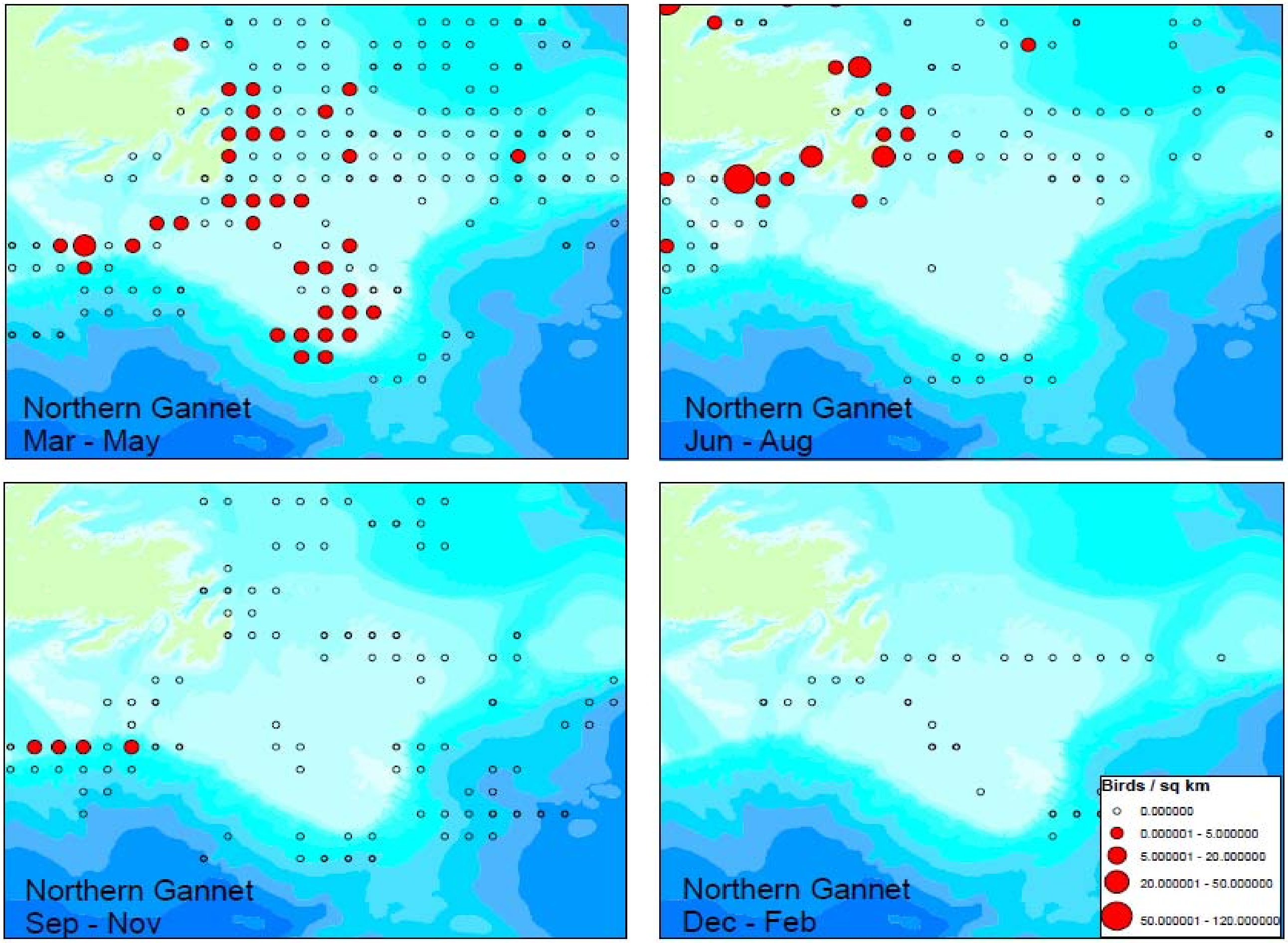
Figure 4.16 Petrel Abundance and Distribution within the Study Area



Source: CWS Pelagic Seabird Database 2008

Northern Gannet observations were the highest during the months of March to May on the tail and southeast shoal area of the Grand Banks and some coastal areas. During the summer months, observations were highest along coastal areas, with few records from the Grand Banks. Northern Gannets were absent during the fall and winter surveys of the Grand Banks (Figure 4.17). Gannets are common near shore and scarce beyond 100 km from shore. The Project Area is beyond the range of most Northern Gannets.

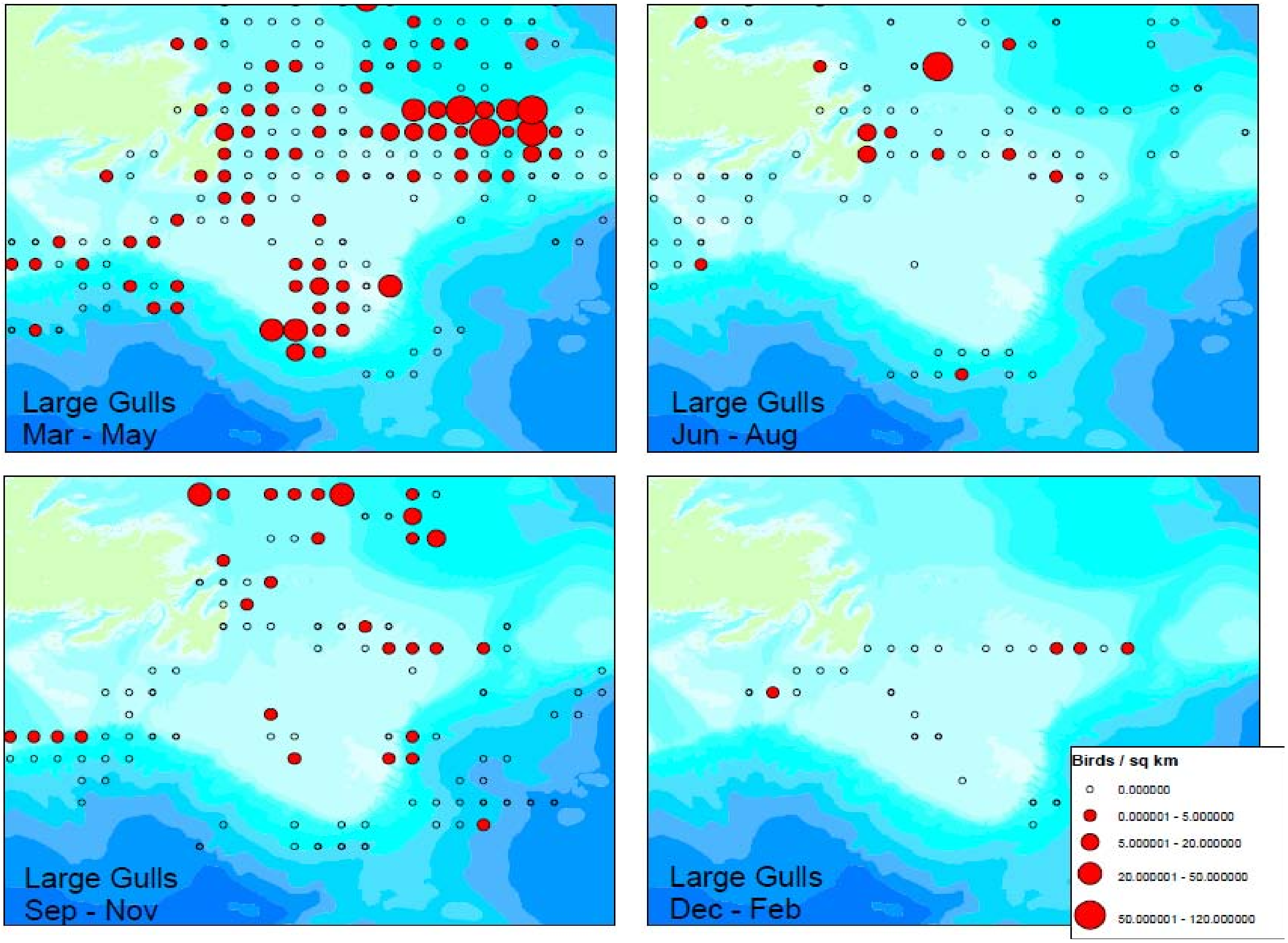
**Figure 4.17	Northern Gannet Abundance and Distribution**



Source: CWS Pelagic Seabird Database 2008

Large gulls were most abundant during the spring along the northeast slope of the Grand Banks and in the Flemish Pass area. Concentrations then disburse to coastal areas and the northeast coast of Newfoundland during the summer and fall months. There were few gulls observed from December to February (Figure 4.18). The Great Black-backed Gull is uncommon near the Project Area after September. Herring, Glaucous and Iceland Gulls are scarce or absent near the Project Area.

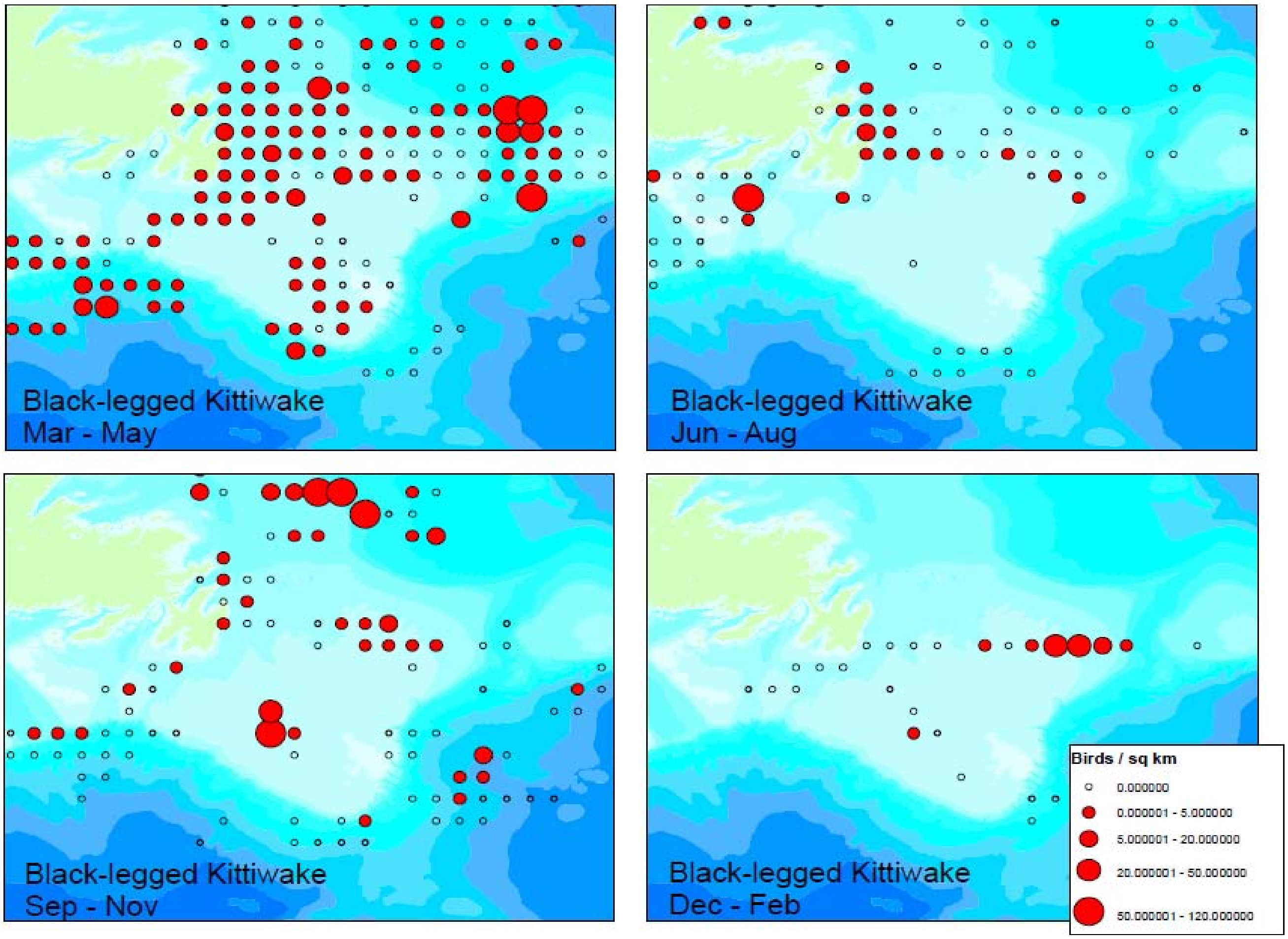
Figure 4.18 Large Gull Abundance and Distribution within the Study Area



Source: CWS Pelagic Seabird Database 2008

Black-legged Kittiwakes were most abundant throughout the northeast Newfoundland Shelf, the northern Grand Banks and the Flemish Pass area during the spring. Highest concentrations were observed along coastal areas during the summer, the northeast Newfoundland Shelf during the fall and the northeast slope of the Grand Banks over the winter (Figure 4.19). Black-legged Kittiwake is a pelagic gull that goes to land only during the breeding season. Non-breeding sub-adults remain at sea for the first year of life. The Black-legged Kittiwake may be present in the Project Area year-round but scarce from May to September.

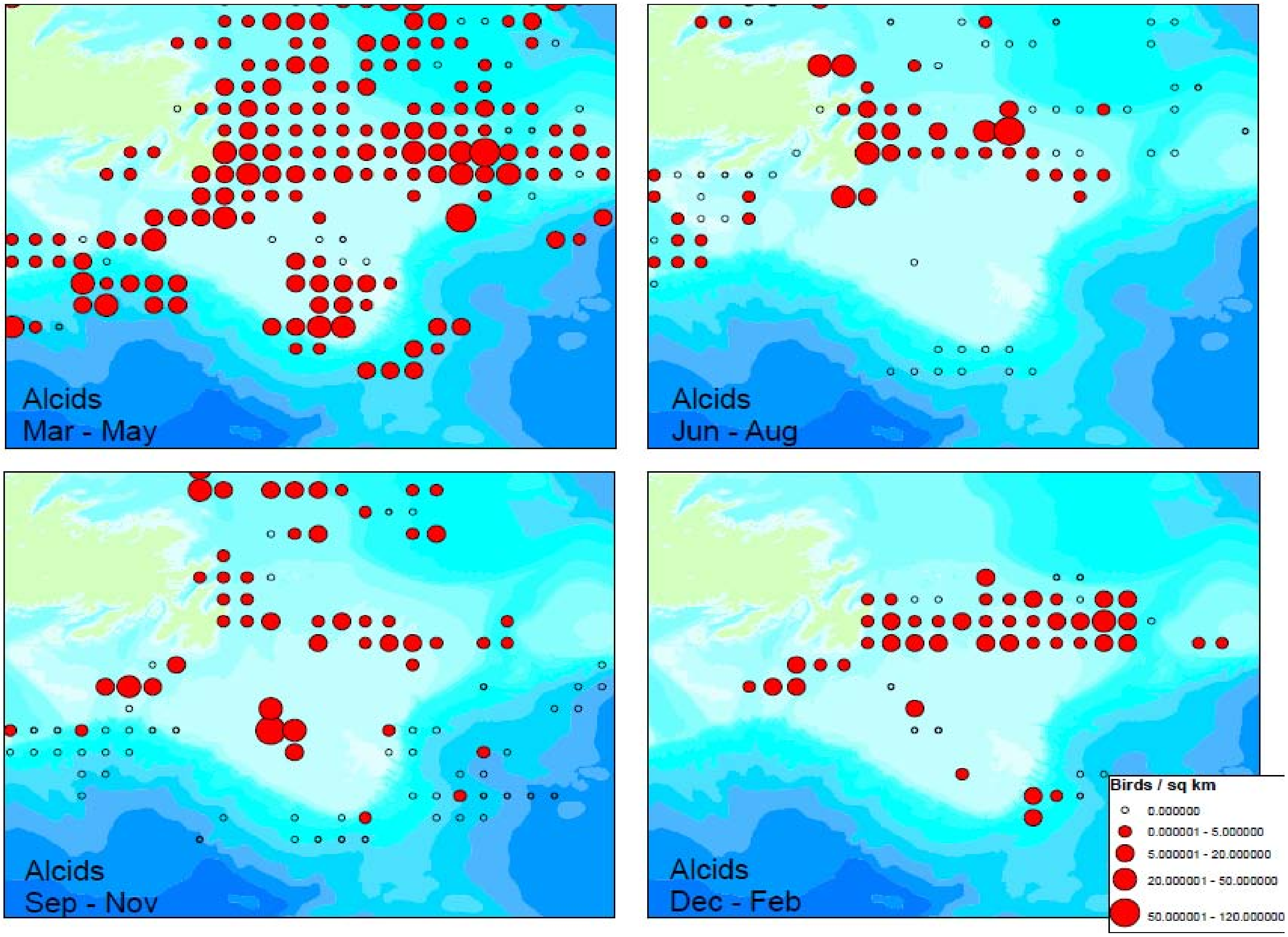
Figure 4.19 Black-legged Kittiwake Abundance and Distribution within the Study Area



Source: CWS Pelagic Seabird Database 2008

Alcids (Dovekie, Common Murre, Thick-billed Murre, Razorbill, and Atlantic Puffins) occur year round on the northern Grand Banks and throughout the Study Area during the spring (Figure 4.20). Concentrations are contracted to the northern Grand Banks and coastal areas during the summer, with large aggregations near the southwest shoal of the Grand Banks during the fall and winter. Most species of Alcidae breed in the North Atlantic, and migrate near through the Study Area. Razorbills are the exception spending most of their time near shore in Newfoundland waters. Thick-billed Murre and Dovekie are breeding species in Arctic regions of the North Atlantic. Both species winter in significantly large numbers in Newfoundland waters including the Study Area. Brown (1988) found that the largest concentrations of Dovkies occurred over the shelfbreaks where apparently large numbers of zooplankton aggregate. They are present in the Study Area mainly during the non-breeding season from October to May. Common Murre and Atlantic Puffin are both locally abundant breeders in eastern Newfoundland. Both are expected to be present in low densities within the Project Area during spring migration, summer and fall migration (April to November). Common Murre is probably present through the winter months as well, but Atlantic Puffin is not likely to occur during winter months.

Figure 4.20 Alcid Abundance and Distribution within the Study Area



Source: CWS Pelagic Seabird Database 2008

4.4.3 Breeding Birds

Eastern Newfoundland is the breeding centre for common murres and Atlantic puffins in the western Atlantic. Northern gannets breed at only six colonies in North America, three in Newfoundland and three in the Gulf of St. Lawrence. Similarly, Baccalieu Island supports more than 3.3 million pairs of Leach's Storm-Petrels, making it the breeding centre for this species in the Atlantic Ocean (NLDOEC 2005). The Grand Banks is also the wintering area for over four million of the five to six million thick-billed murres that nest in western Greenland and the eastern Canadian Arctic, and for 14 million dovekies that nest along northwest Greenland (Lock et al. 1994). It is likely that most of the world population of greater shearwaters (5 to 10 million birds) summers in the North Atlantic (Lock et al. 1994). The sheer number of marine birds using the Grand Banks region results in the area being globally important for marine bird populations.

The number of pairs of seabirds nesting at seabird colonies in eastern Newfoundland is shown in Table 4.9. As well, a large number of coastal species, including gulls, terns, cormorants, waterfowl and shorebirds, frequent the shore zones of the Study Area.

Fifty-seven percent of the northwest Atlantic Puffin population, an estimated 272,729 breeding pairs, nests within the Witless Bay Ecological Reserve (Robertson et al. 2004, Rodway et al. 2003, and Cairns et al. 1989). While a 1996 estimate put the number of breeding pairs of puffins in the Witless Bay Ecological Reserve at 216,000 (Rodway et al. 1996), both recent estimates represent a large increase over a previous estimate in 1979 (Cairns et al. 1989). It appears the number of Atlantic Puffins on Great Island (and probably off Newfoundland in general) is increasing, as puffins expand to inland areas of the Witless Bay Island (Rodway et al. 1996).

In contrast, gull populations have shown some declines. For example, the number of Herring Gull pairs on Gull Island in Witless Bay declined from 3,852 in 1979 to 2,698 in 2000, a reduction of 30 percent, (Robertson et al. 2001). Great Black-backed Gulls also showed a pattern of decline from a 1979 estimate of 118 pairs to only 89 pairs by 2000. A similar trend was observed on Great Island.

An Important Bird Area (IBA) is a site that provides essential habitat for one or more species of breeding or non-breeding birds. There are nine seabird nesting sites on the southeast coast of Newfoundland from Cape Freels to the Burin Peninsula meeting the criteria for an IBA. A grand total of 5.2 million pairs of birds breed at these sites. The Project Area is well beyond the foraging range of breeding birds during the breeding season, approximately May to August. At Witless Bay, Common Murres forage up to 200 km from the breeding site but usually only 50-100 km (Cairns et al. 1990, *in* Gaston and Jones 1998). However, during post-breeding dispersal the Project Area is within range of all seabirds breeding in eastern Newfoundland and Labrador.

Table 4.9 Number of Pairs of Seabirds Nesting at Seabird Colonies in Eastern Newfoundland

Species	Wadham Islands	Funk Island	Cape Freels and Cabot Island	Baccalieu Island	Witless Bay Islands	Cape St. Mary's	Middle Lawn Island	Corbin Island	Green Island
Procellariidae									
Northern Fulmar	-	46[a]	-	12[a]	22[a,f]	Present[a]	-	-	-
Manx Shearwater	-	-	-	-	-	-	13[k]	-	-
Hydrobatidae									
Leach's Storm-Petrel	1,038[d]	-	250[j]	3,336,000[j]	667,086[h,l,j]	-	13,879[h]	100,000[j]	65,280[h]
Sulidae									
Northern Gannet		9,837[b]		1,712[b]	-	12,156[b]	-	-	-
Laridae									
Herring Gull	-	500[j]	-	Present[a]	4,638[e,j]	Present[j]	20[j]	5,000[j]	-
Great Black-backed Gull	Present[d]	100[j]	-	Present[a]	166[e,j]	Present[j]	6[j]	25[j]	-
Black-legged Kittiwake	-	810[j]	-	12,975[j]	23,606[f,j]	10,000[j]	-	50[j]	-
Arctic and Common Terns	376[j]	-	250[j]	-	-	-	-	-	-
Alcidae									
Common Murre	-	412,524[c]	2,600[j]	4,000[j]	83,001[f,j]	10,000[j]	-	-	-
Thick-billed Murre		250[j]	-	181[j]	600[j]	1,000[j]	-	-	-
Razorbill	273[d]	200[j]	25[j]	100[j]	676[f,j]	100[j]	-	-	-
Black Guillemot	25[j]	1[j]	-	100[j]	20+[j]	Present[j]	-	-	-
Atlantic Puffin	6,190[d]	2,000[j]	20[j]	30,000[j]	272,729[f,g,j]	-	-	-	-
TOTALS	**7,902**	**426,268**	**3,145**	**3,385,080**	**1,052,546**	**32,256**	**13,918**	**105,075**	**65,280**

Source: LGL 2008b after [a] Stenhouse and Montevecchi 1999; [b] Chardine (2000); [c] Chardine et al. (2003) [d] Robertson and Elliot (2002); [e] Robertson et al. (2001); [f] Robertson et al. (2004); [g] Rodway et al. (2003); [h] Robertson et al. (2002) [l] Stenhouse et al. (2000); [j] Cairns et al. (1989); [k] Robertson (2002).

4.5 Species at Risk

Section 32 of *SARA* prohibits killing, capturing and destruction of critical habitat for those species listed on Schedule 1 as extirpated, endangered and threatened. Critical habitat is defined as the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species.

Under *SARA*, a 'recovery strategy' and corresponding 'action plan' must be prepared for *endangered*, *threatened*, and *extirpated* species. A 'management plan' must be prepared for species listed as *special concern*. Recovery strategies have been prepared for three species currently listed as either *endangered* or *threatened* under Schedule 1: the leatherback sea turtle (ALTRT 2006), the spotted wolffish (Kulka et al. 2007), and the northern wolffish (Kulka et al. 2007). A management plan has also been prepared for the Atlantic wolffish (Kulka et al. 2007), currently listed as *special concern* on Schedule 1.

The Committee on the Status of Endangered Wildlife in Canada or COSEWIC is a committee of experts which assesses and designates which Canadian wildlife species are in some degree of danger of disappearing. Under *SARA*, COSEWIC is responsible for identifying and providing scientific assessments for species considered as being at risk. These assessments are then passed on to the federal Minister of the Environment. The federal government, through the Governor-in-Council, then decides which species are added to the official list after a review period and public notice. The lists of species at risk that potentially occur in the Study Area are provided in Table 4.10. Note that the species included are either listed under *SARA* and/or given status by COSEWIC.

Table 4.10 Occurrence of Species at Risk within the Study Area

SPECIES		SARA Status	COSEWIC Status	Occurrence in the Study Area
Common Name	**Scientific Name**			
Birds				
Ivory Gull	*Pagophila eburnea*	Schedule 1 – Special Concern	Endangered	May occur but area is not critical habitat for the species
Marine Mammals				
Blue Whale	*Balenoptera musculus*	Schedule 1 - Endangered	Endangered	Occurs but area is not critical habitat for the species
North Atlantic Right Whale	*Eubalaena glacialis*	Schedule 1 - Endangered	Endangered	Occurs but area is not critical habitat for the species
Fin Whale	*Balenoptera physalus*	Schedule 1 – Special Concern	Special Concern	Occurs but area is not critical habitat for the species
Harbour Porpoise	*Phocoena phocoena*	Schedule 2 – Threatened	Special Concern	Occurs but area is not critical habitat for the species
Fish				
Atlantic Cod (NL Pop)	*Gadus morhua*	No Schedule – No Status	Endangered	Occurs but area is not critical habitat for the species
Atlantic Wolffish	*Anarhichas lupus*	Schedule 1 – Special Concern	Special Concern	Occurs but area is not critical habitat for the species
Blue Shark	*Prionace glauca*	No Schedule – No Status	Special Concern	Not likely to occur
Northern Wolffish	*Anarhichas denticulatus*	Schedule 1 - Threatened	Threatened	Occurs but area is not critical habitat for the species
Porbeagle Shark	*Lamna nasus*	No Schedule – No Status	Endangered	Occurs but area is not critical habitat for the species
Shortfin Mako	*Isurus oxyrinchus*	No Schedule – No Status	Threatened	Not likely to occur

SPECIES		SARA Status	COSEWIC Status	Occurrence in the Study Area
Common Name	Scientific Name			
Spotted Wolffish	*Anarhichas minor*	Schedule 1 - Threatened	Threatened	Occurs but area is not critical habitat for the species
Cusk	*Brosme brosme*	No Schedule – No Status	Threatened	Not likely to occur
White Shark	*Carcharodon carcharias*	No Schedule – No Status	Endangered	Not likely to occur
Reptiles				
Leatherback Turtle	*Dermochelys coriacea*	Schedule 1 - Endangered	Endangered	Occurs but area is not critical habitat for the species

Kemp's Ridley turtle and Atlantic loggerhead turtle are listed respectively as endangered and threatened by NMFS and USFWS (1991).

4.5.1 Fish

4.5.1.1 Wolffish

While the decline in abundance and biomass estimates of all three wolfish species has occurred throughout Newfoundland waters, it seems that the decline has been greater in the more northern areas (Divisions 2J, 3K and northern 3L) than in the southern areas (southern 3L, 3N, 3O) for all three species (Simpson and Kulka 2002).

Distribution maps based on spring and fall research vessel surveys between 1992 and 2000 indicate that spotted and striped wolffish occur in the general region of the Project Area, more so during the fall (Kulka et al. 2003). Since 1998, eighty-seven 15 minute trawl tows have been conducted as part of the Hibernia EEM Program. Wolfish have only been collected in 2 of those tows, both of which were in 2004. A striped juvenile wolfish (*Anarhichas lupus*) was caught within the Project Area, and the adult spotted wolfish (*A. minor*) was collected more than 30 km northwest of Hibernia (B. Wicks, pers. comm.).

Northern Wolffish

Northern wolffish in the northwest Atlantic is treated as a single population and is listed as threatened on Schedule 1 of *SARA* due to the rapid decline along the Northeast Newfoundland/Labrador Shelf and the Grand Banks. From 1978 to 1994, abundance in the primary range off northeast Newfoundland declined by 98 percent. The number of locations where the species occurs has also declined (*SARA* website, accessed September 2008).

It is a deep water species, preferring depths from 500 to 1000 m, and is recorded at depths up to 1,504 m (Kulka et al. 2008). Northern wolffish are pelagic fish, spending a great deal of time swimming and feeding on moving creatures in open waters. In summer, mature females lay up to 30,000 extremely large eggs in a nest on the sea floor. Adult northern wolffish are non-migratory. The northern wolffish favours open Continental Shelf water that is cold (usually between 2°C to 5°C). The fish is thought to prefer a rocky or muddy sea floor, but is found over all types of ocean bottoms. There is little known about the reproductive biology of this species, but spawning is believed to occur late in the year (DFO 2004d). Fertilized eggs are deposited on the bottom, but larvae are pelagic (see Simpson and Kulka 2002).

Although the northern wolffish is not targeted by the fishing industry, it is taken as by-catch by offshore trawlers. Groundfish trawls also accidentally kill or maim individuals. Bottom trawling for fish and dredging for scallops and clams damage spawning habitat by disturbing rocks and boulders used for shelter and construction of nests.

Spotted Wolffish

Spotted wolffish are treated as a single population in the northwest Atlantic and are listed as threatened on Schedule 1 of *SARA*, due to the rapid decline along the northeast Newfoundland/Labrador Shelf and the Grand Banks. In the western north Atlantic, they occur primarily off northeast Newfoundland. Since 1978, scientific surveys in the western Atlantic indicate a 96 percent decline in the Canadian population of spotted wolffish over 21 years (equivalent to three generations of wolffish). Spotted wolffish are a predatory bottom-dweller, inhabiting waters of 56 to 1046 m, but usually found at depths of 200 to 750 m (Kulka et al. 2008).

As with the other wolffish species, larvae are pelagic. A seasonal inshore migration is not known. Spawning is thought to occur late in the year (DFO 2004d). Spotted wolffish are found over all ocean-bottom types. The spotted wolffish favours cold, open continental shelf water, with water temperatures between 2°C to 5°C. Distribution maps based on spring and fall research vessel surveys between 1992 and 2000 indicate that spotted wolffish occurs in the general region of the Project Area, more so during the fall (Kulka et al. 2003).

Although the spotted wolffish is not targeted by the fishing industry, it is taken as by-catch by offshore trawlers. Groundfish trawls also accidentally kill or maim individuals. Bottom trawling for fish and dredging for scallops and clams damage spawning habitat by disturbing rocks and boulders used for shelter and construction of nests. In addition, the bottom sediments are re-suspended, smothering spawning areas and damaging gills.

Atlantic (a.k.a. 'Striped') Wolffish

Atlantic or striped wolffish (*Anarhichas lupus*) are listed as special concern on Schedule 1 of *SARA*. On the western side of the north Atlantic, they occur off the coast of west Greenland and southern Labrador, in the Strait of Belle Isle and the Gulf of St. Lawrence. Available data indicate that the number of Atlantic wolffish in Canadian waters has declined by 87 percent from the late 1970s to the mid 1990s. The number of locations where the species occurs has declined and the range where the species is abundant may be shrinking. Even though it has measurably declined, it is thought to be very widespread and to still exist in relatively large numbers (*SARA* website, accessed September 2008). There are no data available on the direct causes of the declines of Atlantic wolffish in the Atlantic. The Atlantic Wolffish was commercially fished at one time as a target species, but now only as a by-catch. Bottom trawling is likely detrimental to the species by destroying and disrupting habitat.

The Atlantic wolffish is a large bottom-dwelling predatory marine fish. Adults can weigh almost 20 kilograms and reach a length of 150 cm. Atlantic wolffish are found over hard clay bottoms at depths from nearshore to 918 m around Newfoundland (Kulka et al. 2008), but they occur in nearshore waters during the summer. Mature Atlantic wolffish migrate to shallow, inshore waters in the spring and spawn in September (Simpson and Kulka 2002). Eggs are laid in a mass that adheres to the bottom and the eggs are guarded by the male. Eggs hatch by mid-December and the larvae are pelagic, but they seldom swim near surface waters and the entire larval stage is spent close to where the eggs were deposited (see Simpson and Kulka 2002).

In the Northwest Atlantic, Atlantic wolffish feed primarily on benthic invertebrates such as echinoderms, molluscs and crustaceans, as well as small amounts of fish. No predators of adult Atlantic wolffish have been identified, but juveniles have been found in the stomachs of Atlantic cod (Scott and Scott 1988).

4.5.1.2 Atlantic Cod (Newfoundland and Labrador Population)

In 2004, the Newfoundland and Labrador population of Atlantic cod was listed as endangered by COSEWIC*.* Public consultations for inclusion of Atlantic cod on Schedule 1 of *SARA* were held, but it was determined that significant socio-economic impacts were anticipated if the Newfoundland and Labrador population were listed under *SARA*. Instead, the approach decided upon was to continue to work with domestic and foreign governments, the fishing industry, non-government organizations and others to rebuild the cod populations using current and new initiatives.

Historically, many of the northern cod stock (NAFO Divisions 2J3KL) migrated between overwintering areas in deep water near the shelf break and feeding areas in the shallower waters both on the plateau of Grand Bank and along the coasts of Labrador and eastern Newfoundland. Some cod remained in the inshore deep water during the winter. These cod spawned on the northeast Newfoundland shelf in late winter and spring, and then migrated shoreward across the shelf to the inshore feeding grounds, annually traversing distances of 500-km and more. The 2003 research bottom-trawl surveys during both spring and fall indicated that the biomass of the northern cod stock cod in the offshore remains extremely low (1% of the average during the 1980s) (DFO 2004e). Distribution maps based on spring and fall DFO RV surveys between 1992 and 2000 indicate that catches of Atlantic cod within the Project Area were low at the time (Kulka et al. 2003).

In March 2003, the Fisheries Resources Conservation Council (FRCC) released some recommendation for the Northern Cod. The Council recommended that a higher level of protection be put in place for the bank sub-stocks. They recommended the establishment of experimental “cod-boxes” be established in the Hawke Channel and the Bonavista Corridor to reduce by-catch mortality and disturbance to spawning and juvenile cod. The FRCC recommended that these areas be closed to commercial fishing activities (except snow crab trapping) and other activities such as seismic activities (www.frcc-ccrh.ca). Rose and Kulka (1999) also identified an area to the north of the Study Area where cod hyper-aggregated prior to the moratorium when it is assumed that the stock was at a low level. This has now become designated as the Cod Box (See Section 4.1.6).

Atlantic cod eggs and larvae are planktonic during the spring and early summer. Larvae and pelagic juveniles are primarily zooplankton feeders but benthic and epibenthic invertebrates become the primary diet upon settlement. As they develop, their prey often includes crab, shrimp, euphausiids capelin, sand lance, redfish, smaller cod, and herring.

4.5.1.3 Cusk

Cusk are at the extreme northern fringe of their range on the southern Grand Banks and would only be itinerant in the Project area. Cusk were rare or absent in each year of DFO surveys from 1980 to 2000 within the Study Area. When present, they were located sporadically on the Flemish Cap, and around the Nose and Southwest Slope of the Grand Bank (Kulka et al 2003). Cusk are listed as Threatened by COSEWIC, but not listed under *SARA*.

Cusk are considered unlikely to occur within the Project Area and are therefore not carried through to assessment.

4.5.1.4 Porbeagle Shark

The population is considered endangered by COSEWIC and is currently not listed by *SARA*. Porbeagle shark is a large cold-water pelagic shark distributed in the western Atlantic from Greenland to Bermuda (COSEWIC 2004a). Its distribution includes all the waters off Newfoundland. Porbeagle shark are specifically found on the St. Pierre Bank and in the Laurentian Channel in the spring and summer months (Scott and Scott 1988). The porbeagle shark is believed to constitute a single population in the northwest Atlantic.

Adults undertake annual migrations between the Gulf of Maine and Georges Bank, to the waters off Newfoundland and the Gulf of St. Lawrence, at a preferred temperature between 5° and 10°C (Campana et al. 2001 as cited in COSEWIC 2004a). They may be found singly or in schools, and are occasionally found close to shore in shallow water during the summer (Campana 2001 as cited in COSEWIC 2004a). They are primarily a mid-water species and feed opportunistically on benthic, pelagic and epipelagic fish species (Joyce et al. 2002, as cited in COSEWIC 2004a), such as the lancetfish (*Alepisaurus* spp.), cod and flounder. Squid also constitute a major portion of their diet (Joyce et al. 2002).

Mating is believed to occur from August to November in the Cabot Strait, off southern Newfoundland and on the Grand Banks. Gestation is approximately eight to nine months and self-reliant young are born from early April to early June (Jensen et al. 2002, as cited in COSEWIC 2004a). Juveniles are not known to migrate and are most common on the Scotian Shelf. Prior to 1991, the most abundant age-class off southern Newfoundland in the fall months was 10 to 15 years old. This is consistent with the use of the area as a mating ground. Between 1998 and 2000, the most abundant age classes in this area were less than age 3 (Campana et al. 2002).

Abundance of porbeagle has declined greatly since it was targeted commercially in the 1990s, (COSEWIC 2004a). Its life history characteristics, including late maturity and low fecundity, make this species vulnerable to overexploitation (COSEWIC 2004a). The capture of this species as bycatch is the only source of human-induced mortality.

Porbeagle sharks are considered unlikely to occur within the Project Area and are therefore not carried through to assessment.

4.5.1.5 Shortfin Mako

COSEWIC designated the shortfin mako as threatened in 2006, and is currently under consideration for *SARA* listing on Schedule 1. In Canadian waters, the shortfin mako shark is most closely associated with warm waters such as in and around the Gulf Stream. The shortfin mako has been recorded from Georges and Browns Bank, along the Continental Shelf of Nova Scotia, the Grand Banks off Newfoundland and even into the Gulf of St. Lawrence. These sharks are not abundant in Canadian waters, due to their preference for warm waters, but neither are they uncommon. The species is highly migratory, with tagging results suggesting that there is a single well-mixed population in the north Atlantic. Atlantic Canada represents the northern extension of their range, and most of their population is believed to reside in more temperate waters. In Canadian waters, the shortfin mako is most closely associated with warm waters such as the Gulf Stream. They prefer temperate to tropical waters with temperatures between 17° and 22°C. The mako would be considered a rare occurrence near the Project Area.

They occur from the surface to 500 m depths and typically well offshore, but makos have occasionally been observed in littoral zones. They feed on fish and marine mammals. There are no known breeding areas in Canadian waters. The status of the mako shark population in Canadian waters was assessed for the first time in 2004, revealing the north Atlantic population had declined since 1986. There are no shark surveys or fishery-independent surveys for shortfin mako in Canadian waters. Therefore, all abundance indices are based on data from commercial or recreational fisheries. Shortfin Mako sharks used to be taken in both the porbeagle and swordfish fisheries. There are no reliable means for estimating the total abundance of mature individuals in Canadian waters, as the total population in Canadian waters is unknown. Shortfin mako by-catch by foreign fleets in the north Atlantic are the most significant source of mortality for the population.

Mako sharks are considered unlikely to occur within the Project Area and are therefore not carried through to assessment.

4.5.1.6 Blue Shark

The blue shark is considered to have a single, highly migratory population in the north Atlantic, a portion of which is present in Canadian waters seasonally. They can be found throughout Atlantic Canada in almost all waters, with a peak occurrence in the late summer and fall. Blue sharks have been found in southeastern Newfoundland and the Grand Banks, mainly between July and December. The abundance index is considered to best represent the whole population and has declined 60 percent from 1986 to 2000, but another index shows no long-term trend for the whole population from 1971 to 2003 (COSEWIC 2006a). COSEWIC has listed blue shark as a species of special concern.

Blue sharks are pelagic, most commonly encountered offshore between the surface and 350 m. They prefer offshore habitats, but have been observed inshore on occasion (COSEWIC 2006a). Water temperature appears to influence their depth and latitudinal distributions, as well as size and sex distributions. Blue sharks are known to occur in waters between 5.6° to 28°C.

Canada's waters (Atlantic and Pacific) provide habitat for primarily subadult (immature) individuals, although adult (mature) specimens are occasionally encountered. Occurrence of blue sharks near the Project Area is considered rare.

Blue sharks used to be taken in both the porbeagle and swordfish fisheries. It appears that recent fishery removals from the north Atlantic have been several tens of thousands of tons annually. Estimated Canadian removals, a small proportion of the total, have been declining since the early 1990s and recently have averaged approximately 600 t/yr. Loss of habitat is not considered a threat for this species (COSEWIC 2006a).

Blue sharks are considered unlikely to occur within the Project Area and are therefore not carried through to assessment.

4.5.1.7 White Shark

White sharks are rare in Canadian waters and are recorded mostly in the Bay of Fundy area. They are extremely rare as far north as the Project Area.

White sharks are considered unlikely to occur within the Project Area and are therefore not carried through to assessment.

4.5.2 Marine Mammals

4.5.2.1 Blue Whale

The blue whale is considered *endangered* by COSEWIC and listed on Schedule 1 of *SARA* as endangered. Blue whales occur throughout the world, but in low numbers. Blue whales are usually sighted singly or in pairs. Estimates are of a few hundred in the western north Atlantic (Sears and Calambokidis 2002) and approximately 1,400 in the entire north Atlantic population. Little is known about the distribution and abundance of blue whales in the northwest Atlantic, especially the waters off eastern Newfoundland.

Blue whales have a coastal and pelagic distribution, frequenting areas of high krill productivity. They are known to reoccur in the Gulf of St. Lawrence, the lower estuary part of the St. Lawrence, and to a lesser extent the west and southwest coasts of Newfoundland. The inshore area on the south coast of Newfoundland - off Burgeo and Connoire Bay - is frequented by blue whales in late winter and early spring (Seton et al. 1992). The blue whale is rarely sighted on the Grand Banks, but there have been 55 sightings recorded within the Study Area since 1945 (Table 4.6).

4.5.2.2 Fin Whale

The Atlantic population of fin whale is considered a species of special concern by COSEWIC and is listed as such on Schedule 1 of *SARA*. Genetic studies indicate that fin whale populations that summer in Nova Scotia, Newfoundland and Labrador and Iceland may be genetically distinct from each other (Arnason 1995). There is current debate as to whether the fin whales of the eastern north Atlantic may comprise two or more stocks (see COSEWIC 2005).

Fin whale abundance in the western North Atlantic is currently thought to be 2,814 individuals (CV = 0.21). Surveys used to derive this estimate are based on areas between Georges Bank and the mouth of the Gulf of St. Lawrence and it is acknowledged that more reliable and wide ranging surveys are required for better estimates (Waring et al. 2006). There are no reliable estimates for the number of fin whales in the NL stock. There is insufficient data to determine population trends of the fin whale in the northwest Atlantic, including the NL stock. They are most abundant in the northeast coast of the island of Newfoundland (Lawson 2006). They may form small groups while feeding, but are usually seen singly or in pairs. Sightings occur from shallow coastal waters to the limits of sighting effort at water depths of over 4,000 m (Lawson 2006).

Fin whales commonly occur in the Study Area (559 sightings since 1945) at least during late spring until fall and infrequent observations have been recorded in the Project Area (Table 4.6). Little is known about their winter distribution although fin whales were observed incidentally during aerial surveys for seabirds during December and January on the Grand Banks (Parsons and Brownlie 1981). On the Grand Banks, the fin whale is associated with the presence of capelin, their predominant prey item in these waters (Piatt et al. 1989; Whitehead and Carscadden 1985). However, fin whales have a varied diet and are known to feed on euphausiids, herring, and sand lance (Edds and Macfarlane 1987; Borobia et al. 1995; COSEWIC 2005).

4.5.2.3 North Atlantic Right Whale

North Atlantic Right Whale is designated endangered by COSEWIC and is listed with this designation on Schedule 1 of the SARA (COSEWIC 2003). The North Atlantic right whale is a slow-moving whale prone to collisions with ships. It feeds on krill and other crustaceans. COSEWIC (2003) estimated that there are 222-238 sexually mature individuals in the population. Off Atlantic Canada, right whales typically concentrate in the Bay of Fundy and off southwestern Nova Scotia. However, some right whales are known to occur off Iceland and it is possible (although highly unlikely) that it may occur in the Project Area (LGL 2007a). Right whales have been recorded 5 times within the Study Area since 1945.

Fujiwara and Caswell (2001) determined statistically that if the population growth rate observed in 1995 were maintained, North Atlantic right whales would become extinct within approximately 200 years. Current threats to the population include declines in reproduction, collisions with ships, entanglement in fishing gear, marine pollution, reduction in food sources and possibly disturbance from tourism (whale watching) boats (COSEWIC 2003c).

4.5.2.4 Harbour Porpoise

Harbour porpoise were initially listed by COSEWIC due to a significant proportion of the population being accidentally killed each year as incidental bycatch, particularly in groundfish gillnet fisheries (COSEWIC 2006b). The magnitude of this problem may have decreased in recent years due to changes in the groundfish fishery. However, there are still many hundreds or thousands of porpoise that die each year by accidental entrapment in fishing gear. The northwest Atlantic population of the harbour porpoise is currently designated by COSEWIC as a species of special concern.

The harbour porpoise is widely distributed throughout temperate waters of the Northern Hemisphere, but its population size in Newfoundland waters is unknown (Gaskin 1992). They are widely distributed on the continental shelves of the northern oceans, and with several separate and distinct populations. Within the Atlantic Ocean, harbour porpoise in the northeast Atlantic are effectively separated from those living in the northwest Atlantic. In eastern Canada, harbour porpoise are found from the Bay of Fundy to Baffin Island. Evidence suggests that there are three discrete populations summering in eastern Canada (Newfoundland and Labrador, Gulf of St. Lawrence and Bay of Fundy-Gulf of Maine). There is likely some mixing of these populations in the winter, when less is known about their distribution. There are no range-wide estimates of the abundance of harbour porpoises in eastern Canada, but it seems likely that the northwest Atlantic population is greater than 50, 000 individuals (*SARA* website). Table 4.6 indicates that observations of the Harbour Porpoise are common in the Study Area, although there are no recorded observations for the Project Area.

As the name suggests, harbour porpoise are often seen in bays (especially in summer), although they have also been seen hundreds of kilometres offshore. Harbour porpoise are most likely to occur in coastal Newfoundland waters from April to October. There have been 209 sightings of 556 harbour porpoise within the Study Area since 1945 (Table 4.6). Harbour porpoise are often seen in small groups, but may form very large groups occasionally (Bjørge and Tolley 2002). Unlike other marine mammals, harbour porpoise do not form groups to increase feeding efficiency, since they feed individually on small schooling fish like capelin, herring and squid (Read 1999). As a small marine mammal with limited energy reserves, harbour porpoise are frequent feeders and their distribution at any given time is associated with the distribution of prey. They are attracted to prey-rich areas, especially of fat-rich prey such as capelin and herring. The species is well adapted to cold water and is seldom found in water warmer than 16°C.

Harbour porpoise become sexually mature at around three years old. Conception and calving occur in late spring or early summer. The gestation period is 10-11 months and calves are weaned after about eight months (COSEWIC 2006).

4.5.3 Sea Turtles – Leatherback Turtle

There is little documentation of the occurrence of sea turtles within the Project Area, but they are important to consider due to their threatened or endangered status, both nationally and internationally. Three unidentified sea turtles have been observed incidentally by a HMDC employee at the Hibernia site (R. Dunphy, pers. comm.).

Leatherback sea turtles are considered endangered by COSEWIC and listed on Schedule 1 of *SARA* as endangered. The population size for leatherbacks is poorly known, but likely exceeds several hundred thousand animals in the Atlantic (DFO 2004f). There is no estimate of what fraction of the population may migrate into Canadian waters. The current population is thought to be declining as major nesting colonies have declined in the last 20 years. The worldwide population of nesting females leatherbacks is estimated at between 26,000 and 43,000 (Dutton et al. 1999). Critical habitat for the leatherback has not been identified, but studies are underway to do so (ALTRT 2006).

Peak leatherback occurrences in Canadian waters are reported during August and September, but observations have been reported nearly every month of the year (ALTRT 2006). In one study of Atlantic Canadian observations, the mean sea surface temperature at the location of leatherback observations was 16.6°C (James *et al.* 2006). Another study of leatherback observations in Newfoundland waters reported a mean temperature of 12.6°C (Goff and Lien 1988). Leatherbacks exhibit diel dive patterns, spending much of the night diving, typically to modest depths, but around sunrise, dives become progressively deeper. Dives are typically less than 200 m deep and last less than 40 minutes (Hays et al. 2004).

Leatherbacks do not migrate along specific routes and therefore there is variability in where leatherbacks occur in Canadian waters each year. However, they do exhibit some foraging site fidelity to shelf and slope waters off Canada and the northeastern United States (James et al. 2006). Frequent observations occur on the Scotia Shelf off Halifax, off the southeast coast of Newfoundland and off the tail of the Grand Banks (ALTRT 2006). The leatherback sea turtle's distribution and movement in Canadian waters is closely associated with the distribution of the jellyfish (*Cyanea and Aurelia* spp.), the leatherback turtle's primarily food item (James *et al.* 2006). Observation frequency is thought to be a result of fishing and observer effort, prey abundance and sea surface temperature. Inter-annual variability within Canadian waters is likely related to variability in the abundance of prey (James et al. 2006). Leatherbacks equipped with satellite tags did not occur near the Project Area, but some did migrate through the Grand Banks south of Newfoundland (James et al. 2005). The first documented sightings of leatherbacks in the Jeanne d'Arc Basin were in mid-August 2006, near the White Rose licence area (Abgrall et al. 2007).

In Canadian waters, incidental capture in fishing gear is a major cause of mortality. Nearly half of the leatherbacks (593 captures) caught during the US pelagic longline fishery between 1992 and 1995, from the Caribbean to Labrador, were captured in waters on and east of the 200 m isobath off the Grand Banks (Witzell 1999). Animals were caught in this region during all months from June to November, with the bulk of captures from July to September. Not surprisingly, leatherback captures within these waters corresponded closely with fishing effort, both clustered near the 200 m isobath. A long lifespan, very high rates of egg and hatchling mortality, and a late age of maturity make this species unusually vulnerable to even small increases in adult and older juvenile mortality rates (COSEWIC 2001).

4.5.4 Birds – Ivory Gull

The Ivory Gull may appear in low numbers in the Study Area, although there have been no sightings of this species in or near the Study Area during recent seismic monitoring programs (LGL 2008 a).

Ivory Gull is a circumpolar breeder that is occasionally known to scavenge (mostly among seal herds) on pack ice in Newfoundland waters. It is listed as endangered by COSEWIC and as a species of special concern on Schedule 1 of *SARA*. In the case that the Ivory Gull is uplisted to endangered on SARA's Schedule 1 during the construction or operation of the proposed Project, the regulations associated with SARA would be applicable. It occurs as a rare winter migrant in Newfoundland waters. It is rarely found far from drifting pack ice at any time of year (Haney and McDonald 1995). It winters in the Arctic, but also off the coast of Newfoundland.

The Ivory Gull may appear in low numbers within the Study Area when pack ice reaches the northern Grand Banks in late winter (February to April). The presence of sea ice is the condition most favourable for Ivory Gull occurrence. Sea ice has occurred near the Hibernia GBS in two years since its installation in 1997.

5.0 SCOPING AND ENVIRONMENTAL ASSESSMENT METHODS

It is generally acknowledged that an environmental assessment must focus on those components of the environment that are valued by society and/or can serve as indicators of environmental change and have the most relevance to the final decision regarding the environmental acceptability of a proposed undertaking. These components are known as Valued Environmental Components (VECs) and may include bio-physical and socio-economic components.

The methods employed in this EA are therefore intended to:

- focus on issues of greatest concern;
- address regulatory requirements, including those identified through the project-specific Scoping Document (Appendix A);
- address issues raised by the public and other stakeholders during project-specific consultation; and
- integrate engineering design and mitigation and monitoring programs into a comprehensive environmental management planning process.

The approach and methods used for the EA are based largely on the work of Beanlands and Duinker (1983), the CEA Agency (1994; 1999), and Barnes et al. (2000), as well as the study team's experience in conducting environmental assessments. The EA methods provide for a rigorous and methodological evaluation of the potential environmental effects that may arise from each Project phase (construction, operation, and abandonment/decommissioning) as well as malfunctions and accidents, with regards to each of the identified VECs. Project related effects are assessed within the context of temporal and spatial boundaries established for each VEC. The evaluation of potential cumulative effects with regard to other projects and activities includes existing, approved and proposed activities that will interact temporally or spatially with the Project.

The following sections describe the scope of the Project and scope of factors to be considered in the EA as determined by the RAs in the Project-specific Scoping Document (Appendix A) and the EA methods used in this assessment including issues scoping, selection of VECs and organization of the effects assessment.

5.1 Scope of the Project

The environmental assessment scope and methodology for the Project have been developed to meet the regulatory requirements of a screening under *CEAA*. The scope of the project is defined as the components of a proposed undertaking relating to a physical work, or a proposed physical activity not relating to a physical work, that are determined to be part of the project for the purposes of the environmental assessment (Canadian Environmental Assessment Agency 2006).

The Project to be assessed, as determined by the RAs in the Project-specific Scoping Document (Appendix A), consists of the following components:

- Construction, installation, operation, maintenance, modification, decommissioning and abandonment of up to 6 drill centres, including seabed excavation and soil deposition;

- Installation, operation, maintenance, modification, decommissioning and abandonment of subsea flowlines/umbilicals and associated equipment (inclusive of injection and production flowlines) tied back to the Hibernia GBS. Upgrades to the Hibernia GBS will be included, if required. This includes any associated seabed trenching, excavation, covering and/or soil deposition;
- Drilling and workover of up to 11 wells per drill centre;
- Vertical Seismic Profiling (VSP) and wellsite/geohazard surveys; and
- Operation of support craft associated with above activities, including but not limited to vessels for the excavation of glory holes, mobile offshore drilling units, supply/standby vessels, helicopters, and shuttle tanker activity that is incremental to that already in existence or expected to be in existence.

Project activities are likely to be undertaken year-round, commencing in 2009 until end of the Project, currently estimated to be 2036. For the HSE, the following is a proposed Project schedule, which is dependent on Project approval and equipment availability:

- geotechnical/Geophysical (wellsite surveys) investigations from summer to fall 2009;
- HSE glory hole excavation from summer to fall 2011;
- subsea equipment installation activities from summer to fall of 2012;
- drilling activities will likely occur year round, commencing in 2012, with possible completion by 2014;
- VSP surveys may occur year round from commencement of drilling activities through to end of production; and
- Production operations are likely to commence in 2012 and will continue year round through to 2036. Abandonment will likely commence after 2036.

For the remaining five drill centres, it is assumed that Project activities will require similar timelines for completion, with activities to commence at any time of the year throughout the life of the Project. The proposed Project is described in more detail in Chapter 2 of this report.

5.2 Factors to be Considered

The EA includes a consideration of the following factors in accordance with Section 16 of *CEAA*:

- The purpose of the Project;
- Alternative means of carrying out the Project which are technically and economically feasible and the environmental effects of any such alternative means;
- The environmental effects of the Project, including those due to malfunctions or accidents that that may occur in connection with the Project and any change to the Project that may be caused by the environment;
- Cumulative environmental effects of the Project that are likely to result from the Project in combination with other projects or activities that has been or will be carried out, including all activities and ancillary activities for the construction, operation and maintenance of the drill centres;
- The significance of the environmental effects described in the two previous bullets;

- Measures, including contingency and compensation measures as appropriate, that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the project;
- The significance of adverse environmental effects following the employment of mitigative measures, including the feasibility of additional or augmented mitigative measures;
- The need for, and the requirements of, any follow-up program in respect of the Project consistent with the requirements of the CEA Act and the SARA; and
- Report on consultations undertaken by HMDC with interested parties who may be affected by program activities and/or the public respecting any of the matters described above.

The scope of the factors to be considered in this EA includes the components identified in Section 5.2 of the Scoping Document provided by the RAs (Appendix A).

5.3 Issues Scoping

The issues scoping exercise conducted in relation to this environmental assessment included:

- review of the Scoping Document issued by C-NLOPB on October 7, 2008;
- consultation with relevant regulatory agencies and other stakeholders;
- a review of other environmental assessments of similar projects in the region and updating with available information on the existing biophysical and socio-economic environments;
- a review of relevant regulations and guidelines related to offshore exploration activities; and
- the professional judgment of the study team.

The Scoping Document (Appendix A) that was prepared by the C-NLOPB, Environment Canada, and the Department of Fisheries and Oceans, as Responsible Authorities (RAs) for this EA identified a number of potential issues to be considered within the EA. These are outlined in Table 5.1 along with a description of how/where these potential issues have been addressed within the EA.

Table 5.1 Potential Issues Identified in the Scoping Document

Issues Identified In Scoping Document	Where Addressed in EA
Physical Environment:	
• Meteorological and oceanographic characteristics in the Study Area, including extreme conditions;	Section 3, Appendix B
• Site-specific sea ice and iceberg conditions, including iceberg scour of the seabed;	Section 3.3, Appendix B
• Overview of physical environmental monitoring, observation and forecasting programs that will be in place for all phases of the project ;	Sections 2.8.3 and 9.3
• Ice management/mitigation procedures to be implemented, including criteria respecting disconnection of project installations and assessment of the efficiency of detection and deflection techniques, and any change to the Project that may be caused by the environment; and	Sections 2.8.3 and 9.3
• Effects of the environment on the Project, including cumulative effects. The effects assessment should pay specific attention to effects of environmental factors on mobile drilling units, and mitigations that may be implemented to reduce these effects.	Section 9

Issues Identified In Scoping Document	Where Addressed in EA
Marine Resources • Characterization, including quantification to the degree possible, of the spatial area of seabed that is predicted to be affected by the following activities should be provided: dredging, trenching and dredge spoil disposal; stitch rock dumping; drill cuttings and other discharges	Sections 2.1.1, 3.5.1 and 3.5.2
Marine and/or Migratory Birds using the Study Area • Spatial and temporal species distributions in the Study Area (observation/monitoring data collected during ongoing petroleum activities should be included); • Species habitat, feeding, breeding, and migratory characteristics of relevance to the Study Area; • Physical displacement as a result of vessel presence (e.g., disruption of foraging activities); • Effects of hydrocarbon spills from accidental events; • Attraction of birds to vessel lighting and flares; • Procedures for handling birds that may become stranded on offshore structures (e.g., rigs, supply vessels, construction vessels); • Means by which bird mortalities associated with project operations may be documented and assessed; • Means by which potentially significant effects upon birds may be mitigated through design and/or operational procedures; and • Environmental effects due to the Project, including cumulative effects.	Sections 4.4 (Existing Conditions); Section 6.5 (Assessment of routine activities including vessel presence, attraction to lights and birds, handling procedures for stranded birds, other mitigation and monitoring); Section 7.2.4 (assessment of cumulative effects on birds) and Section 8.7.4 (assessment of accidental events on birds)
Marine Fish and Shellfish • Characterization of existing environment in the Study Area; • Distribution and abundance of species utilizing the Study Area with consideration of critical life stages (e.g., spawning areas, overwintering, juvenile distribution, migration); • Description, to the extent possible, of location, type, diversity and areal extent of marine fish habitat in the Study Area, in particular those indirectly or directly supporting traditional, aboriginal, historical, present or potential fishing activity, and including any essential/critical (e.g. spawning, feeding, overwintering) habitats; • Means by which potentially significant effects upon fish (including critical life stages) may be mitigated through design, scheduling, and/or operational procedures; and • Environmental effects due to the Project, including cumulative effects.	Section 4.1 (existing conditions in study area); Section 6.2 (effects assessment for routine activities, including mitigation); Section 7.2.2 (assessment of cumulative effects) and Section 8.7.2 (assessment of accidental events)
Marine Mammals and Sea Turtles • Spatial and temporal distribution and abundance of species utilizing the Study Area (observation and monitoring data collected during exploration and development activities operated by Hibernia should be discussed). Data from other recent operations, if available, within the Jeanne d'Arc Basin should also be included; • Description of marine mammal and sea turtle lifestyles/life histories relevant to Study Area; • Means by which potentially significant effects upon marine mammals/sea turtles (including critical life stages) may be mitigated through design, scheduling, and/or operational procedures; and • Environmental effects due to the Project, including cumulative effects.	Sections 4.3 and 4.5.3 (existing conditions in study area); Sections 6.4 and 6.6 (effects assessment for routine activities, including mitigation); Section 7.2.4 and 7.2.6 (assessment of cumulative effects) and Sections 8.7.4 and 8.7.6 (assessment of accidental events)

Issues Identified In Scoping Document	Where Addressed in EA
Species at Risk • A description, to the extent possible, of species at risk as listed in Schedule 1 of the Species at Risk Act (SARA), and those under consideration by COSEWIC in the Study Area, including fish, marine mammals, sea turtles and seabird species; • A description of critical habitat (as defined under SARA), if applicable, relevant to the Study Area; • Means by which adverse effects upon SAR and their critical habitat may be mitigated through design, scheduling, and/or operational procedures; • Monitoring and mitigation, consistent with recovery strategies/action plans (endangered/threatened) and management plans (special concern); • Assessment of effects (adverse and significant) on species and critical habitat, including cumulative effects; • The means by which the Proponent intends to ensure that relevant changes or updates to SARA listed species, including recovery strategies and management plans, are tracked throughout the project life and incorporated into its environmental planning; and • A summary statement stating whether project effects are expected to contravene the prohibitions of SARA (Sections 32 (1), 33, 58(1)).	Section 4.5 (existing conditions in study area; note that there is no critical habitat for SARA-listed species identified within the study area); Section 6.6 (effects assessment for routine activities, including mitigation); Section 7.2.6 (assessment of cumulative effects) and Section 8.7.6 (assessment of accidental events); Section 6.6.8 (Summary Statement)
Sensitive Areas • A description, to the extent possible, of any 'Sensitive" areas in the Study Area such as important or essential habitat to support any of the marine resources identified; • Environmental effects due to the project, including cumulative effects, on those "Sensitive" areas identified; • Means by which adverse effects upon "Sensitive" areas may be mitigated through design, scheduling, and/or operational procedures; and • Environmental effects due to the Project, including cumulative effects, on those sensitive areas identified.	Section 4.1.6 indicates that there are no sensitive/special areas identified within the Affected Area and therefore no further assessment is required.
Marine Use – Noise/Acoustic Environment • Noise and acoustic issues in the marine environment that may be generated from construction activities (e.g., drill centre excavation); drilling operations (e.g., drill rig, thruster-equipped vessels), VSP geohazard/wellsite survey programs and abandonment (wellhead severance); • Disturbance/displacement of VECs and SAR associated with the above activities; • Means by which potentially significant effects may be mitigated through design and/or operational procedures; and • Assessment of effects of noise/disturbance on the VECs and SAR, including cumulative effects.	Section 2.7.1.1 describes noise emissions from the Project. Sections 6 (assessment of routine activities) and Section 7 (assessment of cumulative effects) both assess the effects and identify mitigation (where required) for Project-related noise for all VECs.

Issues Identified In Scoping Document	Where Addressed in EA
Marine Use - Presence of Structures and/or Operations • Size and location of temporary or project-life exclusion zones;	Section 2.8.4
• Description of project-related traffic, including routings, volumes, scheduling and vessel types;	Section 2.4
• Means by which adverse effects upon marine use may be mitigated through design, scheduling and/or operational procedures; and	Section 6.3.4
• Effects of physical presence of structures upon access to fishing grounds, fish research surveys and upon general marine traffic/navigation, including cumulative effects.	Sections 6.3 and 7.2.6
Description of the relationship of the existing Hibernia production project, with the proposed Project (e.g. whether the produced water discharge rate is likely to change or whether any elements of that project, other than the drilling of the wells and subsea construction/installation are additional or supplementary to the project already assessed.)	Section 2.2
Discharges and Emissions • Dredge spoil, drilling muds, fluids and cuttings, produced water, bilge water, grey water, black water, cooling water, deck drainage, blow out preventer fluid; ballast water; etc.; • Characterization, quantification and modelling of expected discharges (e.g., cuttings dispersion; concentration of metals, nutrients, hydrocarbons, biocides) and the timing of discharges, including a description of the models employed; • Means for reduction, re-use and recovery of wastes beyond those specified in regulations and guidelines, including a description of "best available/practicable technology"; and • Environmental effects of discharges, with consideration of EEM data from Hibernia and other Grand Banks production operations, including cumulative effects.	Sections 2.1.1 and 6.1.3.2 (dredge spoil) and 2.6 (all other emissions). Sections 2.6.1.1, and 6.1.3.2. Sections 2.6.1, and 6.4.4. Sections 6 and 7 describe the environmental effects
Air Quality • Annual estimates of rates and quantities of emissions (e.g., as reported through the OWTG, NPRI, and Environment Canada's GHG Facility Reporting), and a description of potential means for their reduction and reporting; • Implications for health and safety of workers that may be exposed to them; • Mitigation and monitoring; and • Assessment of effects, including cumulative effects.	Section 2.7.11
Commercial Fisheries Provide a description of commercial fisheries in the Jeanne d'Arc Basin area including the most recent data available. The information should include: • Description of fisheries in the Study Area (including traditional, existing and potential commercial, recreational and aboriginal/subsistence and foreign fisheries, where practicable); • Traditional historical fishing activity – abundance data for certain species in this area, prior to the severe decline of many fish species (e.g., an overview of survey results and fishing patterns in the survey areas for the last 20 years); • Consideration of underutilized species that may be found in the Study Area as determined by analyses of past DFO research surveys and Industry GEAC survey data, with emphasis on those species being considered for future potential fisheries, and species under moratoria; • Fisheries liaison/interaction policies and procedures; • Program(s) for compensation of affected parties, including fisheries interests, for accidental damage resulting from project activities;	Section 4.2 (existing conditions in the Study Area); Section 6.3 (environmental effects assessment of routine Project Activities); and Section 7.2.3 (cumulative effects assessment).

Issues Identified In Scoping Document	Where Addressed in EA
• Means by which adverse effects upon commercial fisheries may be mitigated through design and/or operational procedures; and • Environmental effects of the Project, including cumulative effects.	
Accidental Events The discussion should not be limited to crude oil, but should consider accidental releases of drilling fluids, drilling muds, other hydrocarbons, and/or chemicals that may be spilled. An update to the information presented in previous environmental assessments should be provided. The information should include: • Quantification of blowout risk; • Quantification of risk of hydrocarbon/chemical spills of all volumes, from all facilities associated with the project (hydrocarbons should not be limited to crude and or diesel, but shall include synthetic based muds and fluids, and other hydrocarbons); Discussion of the potential for spill events from drilling and production activities to enter the marine environment; • Modelled physical fate of oil spills, including descriptions of models and/or analyses that are employed and the physical data upon which they are based; • Description of the marine area likely to be affected by hydrocarbons from a spill event that enters the marine environment; • Fate of hydrocarbons in the marine environment, as determined by spill trajectory analysis; • Mitigation measures to be employed to reduce or prevent such events from occurring; • Contingency plans to be implemented in the event of an accidental release; • Environmental effects of petroleum or chemical spills on all VECs identified, including losses from streamers (VSP and geohazard surveys) and drilling muds/fluids/cuttings, with consideration of effectiveness of spill countermeasures; and • Cumulative effects in consideration of "chronic" oil pollution on the Grand Banks (e.g. spills from other offshore operations, bilge dumping and other discharges from vessels).	Section 8 Section 7.2.6
Environmental Management Provide a general overall description of Hibernia Management and Development Company Limited's environmental management system and its components, including, but not limited to: • Pollution prevention policies and procedures; • Environmental compliance monitoring; • Provisions or management system auditing; • Chemical selection and management procedures; • Fisheries liaison/interaction policies and procedures; • Program(s) for compensation of affected parties, including fisheries interests, for accidental damage resulting from project activities; and • Emergency response plan(s).	Section 2.8, 2.2.1 and Section 6.3.4 for fisheries related policies and procedures.

Issues Identified In Scoping Document	Where Addressed in EA
Biological and Follow-up Monitoring • Discuss the need for and requirements of a follow-up program, including any requirement for compensation monitoring, any required modifications to existing follow-up programs including compensation monitoring, EEM design and implementation, and the any need for baseline information. • Provision of an acceptable fish habitat compensation strategy, including options considered, in accordance with the Department of Fisheries and Oceans "Policy for the Management of Fish Habitat". • Detailed description of monitoring and observations procedures regarding marine mammals, sea turtles, and seabirds (observation protocols consistent with the "Geophysical, Geological, Environmental and Geotechnical Program Guidelines" (C-NLOPB 2008a).	Sections 6.1.7, 6.2.7, 6.3.7, 6.4.7, 6.5.7, and 6.6.7. A proposed fish habitat compensation strategy will be developed separately in consultation with DFO and provided to DFO as part of the HADD permit process.
Abandonment and Decommissioning • Plans for abandonment and/or decommissioning of the project area and associated facilities following termination of production, including any anticipated requirement for post-abandonment monitoring.	Section 2.5

5.4 Stakeholder Consultation

Representatives of key government agencies, non governmental agencies, fishing industry representatives, and other stakeholders were contacted as part of the issues scoping process to discuss the proposed Project, obtain information on the existing environment, and to identify any potential environmental issues of concern.

The following organizations have been consulted by HMDC during the preparation of the environmental assessment:

- Canada-Newfoundland and Labrador Offshore Petroleum Board;
- Department of Fisheries and Oceans;
- Environment Canada;
- One Ocean;
- Fish, Food and Allied Workers Union;
- Association of Seafood Producers;
- Natural History Society and;
- World Wildlife Fund Canada.

HMDC either met with the stakeholder to present an outline of the activities and schedule for the proposed Project or the stakeholder reviewed the Project Description previously submitted to the C-NLOPB and provided comment verbally or in writing. At each meeting there was an open discussion of the Project where HMDC fielded questions from meeting participants following the presentation.

Points raised during the meetings with regulators included:

- Several environmental assessments (EAs) of projects with similar activities have been conducted within the Jeanne d'Arc Basin;

- HMDC could draw on summaries of project descriptions, physical and biological environments and effects assessment, as applicable from previous EAs;
- C-NLOPB advised use of Hibernia EEM data within the EA;
- DFO advised that the Project activities described were likely to require an authorization under subsection 35(2) of the *Fisheries Act* for habitat alteration, disruption or destruction of fish habitat;
- EC advised that an application for Ocean Disposal would be required. EC also advised the use of most current climate, waves and tides data for description of physical environment in the EA. CWS offered a summary of pelagic seabird survey database.

Points or questions raised by representatives of One Ocean and the FFAW following the presentation by HMDC were:

- How is the Hibernia platform “tied in” to the Project;
- Will produced water volumes increase;
- What species were found during surveys of the disposal area;
- When/where is the safety zone in effect;
- What activities are planned in 2009;
- Figures in Project Description should have scales;
- Harvesting areas for crab and shrimp in 2008 may be different than previous three years; and
- Hagfish is the only potential emerging fishery in 3L.

Points or questions raised by a representative of the Association of Seafood Producers the presentation by HMDC were:

- Are the Hibernia EEM results made public or sent to regulators for review?
- How does the tanker access the offshore loading system?
- Snow crab harvesting is expected to change in terms of quotas and spatial distribution in 2009 and beyond.

The World Wildlife Fund (WWF) and the Natural History Society reviewed the Project Description and provided comments in writing and verbally, respectively. The Natural History Society representative commented that environmental assessment predictions should be reviewed in light of actual spill data on the Grand Banks. Also that industry compliance monitoring of oil in water in effluent discharges is not as robust as the Natural History Society would like to see. The WWF commented on the need to consider the Placentia Bay Grand Banks Large Ocean Management Area (PBGB LOMA) initiative. They write “The proposed project should not proceed prior to the completion of the PBGB LOMA IM Plan. If the project is ultimately approved, WWF urges HMDC to work with DFO to ensure identified EBSAs are not impacted and other IM objectives are not compromised”. The WWF also expressed concern of the effects of seismic activity on fish; “We would like to suggest that new seismic surveys be delayed until the results of this study (DFO SEIFish Project) are known”.

HMDC will maintain ongoing consultations with the above groups and is available to discuss issues at all times.

5.5 Selection of Valued Environmental Components

Based on the results of the issues scoping exercise described above, and the regulatory reviews of recent offshore environmental assessments, the following VECs are considered in this EA:

- Marine Fish Habitat;
- Marine Fish and Shellfish;
- Commercial Fisheries;
- Marine Mammals;
- Marine Birds; and
- Species at Risk.

The rationale for the selection of these VECs is provided below.

- **Fish Habitat**: includes coverage of the physical and biological components of the marine environment such as substrate type, water depth, plankton and benthos. Fish habitat has the potential to be adversely affected by Project activities resulting in physical disturbance of the seafloor (i.e., dredging and disposal and installation of subsea infrastructure) and through drill waste discharges. As DFO requires loss of fish habitat to be compensated, a full assessment of the nature and extent of potential Project effects is required. Considering the nature of the proposed Project activities, the benthic component of fish habitat will be the focus of this VEC.
- **Marine Fish and Shellfish**: The commercial fishery is an important element in Newfoundland and Labrador's history, as well as its current socio-cultural and economic environment. The species upon which the fishery depends is therefore an important consideration in the environmental assessment of activities which may influence the marine environment. The VEC will focus on those species of commercial importance or potential to become commercially important, as well as ecologically important species.
- **Commercial Fisheries**: Commercial fisheries were also selected as a VEC because historically, the fishery has played an important role in Newfoundland and Labrador's economy and has helped to define much of the province's character. The fishery remains an integral component of the economy of Newfoundland and Labrador. While current fishing levels within the Project Area are very low, it is acknowledged that given the length of this Project, fishing levels could change over the life of the Project.
- **Marine Mammals**: Whales and seals are key elements in the marine food web, as well the biological and socio-economic environment of Newfoundland and Labrador. They can be sensitive to noise and other anthropogenic disturbances, particularly seismic activities.
- **Marine Birds**: Newfoundland's offshore environment hosts a range of seabirds throughout the year. Seabirds are a key component near the top of the food chain and are an important resource for tourism and recreational activities, and for scientific study. They are therefore important socially, culturally, economically, aesthetically, ecologically and scientifically.
- **Species at Risk**: There are species of marine birds, fish, marine mammals and sea turtles that may occur in the Project Area and interact with the Project and that are protected by *SARA*. Species at Risk are considered a VEC due to regulatory concern and in recognition of their protected status under *SARA*.

These six VECs represent the key environmental components assessed in this document.

5.6 Environmental Effects Assessment Organization

This environmental assessment provides detailed effects analyses for each of the VECs identified in Section 5.5.The specific steps involved in the assessment for each VEC are as follows:

- determining boundaries;
- describing the existing conditions for each VEC;
- identifying potential interactions between VECs and the project's components/activities and outlining existing knowledge regarding these potential interactions;
- defining significance criteria for residual environmental effects;
- assessing environmental effects and mitigations;
- cumulative effects assessment;
- identifying the need, if any, for follow-up requirements; and
- determination of significance of residual effects.

Each of these is described in more detail in the following sections.

5.6.1 Boundaries

The EA considers the potential effects of the proposed Project within spatial and temporal boundaries that encompass the periods and areas during and within which the Project may potentially interact with, and have an effect on, one or more VEC. These boundaries may vary with each VEC and the factors considered, and reflect a consideration of:

- The proposed schedule/timing of the construction, operation, maintenance, and abandonment phases;
- The natural variation of a VEC or subset thereof;
- The timing of sensitive life cycle phases in relation to the scheduling of proposed Project activities;
- Interrelationships/interactions between and within VECs;
- The time required for recovery from an effect and/or return to a pre-effect condition, including the estimated proportion, level, or amount of recovery; and
- The area within which a VEC functions and within which a Project effect may be felt.

5.6.1.1 Spatial Boundaries

Spatial boundaries may be limited to the immediate Project Area or may extend well beyond the immediate footprints as the distribution and/or movement of an environmental component can be local, regional, national or international in extent. Such factors as geographic limits of populations and migration patterns are important considerations in determining boundaries and may influence the extent and distribution of an environmental effect. For this assessment:

- **Project Area** is defined by the spatial extent of project components and activities and is determined primarily by project-specific characteristics. Spatial project boundaries are defined by project "footprints" and may vary between project components and activities. For this Project, activities will be contained within an area that encompasses PL's 1001 and 1005, EL's 1092 and 1093, and SDL's 1001, 1002, 1003, 1004, 1005 and 1041 (see Figure 1.1). The Project Area is contained within a box defined by corners with the following coordinates (decimal degrees):

  - NW -48.96328; 46.95912;
  - NE -48.38654; 46.94740;
  - SE -48.40412; 46.59246; and
  - SW -48.97538; 46.60422.

- **Affected Area** is defined by the area that could potentially be affected by Project activities occurring in the Project Area. The Affected Area varies according to the timing and type of Project activity being considered and the sensitivities of the species or habitat within the particular VEC being assessed. Thus, there are many potential affected areas or geographic extents defined in this EA, depending on Project activities.
  - The largest potential Zone of Influence for the Project would be in the event of an accidental spill or blowout. Maps of predicted spill trajectories are provided in the assessment of accidental events. All other potential Zones of Influence from the Project are likely to remain within the Project Area as shown in Figure 1.1.
  - The effect of the incremental increase in helicopter and vessel traffic associated with this Project is assessed for activities within the Project Area only. Helicopter and vessel traffic outside of the Project Area (i.e., transit to and from the shore base) are regulated activities under the *Canada Shipping Act* and the *Aeronautics Act*, each administered by Transport Canada and would therefore be similar to any other commercial shipping/air traffic.
- **Regional Area (or Study Area**) for the biophysical VECs it is the boundary of the Grand Banks as defined in the Hibernia, Terra Nova and White Rose project EAs. For the Commercial Fisheries VEC, the Study Area is reflective of the area potentially affected by an accidental event.

5.6.1.2 Temporal Boundary

Effects of activities associated with the development of up to six new drill centres have been assessed "year-round" for the period 2009 to 2036 or longer pending possible adjustments to the field life. Dredging and disposal operations would likely occur during the summer months; all other Project activities could occur at any time of the year. Effects of activities with production operations using the new drill centres have been assessed "year-round" for the period 2012 to 2036 or longer pending possible adjustments to the field life. Effects of routine abandonment activities have been assessed for after 2036. The potential of accidental events (i.e., blowouts and batch spills) have also been considered and could occur at any point from 2009 to the end of Project abandonment activities.

5.6.1.3 Administrative Boundaries

Administrative boundaries refer to the spatial and temporal dimensions imposed on the environmental assessment for political, socio-cultural or economic reasons. Spatial administrative boundaries can include such elements as the manner in which natural and/or socio-economic systems are managed. These boundaries are defined for each VEC individually.

5.6.2 Existing Conditions

The existing conditions in the vicinity of the Project are described for Fish Habitat, Marine Fish and Shellfish, Commercial Fisheries, Marine Mammals, Marine Birds, and Species at Risk. For context, a description of the Physical Environment is also provided including climate, oceanography, sea ice and icebergs, bathymetry and geology. The description of existing conditions is based on the following:

- Hibernia EEM programs in 1994,1998, 1999, 2000, 2002, 2004 and 2007;
- Hibernia Development Project EIS (Moil Oil 1985) and component studies;
- Hibernia Well Site Survey (FJG 2005);
- Hibernia South Shallow Hazards Assessment (FJG 2006);
- Hibernia South Glory Hole and Ocean Disposal Site Sediment Survey (JW 2008);
- Hibernia South Glory Hole and Ocean Disposal Site ROV Survey (Pro Dive 2008);
- recent scientific publications and databases relevant to the Grand Banks;
- previous environmental assessment reports from the Jeanne d’Arc Basin, especially
  - recent Husky exploratory drilling EAs and updates (LGL 2002, 2003, 2005a, 2006b, 2007b);
  - StatoilHydro Canada Jeanne d’Arc Basin Area Seismic and Geohazard Program, 2008-2016 and Exploration and Appraisal/Delineation Drilling Program for Offshore Newfoundland, 2008-2016 (LGL 2008 a, b); and
  - SDL 1040 Delineation Drilling Screening (Husky and Norsk Hydro 2006);
- Orphan Basin Strategic Environmental Assessment (C-NLOPB 2003);
- Strategic Environmental Assessment Labrador Shelf Offshore Area (C-NLOPB 2008b);
- DFO database of marine mammal observations;
- CWS pelagic bird survey database; and
- personal communications.

The information available through the above sources is considered to be sufficient and acceptable for the purposes of this environmental assessment. While data gaps are always present when describing the natural environment, the gaps for this Project are not considered of sufficient scale and/or nature to affect the integrity of this assessment.

5.6.3 Potential Interactions and Existing Knowledge

The assessment focuses on identifying and evaluating potential interactions between the Project components and activities and each of the VECs under consideration. As a first step in the effects analysis, potential program-VEC interactions are identified and discussed. Existing knowledge concerning these potential interactions is also reviewed and summarized. A list of potential interactions between the Project activities and each VEC is presented in Table 5.2.

Table 5.2 Potential Project - VEC Interactions

Project Activities and Physical Works	VEC					
	Marine Mammals	Marine Birds	Marine Fish and Shellfish	Marine Fish Habitat	Commercial Fisheries	Species at Risk
Glory Hole Excavation						
Dredge operation and Disposal	✓	✓	✓	✓	✓	✓
Presence of structures	✓	✓	✓	✓		✓
Safety zone			✓	✓	✓	✓
Lights	✓	✓	✓	✓		✓
Deck drainage, bilge water, and ballast water	✓	✓	✓	✓		✓
Sanitary or domestic waste water	✓	✓	✓	✓		✓
Routine air emissions		✓				✓
Marine vessels	✓	✓	✓	✓	✓	✓
Helicopter flights	✓	✓				✓
Drilling						
Presence of structures	✓	✓	✓	✓		✓
Safety zone	✓		✓	✓	✓	✓
Lights	✓	✓	✓	✓		✓
Flaring	✓	✓	✓	✓		✓
Mud operations	✓	✓	✓	✓		✓
Cement			✓	✓		✓
BOP discharge	✓	✓	✓	✓		✓
Cooling water	✓	✓	✓	✓		✓
Deck drainage, bilge water, and ballast water	✓	✓	✓	✓		✓
Sanitary or domestic waste water	✓	✓	✓	✓		✓
Produced water	✓	✓	✓	✓		✓
Supply boat transits	✓	✓	✓	✓	✓	✓
Supply boat on standby	✓	✓	✓	✓	✓	✓
Helicopter flights	✓	✓				✓
Rig operation	✓	✓	✓	✓	✓	✓
Routine air emissions		✓				✓
VSP	✓	✓	✓	✓	✓	✓
Subsea Production Equipment Installation						
Presence of structures	✓	✓	✓	✓	✓	✓
Safety zone			✓	✓	✓	✓
Lights	✓	✓	✓	✓		✓
Production Operation						
Presence of structures	✓	✓	✓	✓	✓	✓
Safety zone	✓		✓	✓	✓	✓
Lights	✓	✓	✓	✓		
Flaring	✓	✓	✓	✓		✓
Cooling water	✓	✓	✓	✓		✓
Deck drainage, bilge water, ballast water and valve operation fluids etc.	✓	✓	✓	✓		✓
Sanitary or domestic waste water	✓	✓	✓	✓		✓
Produced water	✓	✓	✓	✓		✓

Project Activities and Physical Works	VEC					
	Marine Mammals	Marine Birds	Marine Fish and Shellfish	Marine Fish Habitat	Commercial Fisheries	Species at Risk
Supply boat transits	✓	✓	✓	✓	✓	✓
Supply boat on standby	✓	✓	✓	✓	✓	✓
Helicopter flights	✓	✓				✓
Routine air emissions		✓				✓
Abandonment						
Presence of structures	✓	✓	✓	✓	✓	✓
Safety zone	✓	✓	✓	✓	✓	
Lights	✓	✓	✓	✓		✓
Deck drainage, bilge water, and ballast water	✓	✓	✓	✓		
Sanitary or domestic waste water	✓	✓	✓	✓		✓
Routine air emissions		✓				
Marine vessels	✓	✓	✓	✓	✓	✓
Helicopter flights	✓	✓				✓

5.6.4 Residual Environmental Effects Significance Criteria

Evaluating the significance of predicted residual environmental effects is one of the critical stages in an environmental assessment. Significant environmental effects are those adverse effects that will cause a change that will alter the status or integrity of a VEC beyond an acceptable level. In this assessment, environmental effects are evaluated as significant or non significant based on definitions of significance which have been developed and used for each VEC.

The definitions for significant adverse environmental effects integrate key factors such as magnitude (i.e., the portion of the VEC population affected), potential changes in VEC distribution and abundance, effect duration (i.e., the time required for the VEC to return to pre-project levels), frequency, and geographic extent (refer to Section 5.6.5 for a more detailed definition of these criteria). They also include other important considerations such as interrelationships between populations and species, as well as any potential for changes in the overall integrity of affected populations. For each VEC, an adverse environmental effect that does not meet the criteria for a significant environmental effect is evaluated as non significant. A positive effect is one that may enhance a population or resource use activity.

5.6.5 Environmental Effects Assessment

This stage entails the assessment of the potential effects associated with the Project's components/activities and potential accidental events for each of the VECs under consideration. Effects are analyzed qualitatively and, where possible, quantitatively using existing knowledge, professional judgment and appropriate analytical tools. For this assessment, the assessment of accidental events has been completed in a stand-alone section (Section 8).

The following includes some of the key factors that can be considered for determining adverse environmental effects, as per the Agency guidelines (CEA Agency 1994):

- negative environmental effects on the health of biota;
- loss of rare or endangered species;
- reductions in biological diversity;
- loss or avoidance of critical/productive habitat;
- fragmentation of habitat or interruption of movement corridors and migration routes;
- transformation of natural landscapes;
- discharge of persistent and/or toxic chemicals;
- toxicity effects on human health;
- loss of, or detrimental change in, current use of lands and resources for traditional purposes;
- foreclosure of future resource use or production; and
- negative effects on human health or well-being.

Potential environmental effects on each VEC are characterized using the following five descriptors:

- Magnitude – the nature and degree of the predicted environmental effect. Rating depends on the nature of the VEC and the potential effect. For biophysical/ecological VECs the rating system is as follows:
  - Low - Affects a specific group or critical habitat for one generation or less; within natural variation;
  - Medium - Affects a portion of a population or critical habitat for one or two generations; temporarily outside the range of natural variability;
  - High - Affects a whole stock, population or critical habitat (may be due to the loss of an individual(s) in the case of a species at risk) outside the range of natural variability.

  For socio-economic VECs the magnitude of potential effect is defined as:

  - Low - Does not have a measurable effect on valued socio-economic components;
  - Medium - Has a measurable effect on socio-economic components, but is temporary and/or is highly localized;
  - High - Has a measurable and sustained adverse effect on socio-economic components.
- Geographical Extent: describes the area within which an effect of a defined magnitude occurs;
- Frequency: the number of times during a project or a specific project phase that an effect may occur (i.e., one time, multiple);
- Duration: typically defined in terms of the period of time required until the VEC returns to its baseline condition or the effect can no longer be measured or otherwise perceived (defined specifically for each VEC, may be a specific period of time); at a minimum, it is divided into three timeframes: short-term, mid-term and long-term;
- Reversibility: the likelihood that a measurable parameter will recover from an effect, including through active management techniques such as habitat restoration works; and
- Ecological Context: the general characteristics of the area in which the project is located; typically defined as limited or no anthropogenic disturbance (i.e., not substantially affected by

human activity) or anthropogenically developed (i.e., the area has been substantially disturbed by human development or human development is still present).

Where possible, these characteristics are described quantitatively for each residual environmental effect. Where these characteristics cannot be expressed quantitatively, at minimum, they are described using qualitative terms that are defined specifically for the VEC or environmental effect.

5.6.6 Mitigation

Based on the potential interactions identified above and existing knowledge regarding these interactions, technically and economically feasible mitigation measures to reduce or eliminate potential adverse effects are identified.

Where possible, a proactive approach to mitigating potential environmental effects has been taken by incorporating environmental considerations directly into program design and planning (Section 2). Where required and feasible, additional measures are identified in the environmental assessment to further mitigate potential negative effects. These mitigation measures are identified and discussed within the appropriate effects analysis section(s). Residual environmental effects predictions are made, taking into consideration these identified mitigation measures.

5.6.7 Cumulative Environmental Effects

Individual environmental effects are not necessarily mutually exclusive of each other but can accumulate and interact to result in cumulative environmental effects. This environmental assessment includes consideration of cumulative environmental effects for each VEC. The cumulative effects assessment is presented in a stand-alone section (Section 7).

Within-Project cumulative effects (i.e., those due to the accumulation and/or interaction of each project's own environmental effects) are considered as part of the Project-specific environmental effects analyses described above (i.e., the overall effect of each project on a VEC). This section focuses on the cumulative effects of the drilling program in combination with other relevant projects and activities.

The region's natural and human environments have been affected by past and on-going human activities. The description of the existing (baseline) environment reflects the effects of these other actions. The evaluation of cumulative environmental effects considers the nature and degree of change from these baseline environmental conditions as a result of the proposed program in combination with other ongoing and planned projects and activities.

An important step in undertaking a cumulative effects assessment is the identification of other projects whose effects will likely act in combination with those of the project under review to bring about cumulative effects. The CEA Act requires that only projects and activities that have been or will be conducted be considered. The degree of certainty that the project will proceed must therefore be considered (CEA Agency 1999). The other projects and activities considered in this assessment therefore include those that are ongoing or likely to proceed and have been issued permits, licenses, leases or other forms of approval (as specified by CEA Agency 1994). The cumulative effects assessment considers the cumulative effects of the proposed drilling program in combination with the following activities as identified through the Scoping Document (Appendix A):

- marine transportation;

- fishing activities;
- proposed oil and gas activities (as per C-NLOPB registry and other available information);
- ongoing oil and gas activities (including existing production facilities); and
- seismic activity.

Proposed/ongoing oil and gas activities as per the C-NLOPB Public Registry, updated September 21, 2008 include:

- StatoilHydro's proposal to drill a maximum of 27 single and/or dual side-track wells between 2008 and 2016;
- StatoilHydro's proposed 2-D, 3-D and potentially 4-D seismic program;
- StatoilHydro/Husky's proposed exploration/delineation drilling program for the SDL 1040;
- Husky's proposal to develop four new drill centres at White Rose;
- Husky's proposed exploration/delineation drilling program;
- Husky's proposed 3-D seismic surveys and geohazard surveys of their offshore acreage in Jeanne d'Arc Basin;
- Petro-Canada's proposal to conduct a three-dimensional seismic program in the Jeanne d'Arc Basin; and
- Petro-Canada's proposed VSP program in the Terra Nova field.

The above are in addition to the existing three offshore development projects. Substantial future activity is anticipated as the result of the Hebron Development. Initial plans call for the pre-drilling of 12 to 14 wells using a MODU prior to the anticipated first oil in 2016. This will be followed by the tow-out and installation of the Gravity Based Structure for the project. This will be followed by additional development drilling and ultimately, production.

5.6.8 Follow-up

Consideration of a follow-up program is requested for this screening-level environmental assessment. The purpose of the follow-up program is to:

- verify the accuracy of the environmental assessment; and
- determine the effectiveness of mitigation measures.

As part of the environmental effects analysis, appropriate follow-up is described where warranted. Follow-up is considered where there are important Project-VEC interactions, where there is a high level of uncertainty, where significant environmental effects are predicted, or in areas of particular sensitivity.

Follow-up programs should be well-defined and focused to allow for efficient use of time and resources. Follow-up programs are typically associated with longer-term projects, but are considered for discussion purposes in this assessment.

5.6.9 Summary of Residual Environmental Effects Assessment

Significance ratings for the predicted residual environmental effects of each Project component/activity and for the Project as a whole are provided in summary tables for each VEC (see Table 5.3 as an example). Residual effects are those remaining following application of Project mitigation. These predictions must:

- facilitate decision-making with respect to the proposed project;
- clearly specify any degree of uncertainty inherent in the projections;
- clearly identify positive and negative environmental effects (both biophysical and socio-economic) of the proposed project; and
- be amenable to testing and verification where possible through ongoing monitoring initiatives.

Table 5.3 Template for Summary of Environmental Effects

Interactions	
Mitigation	
Significance	
Likelihood of occurrence	
Geographic extent	
Frequency of occurrence (over 27 years)	
Duration of impact	
Magnitude of impact	
Permanence/reversibility	
Significance	
Confidence	
Follow-up and monitoring	

The evaluation of the significance of the predicted residual environmental effects is based on a review of relevant literature and professional judgment. In some instances, assessing and evaluating potential environmental effects is difficult due to limitations of available information. Ratings are therefore provided to indicate the level of confidence in each prediction. The level of confidence ratings provide a general indication of the confidence within which each environmental effects prediction is made based on professional judgment and the effects recorded from similar existing projects. The likelihood of the occurrence of any predicted significant adverse effects is also indicated, based on previous scientific research and experience.

6.0 ENVIRONMENTAL EFFECTS ASSESSMENT

6.1 Marine Fish Habitat

Marine Fish Habitat includes the physical (e.g., substrate, temperature, water depth), chemical (e.g., nutrients), and biological (e.g., benthic macroinvertebrates, marine plants) attributes of the environment that are required by marine fish to carry out life cycle processes (e.g., spawning, rearing, feeding, overwintering, migration). Several commercial species of fish and shellfish have spawning, feeding and nursery habitats on the Grand Banks. Environmental effects of the Project on fish habitat resulting from construction, operation and abandonment are assessed in this section. The assessments of cumulative effects and accidental events on Marine Fish Habitat are presented in Section 7 and 8, respectively.

Although intrinsically related to marine fish habitat; marine fish and shellfish, commercial fisheries, marine mammals, and species at risk are assessed separately in Sections 6.2, 6.3, 6.4, and 6.6 respectively.

6.1.1 Rationale for Selection as Valued Environmental Component

Marine fish habitat is selected as a VEC because of the potential for direct interaction with the Project. Specifically, marine fish habitat was selected as a VEC because of:

- requirements of the Scoping Document (Appendix A)
- specific regulatory requirements of the *Fisheries Act* and *SARA*;
- the direct interaction between marine habitat and routine Project activities;
- the potential interaction between marine habitat and the Project as a result of accidents or malfunctions and;
- the ecological, recreational and commercial importance of marine habitat to the public.

The environmental impact assessment focuses on relevant aspects of Marine Fish Habitat. These aspects were selected in consideration of information presented in the Project description (Section 2), and those Project activities with the potential to interact with the VEC.

6.1.2 Boundaries

6.1.2.1 Spatial Boundary

The spatial boundary for the assessment of potential environmental effects on Marine Fish Habitat includes the area where interactions with the Project are likely to occur, also known as the Affected Area. During routine construction, operation and abandonment activities, interactions between the Project and Marine Fish Habitat are expected to be contained within the Project Area. So, for this VEC, the Affected Area is analogous to the Project Area (Figure 1.1).

6.1.2.2 Temporal Boundary

The temporal boundary of the assessment is defined by the Project's potential interaction with marine fish habitat during construction, operation and abandonment activities. Many Project activities, such as dredging are relatively short-term (i.e., ~ 45 days per glory hole), but as an exact schedule for Project activities within the six potential drill centres is not known, it has been assumed for the purposes of the assessment that interactions with the Project could occur at any time of the year. Project activities are expected to commence in 2009, and continue through to the end of the field life which is currently estimated to be in 2036, but this may be extended over time.

6.1.2.3 Administrative Boundaries

Marine fish habitat is protected in Canada through federal legislation under the *Fisheries Act*. Section 35 of the *Act* prohibits harmful alteration, disruption or destruction of fish habitat referred to as HADD, while Section 36 prohibits deposits of any substances considered deleterious to fish. Environment Canada administers Section 36 of the *Fisheries Act;* while DFO administers Section 35 of the *Act*. Fish habitat is also protected by the DFO *Policy for the Management of Fish Habitat* (DFO 1986). This policy applies to all activities in or near water that threaten the productive capacity of fish habitats. The guiding principle of this policy is to achieve no net loss of the productive capacity of fish habitat and to achieve a net gain in productive capacity of habitat.

6.1.2.4 Technical Boundary

Technical boundaries include the limitations of the available data for fish habitat within the Affected Area and the limits of scientific knowledge specific to the interactions between Project activities and relevant fish habitat characteristics. However, the data which are available to characterize fish habitat and the existing scientific knowledge regarding the potential environmental effects of the Project are considered adequate to support the environmental assessment. The habitat within the Affected Area is considered typical habitat within the Jeanne d'Arc Basin and contains no known unique or critical habitat for fish or shellfish.

Specifically, the description of existing conditions for marine fish habitat (Section 4.1) within the Affected Area and Study Area was based on the following:

- Hibernia EEM programs in 1994,1998, 1999, 2000, 2002, 2004 and 2007;
- Hibernia Development Project EIS (Mobil Oil 1985) and component studies;
- Hibernia Well Site Survey (FJG 2005);
- Hibernia South Shallow Hazards Assessment (FJG 2006);
- Hibernia South Glory Hole and Ocean Disposal Site Sediment Survey (JW 2008);
- Hibernia South Glory Hole and Ocean Disposal Site ROV Survey (Pro Dive 2008);
- recent scientific publications and databases relevant to the Grand Banks;
- previous environmental assessment reports from the Jeanne d'Arc Basin, including,
    - Husky exploratory drilling EAs and updates (LGL 2002, 2003, 2005a, 2006b, 2007b);
    - StatoilHydro Canada Jeanne d'Arc Basin Area Seismic and Geohazard Program, 2008-2016 and Exploration and Appraisal/Delineation Drilling Program for Offshore Newfoundland, 2008-2016 (LGL 2008 a, b); and

- SDL 1040 Delineation Drilling Screening (Husky and Norsk Hydro 2006);

- experience of the study team in offshore EAs; and
- personal communications.

6.1.3 Potential Interactions and Existing Knowledge

Potential interactions between the Marine Fish Habitat VEC and routine Project activities and associated effects include:

- effects associated with discharge of drill mud and cuttings;
- effects associated with dredging and ocean disposal;
- effects of noise from all routine activities (including VSPs, well site surveys and abandonment);
- effects associated with the discharge of waste and wastewater; and
- effects associated with the presence of structures (including subsea equipment and flowlines), lights and flares.

A detailed list of the potential interactions between the Project and Marine Fish Habitat is provided in Section 5.6.3. These interactions could result in a number of potential effects on Marine Fish Habitat. During drilling and dredging, benthic resources may be impacted by physical disturbances and discharges, including the drilling of holes in the seafloor, placing the subsea manifold on the seafloor, discharging drill muds and cuttings, placing anchors, retrieving anchors, dredging and disposal of dredged materials and noise disturbance from seismic activities (VSPs and well site surveys). Effects may include direct smothering, increased turbidity and physical disturbance. In addition, the presence of new subsea structures and the establishment of safety zones can result in habitat alteration/improvement for some species. These potential effects are discussed in further detail below.

As the Project is not predicted to result in an increase in Hibernia production levels (only an extension in the field life), or discharge rates of air emissions and wastewater, potential Project effects during the operation/production stage are consistent with those effects already assessed for the overall Hibernia project. Any requirements for maintenance at the drill centers would be periodic, short-term and would have limited potential for interactions with Marine Fish Habitat.

HMDC is aware of the DFO initiative to establish marine protected areas (MPA's) on the Grand Banks. DFO has identified a number of Ecologically and Biologically Significant Areas (EBSA's) and MPA's could be established within these areas. None of the EBSA's identified thus far overlap with the Project Area. HMDC will continue to monitor the MPA initiative and manage issues, if any, as they arise.

6.1.3.1 Discharge of Drill Muds and Cuttings

Water-based Muds & Cuttings

Discharge of WBM and associated cuttings is regulated by the C-NLOPB. WBMs may be discharged without treatment according to the OWTG. The discharge of WBM may increase metals such as barium, arsenic, cadmium, copper, mercury, lead and zinc in sediments, but these metals are not bioavailable, so they do not accumulate in benthic species. Elevated levels of metals generally occur within 250 to 500 m of the drill site, but sometimes occur further, depending on environmental conditions and the number of wells drilled (see Hurley and Ellis 2004). The primary fish habitat effect of

WBM discharge is physical in that substrate composition changes on the seafloor and there is smothering of sessile benthos near the drill rig.

Sessile epifauna such as bryozoans, barnacles, brittlestars and urchins will be smothered, whereas infauna such as most polychaetes, amphipods and clams are burrowing species and can be expected to resurface from a covering of several centimetres. Based upon the published literature (reviewed in Husky 2000, 2001a; LGL 2005a, 2006b; MMS 2000; CAPP 2001b; Hurley and Ellis 2004; Neff 2005), the benthos can be expected to recover over a period of several months to several years, but most likely within one year after cessation of drilling. Sessile organisms are likely to be smothered in areas where cuttings are greater than 1 cm thick (Bakke et al. 1989). The White Rose Comprehensive Study (Husky Oil 2000) indicated a worst case scenario of an area less than 1 km^2 around each well that would have a depth sufficient to result in some smothering of benthos (Husky 2000; 2001a).

Synthetic-based Cuttings

SBM cuttings are treated as per the OWTG requirements prior to discharge and are subject to C-NLOPB approval. The disposal of whole SBM is prohibited and therefore only cuttings retaining residual SBM after treatment is assessed. SBM cuttings stay closer to the well site and do not disperse as widely as WBMs and cuttings. Thus, no additional mortality (smothering) of sessile benthic invertebrates is expected to occur as a result of SBM discharge as the area will have been subjected to smothering from previous WBM deposition. The primary concern associated with the deposition of treated SBMs is the increased risk of marine habitat contamination.

SBMs are essentially non-toxic (see below) have the potential to biodegrade relatively rapidly (months to years, depending on the conditions), require less mud (compared to WBM) for the same distance drilled and tend to disperse less than WBMs. Effects of SBM on benthic organisms may result from physical smothering or from the anoxic conditions created by the biodegradation which increases the oxygen demand in the sediments. Effects on benthic communities are not simply related to the rate of biodegradation. For example, esters have been found to biodegrade rapidly under laboratory conditions but cause anoxia in the field; whereas olefins degrade slower and may cause fewer effects in benthos (Jensen et al. 1999 in OGP 2003).

Hurley and Ellis (2004) reviewed 19 studies to assess environmental effects associated with SBM and found that the area of detection and scale of biological effects were more localized than for WBM. Changes in the diversity and abundance of benthic organisms were detected within 1000 m of drill sites, but most commonly within the 50 to 500 m range of drill sites (Hurley and Ellis 2004). The results were consistent for both literature review case studies documenting biological effects around wells discharging SBM and WBM, and for the Canadian EEM data. Patin (1999) also noted that biological effects in the form of structural changes in benthic communities can be found up to 1000 m from platforms. This scale of effects apply to wells discharging SBM or WBM and for multiple or single wells drilled at the same site. Beyond the bottom area covered by the cuttings pile, benthic communities generally returned to baseline conditions within one year after cessation of drilling discharges Hurley and Ellis (2004).

Signals of drill muds (i.e., barite) have been detected 5000 m from Terra Nova (18 production wells) and 8000 m from Hibernia (32 production wells) (Hurley and Ellis 2004), but not at levels expected to have any biological effect. SBM in sediments documented from 19 case studies were detected at distances ranging from 100 m to 2000 m from the discharge location (Hurley and Ellis 2004). Patin (1999) noted that environmental parameters usually reach background levels at a distance of a few hundred meters (maximum-up to 1000 m) from the platforms. It is important to note that Hibernia, prior to 2007 operated two drilling rigs simultaneously year round and discharged at essentially the same location. In terms of potential effects, Hibernia can be viewed as a worse case scenario yet, no significant effects have been detected in any of the five EEM programs.

The SBM for this Project will use ParaDrill IA or equivalent, as the base fluid. ParaDrill has an aromatic content of <0.01 percent and a PAH content of <0.001 ppm. It is not toxic acutely or chronically toxic (Payne et al. 2001 a, b; Andrews et al. 2004; Petro-Canada Technical Bulletin n.d).

ParaDrill received a Group E classification by the Offshore Chemical Notification System (OCNS) a classification system employed in the United Kingdom. Group E classification is the best rating achievable under OCNS and is assigned to chemicals that have relatively low toxicity and/or do not bioaccumulate or readily biodegrade.

The toxicity data for ParaDrill IA-35 (Petro-Canada Technical Bulletin n.d.; Harris 1998) are:

- mysid shrimp 96-hour LC50 of >500,000 ppm;
- rainbow trout 96-hour LC50 of >400,000 ppm;
- amphipod (Corophium volutator) 10-day LC50 of 2,633 mg/L;
- Macoma clam 20-day LC50 of >50,000 mg/L;
- echinoid fertilization (Lytechinius pictus) IC50 (20 minutes) of >100 percent; and
- bacterial bioluminescence (Microtox test using Vibrio fischeri) EC50 of >100 percent.

6.1.3.2 Dredging and Disposal

Each drill centre will require a glory hole to protect the wells and associated equipment from potential iceberg scouring impacts. The excavation of the glory hole may be completed by a suction hopper dredge or alternate technology (e.g. clam shell). The potential environmental effects of each technology are similar, but they may differ in extent. The clam shell dredge will side cast the material during glory hole excavation, which will confine sediment dispersion and the disposal pile footprint to near the excavation site. The suction hopper dredge vessel cuts the substrate and vacuums the material up to the vessel, so there is little chance for material to escape in this enclosed system. It is at the disposal site where the dredge spoils will increase water turbidity during discharge. The maximum amount of material to be disposed for each 70 m x 70 m x 10 m glory hole is approximately 159,300 m^3. The dredging vessel is anticipated to be filled to capacity every second day. Glory hole construction and dredge spoil disposal will result in HADD and will require a Section 35 (2) *Fisheries Act* Authorization. The effects of glory hole construction on marine fish habitat are primarily associated with extraction of the benthic community at the dredge site, burial effects associated with dumping of the dredged material and the increase in turbidity at the disposal site.

One effect of increased levels of suspended solids is a reduction in the amount of light that is able to transmit through the water column. If elevated levels of suspended solids are sustained before or during a plankton bloom, a decrease in localized primary productivity may result in the affected area. In turn, the food supply for young fish and shellfish may be diminished. As an apparent adaptation to low light levels, phytoplankton are able to assume “resting stages”, where they may survive for a time until water conditions improve (Stockner and Antia 1976), or the plankton drift to a less turbid area. There may be indirect effects on fish through alterations within the food web structures in the Affected Area.

For example, copepods, an important prey of fish, show negative effects and reduced numbers when there is moderate loading of suspended solids (Robinson and Cuthbert 1996, and references therein). This may have a temporary localized effect on prey selection for some fish species.

Suspended sediments will resettle on the seabed after disturbance. The rate and location of this process is dependent upon the sediment grain size and the water currents in the area. Fines (silt/mud) will drift longer distances in the water column. Observed sediments within the area to be dredged are comprised predominantly of sands and gravels with limited fine material. Given this substrate composition, any re-suspended sediments would be expected to settle through the water column relatively quickly. Hitchcock et al. (1999) monitored the settlement of sediment from a number of dredging operations. The results indicated that in general, the majority of sediments settled within 10 to 15 minutes of release, and coarse sands (>2 mm) and gravels settled out virtually instantaneously.

Studies considering the effects of marine aggregate extraction have concentrated on establishing the rates and processes of macrobenthic recolonization upon cessation of dredging (Kenny et al., 1998; Desprez, 2000; Sarda´ et al., 2000; Van Dalfsen et al., 2000). These studies indicate that dredging causes an initial reduction in the abundance, species diversity, and biomass of the benthic community and that substantial progress towards full restoration of the fauna and sediments can be expected within a period of approximately 2 to 4 years following cessation (Kenny et al., 1998; Sarda´ et al., 2000; Van Dalfsen et al. 2000). It has been suggested (Van Dalfsen et al. 2000) that recolonization of a dredged area by polychaetes occurred within 5 to10 months after the cessation of dredging in a site located within the North Sea, with restoration of biomass to pre-dredge levels anticipated within 2 to 4 years.

Approximately 90 percent of the spoils at the HSE glory hole location consist of fine- to coarse-grained sand with minor gravel. These sediments are expected to disperse and settle in an asymmetric, elliptical pattern within the designated disposal area (see Figure 6.1).

From modeling, the maximum estimated sediment thickness is approximately 4.9 m, occurring approximately 30 m WSW of the disposal site centre. The central spoils mound declines and thins rapidly outward at slopes of about 3° to 1°, becoming less than 1 m thick at radial distances of about 50 m to 120 m (Figure 6.1). The spoils deposit thins to less than 10 cm at distances ranging from approximately 250 m to 500 m from the origin, and then thins further to less than 2 cm at radial distances of about 400 m (NE) to 700 m (SW). The predicted extent of continuous spoils accumulations greater than or equal to 1 cm thick is estimated to be 1,338,790 m^2. The estimated area of spoils deposition increases to 2,283,750 m^2 when all sample bins with accumulations 1 cm thick are included. The total cumulative area of all bins with accumulations 2 cm thick is 983,750 m^2. The range of spoils dispersal can be significantly reduced by timing the discharge events with slack tide periods, but local sediment accumulations will increase accordingly.

As part of the approval process for the Ocean Disposal permit, it is necessary to characterize the chemistry of the materials to be disposed. Sediment sampling has already been conducted for the HSE dredge location, and it is likely that separate Ocean Disposal permits will be required for dredging and disposal at each drill centre. The sediment chemistry at the glory hole is considered to be at background levels for the Project Area (see Section 3.6.2), so there is little risk of contamination during disposal within the Project Area.

The dredge spoils disposal pile for glory hole construction will also create a new physical structure for fish habitat, but cover habitat within the piles footprint. The predicted spoils distribution at the HSE disposal location is shown in Figure 6.1.

6.1.3.3 Noise

A description of the sound levels emitted during the Project is provided in Section 2.7.11.1.

A typical well site survey could have a peak pressure output of 230 dB re 1 µPa @ 1 m (Davis *et al*. 1998), with a single streamer array. A VSP survey will have a peak pressure output of 242 dB re 1 µPa @ 1 m. Data on the impacts of seismic surveys on macroinvertebrates is limited, but the available data suggests that mortality through physical harm is unlikely below sound levels of 220 dB re 1 µPa @ 1 m (Royal Society of Canada 2004). Invertebrates lack swim bladders and hearing organs, two anatomical features where physical damage most likely occurs in aquatic organisms. The Royal Society of Canada (2004) suggests that seismic surveys will have no effect on the marine benthos provided the water depth is greater than 20 m, as will be the case for this Project.

The energy levels emitted from the VSP will be considerably less in source (760 cu. in.) and slightly less in output (242 dB re 1 µPa at 1 m) than typical for 2D or 3D seismic programs (3,000 to 5,000 cu. in. airguns and about 255 dB re 1 µPa at 1 m).

6.1.3.4 Waste and Wastewater

The OWTG encourages the reduction of generated waste and substances of potential environmental concern. As well, wastewater discharge is treated and tested for compliance with OWTG. Furthermore, all drilling and production chemicals that may interact with the marine environment are screened by the OCMS to minimize potential toxicity. Regulation and compliance testing aim to mitigate potential effects on fish habitat. Please see Section 2.7 for a description of Project related waste and wastewater.

Potential effects of waste and waste water discharge include a change in fish habitat quality and potential contamination of fish prey, although in areas very near the point of discharge.

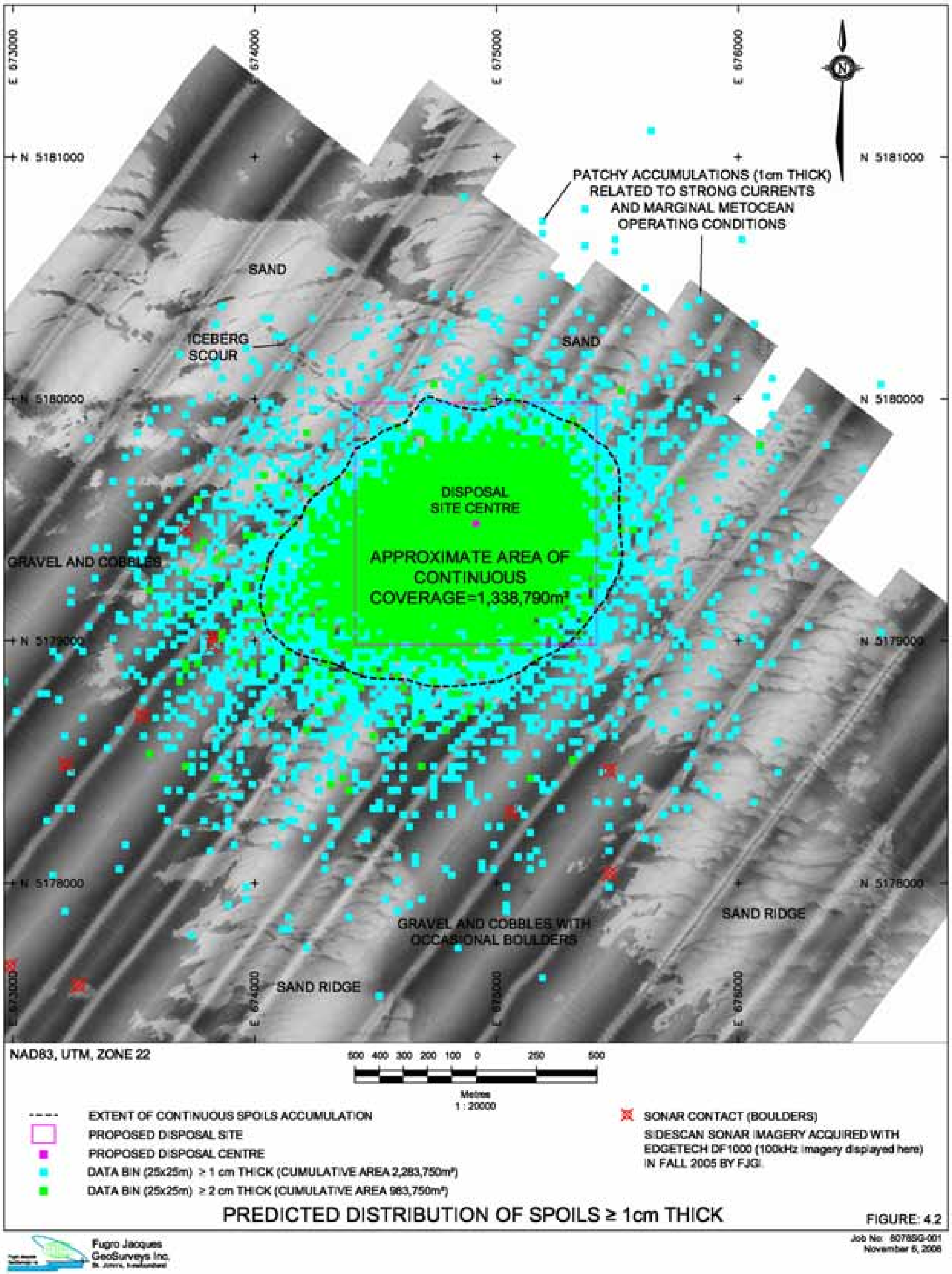
6.1.3.5 Presence of Structures, Lights and Flares

The Project will use either a semi-submersible rig or a drill ship. The semi-submersible would have more subsurface infrastructure than a drillship, so therefore more potential to affect fish habitat. While covering a portion of benthic habitat, the flowlines connected to the GBS and associated rock piles will also add complexity to the benthic habitat, as will the drill centre(s) themselves.

During Project abandonment, there would be some further disturbance of marine fish habitat as a result of removal of some of the sub-sea structures.

The increase in luminescence on the surface of the water from vessel and rig lights and flares may attract some fish species.

Figure 6.1 Predicted Spoils Distribution at HSE Disposal Site



6.1.4 Mitigations

Based on the potential interactions identified above and existing knowledge regarding these interactions, the following technically and economically feasible mitigation measures to reduce or eliminate potential adverse effects of routine Project activities on Marine Fish Habitat have been identified:

- use of water-based drilling muds wherever possible;
- use of non-toxic or low toxicity chemicals and muds, and treating synthetic oil-contaminated cuttings as per the OWTG;
- all wastewater discharges to comply with the OWTG and ship operations will adhere to Annex I of the *International Convention for the Prevention of Pollution from Ships* (MARPOL 73/78);
- use of the OCMS to screen chemicals for the Project;
- solid waste transported to shore and recycled where possible;
- adherence to DFO's Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment;
- all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently; and
- the disposal pile designated for the HSE glory hole will be considered for re-use for disposal of all future glory hole dredge spoils.

6.1.5 Residual Environmental Effects Significance Criteria

A **significant adverse environmental effect** is defined as one that affects marine fish habitat in such a way as to cause a decline or change in abundance and/or distribution of the population over one or more generations and natural recruitment (reproduction and in-migration from unaffected areas) may not re-establish the population to its original (i.e. pre-Project) level within several generations or avoidance of the area becomes permanent.

A **non-significant adverse environmental effect** is defined as an adverse effect that does not meet the above criteria.

6.1.6 Environmental Effects Assessment

6.1.6.1 Water-based Muds and Cuttings

The environmental effects of drill muds and cuttings on marine fish habitat in the Jeanne d'Arc Basin have been assessed several times in the past few years (Husky 2000, Husky and Norsk Hydro 2006, LGL 2005a, 2007b, 2008b). The following is a summary and update of those assessments where more recent information is available.

Section 2.7.1.1 provides a description of the predicted drill mud and cuttings dispersion for this Project. The primary concern associated with the discharge of WBMs and cuttings is the alteration of substrate composition and smothering of the sessile benthic species. Using the dispersion modeling results from SDL 1040 (Husky and Norsk Hydro 2006), 17.8 nm from Hibernia South, cuttings should be deposited in a radius of 50 m from the well site, and having a typical thickness ranging between 1.5 cm and 1.5 m.

Sessile invertebrates are likely to be smothered within a depositional area where the cuttings are greater than 1 cm thick (Bakke et al. 1989). Thus, sessile epifauna such as bryozoans, barnacles, brittlestars and urchins will be smothered within 50 m of the well. Infauna, such as most polychaetes, amphipods and clams, will be less affected as they are burrowing species and can be expected to resurface from a covering of several centimetres. With continued disturbance, these species will likely move to a more suitable area.

The White Rose Comprehensive Study (Husky Oil 2000) indicated a worse case scenario of an area less than 1 km^2 around each well that would have a depth sufficient to result in some smothering (Husky 2000; 2001a). The drilling for this Project should result in effects well below this. Under the scenario of two MODUs concurrently drilling exploration/delineation wells in the Project Area, and assuming that WBM and cuttings will cover an area of the seabed of about 0.8 km^2 to a thickness of at least one centimetre per well, an approximate total of 1.6 km^2 of fish habitat could be concurrently smothered within the Project Area, representing about 0.09% of the total area of the Project Area.

WBMs are expected to remain in suspension in the deep water boundary layer. The boundary layer will have an expected thickness of 1 m and will extend in a 200 m diameter from the drill site. Since drill mud will remain in suspension, the most likely species to be affected by drill mud release are filter feeders. Contamination associated with the use of WBMs is of minimal concern to the environment since it is virtually free of hydrocarbons and the metals present are in a form that is not readily bioavailable. Additives to WBMs are selected for use in accordance with the Offshore Chemical Selection Guidelines (NEB et al. 1999), which ensures that the additives selected have an acceptable risk to the environment. Metals from WBMs and cuttings have not been demonstrated to cause biological effects (CAPP 2001; Hurley and Ellis 2004).

As described above, the residual effects of water-based mud and cuttings discharge on Marine Fish Habitat will be localized and short term and are therefore considered non- significant.

6.1.6.2 Synthetic-based Muds and Cuttings

The depositional model used for the SDL 1040 Delineation Drilling Screening EA predicted that SBM cuttings will be deposited on the seafloor within approximately 40 m of the drilling platform with a maximum thickness of 0.5 m (Husky and Norsk Hydro 2006). Thus, no additional mortality (smothering) of sessile benthic invertebrates or change in substrate composition is expected to occur due to the discharge of SBMs since the area (50 m from the well) will have been subjected to smothering from previous WBMs deposition. The primary concern associated with the deposition of treated SBMs is the increased risk of fish habitat contamination.

Discharges are subject to board approval and discharge of whole SBM is not permitted. SBMs have very low toxicity potential (see above), have the potential to biodegrade relatively rapidly, require less mud (compared to WBM) for the same distance drilled and tend to disperse less than WBMs because of clumping properties of SBMs. Differences in benthic infaunal species abundance and richness indices are not detected beyond distances of 250 to 500 m from well sites with recovery of benthic communities occurring within one year of well completion (MMS 2000; CAPP 2001; NEB et al. 2002; Hurley and Ellis 2004). The effects of drill mud and cuttings release on the Grand Banks has been assessed in the Hibernia EA (Mobil Oil 1985), White Rose EA and addendum (Husky Husky 2000; 2001a), the Terra Nova EA (Petro Canada 1997), SDL 1040 Delineation Drilling Screening (Husky and NorskHydro Canada 2006) and the Husky exploratory drilling EAs and updates (LGL 2003, 2005a, 2006b, 2007b). Primary literature and industry reports on the effects of drill mud and cuttings have been reviewed in MMS (2000), CAPP (2001a, b), NEB et al. (2002), Buchanan et al. (2003), Hurley and Ellis (2004) and Neff (2005). Results from the EEM programs at Hibernia, White Rose and Terra Nova have confirmed their respective assessment predictions of no significant effect on the marine environment for those production projects. Mathieu et al. (2005) and Deblois et al. (2005) also concluded that the Terra Nova project demonstrated no significant effects on fish health and fish habitat after a three-year period where six wells were drilled using a combination of water-based and synthetic-based muds.

The residual effect of synthetic-based mud and cuttings discharge on Marine Fish Habitat is considered non-significant.

6.1.6.3 Dredging and disposal

Suspended sediments will resettle on the seabed after disturbance. The rate and location of this process is dependent upon the sediment grain size and the water currents in the area. Fines (silt/mud) will drift longer distances in the water column. Observed sediments within the area to be dredged are comprised predominantly of sands and gravels with limited fine material. Given this substrate composition, any re-suspended sediments would be expected to settle through the water column relatively quickly.

The sediment chemistry at the glory hole is considered at background levels for the Project Area (see Section 3.6.2), so there is no risk of contamination during disposal.

DFO has determined that the glory hole(s) dredging and dredge spoils disposal will result in a HADD. The total area of the HADD has yet to be determined, but HMDC will comply with the DFO policy of no net loss of the productive capacity of fish habitat from this Project.

The spatial and temporal scales of any effects for suspended solids and the high potential for reversibility and the commitment for habitat compensation means the environmental effects on Marine Fish Habitat from dredging and disposal are considered non-significant.

6.1.6.4 Noise

Noise does affect the quality of fish habitat. The assessment of the change in habitat quality on fish and shellfish is considered in Section 6.2. The U.S. Minerals Management Service's environmental assessment of geophysical exploration in the Gulf of Mexico supports the conclusion that there is no documented evidence of a measurable impact to benthic communities from streamer surveys, VSP surveys or remote sensing surveys (MMS 2004a). VSP impulses may cause mortality in plankton and ichthyoplankton near the source, but the spatial (meters) and temporal (2 to 3 days per well) scales are considered to result in non-significant environmental effects.

6.1.6.5 Waste and Wastewater

All chemicals having potential to be discharged to the marine environment will be screened in accordance with the C-NLOPB offshore chemical selection guidelines. All waste and wastewater discharges are of limited duration and frequency during Project Construction. Any discharge with potential for toxicity to the marine environment is regulated and monitored for compliance, so the risk of contamination of biota is limited. Organic matter associated with discharges will disperse quickly in an open ocean environment and degraded by bacteria. The effects of this relatively small amount of waste and wastewater on the offshore marine environment are considered non-significant.

6.1.6.6 Presence of Structures, Lights and Flares

Subsea structures associated with this Project (i.e., rig anchors, pipelines, rock piles), introduce diversity to a relatively homogeneous fish habitat. The added physical diversity tends to congregate potential prey species attracted by the increase in productivity resulting from habitat disturbance (e.g., small amount of substrate disturbance and suspended sediment) and biofouling. Flowlines may be stabilized by burial or stitch rock dumping. Experience in trying to excavate the hardpan material has proven difficult and a slow process. Terra Nova attempted flowline burial and stopped in favour of stitch rock dumping. Stitch rock dumping will result in a reduced impact on the seabed in that seabed trenching and sidecasting will not be necessary and the associated siltation will be avoided. Rock piles have the added positive effect of providing habitat diversity and surface area for colonization of marine organisms. Subsea structures also disturb or alter fish habitat from baseline conditions, so that any added productivity is balanced by the loss. The effect of lights from vessels and drill rigs will be contained to the immediate area surrounding the structure. See Section 6.2.5.3 for a discussion on the effects of lights on fish and shellfish. HMDC has initiated a habitat compensation strategy to ensure that there is no net loss of fish habitat productivity as a result of this Project. Any affect of the Project on Marine Fish Habitat are therefore considered non-significant.

6.1.6.7 Abandonment

The disturbance associated with decommissioning and abandonment activities (primarily associated with noise generated during removal of the wellhead and other infrastructure) will be of short duration and will mostly occur directly at the wellsite. The activities required for abandonment will comply with applicable regulations of the day. The likely residual environmental effects of decommissioning and abandonment on Marine Fish Habitat are considered non-significant.

6.1.7 Follow-up

The current Hibernia EEM consists of sediment chemistry, sediment toxicity, water chemistry, taint, fish health and analysis of potential contaminant substances (body burden) in tissues of American plaice (*Hipploglossoides platessoides*) (HMDC 2008). The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate.

Pursuant to the OWTG, compliance monitoring of both the drilling and production effluent discharges will be conducted.

A fish habitat compensation monitoring program will also be implemented to ensure no net loss of productive capacity in fish habitat as a result of this Project.

6.1.8 Summary of Potential and Residual Environmental Effects

Based on the ratings of magnitude, geographic extent and duration for each routine activity that will potentially interact with Marine Fish Habitat, the residual effects of the Project during construction operation and abandonment are predicted to be non-significant. A summary of the residual environmental effects of the Project on Marine Fish Habitat after mitigations is provided in Table 6.1.

Table 6.1 Summary of Environmental Assessment for Marine Fish Habitat

<table>
<tr><th colspan="2">Interactions</th></tr>
<tr><td colspan="2">♦ effects associated with discharge of drill mud and cuttings;
♦ effects associated with dredging and ocean disposal;
♦ effects of noise from all routine activities (including VSPs and well site surveys and abandonment);
♦ effects associated with the discharge of waste and wastewater; and
♦ effects associated with the presence of structures and lights.</td></tr>
<tr><th colspan="2">Mitigation</th></tr>
<tr><td colspan="2">♦ use of water-based drilling muds wherever possible;
♦ non-toxic or low toxicity chemicals and muds, and treating any synthetic oil-contaminated cuttings as per the OWTG;
♦ all wastewater discharges to comply with the OWTG and ship operations will adhere to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78);
♦ use of the OCMS to screen chemicals for the Project;
♦ solid waste transported to shore and recycled where possible;
♦ compliance with DFO's Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment;
♦ use of OCMS for chemical selection;
♦ all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently; and
♦ the HSE Ocean Disposal site will be considered for re-use for future disposal of spoils from construction of other glory holes.</td></tr>
<tr><th colspan="2">Significance</th></tr>
<tr><td>Likelihood of occurrence</td><td>Will occur</td></tr>
<tr><td>Geographic extent</td><td>• Drilling muds and cuttings: < 1km
• Noise: < 10 km
• Waste and wastewater: < 1km
• Dredging and disposal:<10 km
• Presence of structures and lights: <1 km</td></tr>
<tr><td>Frequency of occurrence
(over 27 years or longer)</td><td>• Drilling muds and cuttings: 1- 3 wells per year,
• Noise: 1-3 wells per year; 1-2 glory holes per year; 1 VSP survey per well; one geohazards survey per drill centre; 1-2 manifolds per drill centre;
• Waste and wastewater: continuous during each well, glory hole and subsea installation; valve control fluid venting approx 15 times per well per year;
• Dredging and disposal: 1-2 glory holes per year, and
• Presence of structures and lights : continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment, for the life of the Project.</td></tr>
<tr><td>Duration of impact
(over 27 years or longer)</td><td>• Drilling muds and cutting: 128 days each, up to 66 wells in total;
• Noise: drilling - 128 days each, up to 66 wells in total; glory hole - 45 days each, up to 6 in total; 1 VSP survey per well, 1-3 days each; 1 geohazards survey per glory hole; 1-2 manifolds per drill centre, 30-40 days each;
• Waste and wastewater: continuous during each well, glory hole and subsea installation;
• Dredging and disposal: 45 days per year, up to 6 glory holes
• Presence of structures: continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment(pipelines, wellheads), for the life of the project.</td></tr>
<tr><td>Magnitude of impact</td><td>Low (temporary during construction and habitat losses will be mitigated or compensated.)</td></tr>
<tr><td>Permanence/reversibility</td><td>Reversible</td></tr>
<tr><td>Significance</td><td>Non significant</td></tr>
<tr><td>Confidence</td><td>High</td></tr>
<tr><th colspan="2">Follow-up and monitoring</th></tr>
<tr><td colspan="2">▪ The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate and pending C-NLOPB approval.
▪ Pursuant to the OWTG, compliance monitoring of all effluent discharges will be conducted.
▪ A habitat compensation monitoring program will also be implemented to ensure no net loss of productive capacity in habitat as a result of this Project.</td></tr>
</table>

6.2 Marine Fish and Shellfish

The assessment of Marine Fish and Shellfish focuses on those species of commercial importance or those having potential to become commercially important, as well as ecologically important species. Effects of the Project on fish and shellfish resulting from construction, operation and abandonment are assessed in this section. The assessments of cumulative effects and accidental events on fish and shellfish are assessed in Chapter 7 and 8, respectively. The effects of the Project on the physical and biological components of fish habitat are evaluated and presented in Section 6.1. Marine fish species at risk are assessed in Section 6.6.

6.2.1 Rationale for Selection as Valued Environmental Component

Marine Fish and Shellfish is selected as a VEC because of the potential for direct interaction with the Project and due to:

- specific regulatory requirements of the *Fisheries Act* and *SARA*;
- requirements in the Project-specific Scoping Document (Appendix A);
- the direct interaction between marine fish and shellfish and routine Project activities, as well as accidental events; and
- the ecological, recreational and commercial importance of marine fish and shellfish to the public.

6.2.2 Boundaries

While the spatial and temporal extents of the Project are known, in most cases the spatial and temporal distribution of the fish and shellfish species within the Project Area is not precisely known. Therefore, as a precautionary approach for the purposes of this assessment, it is assumed that VEC species known to occur regularly on the northern Grand Banks (as indicated by fisheries data and DFO RV surveys), may occur in the Project Area and be potentially affected by Project activities. This includes migratory species (e.g., capelin) as well as sessile invertebrates (e.g., clams). Ecological boundaries for fish vary among species due to differences in home ranges, migration patterns and life histories.

Spatial Boundary

The spatial boundary for the assessment of potential environmental effects on the Marine Fish and Shellfish VEC includes the area where interactions with the Project are likely to occur, also known as the Affected Area. During routine construction, operation and abandonment activities, interactions between the Project and Marine Fish and Shellfish are expected to be contained within the Project Area. So, for this VEC for the assessment of routine activities, the Affected Area is analogous to the Project Area (Figure 1.1).

Temporal Boundary

The temporal boundary of the assessment is defined by the Project's potential interaction with marine fish and shellfish during construction, operation and abandonment activities. Many Project activities, such as dredging are relatively short-term (i.e., ~ 45 days per glory hole), but as an exact schedule for Project activities within the six potential drill centres is not known, it has been assumed for the purposes of the assessment that interactions with the Project could occur at any time of the year. Project activities are expected to commence in 2009, and continue through to the end of the field life which is currently estimated to be in 2036, but this may be extended over time.

6.2.2.1 Administrative Boundaries

Marine fish and fish habitat are protected by federal legislation. Fish habitat is protected under the federal *Fisheries Act* and by DFO's *Policy for the Management of Fish Habitat* (DFO 1986). This policy applies to all projects and activities in or near the water that could alter or destroy fish habitat by chemical, physical or biological means. The guiding principal of this policy is to achieve no net loss of the productive capacity of fish habitats. Section 35 of the *Fisheries Act* ensures no harmful alteration, disruption or destruction of fish habitat. Section 36 of the *Fisheries Act* ensures no deposits of any substance considered deleterious to fish into the environment. Environment Canada administers Section 36 of the *Fisheries Act* while DFO administers Section 35.

Marine fish populations are also affected by the DFO administration of commercial fishery quotas and closures.

6.2.2.2 Technical Boundaries

Technical boundaries include the limitations of the available data for marine fish and shellfish within the Affected Area and the limits of scientific knowledge specific to the interactions between Project activities and relevant species. However, the data which are available to characterize marine fish and shellfish within the Affected Area and the existing scientific knowledge regarding the potential environmental effects of the Project are considered adequate to support the environmental assessment. The marine fish and shellfish species within the Affected Area are considered typical within the Jeanne d'Arc Basin and the Affected Area contains no known unique or critical habitat for fish or shellfish.

Specifically, the description of existing conditions for marine fish and shellfish (Section 4.1) within the Affected Area and Study Area was based on the following:

- Hibernia EEM programs in 1994,1998, 1999, 2000, 2002, 2004 and 2007;
- Hibernia Development Project EIS (Mobil Oil 1985) and component studies;
- Hibernia Well Site Survey (FJG 2005);
- Hibernia South Shallow Hazards Assessment (FJG 2006);
- Hibernia South Glory Hole and Ocean Disposal Site Sediment Survey (JW 2008);
- Hibernia South Glory Hole and Ocean Disposal Site ROV Survey (Pro Dive 2008);
- recent scientific publications and databases relevant to the Grand Banks;
- previous environmental assessment reports from the Jeanne d'Arc Basin, including,
  - Husky exploratory drilling EAs and updates (LGL 2002, 2003, 2005a, 2006b, 2007b)
  - StatoilHydro Canada Jeanne d'Arc Basin Area Seismic and Geohazard Program, 2008-2016 and Exploration and Appraisal/Delineation Drilling Program for Offshore Newfoundland, 2008-2016 (LGL 2008 a, b); and
  - SDL 1040 Delineation Drilling Screening (Husky and Norsk Hydro 2006);

- experience of the study team in offshore EAs; and
- personal communications.

6.2.3 Potential Interactions and Existing Knowledge

Potential interactions and resulting effects, between the Marine Fish and Shellfish VEC and routine Project activities include:

- effects associated with discharge of drill mud and cuttings;
- effects associated with dredging and ocean disposal;
- effects of noise from all routine activities (including VSPs, wellsite surveys and abandonment activities);
- effects associated with the discharge of waste and wastewater; and
- effects associated with the presence of structures, lights and flares (including subsea equipment and flowlines).

A detailed list of the potential interactions between the Project and Marine Fish and Shellfish is provided in Section 5.6.3. These interactions could result in a number of potential effects on Marine Fish and Shellfish, including changes in distribution or abundance, behavioral responses such as startle responses, physical injury or mortality and bioaccumulation/tainting through contamination of habitat and food sources. These potential effects are discussed in further detail below.

As the Project is not predicted to result in an increase in Hibernia production levels (only an extension in the field life), or discharge rates of air emissions and wastewater, potential Project effects during the operation/production stage are consistent with those effects already assessed for the overall Hibernia project. Any requirements for maintenance at the drill centers would be periodic, short-term and would have limited potential for interactions with Marine Fish and Shellfish.

HMDC is aware of the DFO initiative to establish marine protected areas (MPA's) on the Grand Banks. DFO has identified a number of Ecologically and Biologically Significant Areas (EBSA's) and MPA's could be established within these areas. None of the EBSA's identified thus far overlap with the Project Area. HMDC will continue to monitor the MPA initiative and manage issues, if any, as they arise.

6.2.3.1 Discharge of Drill Muds and Cuttings

Water-based Muds and Cuttings

Discharge of WBM and associated cuttings is regulated by the C-NLOPB. WBMs may be discharged without treatment (NEB et al. 2002). Contamination and tainting of fish and shellfish from WBMs are of minimal concern since they are virtually free of hydrocarbons and the metals present are not readily bioavailable. WBMs have not been shown to cause biological effects (Hurley and Ellis 2004; CAPP 2001). However, laboratory studies suggest the physical properties of the suspended particulate in WBMs at concentrations less than 10 mg/L may affect sea scallop feeding, growth and reproduction (Cranford et al. 2005).

The primary effect of WBMs on fish and shellfish is actually a physical disturbance near the drill site. Effects will range from eliciting a startle response (avoidance of the area of deposition) in motile benthic fish and shellfish to smothering of sessile invertebrates. Sessile organisms are likely to be smothered in areas where cuttings are greater than 1 cm thick (Bakke et al. 1989). Larger shellfish such as clams and scallops may not be greatly affected however, since clams are a burrowing species that may resurface from several centimeters of cover and scallops may actually move from the area of disturbance. Crab and finfish species would almost certainly avoid an area of disturbance.

Synthetic-based Cuttings

The disposal of whole SBM is prohibited and therefore only cuttings retaining residual SBM after treatment is discussed. SBM cuttings stay closer to the well site and do not disperse as widely as WBMs and cuttings. Thus, no additional mortality (smothering) of sessile benthic invertebrates is expected to occur due to the discharge of SBM cuttings since the area will have been subjected to smothering from previous WBM and cuttings deposition. Hurley and Ellis (2004) reviewed 19 studies to assess environmental effects associated with SBM cuttings and found that the area of detection and scale of biological effects were more localized than for WBM. Biological impacts were generally detected at distances of 50 to 500 m from well sites.

SBM cuttings are treated to achieve the OWTG requirements prior to discharge. Discharges are subject to board approval and discharge of whole SBM is not permitted. SBMs are essentially non-toxic (see below) have the potential to biodegrade relatively rapidly (months to years, depending on the conditions), require less mud (compared to WBM) for the same distance drilled and tend to disperse less than WBMs.

The SBM for this project will use ParaDrill IA or equivalent, as the base fluid. ParaDrill has an aromatic content of <0.01 percent and a PAH content of <0.001 ppm. It is not toxic acutely or chronically toxic (Payne et al. 2001 a, b; Andrews et al. 2004; Petro-Canada Technical Bulletin n.d.)

ParaDrill received a Group E classification by the Offshore Chemical Notification System (OCNS), a classification system employed in the United Kingdom and one which has been adopted in the C-NLOPB OCMS. Group E classification is the best rating achievable under OCNS and is assigned to chemicals that have relatively low toxicity and/or do not bioaccumulate or readily biodegrade.

The toxicity data for ParaDrill IA (Petro-Canada Technical Bulletin n.d.; Harris 1998) are:

- mysid shrimp 96-hour LC50 of >500,000 ppm;
- rainbow trout 96-hour LC50 of >400,000 ppm;
- amphipod (*Corophium volutator*) 10-day LC50 of 2,633 mg/L;
- *Macoma* clam 20-day LC50 of >50,000 mg/L;
- echinoid fertilization (*Lytechinius pictus*) IC50 (20 minutes) of >100 percent fertilization; and
- bacterial bioluminescence (Microtox test using *Vibrio fischeri*) EC50 of >100 percent light emittance.

Toxicity studies conducted by DFO using American plaice, winter flounder (*Pleuronectes americanus*) and an amphipod (*Rhepoxynius abronius*) on Hibernia drill cuttings and solids (Payne et al. 2001a; b) found:

- no acute toxicity in juvenile American plaice exposed for 30 days to Hibernia cuttings approximating hydrocarbon concentrations found 200 to 500 m from platforms in the North Sea;
- no acute toxicity in adult winter flounder exposed to Hibernia cuttings for 90 days; and

- in a dose response study using amphipods, a toxic response at 5,000 ppm hydrocarbon concentration only.

In Hibernia's 2000 EEM report a single sediment toxicity response, based on the amphipod bioassay, was observed at a station located 200 meters from the platform. At the time the average hydrocarbon concentration at the sampling station was found to be 1086 mg/l (range 6.44 to 4170). This type of response was expected and the release of SBM cuttings was the primary source of these hydrocarbons. No such responses occurred at any sampling beyond 200 m and this response did not re-occur after SBM cuttings reinjection commenced in 2001, suggesting that recovery is rapid.

As well, chronic toxicity studies showed limited bioaccumulation of polycyclic aromatic hydrocarbons (PAH) in flounder exposed to sediments containing high levels of petroleum hydrocarbons (Hurley and Ellis 2004).

Results from laboratory studies have suggested an apparent weight loss of sea scallop somatic and reproductive tissues when exposed to ParaDrill IA at concentrations of 1.5 mg/L however, the effects were reversed after exposure ceased and little effect was noted at lower concentrations (Armsworthy et al. 2005). The authors also concluded that the fine particles of bentonite and barite found in drill mud is most likely the primary cause of effects on scallop tissue growth. Hamoutene et al. (2004) exposed lobsters to the SBM (IPAR) over a 20-day period and concluded that there was little or no potential for negative effects.

The highest risk of fish and shellfish contamination and associated tainting most likely exist for bottom-dwelling species (Patin 1999). However, Peterson et al. (1996) failed to detect evidence of exposure or sublethal impacts on demersal fish species, concluding that the mobility of fish species offers negligible exposure to hydrocarbons and other contaminants. As well, DFO studies on American plaice, suggest little potential for toxicity or health effects (Cranford et al. 2001, Payne et al. 1995).

Drilling discharges appear to have minor effects on fish health. EEM programs for Grand Bank production facilities have observed no fish health effects for any of the tested species (Hurley and Ellis 2004). Fish health assessments include investigations of condition indices, skin and organ lesions, liver and gill histopathology and levels of MFO enzymes in American plaice (Mathieu et al., 2004).

6.2.3.2 Dredging and Disposal

Each drill centre will require a glory hole to protect the wells and associated equipment from iceberg scour impacts. The excavation of the glory hole may be completed by a suction hopper dredge or alternate technology, such as the clam dredge. The potential environmental effects of each technology are similar, but they may differ in extent. The clam shell dredge will side cast the material during glory hole excavation, which will confine sediment dispersion and the disposal pile footprint to near the excavation site. The suction hopper dredge vessel cuts the substrate and vacuums the material up to the vessel, so there is little chance for material to escape in this enclosed system. It is at the disposal site where the disposal of dredge spoils will increase water turbidity during discharge.

Shellfish are generally more susceptible to the effects of increased sediment load than finfish because they are filter feeders (Petticord 1980). If the levels of suspended solids are sufficient, inorganic sediment loading can cause macroinvertebrates to ingest sediment particles that may inhibit digestion. Under extreme sediment loading, shellfish tend to stop feeding for as long as required.

Suspended solids may have lethal, sublethal or behavioural effects on finfish. Eggs and larvae of finfish and shellfish are generally more prone to physical damage from increased levels of suspended sediment because they are passive drifters and cannot avoid the affected area like the post-settlement life stages. Total suspended solid (TSS) levels of 1,000 mg/L have caused mechanical damage to herring larvae (Boehlert and Yoklavich 1984). Suspended sediment may cause respiratory and feeding problems for finfish species in the area or they may simply avoid the area of construction activity (Robinson and Cuthbert 1996, and references therein). The severity of effects of suspended sediments increases as a function of sediment concentration and duration of exposure (Newcombe and Jensen 1996). Sublethal effects in several fish species have been reported after several days of exposure to suspended sediment concentrations of approximately 650 mg/L or greater (Appleby and Scarratt 1989). Concentrations of this magnitude would likely be localized to the immediate site of seabed disturbance and within the area fish are expected to avoid due to construction activity. In conditions of extreme sediment load, mortality of finfish and shellfish results from extreme oxygen deficient water or respiratory obstruction. Levels of 100,000 mg/L kaolin resulted in an average mussel (*Mytilus edulis*) mortality of 10 percent after 5 and 11 days (Peddicord 1980).

The sediment chemistry at the glory hole is considered to be at background levels for the Project Area (see Section 3.6.2), so there is little risk of contamination during disposal within the Project Area.

Fish and shellfish may feed in the disposal area on epifaunal and infaunal organisms discharged with dredge spoils, once conditions are suitable.

DFO has determined that the glory hole(s) dredging and dredge spoils disposal will result in a HADD. The total area of the HADD has yet to be determined, but HMDC will comply with the DFO policy of no net loss of the productive capacity of fish habitat from this Project.

6.2.3.3 Noise

Sources of noise associated with the Project include geohazard surveys, VSP surveys, drilling activities, dredging and disposal activities, marine traffic and abandonment activities. Wells for this Project will be drilled by drill ship or a semi-submersible rig (e.g., *Glomar Grand Banks*). Semi-submersibles are quieter than drill ships (Richardson et al. 1995). A description of the sound levels emitted during the Project is provided in Chapter 2.7.11.1. Noise produced as a result of dredge vessel operation and geotechnical drilling could potentially have an effect on biota at some distance from the dredge/drilling vessel, although to a much lesser extent and magnitude than a seismic source from a VSP wellsite or geohazard survey.

All species of fish have the ability to hear, and some use sound to find prey, detect and avoid predators and for communication. The range of hearing for most fish is estimated to be below 1,000 Hz however, some fish can hear sound up to 3,000 Hz. The lack of scientific study, particularly field experiments on the effects of noise on fish and invertebrates, makes it difficult to evaluate the effect of a particular type of sound on a particular species. Effects can range from no measurable effect to internal damage. In between, there are shifts in temporary or permanent hearing thresholds, and changes in avoidance and social behaviour (Popper 2003).

Fish with swim bladders and specialized auditory couplings to the inner ear (e.g., herring) are highly sensitive to sound pressure. Fish with a swim bladder but without a specialized auditory coupling (e.g., cod and redfish) are moderately sensitive, while fish with a reduced or absent swim bladder (e.g.

mackerel and flounder) have low sensitivity (Fay 1988). Benthic macro-invertebrates are less sensitive to sound because few invertebrates have gas-filled spaces.

Literature relating to the effects of sound on fish and shellfish deal mainly with noise from seismic data acquisition, but there are papers specific to effects of drilling noise on fish. Otherwise there are few papers concerning the effects of noise on fish or shellfish from other relevant project activates. Little is known about invertebrate reactions to sound, but Christian et al. (2004) reported that exposure to seismic sound did not appear to decrease the catch rates of snow crab.

Numerous studies have been conducted on fish mortality as a result of exposure to seismic sound sources (i.e., Falk and Lawrence 1973; Holliday et al. 1987; La Bella et al. 1996; Santulli et al. 1999; McCauley et al. 2000a; 2000b; 2003; Thomsen 2002; IMG 2002; Hassel et al. 2003). No fish mortalities have been reported, but physical injury of adult fish is possible within a few tens of metres (Turnpenney and Nedwell 1994) and auditory damage in fish is possible within a few hundreds of metres (McCauley et al. 2000a). Other studies have shown that egg and larval mortality is possible only within a few metres of a seismic sound source (Pearson et al. 1994), so any effect on eggs and larvae is not likely discernible from natural mortality.

There are well documented observations of fish and invertebrates exhibiting behaviours that appeared to be in response to exposure to seismic sound including a startle response, a change in swimming direction and speed, or a change in vertical distribution (Hassel et al. 2003; Wardle et al. 2001; McCauley et al. 2000a; 2000b; Pearson et al. 1992; Schwarz and Greer 1984; Blaxter et al. 1981). Some studies indicate that such behavioural changes are very temporary while others imply that effects on behaviours/distributions may last for a number of days (Engås et al. 1996; Løkkeborg 1991; Skalski et al. 1992).

Davis et al. (1998) summarized that most schools of fish will not show avoidance to ships if they are not in the path of the approaching vessel. Schools that a vessel passes over may show lateral avoidance or compress towards the bottom. Observed responses indicate that the fish schools are quite variable and depend on species, life history stage, current behaviour, time of day, whether the fish have fed and how the sound propagates in a particular setting.

6.2.3.4 Waste and Wastewater

The OWTG encourage the reduction of generated waste and substances of potential environmental concern. As well, wastewater discharge is treated and tested to ensure compliance with OWTG. Furthermore, all drilling and production chemicals that may interact with the marine environment are screened by the OCMS to minimize potential toxicity. Regulation and compliance testing aim to mitigate potential effects on fish and shellfish. Please see Sections 2.7 for a description of Project related waste and wastewater.

Potential effects of waste and waste water discharge include a change in fish habitat quality and potential contamination of fish prey, although in areas very near the point of discharge.

6.2.3.5 Presence of Structures, Lights and Flares

The Project will use either a semi-submersible rig or a drill ship. The presence of a MODU has the potential to attract fish (Love *et al*. 2000). However, there is no scientific evidence to support the theory that rigs enhance or reduce regional stocks of marine fishes. Cod have been seen to congregate near offshore production facilities in the North Sea (Picken and McIntrye 1989).

A temporary safety zone would extend approximately 500 m from a drill ship and approximately 1.25 or 1.65 km from the drill centre for a semi-submersible rig, depending on the anchor arrangement. Thus, the safety zone will range from 1 to 5 or 8.2 km^2 in total area, per drill rig. A safety zone of 500 m would be required on either side of all flowlines and drill centre(s) post drilling. The current safety zone around the Hibernia GBS and OLS would be expanded. The semi-submersible would have more subsurface infrastructure than a drillship, so therefore more potential to influence fish and shellfish. The flowlines and associated rock piles will also introduce new structures to benthic species, as will the drill centre(s) themselves. The Hibernia GBS and OLS infrastructure would remain. Crab species, including snow crab are able to scale pipelines on the seafloor (Martec et al. 2004), so movement and migration effects are not expected.

Some fish species may be attracted to the drill rig due to illumination and the artificial reef effect. The rig may attract fish species whose potential prey may congregate near the rig. The lights may also attract additional finfish species and squid. Operational lights used in or near the marine environment may affect pelagic migratory fish species. Changes in juvenile herring and sand lance distribution at night have been observed in artificially lighted areas on the Pacific coast, which may have attracted their predators (Nightingale and Simenstad 2002). Many planktonic species and life stages are phototaxic; floating to near surface during the day and settling to deeper water at night. Any lights on the water at night may attract nekton that has active swimming ability.

6.2.4 Mitigations

Based on the potential interactions identified above and existing knowledge regarding these interactions, the following technically and economically feasible mitigation measures to reduce or eliminate potential adverse effects of the Project on fish and shellfish have been identified:

- use of water-based drilling muds wherever possible;
- use of non-toxic or low toxicity chemicals and muds, and treating synthetic oil-contaminated cuttings as per the OWTG;
- all wastewater discharges will comply with the OWTG and ship operations will adhere to Annex I of the *International Convention for the Prevention of Pollution from Ships* (MARPOL 73/78);
- use of OCMS for chemical selection for the Project;
- solid waste transported to shore and recycled where possible;
- adherence to DFO’s Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment;
- all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently; and
- the disposal pile designated for the HSE glory hole will be considered for re-use for disposal of all future glory hole dredge spoils.

6.2.5 Residual Environmental Effects Significance Criteria

A **significant adverse environmental effect** is defined as one that affects a fish or shellfish population or portion thereof in such a way as to cause a decline or change in abundance and/or distribution of the population over one or more generations and natural recruitment (reproduction and in-migration from unaffected areas) may not re-establish the population to its original (i.e. pre-Project) level within several generations or avoidance of the area becomes permanent.

A **non-significant adverse environmental effect** is defined as an adverse effect that does not meet the above criteria.

6.2.6 Environmental Effects Assessment

6.2.6.1 Water-based Muds and Cuttings

The environmental effects of drill muds and cuttings on fish and shellfish in the Jeanne d'Arc Basin have been assessed several times in the past few years (Husky 2000, Husky and Norsk Hydro 2006, LGL 2005a, 2007b, 2008b). The following is a summary and update of those assessments where more recent information is available.

Section 2.7.1.1 provides a description of the predicted drill mud and cuttings dispersion from Project drilling. Essentially, since WBMs and cuttings are deposited directly to the seafloor, these solids do not become widely dispersed, but settle around the drill rig. The primary concern associated with the discharge of WBMs and cuttings therefore is smothering of the sessile benthic species. Cuttings dispersion modeling completed for the SDL 1040 EA (Husky and Norsk Hydro 2006), 17.8 nm from Hibernia South, predicted cuttings deposition in a radius of 50 m from the well site, having a typical thickness ranging between 1.5 cm and 1.5 m. Sessile invertebrates are likely to be smothered within a depositional area where the cuttings are greater than 1 cm thick (Bakke et al. 1989). Thus, sessile epifauna such as bryozoans, barnacles, brittlestars and urchins will be smothered within 50 m of the well. Infauna, such as most shannies, blennies, sandlance, and clams, will be less affected as they are burrowing species and can be expected to resurface from a covering of several centimetres. With continued disturbance, these species will likely move to a more suitable area. The cuttings deposition is expected to elicit a startle response in motile fish (i.e. sculpins, rays and flatfish) and shellfish (i.e. crab), and them moving away from the potential zone of influence.

WBMs are expected to remain in suspension in the deep water boundary layer. The boundary layer will have an expected thickness of 1 m and will extend in a 200-m diameter from the drill site. Since drill mud will remain in suspension the most likely species to be affected by drill mud release are filter feeders. Cranford et al. (2005) demonstrated in laboratory studies that suspended WBMs at concentrations less than 10 mg/L may affect sea scallop feeding, growth and reproduction. As well, the fine particles of bentonite and barite found in drill mud can interfere with digestion and feeding of scallops (Armsworthy et al. 2005) and possibly other bivalve species (Barlow and Kingston 2001).

The White Rose Comprehensive Study (Husky Oil 2000) indicated a worse case scenario of an area less than 1 km^2 around each well that would have a depth sufficient to result in some smothering (Husky 2000; 2001a). The drilling for this Project should result in effects well below this. Under the scenario of two MODUs concurrently drilling exploration/delineation wells in the Project Area, and assuming that WBM and cuttings will cover an area of the seabed of about 0.8 km^2 to a thickness of at least one centimetre per well, an approximate total of 1.6 km^2 of fish habitat could be concurrently smothered within the Project Area, representing about 0.09% of the total area of the Project Area.

Contamination associated with the use of WBMs is of minimal concern to the environment since it is virtually free of hydrocarbons and the metals present are in a form that is not readily bioavailable. Additives to WBMs are screened in accordance with the *Offshore Chemical Selection Guidelines* (NEB et al. 1999), which ensures that the additives selected have an acceptable level of risk to the environment. Metals from WBMs and cuttings have not been demonstrated to cause biological effects (CAPP 2001; Hurley and Ellis 2004). Tainting or contamination of fish species is not expected to be associated with WBMs.

As the effects of water-based mud discharge on Fish and Shellfish are considered to be localized, short-term and reversible, the residual adverse environmental effects are rated as non-significant.

6.2.6.2 Synthetic-based Muds and Cuttings

The cuttings depositional model used for the SDL 1040 Delineation Drilling Screening EA predicted that SBM cuttings will be deposited on the seafloor within approximately 40 m of the drilling platform with a maximum thickness of 0.5 m (Husky and Norsk Hydro 2006). Thus, no additional mortality (smothering) of sessile benthic invertebrates is expected to occur due to the discharge of SBMs since the area (50 m from the well) will have been subjected to smothering from previous WBMs deposition. The primary concern associated with the deposition of treated SBMs is the increased risk of fish and shellfish contamination.

Discharges are subject to board approval and discharge of whole SBM is not permitted. SBM's have very low toxicity potential (see above), have the potential to biodegrade relatively rapidly, require less mud (compared to WBM) for the same distance drilled and tend to disperse less than WBMs because of clumping properties of SBMs. Differences in benthic infaunal species abundance and richness indices are not detected beyond distances of 250 to 500 m from well sites with recovery of benthic communities occurring within one year of well completion (MMS 2000; CAPP 2001; NED et al. 2002; Hurley and Ellis 2004). Organisms most likely to be affected from the release of SBMs are filter feeders such as scallops which have demonstrated somatic and reproductive tissue weight loss when exposed to ParaDrill IA at concentrations of 1.5 mg/L (Armsworthy et al. 2005), which will likely extend beyond 500 m. However, this study concluded that the fine particles of bentonite and barite found in drill mud and not the ParaDrill IA were most likely the primary cause of effects on scallop tissue growth. Recent EAs have predicted a total area of impact of less than one km^2 from multi-well drilling based on modelling and published literature.

The effects of drill mud and cuttings release on the Grand Banks has been assessed in the Hibernia EA (Mobil Oil 1985), White Rose EA and addendum (Husky 2000; 2001a), the Terra Nova EA (Petro Canada 1997), SDL 1040 Delineation Drilling Screening (Husky and NorskHydro Canada 2006) and the Husky exploratory drilling EAs and updates (LGL 2003, 2005a, 2006b, 2007b). Primary literature and industry reports on the effects of drill mud and cuttings have been reviewed in MMS (2000), CAPP (2001a,b), NEB et al.(2002), Buchanan et al. (2003), Hurley and Ellis (2004) and Neff (2005). In all cases, predicted effects were declared to be not significant.

Results from the EEM programs at Hibernia, White Rose and Terra Nova have confirmed the respective assessment predictions of no significant effect on the marine environment for those production projects. Mathieu et al. (2005) and Deblois et al. (2005) also concluded that the Terra Nova project demonstrated no significant effects on fish health and fish habitat after a three-year period where six wells were drilled using a combination of water-based and synthetic-based muds.

The residual adverse environmental effects of synthetic-based mud discharge on Fish and Shellfish are considered non-significant.

6.2.6.3 Dredging and disposal

Suspended sediments will resettle on the seabed after disturbance. The rate and location of this process is dependent upon the sediment grain size and the water currents in the area. Fines (silt/mud) will drift longer distances in the water column. Observed sediments within the area to be dredged are comprised predominantly of sands and gravels with limited fine material. Given this substrate composition, any re-suspended sediments would be expected to settle through the water column relatively quickly.

The sediment chemistry at the glory hole is considered to be at background levels for the Project Area, so there is no risk of contamination during disposal within the Project Area. The newly available food source at the disposal area will provide food for snow crab, skate, and any flatfish or benthic feeder in the area.

The localized area of effect from suspended solids, resulting depositional area and the high potential for reversibility will limit the magnitude of effects as a result of sedimentation. The residual adverse environmental effects of dredging and disposal on Fish and Shellfish are considered non-significant.

6.2.6.4 Noise

Most available literature indicates that the effects of noise on fish are transitory and if short-lived and outside a critical period, are expected not to translate into biological or physical effects. In most cases, it appears that behavioural effects on fish as a result of noise should result in negligible effects on individuals and populations.

Noise from a seismic source array used in VSP or geohazard surveys may cause mortality of fish and shellfish eggs and larvae within tens of meters, if they come near the source. Physical effects on fish may occur within a few hundred meters of this magnitude sound source, but no mortality of fish or shellfish is expected. Fish will likely be startled and avoid the area temporarily within a few kilometers.. Other sources of noise during the Project (i.e. dredge, pipe laying vessels drill rig) will be less in magnitude and each of limited duration, with little potential for overlap. Due to the spatial limits of mortality and potential physical effects, and due to the temporary nature of behavioral effects, noise is considered a non-significant environmental effect on Fish and Shellfish.

6.2.6.5 Effects of Waste and Wastewater

Waste water discharge is treated and tested to ensure compliance with OWTG. All drilling and production chemicals that may interact with the marine environment are screened by the OCMS to minimize potential toxicity. All discharges are of limited duration and frequency. Organic matter associated with discharges will disperse quickly in an open ocean environment and degraded by bacteria. The environmental effect of this relatively small amount of organic matter and nutrients within the offshore marine environment for Marine Fish and Shellfish is considered non-significant.

6.2.6.6 Presence of Structures and Lights

The material used for dropped object protection near the GBS and rock piles along flowlines may attract benthic fish species in particular, as the structures will add diversity to the habitat. The safety zones will restrict commercial fishing so the areas could serve as a temporary refuge for some fish species, including commercial species. The drill rigs safety zone would be temporary, lasting approximately 128 days per well. But as the safety zones around sub-sea structures will be in place for the life of the Project, there could be a small, positive residual effect on some fish species from the increased foraging opportunities and the decreased potential for fishing activity.

6.2.6.7 Abandonment

The disturbance associated with decommissioning and abandonment activities (primarily associated with noise generated during removal of the wellhead and other infrastructure) will be of short duration and occur directly at the wellsite. The activities required for abandonment will comply with applicable regulations of the day. The residual adverse environmental effects of decommissioning and abandonment on fish and shellfish will be localized, short-term and reversible and are predicted to be non-significant.

6.2.7 Follow-up

The current Hibernia EEM consists of sediment chemistry, sediment toxicity, water chemistry, taint, fish health and analysis of potential contaminant substances (body burden) in tissues of American plaice (HMDC 2008). The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate.

Pursuant to the OWTG, compliance monitoring of both the drilling and production effluent discharges will be conducted.

A fish habitat compensation monitoring program will also be implemented to ensure no net loss of productive capacity in fish habitat as a result of this Project.

6.2.8 Summary of Potential and Residual Environmental Effects

Based on the ratings of magnitude, geographic extent and duration for each routine activity that will potentially interact with Fish and Shellfish, the residual effects of the Project during construction, operation and abandonment are predicted to be non-significant. A summary of the potential environmental effects of the Project on Marine Fish and Shellfish after mitigations is provided in Table 6.2.

Table 6.2 Summary of Environmental Assessment for Marine Fish and Shellfish

<table>
<tr><th colspan="2">Interactions</th></tr>
<tr><td colspan="2">♦ effects associated with discharge of drill mud and cuttings;
♦ effects associated with dredging and ocean disposal;
♦ effects of noise from all routine activities (including VSPs and wellsite surveys and abandonment activities);
♦ effects associated with the discharge of waste and wastewater; and
♦ effects associated with the presence of structures and lights.</td></tr>
<tr><th colspan="2">Mitigation</th></tr>
<tr><td colspan="2">♦ use of water-based drilling muds wherever possible;
♦ use of non-toxic or low toxicity chemicals and muds, and treating synthetic oil-contaminated cuttings to meet the OWTG;
♦ all wastewater discharges will comply with the OWTG and ship operations will adhere to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78);
♦ solid waste transported to shore and recycled where possible;
♦ compliance with DFO's Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment;
♦ use of OCMS for chemical selection;
♦ all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently; and
♦ the HSE Ocean Disposal site will be re-used for future disposal of spoils from construction of other glory holes.</td></tr>
<tr><th colspan="2">Significance</th></tr>
<tr><td>Likelihood of occurrence</td><td>Will occur</td></tr>
<tr><td>Geographic extent</td><td>• Drilling muds and cuttings: < 1km
• Noise: < 10 km
• Waste and wastewater: < 1km
• Dredging and disposal: <10 km
• Presence of structures and lights: <1 km</td></tr>
<tr><td>Frequency of occurrence
(over 27 years or longer)</td><td>• Drilling muds and cuttings: 1- 3 wells per year;
• Noise: 1-3 wells per year; 1 -2 glory holes per year; 1 VSP survey per well; one geohazards survey per drill centre; 1-2 manifolds per drill centre;
• Waste and wastewater: continuous during each well, glory hole and subsea installation, valve control fluid venting approx 15 times per well per year;
• Dredging and disposal: 1-2 glory holes glory holes per year; and
• Presence of structures and lights: continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment, for the life of the project.</td></tr>
<tr><td>Duration of impact
(over 27 years or longer)</td><td>• Drilling muds and cutting: 128 days each, up to 66 wells in total;
• Noise: drilling - 128 days each, up to 66 wells in total; glory hole - 45 days each, up to 6 in total; 1 VSP survey per well, 1-3 days each; 1 geohazards survey per glory hole; 1-2 manifolds per drill centre, 30-40 days each;
• Waste and wastewater: continuous during each well, glory hole and subsea installation;
• Dredging and disposal: 45 days per year, up to 6 glory holes;
• Presence of structures and lights: continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment, for the life of the project.</td></tr>
<tr><td>Magnitude of impact</td><td>Low (eggs and larval mortality is not distinguishable from natural variability) physical effects of limited spatial scope and behavioral affects are temporary.</td></tr>
<tr><td>Permanence/reversibility</td><td>Reversible</td></tr>
<tr><td>Significance</td><td>Non significant</td></tr>
<tr><td>Confidence</td><td>High</td></tr>
<tr><th colspan="2">Follow-up and monitoring</th></tr>
<tr><td colspan="2">▪ The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate and pending C-NLOPB approval.
▪ Pursuant to the OWTG, compliance monitoring of all effluent discharges will be conducted.
▪ A habitat compensation monitoring program will also be implemented to ensure no net loss of productive capacity in habitat as a result of this Project.</td></tr>
</table>

6.3 Commercial Fisheries

This section assesses the potential effects of routine events during construction, operation and abandonment of the Project on commercial fisheries. The Commercial Fisheries VEC will assess the effects of the Project on the activity of commercial harvesting (i.e., the process of catching fish for commercial sale). The effects on fish and shellfish and fish habitat are assessed separately (Section 6.1 and 6.2 respectively). Cumulative effects are assessed in Section 7. Accidentals, malfunctions and unplanned events, are assessed in Chapter 8.

Potential interactions with, and effects on, fisheries science/research surveys (industry-led and DFO) are also included in this section because the potential effects' pathways are the same (i.e. the surveys are conducted essentially by "fishing"), and because these surveys are concerned primarily with commercial stock status. There are no aboriginal fisheries within the Study Area and therefore aboriginal fisheries have not been considered further within this assessment.

6.3.1 Rationale for Selection as Valued Environmental Component

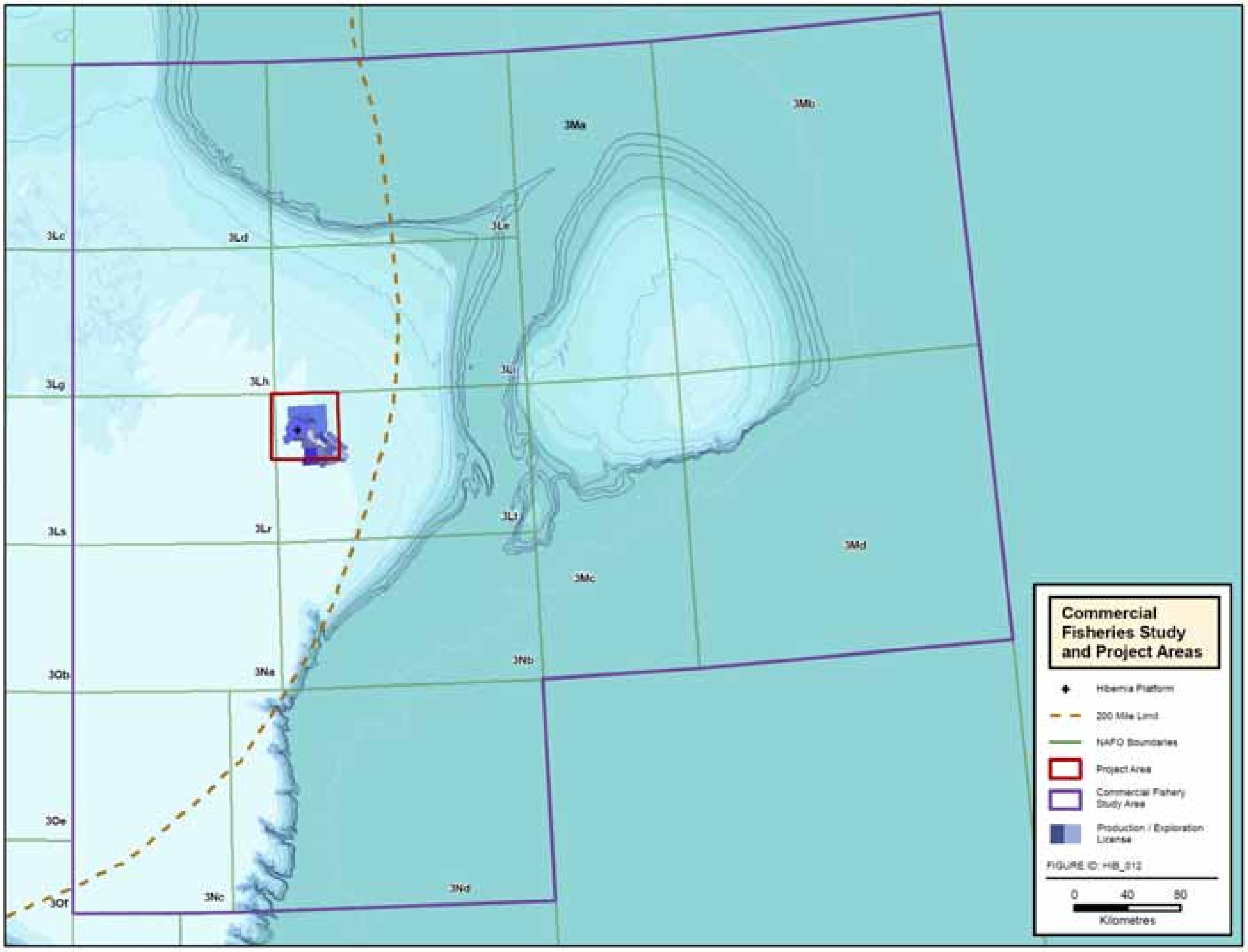
The commercial fishery on the northern Grand Banks is an industry having significant economic value and given the planned construction, operation and abandonment activities associated with this Project, the RAs have specifically required the Proponent to consider the effects of the Project on commercial fisheries (see Appendix A), including change/degradation of the productive capacity of aquatic systems which is addressed in Section 6.1. While there is currently little commercial fishing activity in the Project Area, it is acknowledged that the Project will operate for many years and commercial fishing levels in the Project Area could change and increase within the lifespan of the Project.

6.3.2 Boundaries

6.3.2.1 Spatial Boundary

The Project Area is located within NAFO Unit Area (UA) 3Lt. The spatial boundary for the assessment of potential environmental effects on the Commercial Fisheries VEC includes the area where interactions with the Project are likely to occur. During routine construction, operation and abandonment activities, interactions between the Project and Commercial Fisheries are expected to be contained within 10 nm outside the Project Area, which becomes the Affected Area for the assessment of routine Project activities. The Study Area also contains the UAs 3Lh, 3Li, 3Lr, 3Lt, 3Ld, 3Le, 3Ma, 3Mb, 3Md, 3Na, 3Nb, 3Nc and 3Nd (Figure 6.2).

Figure 6.2 Commercial Fisheries Project Area and Study Area



6.3.2.2 Temporal Boundary

The temporal boundary of the assessment is defined by the Project's potential interaction with Commercial Fisheries during construction, operation and abandonment activities. Many Project activities, such as dredging are relatively short-term (i.e., ~ 45 days per glory hole), but as an exact schedule for Project activities within the six potential drill centres is not known, it has been assumed for the purposes of the assessment that interactions with the Project could occur at any time of the year. Project activities are expected to commence in 2009, and continue through to the end of the field life which is currently estimated to be in 2036, but this may be extended over time.

6.3.2.3 Technical Boundaries

The statistical data and analysis in this EA are based primarily on time-series data from DFO, Newfoundland and Labrador Region and Maritimes Region, describing the quantity, month and location (by fisheries management UA) of fish harvesting (2005 to 2007), which is the most recent data available. These data are geo-referenced by harvesting location, so we are able to plot recent fishing activity within the Study Area and Project Area.

The data available to characterize the commercial fisheries activities within the Study Area is considered sufficient for the purposes of this assessment.

6.3.3 Potential Interactions and Existing Knowledge

Potential interactions between routine activities related to the Project and the Commercial Fisheries VEC are interactions between fishing gear and vessels (fouling or losing gear, vessel conflicts), access to fishing grounds from safety zone restrictions, and fish “catchability” (issues related to scaring fish from a harvesting area or away from fishing gear). Each of these potential interactions is described below.

HMDC is aware of the DFO initiative to establish marine protected areas (MPA's) on the Grand Banks. DFO has identified a number of Ecologically and Biologically Significant Areas (EBSA's) and MPA's could be established within these areas. None of the EBSA's identified thus far overlap with the Project Area. HMDC will continue to monitor the MPA initiative and manage issues, if any, as they arise.

6.3.3.1 Fishing Gear and Vessels

Ships and boats associated with the Project could interfere with fish harvesting activities if they interfere with the operation of fishing vessels or fishing gear. Such conflicts are more likely to involve fixed fishing gear (e.g. crab pots), and might result in gear damage, gear loss, loss of catch and increased operational expenses for harvesters. While supply vessels and support ships pose minimal risk to fishing gear (no more than other ocean-going ships or other fishing vessels in the area), surveys such as VSP and geohazard surveys during drilling do pose more of a specific risk if the seismic equipment is towed through the water. Seismic survey/fishing gear conflicts do occur sometimes once or twice a year in Atlantic Canada, though not usually as the result of localized VSP surveys, which are very small scale (i.e., on the order of a few km).

6.3.3.2 Access to Fishing Grounds

Because fishing will not be safe within the designated safety zones (see Figure 2.6), the effect of exclusion has the potential to interact with commercial fisheries. However, since the zones will be located in areas where very little commercial fishing has occurred in recent years (see Section 4.2), the safety areas are expected to have little operational or economic impact on fish harvesters.

If sites selected for DFO science surveys happen to be within an active safety zone, alternative sites can be used (DFO typically selects equivalent alternative sites, for example, for random stratified surveys).

6.3.3.3 Catchability

As discussed in Section 6.2.3.3, noise from shipping, dredging, drilling, geohazard and VSP surveys can affect fish and invertebrates. Project-related noise will occur during all Project phases (see Section 2.7.11.1) although the most concern for potential effects on fish harvesting would be during drilling (e.g., VSP and well site surveys). On a much smaller scale, similar effects could also result from drilling and dredging operations. This section considers only those aspects of noise-induced responses that might affect harvesting success.

Fisheries industry representatives have registered concerns in the past that seismic survey sound sources, in particular, may scare finfish from their fishing locations, or discourage benthic species (such as snow crab) from entering fixed fishing gear. There are also scientific reports of decreases in finfish catch rates near seismic arrays. There is debate on the duration and geographic extent of the effect, however. Reports range from fish quickly returning to the area after source arrays were activated, to finfish catch rates several kilometers away taking days to return to normal (Engås et al. 1996; Løkkeborg 1991; Skalski et al. 1992). In any case, compared to a conventional 2-D or 3-D geophysical survey, a very small area would be affected by VSP sound, since the area where the activities would take place will be quite small (i.e., in the immediate area of the drilling location). Also, the VSP sound source is also typically smaller and the noise generated is lower than typical seismic arrays. In addition, VSP surveys would be expected to last for just 12 to 36 hours per well.

Snow crab is the species that would be of concern to fishers nearest the Project Area, though very little harvesting has been recorded within the Project Area (Section 4.2). Studies on snow crab do not indicate significant effects on catch rates or behaviour related to seismic surveying. There are no indications of acute or mid-term mortality on adult snow crab due to seismic activity, nor does there appear to be any effect on the survival of embryos carried on the female or on the locomotion of the larvae after hatch (DFO 2004g). Christian et al. (2004) conducted a behavioural investigation during which caged snow crabs were positioned 50 m below a seven-gun array. Observations on the crabs' responses to seismic shooting were recorded by remote underwater camera. No obvious startle behaviours were observed.

6.3.4 Mitigations

The C-NLOPB *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2008a) provide guidance aimed at minimizing any impacts of VSP/well-site surveys on commercial fish harvesting. These *Guidelines* were developed based on best practices during previous years' surveys in Atlantic Canada, and on guidelines from other national jurisdictions. The relevant *Guidelines* state (Appendix 2, Environmental Mitigative Measures):

1.a) The operator should implement operational arrangements to ensure that the operator and/or its survey contractor and the local fishing interests are informed of each other's planned activities. Communication throughout survey operations with fishing interests in the area should be maintained.

1.b) Where feasible, a soft-start approach – a gradual ramp-up of airguns - should be implemented prior to survey. Ramp up procedures should follow measures outlined below in Section 2(e)

1.c) The operator should publish a Canadian Coast Guard "Notice to Mariners" and a "Notice to Fishers" via the CBC Radio program Fisheries Broadcast.

1.d) Operators should implement a gear and/or vessel damage compensation program, to promptly settle claims for loss and/or damage that may be caused by survey operations. The scope of the compensation program should include replacement costs for lost or damaged gear and any additional financial loss that is demonstrated to be associated with the incident. The operator should report on the details of any compensation awarded under such a program.

1.e) Procedures must be in place on the survey vessel (s) to ensure that any incidents of contact with fishing gear are clearly detected and documented (e.g., time, location of contact, loss of contact, and description of any identifying markings observed on affected gear). As per Section 4.2 of these Guidelines, any incident should be reported immediately to the 24-hour answering service at (709) 778-1400 or to the duty officer at (709) 682 4426.

HMDC and its contractors will implement each of these mitigative measures for any such surveys required for the Project.

Section 4.9 of the C-NLOPB's Guidelines Respecting Drilling Programs in the Newfoundland Offshore Area state, "*the operator should provide for the advance notification of persons engaged in fishing activities in the proposed area of operations and the measures to be put in place to eliminate any potential mutual interference.*"

The locations of the Project safety zones will be well publicized and communicated to fishers and DFO, and HMDC will continue to communicate with fishers and DFO about fishing and survey activities in these areas.

In general, the timing and locations of planned Project activities will be provided to fishers who may be operating in the vicinity of the Project Area via a Canadian Coast Guard "Notice to Mariners" and a CBC Radio Fisheries Broadcast "Notice to Fishers".

Harvesting locations for each species can vary between years, as well as within the same season, due to migration patterns, catch rates, quotas, resource issues, weather, technology, and fuel costs. Effective communication of all operations in the Project Area is imperative.

The HMDC Fisheries Code of Practice and the Fisheries Compensation Program for Gear and Vessel Damage and Oil Spills will apply to this project.

6.3.5 Residual Environmental Effects Significance Criteria

A significant adverse socioeconomic effect on commercial fisheries/aquaculture is defined as one that is likely to cause any one or more of the following:

- excludes fishers from using 10 percent or more of the fishable area for the targeted species for all or most of the fishing season;
- 10 percent or more of the vessels in a fishery are excluded from the fishable area of the targeted species for all or most of the fishing season;
- a measurable reduction in fisher income (profitability) due to a decrease in catchability of target species in 10 percent or more of the fishable area for the targeted species; and/or
- uncompensated damage to fishing gear or vessels.

A non-significant adverse socioeconomic effect on commercial fisheries is defined as one that excludes fishers from using less than 10 percent of the fishable area for the targeted species for all or most of the season; and/or less than 10 percent of the vessels in a fishery are excluded from a targeted species fishable area for all or most of the fishing season; and/or results in a reduction in profits due to a decrease in catchability of target species in less than 10 percent of the fishable area for the targeted species.

6.3.6 Residual Adverse Environmental Effects Assessment and Summary

As Section 4.2 illustrates, there is very little harvesting recorded within the Project Area in any month from 2005 to 2007, inclusive. The only recorded harvest in the area during the period were two reported catches of snow crab, one catch in 2005 and one catch in 2006, 15 tonnes in total, or 0.18 percent of the 3Lt catch between 2005 and 2007. It is recognized that the time frame of the Project is sufficiently long that the status of fishing activity in the Project Area could change over time. However, if fishing effort were to increase in the Project Area in the future, the mitigation measures identified above would be effective in mitigating potential adverse effects. Decommissioning activities, when they occur, will be short-term and localized to the glory hole locations.

Industry and DFO research programs for 2009 are expected to follow the same trends as recent years (J. Coady, pers. comm.), but there may be new research initiatives in any year, which will be communicated to all industry contacts as they arise. Previous coordination between offshore oil and gas operators, the FFAW and DFO has proved to successfully mitigate the potential for overlap between offshore oil and gas activities and DFO/Industry research surveys. FFAW and DFO will be notified of survey locations and Project timing as soon as they are known.

With these mitigations in place (including compensation if a conflict with gear were to occur), and in light of the localized nature of VSP surveys, their small footprint, short duration (2 to 3 days), and the lack of past harvesting activities in the Project Area, any effects from Project activities during construction, operation and abandonment are considered non-significant (Table 6.3).

Table 6.3 Summary of Environmental Assessment for Commercial Fisheries

Interactions	
♦ interactions between fishing gear and vessels (fouling or losing gear, vessel conflicts), ♦ access to fishing grounds from safety zone restrictions; and ♦ fish “catchability” (issues related to scaring fish from a harvesting area or away from fishing gear).	
Mitigation	
♦ Operational arrangements will be made to ensure that the operator and/or its survey contractor and the local fishing interests are informed of each other’s planned activities. Communication throughout survey operations with fishing interests in the area should be maintained. ♦ Where feasible, a soft-start approach – a gradual ramp-up of airguns - will be implemented prior to survey. ♦ The operator should publish a Canadian Coast Guard “Notice to Mariners” and a “Notice to Fishers” via the CBC Radio program Fisheries Broadcast. ♦ Section 4.9 of the C-NLOPB’s Guidelines Respecting Drilling Programs in the Newfoundland Offshore Area state, “the operator should provide for the advance notification of persons engaged in fishing activities in the proposed area of operations and the measures to be put in place to eliminate any potential mutual interference.” ♦ The locations of the Project safety zones will be well publicized and communicated to fishers and DFO, and HMDC will continually communicate with fishers and DFO about fishing and survey activities in these areas during construction.	
Significance	
Likelihood of occurrence	Will occur
Geographic extent	• Drilling muds and cuttings: < 1km • Noise: < 10 km • Waste and wastewater: < 1km • Dredging and disposal: <10 km • Presence of structures and lights: <1 km
Frequency of occurrence (over 27 years or longer)	• Drilling muds and cuttings: 1- 3 wells per year; • Noise: 1-3 wells per year; 1-2 glory holes per year; 1 VSP survey per well; one geohazards survey per drill centre; 1-2 manifolds per drill centre; • Waste and wastewater: continuous during each well, glory hole and subsea installation, valve control fluid venting approx 15 times per well per year. • Dredging and disposal: 1-2 glory holes per year; and • Presence of structures and lights: continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment, for the life of the project.
Duration of impact (over 27 years or longer)	• Drilling muds and cutting: 128 days each, up to 66 wells in total; • Noise: drilling - 128 days each, up to 66 wells in total; glory hole - 45 days each, up to 6 in total; 1 VSP survey per well, 1-3 days each; 1 geohazards survey per glory hole; 1-2 manifolds per drill centre, 30-40 days each; • Waste and wastewater: continuous during each well, glory hole and subsea installation; • Dredging and disposal: 45 days per year, up to 6 glory holes; • Presence of structures and lights: continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment, for the life of the project.
Magnitude of impact	Low (little current fishing activity within and near Project Area)
Permanence/reversibility	Reversible
Significance	**Non significant**
Confidence	High
Follow-up and monitoring	
▪ The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate. ▪ Pursuant to the OWTG, compliance monitoring of all effluent discharges will be conducted. ▪ A habitat compensation monitoring program will also be implemented to ensure no net loss of productive capacity in habitat as a result of this Project.	

6.4 Marine Mammals

In this chapter, the assessment of marine mammals includes baleen whales (Mysticetes), toothed whales (Odontocetes), dolphins (Delphinids), and seals (Pinnipeds). Species listed under *SARA* or considered at risk by COSEWIC, are assessed as separately as Species at Risk (Section 6.6). Those species that are not considered at risk and may interact with the Project are considered within this VEC. The potential environmental effects of the Project resulting from construction, operation and abandonment activities are considered in this section. The effects of all accidental events except collision between mammals and vessels are assessed in Chapter 8. Cumulative environmental effects on marine mammals in consideration with other Projects and/or activities are assessed in Chapter 7.

Although intrinsically linked with marine mammals, marine fish habitat and marine fish and shellfish are considered as separate VECs (Sections 6.1 and 6.2, respectively) as are commercial fisheries (Section 6.3).

6.4.1 Rationale for Selection as Valued Environmental Component

Marine mammals were selected as a VEC for several reasons. They play a critical role in the marine ecosystem, the significance of which is manifested in regulatory protection, scientific study and public concern.

Specifically, marine mammals were selected as a VEC because of:

- specific regulatory requirements of the *Fisheries Act* and *SARA*;
- requirements of the Project-specific Scoping Document (Appendix A);
- the direct interaction between marine mammals and routine Project activities, as well as accidents and malfunctions; and
- the ecological, recreational and commercial importance of marine mammals to the public.

The environmental assessment focuses on relevant aspects of marine mammals. These aspects were selected in consideration of information presented in the Project description (Chapter 2), and those Project activities with the potential to interact with the VEC.

6.4.2 Boundaries

6.4.2.1 Spatial Boundary

The spatial boundary for the assessment of potential environmental effects on the Marine Mammal VEC includes the area where interactions with the Project are likely to occur, also known as the Affected Area. During routine construction, operation and abandonment activities, interactions between the Project and Marine Mammals are expected to be contained within a 10 nm radius of the Project Area. The habitat within the Affected Area is considered typical habitat within the Jeanne d'Arc Basin and contains no known unique or critical habitat for marine mammals. Considering the home range of marine mammals and their widespread distribution and migration patterns, the Study Area used for Marine Mammals is consistent with the original Hibernia EIS Study Area (Figure 6.3).

6.4.2.2 Temporal Boundary

The temporal boundary of the assessment is defined by the Project's potential interaction with marine mammals during construction, operation and abandonment activities. Many Project activities, such as dredging are relatively short-term (i.e., ~ 45 days per glory hole), but as an exact schedule for Project activities within the six potential drill centres is not known, it has been assumed for the purposes of the assessment that interactions with the Project could occur at any time of the year. Project activities are expected to commence in 2009, and continue through to the end of the field life which is currently estimated to be in 2036 but this may be extended over time.

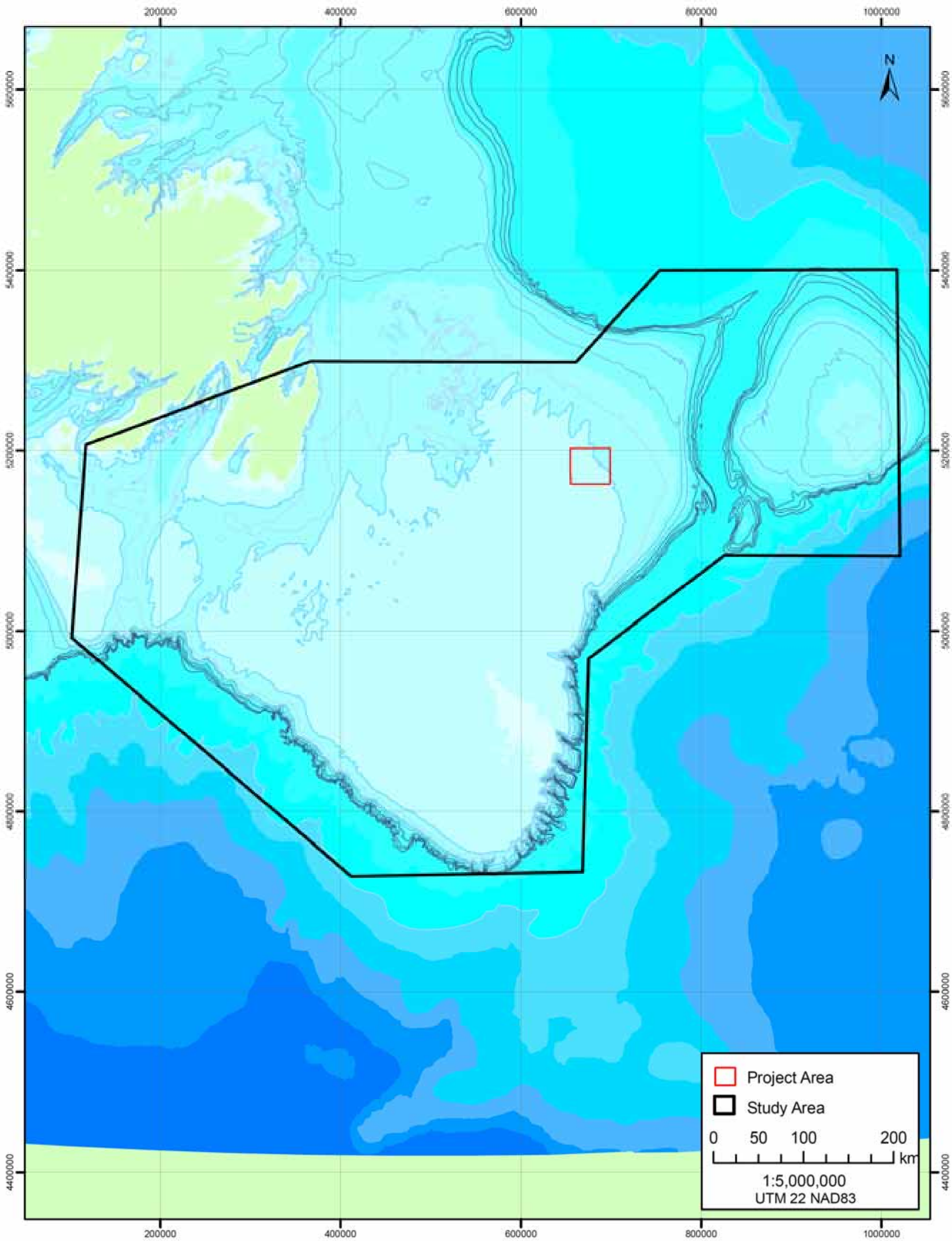
6.4.2.3 Administrative Boundaries

Marine mammals are protected in Canada through federal legislation under the *Fisheries Act*. Section 35 of the Act ensures no HADD of fish habitat, while Section 36 ensures no deposits of any substances considered deleterious to fish. Marine mammals are included in the definition of fish, under the *Act*. Environment Canada administers Section 36 of the *Fisheries Act* while the Department of Fisheries and Oceans (DFO) administers Section 35 of the Act. Also part of the *Fisheries Act*, the *Marine Mammal Regulations* stipulate that "No person shall disturb a marine mammal except when fishing for marine mammals under the authority of these regulations".

6.4.2.4 Technical Boundary

Technical boundaries include the limitations of the available data for marine mammals within the Study Area (Figure 6.3) and the limits of scientific knowledge specific to the interactions between Project activities and relevant marine mammal characteristics. Although data characterizing the existing environment for marine mammals continue to be somewhat limited, due to the unpredictability of marine mammal distribution on the Grand Banks and the difficulties associated with recording marine mammals at sea, the data available to characterize the existing environment and knowledge on Project-VEC interactions are judged by the study team to be sufficient to support the assessment.

Figure 6.3 Marine Mammal Study Area



Specifically, the description of existing conditions for whales (Section 4.3) within the Affected Area and Study Area was based on the following:

- Hibernia Development Project EIS (Mobil Oil 1985) and component studies;
- previous environmental assessment reports from the Jeanne d'Arc Basin, especially
  - recent Husky exploratory drilling EAs and updates (LGL 2002, 2003, 2005a, 2006b, 2007b);
  - StatoilHydro Canada Jeanne d'Arc Basin Area Seismic and Geohazard Program, 2008-2016 and Exploration and Appraisal/Delineation Drilling Program for Offshore Newfoundland, 2008-2016 (LGL 2008 a, b); and
  - SDL 1040 Delineation Drilling Screening (Husky and Norsk Hydro 2006);
- Orphan Basin Strategic Environmental Assessment (C-NLOPB 2003);
- Strategic Environmental Assessment Labrador Shelf Offshore Area (C-NLOPB 2008b);
- DFO data base of mammal observation and survey data;
- scientific publications and databases relevant to the Grand Banks;
- experience of the study team in offshore EAs; and
- personal communications.

6.4.3 Potential Interactions and Existing Knowledge

Potential interactions between Marine Mammals and routine Project activities and subsequent effects include:

- effects of noise from all routine activities (including VSPs, well site surveys and abandonment);
- effect from collisions with vessels;
- effects associated with discharge of drill mud and cuttings;
- effects associated with the discharge of waste and wastewater;
- effects associated with dredging and ocean disposal; and
- effects associated with the presence of structures, lights and flares (including subsea equipment and flowlines).

A detailed list of the potential interactions between the Project and Marine Mammals is provided in Section 5.6.3. These interactions could result in a number of potential effects on Marine Mammals, including behavioural effects, contamination or change in availability of prey, and physical injury or mortality (i.e., from vessel collisions).

As the Project is not predicted to result in an increase in Hibernia production levels (only an extension in the field life), or discharge rates of air emissions and wastewater, potential Project effects during the operation/production stage are consistent with those effects already assessed for the overall Hibernia project. Any requirements for maintenance at the drill centers would be periodic, short-term and would have limited potential for interactions with marine mammals. HMDC is aware of the DFO initiative to establish marine protected areas (MPA's) on the Grand Banks. DFO has identified a number of Ecologically and Biologically Significant Areas (EBSA's) and MPA's could be established within these areas. None of the EBSA's identified thus far overlap with the Project Area. HMDC will continue to monitor the MPA initiative and manage issues, if any, as they arise.

6.4.3.1 Noise

Noise may be generated by drilling, dredging, pipe laying, geohazard survey, VSP survey, supply and support vessels and helicopters. A description of the sound levels emitted during the Project is provided in Section 2.7.11.1.

Marine mammals are highly dependent on sound for communicating, detecting predators, locating prey and in toothed whales, echolocation. Underwater ambient or anthropomorphic sounds may prevent an animal from detecting another sound through a process known as masking. Marine mammals have evolved in an environment that contains a variety of natural sounds and as such, some degree of masking occurs naturally. Marine mammals have evolved to reduce the impacts of masking (NRC 2003), such as increasing the average vocalization level, frequency and duration (see Wartzok et al. 2004). Given that mammal response will vary by species and between individuals, the zone of potential influence of noise on marine mammals is highly variable.

Toothed whales (e.g. dolphins, pilot whale, and sperm whale) communicate using two types of sounds: 1) continuous, narrowband, frequency-modulated signals which range in duration from several tenths of a second to several seconds and range in frequency from approximately 2 to 25 kHz (Tyack and Clark 2000); and 2) broadband click trains with peak frequencies that vary from tens of kilohertz to well over 100 kHz (Norris and Evans 1966; Au 1980). Click trains contain few to hundreds of clicks and are used for communication, navigation and object detection and discrimination (Au 1993). The low frequency spectrum of industrial noise generally will not overlap with the high frequency echolocation of toothed whales. The side-scan sonar emits pulses of sound in narrow beams at 105 and 390 kHz. The echo-sounder emits pulses at 24, 200 and 240 kHz. The 105 kHz pulse from the side-scan sonar and the 24 kHz pulse from the echo-sounder are likely audible to toothed whales, but significant masking of communication signals is improbable due to the fact that the pulses are short and have narrow band widths.

Baleen whales (e.g., minke, humpback and fin whales) communicate using low frequency sounds (generally between 25 Hz and 4 kHz (Erbe 2002, Richardson et al. 1995)) that can propagate for long distances. These sounds range in duration from 50 msec thumps produced by minke whales (Winn and Perkins 1976; Thompson et al. 1979) to moans produced by blue whales, which can have durations up to 36 sec (Cummings and Thompson 1971).

Most pinnipeds (i.e., seals) produce sounds with dominant frequencies between 0.1 and 3 kHz (Richardson et al. 1995). Underwater hearing of true seals (Phocidae) is characterized by a relatively flat response over the range of 1 to 30 kHz. Hearing sensitivity has not been measured at frequencies below 1 kHz except in one harbour seal where the 100 Hz threshold was measured at 96 dB re 1 µPa (Kastak and Schusterman 1995). In general, in-air pinniped hearing is thought to deteriorate as frequency decreases below 2 kHz and above 11 kHz (Richardson et al. 1995). Pinnipeds communicate using both air and waterborne vocalizations. Males use airborne vocalizations to establish and defend territories, to communicate dominance and to attract mates. Females use airborne vocalizations to establish mother-pup bonds critical for locating offspring when returning to crowded colonies after extended foraging periods. The primary purpose of underwater vocalizations is uncertain, but it is thought to be used for social communication. These vocalizations are typically limited to barks and clicks at frequencies ranging from less than one to four kHz (Richardson et al. 1995). It is generally accepted that pinnipeds do not engage in echolocation (Schusterman et al. 2000). The underwater hearing capabilities of seals are not as acute as those of other mammals that spend their entire lives under water (Richardson et al. 1995). Many seals spend a significant amount of time on land and because of the need to hear in both air and water they do not possess acute hearing in either of these mediums (National Research Council 2003). The frequencies contained in seismic and sub-bottom profiler pulses do overlap with some frequencies used by pinnipeds, but side-scan sonar and echo-sounder signals do not overlap with the predominant frequencies of pinniped calls, which avoids significant masking.

6.4.3.2 Vessel Collisions

In addition to the dredge and pipe laying vessel, approximately three to four supply boat transits will occur every week during drilling and one supply vessel will remain at the drilling location on standby.

Depending on the circumstance, the response to approaching vessels is highly variable between mammal species and even within a species. Between species, a response to noise can be in the form of changes in swimming direction and speed, breathing rate and vocalization (Richardson et al. 1995). For example, minke whales will avoid fast moving vessels but are known to approach stationary or slow moving vessels (Richardson et al. 1995). Humpback whales have been observed both to make no attempt to avoid moving ships in an offshore environment and to respond to boats at distances of at least 0.5 to 1 km (and in some cases several kilometres), especially if the boat is approaching the whale (Watkins 1986). Humpback mother and newborn calf groups have been seen avoiding near-shore waters where human activities are intense (Richardson et al. 1995). In another study, the primary reaction of humpbacks to approaching small boats was an increase in swim speed (Scheidat et al. 2004). Studies in Alaska summering grounds observed that humpback whales retreat and alter respiration and diving cycles when vessels were within a few kilometers, but on other occasions, they made no response to tankers passing within 800 m (Richardson et al. 1995, Scheidat et al. 2004). Humpbacks are more likely to respond to a sudden increase in sound pressure levels than to one that is continuously present (Malme et al. 1985). Minke whales are more inclined to approach stationary or slow moving vessels (Richardson et al. 1995). Sei whales are reported to exhibit more avoidance behavior than fin whales when approached in a vessel (Perry et al. 1999). Fin and right whales are more likely to tolerate a stationary noise source than one that is approaching (Watkins 1986). Some species appear to be more sensitive than others and if individual mammals have been exposed to similar noise and activities in the past, they may become habituated to a familiar disturbance.

Responses of toothed whales to vessels also vary within and among species and range from avoidance to bowriding (Baird and Stacey 1991a; 1991b; Stacey and Baird 1991; Mullin et al. 1994a; 1994b). For dolphins, reaction to vessels appears to be related to the dolphins' activity and their history of harassment. Dolphins that are resting tend to avoid vessels, those that are foraging tend to ignore vessels and those that are socializing may approach vessels (Richardson et al. 1995). Dolphins that have been sensitized by previous harassment tend to avoid vessels (Au and Perryman 1982). Larger toothed whales, such as sperm whales and beaked whales, generally seem to avoid vessels (Sorensen et al. 1984).

World-wide, there were 292 reported vessel collisions with marine mammals from 1975 to 2002, but many collisions go undetected or unreported (Jensen and Silber 2003). Large vessels traveling at more than 14 knots are the principal source of ship strike mortalities in whales (Laist et al. 2001). High speed container ships are considered to be potentially one of the greatest threats to blue whales. Table 6.4 lists the percentage of reported collisions by vessel type.

Table 6.4 Percentage of Reported Collisions with Mammals by Vessel Type

Vessel Type	Percentage
Navy Vessels	17.1%
Container/cargo ships/freighters	14.9 %
Whale-watching vessels	14.2 %
Cruise ship liners	12.7 %
Ferries	11.9 %
Coast guard vessels	6.7 %
Tankers	6.0 %
Recreational vessels and steamships	5.2 %
Fishing vessels	3.0 %
Dredge boat, research vessel, pilot boat, and whaling catcher boat	0.75 % each

Source: data from Jensen and Silber 2003

Of the 58 incidents where vessel speed was reported, 26 percent of incidents occurred when vessels were traveling between 12 and 15 knots; 16 percent occurred when vessels were traveling between 16 and 18 knots and 12 percent when traveling between 19 and 21 knots (Jensen and Silber 2003).

6.4.3.3 Drilling Muds/Cuttings Management

The potential effect of drill mud and cuttings on marine mammals is essentially limited to the degree that their food supply is affected. Contamination of the marine mammals food supply is of limited concern. Baleen whales feed on plankton and on small schooling fish, like capelin, from the water column. Toothed whales (i.e., dolphins) feed primarily on fish and squid, some of which may be benthic species. Seals are known to feed on fish from the water column as well as from benthic habitats. The area where benthic species are potentially affected is limited to 0.09% of the Project Area for each well, so drill cuttings are unlikely to affect marine mammal prey.

6.4.3.4 Waste and Wastewater Discharge

The OWTG encourage the reduction of generated waste and substances of potential environmental concern. As well, wastewater discharge is treated and tested for compliance with OWTG. Furthermore, all drilling and production chemicals that may interact with the marine environment are screened by the OCMS to minimize potential toxicity. Regulations and compliance testing aim to mitigate potential effects on the marine environment. Please see Section 2.7 for a description of Project related waste and wastewater.

Treated oily-water discharge could potentially oil seals. However, seals rely on blubber rather than fur for insulation, and are therefore less likely to be affected by exposure to oily water.

Potential effects of waste and waste water discharge include a change in marine mammal habitat quality and potential contamination of mammal prey, although in areas very near the point of discharge.

Where marine discharges introduce limiting nutrients to the water column (e.g. nitrogen), an increase in primary productivity may occur thereby increasing the available food supply for many marine species including mammals.

6.4.3.5 Dredging and Disposal

Each drill centre will require a glory hole to protect the well from iceberg impacts. The excavation of the glory hole may be completed by a suction hopper dredge or alternate technology (e.g. clam shell). The potential environmental effects of each technology are similar, but they may differ in extent. The clam shell dredge will side cast the material during glory hole excavation, which will confine sediment dispersion and the disposal pile footprint to near the excavation site.

Sediment suspension caused during dredging of the glory hole(s) and the disposal of dredge spoils will result in increased turbidity within the water column. At the dredge site, disturbed material will remain near the seafloor. However, at the dredge spoils disposal site, material may be discharged from near surface, so turbidity will be affected through the water column. Observed sediments within the area to be dredged are comprised predominantly of sands and gravels with limited fine material, which will increase the rate of settlement.

Marine mammals will likely avoid the dredge and disposal areas due to the noise created by vessel operations. Direct effects on mammals are unlikely and any effects on plankton from increased turbidity at the disposal site are very localized compared to the feeding area available to marine mammals.

6.4.3.6 Presence of Structures, Lights and Flares

Marine mammals would most likely avoid the immediate area around drilling activities due to physical activities and underwater sound generated by equipment like the dredger, drill rig, and FPSO and attendant vessels. It is possible that marine mammals may be attracted to subsea structures if the artificial reef effect occurs and availability of prey increases.

6.4.4 Mitigations

Based on the potential interactions identified above and existing knowledge regarding these interactions, the following technically and economically feasible mitigation measures to reduce or eliminate potential adverse effects of routine Project activities on marine mammals have been identified:

- use of non-toxic or low toxicity chemicals and muds, and treating synthetic oil-contaminated cuttings as per the OWTG;
- all wastewater discharges to comply with the OWTG and ship operations will adhere to Annex I of the *International Convention for the Prevention of Pollution from Ships* (MARPOL 73/78);
- use of OCMS for screening chemicals to be used;
- helicopters will maximize flying altitude and are prohibited from flying over wildlife for passengers to view;
- collision avoidance practices including constant speed and course maintained by all Project vessels. Vessel traffic will be limited to routes between the MODU and the shorebase, survey areas around the well-site, ice surveillance and support to other operators; and
- adherence to the *Statement of Canadian Practice on the Mitigation of Seismic Noise* in the Marine Environment and the mitigations outlined in the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (2008).

6.4.5 Residual Environmental Effects Significance Criteria

A **significant adverse environmental effect** is defined as one that affects a marine mammal population or portion thereof in such a way as to cause a decline or change in abundance and/or distribution of the population over one or more generations and natural recruitment (reproduction and in-migration from unaffected areas) may not re-establish the population to its original (i.e., pre-Project) level within several generations or avoidance of the area becomes permanent.

A **non-significant adverse environmental effect** is defined as an adverse effect that does not meet the above criteria.

6.4.6 Environmental Effects Assessment

6.4.6.1 Noise

The most likely activity of marine mammals in the Affected Area is feeding, and some communications may occur between some whales during this activity. If mammals are discouraged from this area by noise or if their feeding efficiency is diminished as a result of masking, the effect would be of limited spatial extent and duration. Marine mammals will avoid an area of noise, especially if there are sudden changes in frequency or intensity. Marine mammals are generally more tolerant of stationary sources of noise than moving sources. This seems especially true for seals which will approach a stationary vessel or fixed platform (LGL et al. 2000). Dolphins and other toothed whale species have also reportedly approached offshore drilling platforms (Richardson et al. 1995).

Behavioral responses by baleen whales to seismic pulses have been documented however, the received level of pulsed sounds necessary to elicit these reactions are typically well above the minimum detectable levels (Richardson et al. 1986; 1995; 1999). In addition, baleen whales have often been seen well within distances where seismic sounds would be audible and yet show no obvious reaction to those sounds (C-NLOPB 2005). Little is known about the significance of how a temporary interruption in sound detection affects mammals (Richardson et al. 1995). In general though, the impact of both natural and man-made noise is less severe when it is intermittent rather than continuous (NRC 2003). Most of the noise generated from this project will be intermittent. However, the drilling unit emits some noise continuously during operation.

A broadband received sound pressure level of 160 dB re 1 µPa (rms) or greater is currently the best estimate available to indicate potential concern for disruption of marine mammals behavioural patterns (NMFS 2003), however, noise levels below 160 dB re 1µPa have also been known to elicit behavioural disturbances in marine mammals (NRC 2005). The spatial extent of any such avoidance behaviour by most common species in the area (i.e., humpback and minke whales) can be expected to be 0.5 to 1 km. Humpbacks exhibited no avoidance when exposed to simulated semi-submersible and drill platform noises (Malme et al. 1985). Under typical ambient noise conditions, low frequency noise from a drilling platform might be detectable no more than 2 km away near a shelf break (Richarson and Malme 1995).

Little is known about the potential for the sounds produced during geohazard surveys to cause auditory threshold shifts or other effects in marine mammals. Data suggests that if these effects do occur, they would only occur in close proximity to the sound sources. Thus, species that show behavioral avoidance of noise, including most baleen whales, some toothed whales and some pinnipeds, would not likely experience threshold shifts or other physical effects (C-NLOPB 2005).

Because seismic and sub-bottom profiler pulses are intermittent and predominantly low frequency, masking effects are expected to be negligible for toothed whales. However, while Madsen et al. (2002) reported that sperm whales off northern Norway continued calling in the presence of seismic pulses, Bowles et al. (1994) reported that sperm whales ceased calling when exposed to pulses from a distant seismic ship. Therefore, the noise frequencies created during marine construction activities do overlap with the sounds of baleen whales and will reduce the area of auditable sound for the whale. Most of the acoustic energy in the sound pulses produced by airguns lies below 200 Hz and the sub-bottom profiler has a frequency bandwidth of 500 Hz to 6 kHz. These pulses overlap with frequencies used by baleen whales, but the discontinuous, short duration nature of the sounds is expected to result in limited masking of baleen whale calls. Side-scan sonar and echo-sounder signals do not overlap with the predominant frequencies of baleen whale calls, which avoids significant masking.

The frequencies contained in seismic and sub-bottom profiler pulses do overlap with some frequencies used by pinnipeds, but the discontinuous, short duration nature of the pulses is expected to result in limited masking of pinniped calls. Side-scan sonar and echo-sounder signals do not overlap with the predominant frequencies of pinniped calls, which avoids significant masking.

Helicopter traffic noise may elicit diving behaviour in many marine species. Minke whales have changed course or gone into a slow dive in response to helicopters flying at an altitude of 230 m (Leatherwood et al. 1982) and seals may also dive in response to low-flying aircraft. However, the effect is temporary.

Noise generated during the removal of the wellhead and other infrastructure will be of short duration and localized. It is unlikely that explosives will be required to remove the wellhead. Temporary avoidance of an area due to noise is the most likely effect from a drilling project on marine mammals.

The effect of noise on marine mammals is considered highly reversible therefore, once the source is removed, marine mammals are expected to return to the area (Davis et al. 1987). Each activity, except supply vessels and personnel flights will likely occur in sequence with little chance for more than one activity at a time. The Project Area offers no unique habitat or feeding areas for marine mammals or sea turtles. Similar alternate sites are available in the immediate area, so the fitness of any species of marine mammals will not be affected. The residual adverse environmental effect of the noise generated by Project activities on Marine Mammals are considered non-significant.

6.4.6.2 Vessel Collisions

Collisions of vessels with marine mammals during routine Project activities are considered unlikely, but possible. Habituation is possible when the same boats regularly visit a site (Bonner 1982). The current level of commercial and industrial activity within the area may have habituated repeat visitors. The smaller vessels required during construction are more maneuverable than tankers so if a mammal is in the path of a vessel, every safe effort will be made by the vessel operator to avoid collision, if the mammals has not moved upon approach.

When approached by a vessel, whales usually dive or make changes in swimming speed or direction (Watkins 1986), but the reaction can be quite variable between species and even within a species. There are several biotic and abiotic factors which may influence the reaction, such as whether or not the animal is feeding or the speed and size of the approaching vessel.

Large vessels traveling at more than 14 knots are the principal source of ship strike mortalities in whales (Laist et al. 2001). By nature of the slow and steady movement of each vessel during construction, operation and abandonment phases for this Project, and the practice of avoiding concentrations of marine mammals, the risk of collision is low and therefore the environmental effect of vessel traffic on marine mammals is predicted to be non significant.

6.4.6.3 Drilling Muds/Cuttings Management

Drill cuttings are unlikely to affect marine mammals as the marine mammal species that commonly occur in the Project Area do not typically feed on benthos. The environmental effect of drill muds/cuttings on marine mammals is considered non significant.

6.4.6.4 Waste and wastewater

Marine mammals may not be directly or indirectly affected by the waste discharges from the rig because they are likely to avoid the noise from rigs and therefore the associated discharges. Any contact with the rig discharges will likely be short-term. All drilling discharges will meet the OWTG which were established to protect the environment. Rig discharges are expected to be temporary, non-bioaccumulating, non-toxic in nature, and subject to high dilution in the open ocean. Thus, measurable effects on marine mammals are not expected as a result of this Project. The residual adverse environmental effect of waste and wastewater from routine Project activities on marine mammals is considered non-significant.

6.4.6.5 Dredging and Disposal

Marine mammals may avoid the area of dredging or disposal, due to noise or if the habitat quality becomes unsuitable due to turbidity. Neither the dredge and disposal areas are known to be of any more significance in terms of habitat or feeding areas for mammals than other areas of the Grand Banks. Given the temporary nature of the disturbance, any effects from dredging and disposal on marine mammals are considered non-significant.

6.4.6.6 Presence of Structures, Lights and Flares

The potential interaction between the presence of new structures (i.e., rig, anchors, pipelines, well head, etc.) and marine mammals is limited. The structures are not expected to present any physical obstruction as marine mammals will avoid collision with stationary structures of this size (the risk of collision with vessels is assessed separately above). The limited potential of attraction of mammals may be offset by a more likely avoidance of noise from the structure. The residual adverse environmental effects are therefore assessed as non-significant.

6.4.6.7 Abandonment

The disturbance associated with decommissioning and abandonment activities (primarily associated with noise generated during removal of the wellhead and other infrastructure) will be of short duration and occur directly at the wellsite. The level of vessel traffic would be similar to that currently experienced in the area. The activities required for abandonment will comply with applicable regulations of the day. The residual adverse environmental effects of abandonment activities on marine mammals are considered to be non-significant.

6.4.7 Follow-up

An environment observer will collect data on marine mammals, and possibly seabird occurrences as required under the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* and the *Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment*.

Pursuant to the OWTG, compliance monitoring of both the drilling and production effluent discharges will be conducted. The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate.

6.4.8 Summary of Potential and Residual Environmental Effects

Based on the ratings of magnitude, geographic extent and duration for each routine activity that will potentially interact with Marine Mammals, the residual environmental effects of the Project for construction, operation and abandonment are predicted to be non-significant. A summary of the potential environmental effects of the Project on Marine Mammals after consideration of mitigation is provided in Table 6.5.

Table 6.5 Summary of Environmental Assessment for Marine Mammals

<table>
<tr><th colspan="2">Interactions</th></tr>
<tr><td colspan="2">♦ effects of noise from all routine activities (including VSPs, well site surveys and abandonment);
♦ effect from collisions with vessels;
♦ effects associated with discharge of drill mud and cuttings;
♦ effects associated with the discharge of waste and wastewater;
♦ effects associated with dredging and ocean disposal; and
♦ effects associated with the presence of structures, lights and flares.</td></tr>
<tr><th colspan="2">Mitigation</th></tr>
<tr><td colspan="2">♦ use of non-toxic or low toxicity chemicals and muds, and treating any synthetic oil-contaminated cuttings as per the OWTG;
♦ discharges will comply with the OWTG and ship operations will adhere to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78);
♦ use of OCMS for screening chemicals to be used;
♦ helicopters will maximize flying altitude and are prohibited from flying over wildlife for passengers to view;
♦ Collision avoidance practices, including constant speed and course maintained by all Project vessels. Vessel traffic will be limited to routes between the MODU and the shorebase, survey areas around the well-site, ice surveillance and support to other operators; and
♦ Adherence to the Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment and the mitigations outlined in the Geophysical, Geological, Environmental and Geotechnical Program Guidelines (2008).</td></tr>
<tr><th colspan="2">Significance</th></tr>
<tr><td>Likelihood of occurrence</td><td>Will occur</td></tr>
<tr><td>Geographic extent</td><td>• Drilling muds and cuttings: < 1km
• Noise: < 10 km
• Waste and wastewater: < 1km
• Dredging and disposal: <10 km
• Presence of structures and lights: <1 km</td></tr>
<tr><td>Frequency of occurrence
(over 27 years or longer)</td><td>• Drilling muds and cuttings: 1- 3 wells per year;
• Noise: 1-3 wells per year; 1-2 glory holes per year; 1 VSP survey per well; one geohazards survey per drill centre; 1-2 manifolds per drill centre;
• Waste and wastewater: continuous during each well, glory hole and subsea installation; valve control fluid venting approx 15 times per well per year;
• Dredging and disposal: 1-2 glory holes per year; and
• Presence of structures and lights: continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment, for the life of the project. .</td></tr>
<tr><td>Likelihood of occurrence</td><td>Will occur</td></tr>
<tr><td>Duration of impact
(over 27 years or longer)</td><td>• Drilling muds and cuttings: 128 days each, up to 66 wells in total;
• Noise: drilling - 128 days each, up to 66 wells in total; glory hole - 45 days each, up to 6 in total; 1 VSP survey per well, 1-3 days each; 1 geohazards survey per glory hole; 1-2 manifolds per drill centre, 30-40 days each;
• Waste and wastewater: continuous during each well, glory hole and subsea installation;
• Dredging and disposal: 45 days per year, up to 6 glory holes;
• Presence of structures and lights: continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment, for the life of the project.</td></tr>
<tr><td>Magnitude of impact</td><td>Low (avoidance will be temporary, localized and of little biological consequence; physiological impacts not expected)</td></tr>
<tr><td>Permanence/reversibility</td><td>Reversible</td></tr>
<tr><td>Significance</td><td>Non significant</td></tr>
<tr><td>Confidence</td><td>High</td></tr>
<tr><th colspan="2">Follow-up and monitoring</th></tr>
<tr><td colspan="2">▪ During the geohazards survey an environment observer will collect data on marine mammal occurrences and behaviour and will communicate requirements outlined in the Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment and the Geophysical, Geological, Environmental and Geotechnical Program Guidelines to seismic and marine crews.
▪ Pursuant to the OWTG, compliance monitoring all effluent discharges will be conducted.
▪ The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate.</td></tr>
</table>

6.5 Marine Birds

The Marine Birds VEC considers the potential effects of Project activities during construction, operation and decommissioning on the following families of marine birds that occur in offshore Newfoundland waters: *Procellariidae* (fulmars and shearwaters), *Hydrobaridae* (storm-petrels), *Sulidae* (gannets), P*halaropodinae* (phararopes), *Laridae* (gulls, terns, kittiwakes, jaegers, skuas) and *Alcidae* (dovekie, murres, razorbills, puffins).

An emphasis is placed on pelagic seabirds because of the location of the Project on the Grand Banks where these birds occur. Pelagic seabirds spend the majority of their lives on the open ocean, only coming to shore to breed, and are therefore most likely to be affected by Project activities. In this section, the potential effects of the routine activities associated with the proposed drill centre development and production operations on marine birds are evaluated. Species of Marine Birds listed under *SARA* or considered at risk by COSEWIC are assessed within the Species at Risk VEC (Section 6.6). The effects of accidental events on marine birds are assessed in Chapter 8. Cumulative environmental effects in consideration with other projects and/or activities are assessed in Chapter 7.

6.5.1 Rationale for Selection as a Valued Ecosystem Component

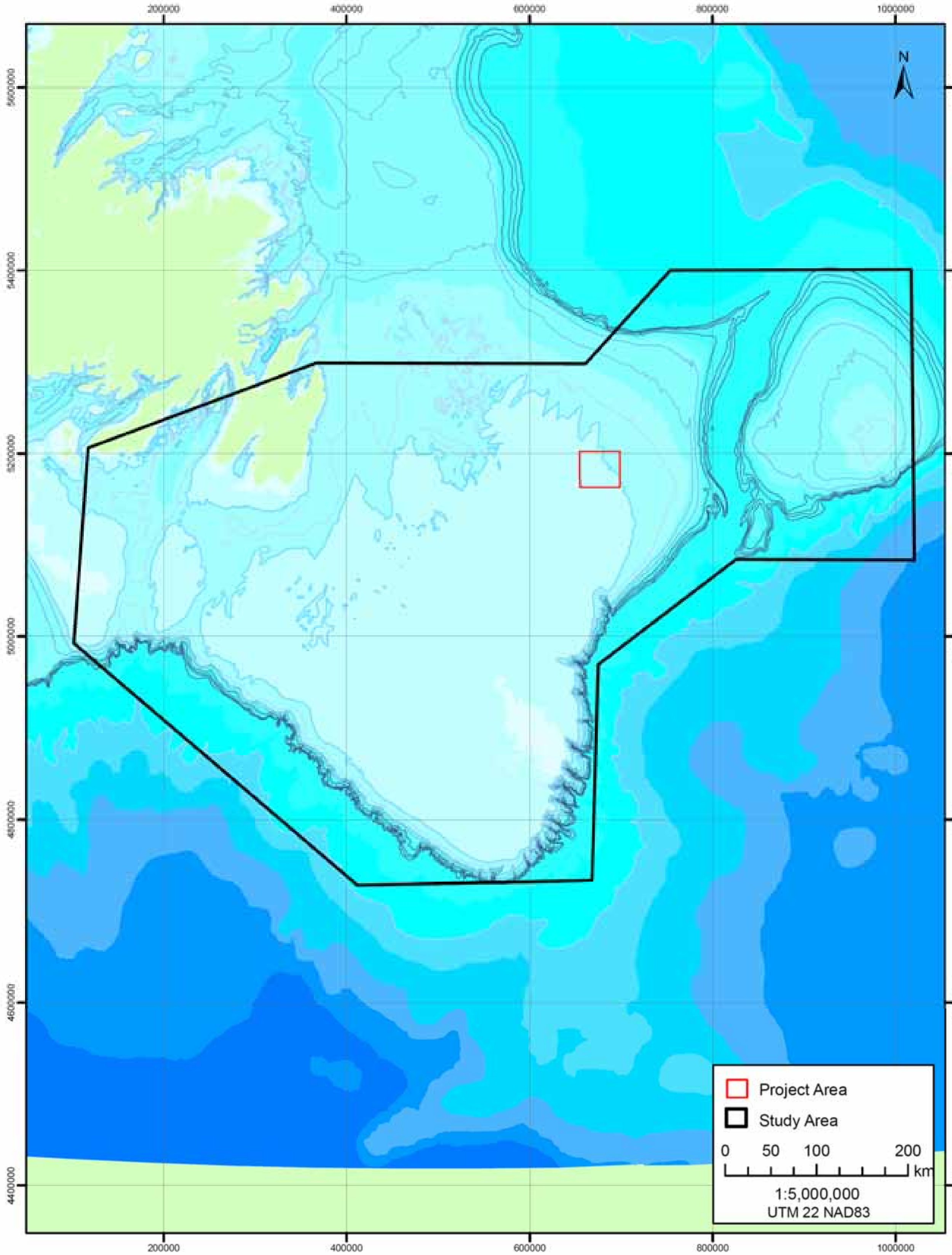
Newfoundland has seabird colonies of world significance and they number among the world's largest and most easily accessed colonies (Important Bird Areas 2007). Marine birds were selected as a VEC because of the potential interactions with Project activities or infrastructure that could affect their habitat, behaviour, breeding success and ecological role. Marine birds are protected under the *Migratory Bird Convention Act*, administered by Environment Canada. Marine birds are also considered a VEC because of regulatory concern (Appendix A) and their sensitivity to oil in the marine environment.

6.5.2 Boundaries

6.5.2.1 Spatial Boundary

The spatial boundary for the assessment of potential environmental effects on the Marine Bird VEC includes the area where interactions with the Project are likely to occur, also known as the Affected Area. During routine construction, operation and abandonment activities, interactions between the Project and Marine Birds are expected to be contained within a 10 nm radius of the Project Area. The habitat within the Affected Area is considered typical habitat within the Jeanne d'Arc Basin and contains no known unique or critical habitat for Marine Birds. Considering the home range of marine birds and their widespread distribution and migration patterns, the Study Area used for Marine Birds is consistent with the original Hibernia EIS Study Area (Figure 6.4).

Figure 6.4 Marine Birds Study Area



6.5.2.2 Temporal Boundary

The temporal boundary of the assessment is defined by the Project's potential interaction with Marine Birds during construction, operation and abandonment activities. Many Project activities, such as dredging are relatively short-term (i.e., ~ 45 days per glory hole), but as an exact schedule for Project activities within the six potential drill centres is not known, it has been assumed for the purposes of the assessment that interactions with the Project could occur at any time of the year. Project activities are expected to commence in 2009, and continue through to the end of the field life which is currently estimated to be in 2036, but this may be extended over time.

6.5.2.3 Administrative Boundaries

Marine birds are protected federally under the *Migratory Birds Convention Act,* which is administered by Environment Canada. This Act contains a prohibition against harming of any migratory bird, nest or eggs. Prohibition 5.1 (1) of the *Act* states that "No person or vessel shall deposit a substance that is harmful to migratory birds, or permit such a substance to be deposited, in waters or an area frequented by migratory birds or in a place from which the substance may enter such waters or such an area."

6.5.2.4 Technical Boundary

Technical boundaries include the limitations of the available data for Marine Birds within the Study Area and the limits of scientific knowledge specific to the interactions between Project activities and Marine Birds and their habitat. However, the data available to characterize the existing environment and knowledge on Project-VEC interactions are considered sufficient to support the assessment.

Specifically, the description of existing conditions for Marine Birds (Section 4.4) within the Study Area was based on the following:

- Hibernia Development Project EIS (Mobil Oil 1985) and component studies;
- previous environmental assessment reports from the Jeanne d'Arc Basin, including
    - recent Husky exploratory drilling EAs and updates (LGL 2002, 2003, 2005a, 2006b, 2007b);
    - StatoilHydro Canada Jeanne d'Arc Basin Area Seismic and Geohazard Program, 2008-2016 and Exploration and Appraisal/Delineation Drilling Program for Offshore Newfoundland, 2008-2016 (LGL 2008 a, b); and
    - SDL 1040 Delineation Drilling Screening (Husky and Norsk Hydro 2006);
- Orphan Basin Strategic Environmental Assessment (C-NLOPB 2003);
- Strategic Environmental Assessment Labrador Shelf Offshore Area (C-NLOPB 2008b);
- CWS data base of opportunistic survey data;
- scientific publications and databases relevant to the Grand Banks;
- experience of the study team in offshore EAs; and
- personal communications.

6.5.3 Potential Interactions and Existing Knowledge

Potential interactions between Marine Birds and Project-related activities, and associated effects are as follows:

- effects associated with the presence of structures (including subsea equipment and flowlines);
- effects associated with lights and flares;
- effects associated with waste and wastewater discharge and atmospheric emissions; and
- effects of noise from all routine activities (including VSPs, well site surveys and abandonment);
- effects of vessel and helicopter traffic.

A detailed list of the potential interactions between the Project and Marine Birds is provided in Section 5.6.3. These interactions could result in a number of potential effects on Marine Birds.

As the Project is not predicted to result in an increase in Hibernia production levels (only an extension in the field life), or discharge rates of air emissions and wastewater, potential Project effects during the operation/production stage are consistent with those effects already assessed for the overall Hibernia project. Any requirements for maintenance at the drill centers would be periodic, short-term and would have limited potential for interactions with Marine Birds.

HMDC is aware of the DFO initiative to establish marine protected areas (MPA's) on the Grand Banks. DFO has identified a number of Ecologically and Biologically Significant Areas (EBSA's) and MPA's could be established within these areas. None of the EBSA's identified thus far overlap with the Project Area. HMDC will continue to monitor the MPA initiative and manage issues, if any, as they arise.

6.5.3.1 Presence of Structures

The physical structures that may interact with Marine Birds are present primarily during the construction and drilling activities for this Project (i.e., drill rigs and vessels). The subsea structures required for Project operation (flowlines, and wellheads) are not expected to interact with Marine Birds.

A drilling rig may create an artificial reef effect that could alter the local abundance and distribution of fish, thus concentrating a food source that may attract marine birds to platforms. There has been little quantification of associations of seabirds with offshore installations, although such associations have been regularly noted (Wiese et al. 2001). Galley and sewage discharges further attract seabirds to these artificial habitats and in fact may attract birds directly in much the same way as sewer outlets (Wiese et al. 2001). Tasker et al. (1986) observed that bird density (birds/km^2) was seven times greater within a 500-m radius of a platform than in the surrounding area. Similarly, seabird concentrations around platforms on the Grand Banks were 19 to 38 times higher than on survey transects leading to the platforms (Wiese and Montevecchi 1999).

6.5.3.2 Lights and Flares

Seabirds primarily navigate by sight, and lights can be an eye-catching visual cue (Wiese et al. 2001). Attraction to lights can potentially result in disorientation, especially during periods of drizzle and fog (Weir 1976, Wiese et al. 2001) and collision with the vessel lights or infrastructure. Attraction could also result in continuous circling around the lights, using energy and delaying foraging or migration, and can result in starvation (Bourne 1979). As well, during shipboard studies conducted in 1999, Leach's Storm

Petrels were observed being attacked by Great Black-backed Gulls after the petrels appeared confused by the lights of vessels and platforms, adding predation as an additional potential problem for species such as Leach's Storm Petrel (Wiese and Montevecchi 2000). The greatest period of risk of attraction to offshore lights is in September when birds are moving to offshore wintering grounds. Storm Petrels and other *Procellariformes* (tube-nosed seabirds) are nocturnal foragers on bioluminescent prey and are, therefore, naturally pre-disposed to attraction to light of any kind (Imber 1975).

There could be short-duration flaring by the drill rig should well testing be necessary. While gas flaring will also produce light that may attract birds, heat and noise generated by the flare may actually deter birds from the immediate area. There are no study results for the Grand Banks concerning the effects of lights and flares on marine birds. However, 52 Leach's Storm Petrels were recovered and released with no mortality observed during monitoring on board a Terra Nova vessel over a three-week period during the summer of 1998 (Husky Oil 2000).

6.5.3.3 Waste and Wastewater Discharges and Atmospheric Emissions

There are several types of discharges that marine birds may interact with during drilling of the well. Marine birds exposed to metals from produced water or drill muds could potentially experience harmful effects. However, a study by Gallagher et al. (1999) found that very high concentrations of heavy metals were required to produce a physiological response in Mallard ducklings (*Anus platyrhynchos*). The concentrations required to produce such a physiological effect were higher than would be expected at an offshore site (Husky 2000).

The release of any blowout preventer fluid by a drill rig or valve control fluid during production operations will have minimal effects on marine birds because low-toxicity glycol-water mixes will be used and the periodic near-bottom releases will be low volume. Drilling will require seawater, most of which will be chlorinated for anti-fouling purposes and used as cooling water. Minimal effects of cooling water on marine birds are expected due to low use concentrations, large dilution factors and the small area of any thermal effect.

Other waste materials, such as deck drainage and bilge waters, may negatively affect marine bird health due to the presence of residual hydrocarbons. The attraction of gulls to platforms as a result of discharges of sanitary and domestic waste may increase the potential for predation of smaller marine birds such as Leach's Storm Petrels. Atmospheric emissions could affect the health of some marine birds, particularly those that remain at the drilling rig for extended periods.

6.5.3.4 Noise

Sources of noise associated with the Project include geohazard surveys, VSP surveys, drilling activities, dredging and disposal activities, marine and air traffic and abandonment activities. The most intense sound source from this Project would occur during a potential 2 to 3 day VSP survey during the drilling of each well. The VSP array is not as intense and is more localized compared to a 2-D or 3-D seismic survey, so the potential effects are less. Section 2.7.11.1 contains a listing of noise source intensity estimates.

The atmospheric noise generated by this Project is of little concern for seabirds, the loudest source being from a helicopter, which will likely be avoided by seabirds. Underwater noise has the greatest potential for affects on Marine Birds.

Only the Alcidae (Dovekie, Common Murre, Thick-billed Murre, Razorbill, Black Guillemot and Atlantic Puffin) spend measurable time underwater during forage dives. They typically spend 25 to 40 seconds underwater during each dive (Gaston and Jones 1998) and have the potential to be exposed to underwater noise. Most species of seabirds that may be present in the marine portion of the Affected Area spend only a few seconds underwater during a foraging dive; therefore, there would be minimal opportunity for exposure.

6.5.3.5 Vessel and Aircraft Traffic

Support vessels may affect Marine Birds through discharges, lighting, the physical presence of the structure and noise. Marine birds on the Grand Banks are habituated to vessel activity and some birds such as gull species and Northern Fulmar (*Fulmaris glacialis*) are actually attracted to ships and often stay with them for extended periods (Montevecchi et al. 1999; Wahl and Heinemann 1979; Brown 1986). Direct effects to Marine Birds are not anticipated because these species are highly mobile and can avoid vessels by flying or diving. Energy expended during these events would be minimal and have no physiological effect on the birds.

Research has shown that seabirds react most strongly to low-level flights and the effects of these responses tend to be short-lived. Helicopter overflights at 300 m failed to cause a visible reaction among moulting sea ducks in the North Sea, while overflights at 100 m resulted in short-term avoidance reactions (Ward and Sharp 1974). As with their response to vessel traffic, seabirds may habituate to air traffic over time.

6.5.4 Mitigation

Based on the potential interactions identified above and existing knowledge regarding these interactions, the following technically and economically feasible mitigation measures to reduce or eliminate potential adverse effects of the Project on Marine Birds have been identified:

- use of water-based drilling muds wherever possible;
- non-toxic or low toxicity chemicals and muds, and treating any synthetic oil-contaminated cuttings as per the OWTG;
- all wastewater discharges to comply with the OWTG and ship operations will adhere to Annex I of the *International Convention for the Prevention of Pollution from Ships* (MARPOL 73/78);
- use of the OCMS to screen chemicals for the Project;
- solid waste transported to shore and recycled where possible;
- discharge of drilling muds, fluids/solids, food and sanitary waste below the surface;
- implementation of appropriate procedures for release of stranded birds to minimize the effects of vessel lighting on birds (as per the CWS seabird handling permit);
- adherence to the *Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment (see C-NLOPB 2008a)*
- all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently;
- avoidance of seabird colonies by aircraft and vessels.

6.5.5 Residual Environmental Effects Significance Criteria

A **significant adverse environmental effect** on marine birds is one that affects marine bird populations (e.g. direct mortality, change in migratory patterns, habitat avoidance) in a way that causes a decline in abundance or change in distribution of population(s) of indicator/representative species within the Study Area. Natural recruitment may not re-establish the population(s) to its original level within one generation.

A **non-significant adverse environmental effect** is defined as an adverse effect that does not meet the above criteria.

6.5.6 Environmental Effects Assessment

6.5.6.1 Presence of Structures

During drilling activities, the drill rig could attract marine birds to the area however, the presence of a drill rig is expected to have negligible effects on gulls and other species that may be attracted to the Project site. There is an increased risk of predation by these species on smaller birds such as storm petrels. However, it is not expected that there will be any significant change in regional bird populations due to the presence of drilling rigs, which are present for only a short-term. The residual adverse environmental effects on Marine Birds caused by the presence of structures and vessels are considered localized, short-term, reversible and non-significant.

6.5.6.2 Lights and Flares

Sources of light from this Project are primarily associated with drilling and construction activities. The construction activities of dredging, drilling and subsea installation may occur concurrently. There are no additional sources of light from Project operational activities. Some individuals of some species in the area may be habituated to this type of lighting due to the other projects currently operating in area. Flaring will occur very infrequently, if at all, during drilling for the Project.

While all vessels and offshore structures have navigation and warning lights that may attract Marine Birds, lighting on supply vessels and drilling rigs may attract Marine Birds more readily than other vessels as the illuminated areas will be larger and more intense. Storm-petrels are particularly susceptible to light attraction because of their nocturnal feeding habits. Marine birds may also be attracted to flares resulting in mortalities. However, the heat and noise generated by the flare will likely deter marine birds from the immediate area of the flare and it is anticipated that flaring will occur for only a short period during well testing, if it occurs at all. Given that the above effects are localized, short-term and reversible and are unlikely to affect regional populations, the residual adverse effects on Marine Birds caused by lights and flares are considered non-significant.

6.5.6.3 Waste and Wastewater Discharges and Atmospheric Emissions

It is anticipated that drilling mud and cuttings will have negligible effects on marine birds at the water surface as these materials are discharged below the surface and fall to the seafloor. Other discharges such as blowout preventer fluid and subsea valve control fluids will have low toxicity and will consist primarily of glycol and water and will have acceptable OCMS ratings. Other waste streams containing oils, such as produced water, deck drainage and bilge water, will be treated, recycled, or discharged below the water surface. All discharged waste will comply with the OWTG. Drilling will require seawater, most of which will be used as chlorinated cooling water. Minimal effects of cooling water on marine birds are expected due to low use concentrations, large dilution factors and the area of thermal effects will be small.

Domestic refuse will be transported to shore and will not interact with Marine Birds. However, sanitary and food waste will be macerated to a particle size of 6 mm or less and discharged below the surface. Gulls may be attracted to the discharge area, however the small amount discharged below the surface is not likely to result in an increase in gull populations in the area.

Atmospheric emissions will occur from the drilling rig. However, all equipment is designed to meet regulatory requirements for emissions and regular maintenance plans ensure equipment operates efficiently. As a result, risks associated with emissions of potentially harmful materials will be negligible in that emissions are expected to rapidly disperse to undetectable levels.

The effects of waste and wastewater discharge and atmospheric emissions on Marine Birds are therefore localized, short-term and reversible. The residual adverse environmental effects are considered to be non-significant.

6.5.6.4 Noise

Atmospheric noise from this Project is not concern for Marine Birds. Underwater noise sources are intermittent (e.g., VSP survey of 2 to 3 days) during construction activities and localized and exposure of Marine Birds will therefore be limited. Residual adverse environmental effects of noise on Marine Birds are considered non significant.

6.5.6.5 Vessel and Air Traffic

Some Marine Birds on the Grand Banks are adapted to vessel activity, and while some species are attracted to vessels, all Marine Birds are highly mobile and can easily avoid interactions with vessels. Helicopters servicing the Project will avoid major colonies along the eastern Avalon Peninsula and will fly at a minimum of 600 m above sea surface whenever possible. Disturbance to marine birds on the water surface will be negligible when aircraft are 600 m above the sea surface. When taking off and landing on platforms, marine birds in the vicinity may be disturbed. However, birds that associate with the offshore platforms will likely become habituated to the activity and potential residual adverse effects are considered non significant.

6.5.6.6 Abandonment

The disturbance associated with decommissioning and abandonment activities (primarily associated with vessel and helicopter traffic) will be of short duration and occur directly at the drilling center. The residual adverse environmental effects of decommissioning and abandonment on Marine Birds are considered non significant.

6.5.7 Follow-up

An extensive amount of seabird data has been collected under an ongoing ESRF funded program which is coordinated by the CWS. HMDC will provide the opportunity for the trained observers under this program to collect seabird data from the MODU, construction/dredging vessels or during seismic surveys. The ESRF program has been and continues to be very successful with reliable, high quality data generated and professionally reported.

Stranded seabirds that may have been attracted to vessel lighting will be managed in accordance with handling procedures described in the CWS seabird handling permit.

6.5.8 Summary of Potential and Residual Environmental Effects

Based on the ratings of magnitude, geographic extent and duration for each routine activity that will potentially interact with Marine Birds, the residual environmental effects of the Project for construction, operation and abandonment are predicted to be non-significant. A summary of the potential environmental effects of the Project on Marine Birds after consideration of mitigation is provided in Table 6.6.

Table 6.6 Summary of Environmental Assessment for Marine Birds

Interactions	
♦ effects associated with the presence of structures; ♦ effects associated with lights and flares; ♦ effects associated with waste and wastewater discharge and atmospheric emissions; and ♦ effects of noise from all routine activities (including VSPs, well site surveys and abandonment); ♦ effects of vessel and helicopter traffic.	
Mitigation	
♦ use of water-based drilling muds wherever possible; ♦ non-toxic or low toxicity chemicals and muds, and treating any synthetic oil-contaminated cuttings as per the OWTG; ♦ all wastewater discharges to comply with the OWTG and ship operations will adhere to Annex I of the *International Convention for the Prevention of Pollution from Ships* (MARPOL 73/78); ♦ use of the OCMS to screen chemicals for the Project; ♦ solid waste transported to shore and recycled where possible; ♦ discharge of drilling muds, fluids/solids, food and sanitary waste below the surface; ♦ implementation of appropriate procedures for release of stranded birds to minimize the effects of vessel lighting on birds; ♦ adherence to the *Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment (see C-NLOPB 2008a)* ♦ all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently; and ♦ avoidance of seabird colonies by aircraft and vessels.	
Significance	
Likelihood of occurrence	Will occur
Geographic extent	• Drilling muds and cuttings: < 1km^2 • Noise: < 10 km • Waste and wastewater: < 1km • Dredging and disposal: <10 km • Presence of structures and lights: <1 km
Frequency of occurrence (over 27 years or longer)	• Drilling muds and cuttings: 1- 3 wells per year; • Noise: 1-3 wells per year; 1-2 glory holes per year; 1 VSP survey per well; one geohazards survey per drill centre; 1-2 manifolds per drill centre; • Waste and wastewater: continuous during each well, glory hole and subsea installation; valve control fluid venting approx 15 times per well per year; • Dredging and disposal: 1-2 glory holes per year; and • Presence of structures and lights: continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment, for the life of the project. .
Duration of impact (over 27 years or longer)	• Drilling muds and cutting: 128 days each, up to 66 wells in total; • Noise: drilling - 128 days each, up to 66 wells in total; glory hole - 45 days each, up to 6 in total; 1 VSP survey per well, 1-3 days each; 1 geohazards survey per glory hole; 1-2 manifolds per drill centre, 30-40 days each; • Waste and wastewater: continuous during each well, glory hole and subsea installation; • Dredging and disposal: 45 days per year, up to 6 glory holes; • Presence of structures and lights: continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment, for the life of the project.
Magnitude of impact	Low (avoidance will be temporary, localized and of little biological consequence; physical effects are unlikely)
Permanence/reversibility	Reversible
Significance	**Non significant**
Confidence	High
Follow-up and monitoring	
▪ Stranded seabirds managed as per CWS permit. ▪ Seabird distribution data collected under CWS coordinated study.	

6.6 Species at Risk

For the purposes of this screening report, Species at Risk refers to those species of marine fish, mammals, birds, and reptiles listed federally under *SARA* and/or designated by COSEWIC, which are most likely to occur in the Affected Area and therefore potentially interact with the Project. Those species are:

Marine Mammals

- harbour porpoise;
- fin whale;
- blue whale;
- right whales;

Sea Turtles

- leatherback sea turtle;

Marine Fish

- Atlantic cod;
- northern wolffish;
- spotted wolffish;
- Atlantic wolfish;

Marine Birds

- Ivory Gull.

It also considers the associated habitats, as protected under *SARA.* Many of the issues of concern, potential interactions with the Project, as well as mitigations and management strategies for species at risk are similar to that presented elsewhere in this report for non-listed species in the Affected Area. On an ecosystem basis, the listed and non-listed species and their habitats are often highly integrated. This section assesses the potential effects of Project construction, operation and abandonment on species at risk. Accidentals, malfunctions and unplanned events, are assessed in Chapter 8. Cumulative effects are assessed in Chapter 7.

Although intrinsically related to species at risk, marine fish habitat, fish and shellfish, marine mammals, and marine birds are assessed separately in Sections 6.1, 6.2, 6.4, and 6.5 respectively.

6.6.1 Rationale for Selection as a Valued Ecosystem Component

Species at risk is a VEC for this assessment for several key reasons:

- species at risk and their habitat are legally protected under federal legislation and the Proponent is therefore required to demonstrate that the Project will not result in significant effects on these species;

- due to their nature, species at risk can be more vulnerable to human-induced changes in their habitat or populations levels and can therefore require special consideration with respect to mitigation strategies;
- several federally listed marine species at risk have the potential to occur in the Affected Area; and
- the Scoping Document (Appendix A) includes the requirement to consider species at risk that may be affected by the Project.

6.6.2 Boundaries

6.6.2.1 Spatial Boundary

The spatial boundary for the assessment of potential environmental effects on the Species at Risk VEC includes the area where interactions with the Project are likely to occur, also known as the Affected Area. During routine construction, operation and abandonment activities, interactions between the Project and Species at Risk are expected to be contained within a 10 nm radius of the Project Area. The habitat within the Affected Area is considered typical habitat within the Jeanne d'Arc Basin and contains no identified unique or critical habitat for any of the Species at Risk being considered.

Considering the home range of some species at risk and their widespread distribution and migration patterns, the Study Area used for Species at Risk is consistent with the original Hibernia EIS Study Area (see Figure 6.3).

6.6.2.2 Temporal Boundary

The temporal boundary of the assessment is defined by the Project's potential interaction with marine mammals during construction, operation and abandonment activities. Many Project activities, such as dredging are relatively short-term (i.e., ~ 45 days per glory hole), but as an exact schedule for Project activities within the six potential drill centres is not known, it has been assumed for the purposes of the assessment that interactions with the Project could occur at any time of the year. Project activities are expected to commence in 2009, and continue through to the end of the field life which is currently estimated to be in 2036, but this may be extended over time.

6.6.2.3 Administrative Boundaries

Species at risk are protected under *SARA,* administered by Environment Canada, Parks Canada and DFO. The purposes of *SARA* are to prevent Canadian indigenous species, subspecies and distinct populations of wildlife from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species, and to encourage the management of other species to prevent them from becoming at risk. Section 32 of *SARA* prohibits killing, capturing and destruction of critical habitat for those species listed on Schedule 1 as extirpated, endangered and threatened. Critical habitat is defined as the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species.

The main provisions of *SARA* are scientific assessment and listing of species, species recovery, protection of critical habitat, compensation, permits and enforcement. The Act also provides for development of official recovery plans for species found to be most at risk, and management plans for species of special concern. Currently, recovery strategies and/or management plans are in place for the three species of wolffish and for leatherback turtle. The official federal list of wildlife and plant species at risk in Canada is Schedule 1 of *SARA*. Only species on Schedule 1 of *SARA* are subject to the permit and enforcement provisions of the Act. The List includes species of special concern, extirpated, endangered and threatened species. Schedules 2 and 3 of *SARA* identify species that were designated at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) prior to October 1999 and must be reassessed using revised criteria before they can be considered for addition to Schedule 1.

Marine mammals and fish, including those species designated at risk, are protected in Canada through federal legislation under the *Fisheries Act*. Section 35 of the *Fisheries Act* ensures no harmful alteration, disruption or destruction of fish habitat, while Section 36 ensures no deposits of any substances considered deleterious to fish. Marine mammals are included in the definition of fish under the *Act*. Environment Canada administers Section 36 of the *Fisheries Act* while DFO administers Section 35 of the *Act*. The *Marine Mammal Regulations* under the *Fisheries Act* stipulate that "No person shall disturb a marine mammal except when fishing for marine mammals under the authority of these regulations".

6.6.2.4 Technical Boundary

Technical boundaries include the limitations of the available data for Species at Risk within the Study Area and the limits of scientific knowledge specific to the interactions between Project activities and relevant species physiologies, behaviors and life histories. Although data characterizing the existing environment for species at risk continue to be somewhat limited, due to the unpredictability of marine mammal, sea turtle, fish and bird species distribution on the Grand Banks, the data available to characterize the existing environment and knowledge on Project-VEC interactions are judged by the study team to be sufficient to support the assessment.

The habitat within the Affected Area is considered typical habitat within the Jeanne d'Arc Basin and contains no known unique or critical habitat for any species at risk.

Specifically, the description of existing conditions for species at risk (Section 4.5) within the Affected Area and Study Area was based on the following:

- Hibernia Development Project EIS (Mobil Oil 1985) and component studies;
- previous environmental assessment reports from the Jeanne d'Arc Basin, especially
  - recent Husky exploratory drilling EAs and updates (LGL 2002, 2003, 2005a, 2006b, 2007b);
  - StatoilHydro Canada Jeanne d'Arc Basin Area Seismic and Geohazard Program, 2008-2016 and Exploration and Appraisal/Delineation Drilling Program for Offshore Newfoundland, 2008-2016 (LGL 2008 a, b); and
  - SDL 1040 Delineation Drilling Screening (Husky and Norsk Hydro 2006);
- Orphan Basin Strategic Environmental Assessment (C-NLOPB 2003);
- Strategic Environmental Assessment Labrador Shelf Offshore Area (C-NLOPB 2008b);
- DFO data base of marine mammal observer and survey data;
- scientific publications and databases relevant to the Grand Banks;
- experience of the study team in offshore EAs; and
- personal communications.

6.6.3 Potential Interactions and Existing Knowledge

Potential interactions, between Species at Risk and routine Project activities include:

- effects of noise from all routine activities (including VSPs, well site surveys and abandonment);
- effect from collisions with vessels;
- effects associated with discharge of drill mud and cuttings;
- effects associated with the discharge of waste and wastewater;
- effects associated with dredging and ocean disposal; and
- effects associated with the presence of structures, lights and flares (including subsea equipment and flowlines).

A detailed list of the potential interactions between the Project and Species at Risk is provided in Table 6.7. These interactions could result in a number of potential effects on Species at Risk.

As the Project is not predicted to result in an increase in Hibernia production levels (only an extension in the field life), or discharge rates of air emissions and wastewater, potential Project effects during the operation/production stage are consistent with those effects already assessed for the overall Hibernia project. Any requirements for maintenance at the drill centers would be periodic, short-term and would have limited potential for interactions with Species at Risk.

HMDC is aware of the DFO initiative to establish marine protected areas (MPA's) on the Grand Banks. DFO has identified a number of Ecologically and Biologically Significant Areas (EBSA's) and MPA's could be established within these areas. None of the EBSA's identified thus far overlap with the Project Area. HMDC will continue to monitor the MPA initiative and manage issues, if any, as they arise.

Table 6.7 Project Interactions with Species at Risk Components

Project Activities and Physical Works	VEC			
	Marine Mammal SAR	Marine Bird SAR	Marine Fish SAR	Sea Turtle SAR
Glory Hole Excavation				
Dredge operation and Disposal	✓	✓	✓	✓
Presence of structures	✓	✓	✓	✓
Safety zone			✓	
Lights	✓	✓	✓	✓
Deck drainage, bilge water, and ballast water	✓	✓	✓	✓
Sanitary or domestic waste water	✓	✓	✓	✓
Routine air emissions		✓		
Marine vessels	✓	✓	✓	✓
Helicopter flights	✓	✓		✓
Drilling				
Presence of structures	✓	✓	✓	✓
Safety zone			✓	
Lights	✓	✓	✓	✓
Flaring		✓		
Mud operations	✓	✓	✓	✓

Project Activities and Physical Works	VEC			
	Marine Mammal SAR	Marine Bird SAR	Marine Fish SAR	Sea Turtle SAR
Cement	✓		✓	✓
BOP discharge	✓	✓	✓	✓
Cooling water	✓	✓	✓	✓
Deck drainage, bilge water, and ballast water	✓	✓	✓	✓
Sanitary or domestic waste water	✓	✓	✓	✓
Produced water	✓	✓	✓	✓
Supply boat transits	✓	✓	✓	✓
Supply boat on standby	✓	✓	✓	✓
Helicopter flights	✓	✓	✓	✓
Rig operation	✓	✓	✓	✓
Routine air emissions		✓		
VSP	✓	✓	✓	✓
Subsea Production Equipment Installation				
Presence of structures	✓	✓	✓	✓
Safety zone			✓	
Lights	✓	✓	✓	✓
Production Operation				
Presence of structures	✓	✓	✓	✓
Safety zone			✓	✓
Lights	✓	✓	✓	✓
Flaring	✓	✓	✓	
Cooling water	✓		✓	✓
Deck drainage, bilge water, and ballast water	✓	✓	✓	✓
Sanitary or domestic waste water	✓	✓	✓	✓
Produced water	✓	✓	✓	✓
Supply boat transits	✓	✓	✓	✓
Supply boat on standby	✓	✓	✓	✓
Helicopter flights	✓	✓		✓
GBS operation	✓	✓	✓	✓
Routine air emissions		✓		
Sanitary or domestic waste water	✓	✓	✓	✓
Abandonment				
Presence of structures	✓	✓	✓	✓
Safety zone			✓	
Lights	✓	✓	✓	✓
Deck drainage, bilge water, and ballast water	✓	✓	✓	✓
Sanitary or domestic waste water	✓	✓	✓	✓
Routine air emissions		✓		
Marine vessels	✓	✓	✓	✓
Helicopter flights	✓	✓		✓

6.6.3.1 Discharge of Drill Muds and Cuttings

A physical and chemical description of the discharge of mud and cuttings can be found in Section 2.7.1.

Marine Mammal Species at Risk

The discharge of drill muds and cuttings are not expected to interact with these species directly, since mammals will likely avoid the immediate areas of discharge due to noise avoidance. Any potential of an indirect effect on these species from an impact on their food supply is also unlikely since the drilling wastes are contained to the seafloor near the rig. Fin, right and blue whales feed on plankton and on small schooling fish, like capelin, from the water column, which will not be affected by the discharge of drill waste. As well, harbour porpoise feed primarily on schooling fish from the water column.

Sea Turtle Species at Risk

As with the mammal species at risk, the leatherback will not likely be affected by the discharge of drilling mud and cuttings due to avoidance of the immediate area and because they feed primarily on jellyfish in the upper water column.

Marine Fish Species at Risk

As discussed in Section 6.2.6 the primary effect of drilling mud and cuttings discharge on fish, including those species at risk, is the physical disturbance near the drill site. Contamination of the fish or their prey is of limited concern due to the spatial extent of potential effects. As well, there is little potential for toxicity or health effects on American plaice from drilling waste (Cranford et al. 2001, Payne et al. 1995), which live in close contact with the substrate and feed on more epifauna and infauna compared to those fish species at risk with potential to occur at the site. Potential effects include avoidance of the area of deposition by marine fish species at risk and smothering of potential prey for these species.

Marine Bird Species at Risk

There is no interaction expected between the discharge of drilling waste and the Ivory Gull.

6.6.3.2 Noise

Sources of noise associated with the Project include geohazard surveys, VSP surveys, drilling activities, dredging and disposal activities, marine and air traffic and abandonment activities. The most intense sound source from this Project would occur during a potential 2 to 3 day VSP survey during the drilling of each well. The VSP array is not as intense and is more localized compared to a 2-D or 3-D seismic survey, so the potential effects are less. The available literature on the effects of seismic sound on fish is for 2-D and 3-D sources. Section 2.7.11.1 contains a listing of noise source intensity estimates.

Marine Mammal Species at Risk

The US National Marine Fisheries Service (NMFS) has developed criteria for marine mammal seismic exposure. The level considered harmful to whales is 180 dB and sound levels of 160 dB are considered to cause harassment to whales (NMFS 2000). Whales are not expected to be exposed to these sound levels since they will likely be deterred from the immediate area by the ramp-up of airgun pressure. These criteria are considered conservative in that mammals may tolerate higher sound levels before they are actually harmed or harassed.

Based on the literature reviewed in Richardson et al. (1995), it is apparent that most small and medium-sized toothed whales (e.g., harbour porpoise) exposed to prolonged or repeated underwater sounds are unlikely to be displaced unless the overall received level is at least 140 dB re 1 µPa. NMFS policy is under review and currently states that cetaceans should not be exposed to pulsive sounds exceeding 180 dB re 1 µPa (rms) (NMFS 2000).

Baleen whales generally avoid intense noise sources (i.e. an operating array), but the avoidance radii appear to be quite variable. Baleen whales, like the fin and blue whales, may deviate from a migratory route, suspend feeding or avoid the area. The biological significance of such a change in behavior is considered slight since there are no critical habitats identified within the Affected Area and there are alternate feeding and migratory routes. The significance of this effect will increase if mammals are displaced from feeding, resting, breeding or nursery areas where there are no alternates or where mammals are diverted from routes for which there are no alternates or where alternate routes could be used, but at substantially greater costs (DFO 2004a). The impact of a loss of feeding opportunity on an individual will depend on factors like the availability of alternate feeding locations and species, time since previous feed, age and species. Marine mammals are opportunistic feeders and have adapted to the variability in prey abundance, so usually are not reliant on any single location for food.

Fin whales are expected to avoid the area of 160 dB and higher, thereby avoiding physiological harm. Marine mammals in the Gully on the coast of Nova Scotia, including the northern bottlenose, blue, fin and sperm whales did not avoid sound of 145 dB re 1 µPa (rms) after several weeks of exposure (Gosselin and Lawson 2004). If whales are deterred from an area in one year, it is not known whether it will affect their use of that area in subsequent years (C-NLOPB 2005). However, studies of grey and bowhead whales have demonstrated continuous use of areas of seismic activities (C-NLOPB 2005 and references therein). Few studies have been conducted on the reaction of toothed whales to seismic activity but there are numerous observations of dolphins and porpoises bow riding active seismic vessels (C-NLOPB 2005). Several observations during seismic activity on sperm whales have concluded little detectable effect (see C-NLOPB 2005).

There are reports of whales altering vocalization patterns when exposed to industrial and seismic noise and there are reports of no alteration in vocalization during seismic exposure (DFO 2004a). Whether there is a consequence to any change in vocalization pattern is difficult to determine, but there is potential for reduced ability to communicate information about feeding, breeding, parental care, predator avoidance or maintenance of social grouping. Several species of baleen whales have been observed to continue calling in the presence of seismic pulses, including bowhead whales (Richardson et al. 1986), blue whales and fin whales (McDonald et al. 1995). It is presently unknown whether mammal exposure to seismic sound results in reduced communication efficiency (DFO 2004a). There have also been no direct studies of the potential for seismic sound to reduce the efficiency of echolocation in marine mammals, or the potential to hamper passive acoustic detection of prey or predators by marine mammals (DFO 2004a). There is a concern, however, that mammals exposed to seismic sounds can have a reduced ability to avoid anthropogenic threats such as ship strikes and fishing net entanglements, but the threat has not been demonstrated (DFO 2004a).

In general, avoidance of the Affected Area by marine mammal species at risk is not expected for prolonged periods. Project activities may illicit a startle response, causing increased heart rate and breathing or a change in swimming path, but these responses are not considered biologically critical (Erbe 2000). If the opportunity for feeding is presented to marine mammal species at risk within the

Affected Area, they may tolerate noise they may otherwise avoid while feeding (Wartzok et al. 2004) and then move out of the Affected Area.

Sea Turtle Species at Risk

Very little information is available on sea turtle hearing, but the available information indicates that turtles hear at low frequency (100 to 500 Hz (Office of Naval Research website 2002); 100 to 700 Hz (Australia Department of Environment 2003)) range and are therefore more like seals than other marine mammals. Very little is known about the importance of hearing to sea turtles. It has been suggested that sound may play a role in navigation but recent studies suggest that visual, wave and magnetic cues are the main navigational cues used by hatchling and juvenile sea turtles (Lohmann and Lohmann 1998; Lohmann et al. 2001). Thus, masking is unlikely to be a significant issue for sea turtles exposed to pulsed sounds from project activities. Data is not available on the behavioural reactions of sea turtles to seismic sound or sonar.

There are very few studies on the effects of noise on sea turtles. In a caged study, sea turtles increased their swimming speed when exposed to a 166 re 1 μPa (rms) sound from an air sleeve, firing every 10 seconds (McCauley et al. 2000a or b). The turtle's behaviour became more erratic when the received level was increased to 175 dB re 1 μPa (rms). The authors suggested that the erratic behaviour would translate into avoidance behaviour in nature. They suggest that behaviour changes may be observed at approximately 2 km and avoidance behaviour at approximately 1 km from a typical sleeve array (2,678 in^3, 12-elements) operating in 100 to 120 m of water. This scale of avoidance is not expected to affect the migration of sea turtles but if the seismic activity prevented them from entering a preferred feeding area for a prolonged period, there could be negative impacts (C-NLOPB 2005). There are no known feeding areas for sea turtles within the Affected Area.

In general, sea turtles are likely to avoid underwater noise (McCauley et al. 2000). Avoidance may reduce the risk of potential physiological effects of noise exposure. Sea turtles are not believed to use hearing for prey detection or navigation therefore, masking is unlikely to be an important issue for sea turtles. Avoidance of the Affected Area is also not expected to cause any biological effects given that the area is not known to congregate jellyfish, a primary prey item. Jellyfish are transitory, with distributions changing within and between years, so there is no more reason to expect jellyfish within the Affected Area than any other area of the Grand Banks.

Marine Fish Species at Risk

No fish mortalities have been reported from seismic sources, but physical injury of adult fish is possible within a few tens of metres (Turnpenney and Nedwell 1994) and auditory damage in fish is possible within a few hundreds of metres (McCauley et al. 2000a). Other studies have shown that egg and larval mortality is possible only within a few metres of a seismic sound source (Payne 2004; Pearson et al. 1994). There is very little information on the sublethal effects of fish and invertebrate exposure to seismic noise (Payne 2004). Potential effects may include damage to hearing, eyesight or internal organs, but the distance at which these or other physiological effects occur is unknown and may extend beyond 5 m (Payne 2004).

If present within the Affected Area, wolffish and any eggs that may occur, are generally found on or near bottom, so approximately 100 m away from the sound source, which will eliminate any potential physical impact on these life stages. It is the near surface larval stages that could potentially be directly affected by seismic activity. Seismic activity synchronized with periods of larval hatching has the greatest potential for harm (Kulka et al. 2007). There are no reports of either of the wolffish species spawning within the Affected Area. However, there is insufficient information to determine potential effects (Kulka et al. 2007).

Atlantic cod may also occur within the Affected Area. Compared to other species, cod is considered a moderately sensitive species in terms of hearing (see Section 6.2.3.3). A measurable behavioural response is anticipated in the range of 160 to 188 dB re 1 μPa (Turnpenny and Nedwell 1994), which may be expected from this Project; temporary avoidance of the immediate area around the noise may be a result. DFO (2004a) concludes that some fish exposed to seismic sounds are likely to exhibit a startle response, a change in swimming pattern and/or a change in vertical distribution. However, these effects are expected to be short term and of low ecological significance except where fish reproductive activity may be affected.

The greatest risk from noise would also apply to cod eggs and larvae near the surface. Cod larvae may be present on the northern Grand Banks from May to July (Dalley et al. 2000). Cod have not spawned near the Affected Area in recent years, but have historically (Ollerhead et al. 2004). No measurable effect of noise on cod is expected due to the low probability of spatial and temporal overlap between the VSP survey of 2 to 3 days per well and the presence of cod eggs and larvae near the source.

Fish sounds are normally generated in the range of 50 to 3,000 Hz. Fish use sound for communication, navigation and sensing of prey and predators. In particular, sound transmission is thought to play an important role in cod and haddock mating (Engen and Folstad 1999; Hawkins and Amorin 2000). Seismic signals are typically in the range of 10 to 200 Hz (Turnpenny and Nedwell 1994) and will therefore overlap slightly with signals produced by fish. However, detecting a signal does not mean the fish will have any measurable reaction to the noise.

Marine Bird Species at Risk

Ivory Gulls are not expected to be affected by noise from the Project.

6.6.3.3 Collisions with Vessels

In addition to the dredge and pipe laying vessel, approximately three to four supply boat transits will occur every week during Project construction activities and one supply vessel will remain at the drilling location on standby.

Marine Mammal Species at Risk

Fin whales and right whales are more likely to tolerate a stationary noise source than one that is approaching (Watkins 1986). Harbour porpoise are known to avoid vessels and do not bowride. Larger toothed whales, such as sperm whales and beaked whales, generally seem to avoid vessels (Sorensen et al. 1984). Some species appear to be more sensitive than others and if individual mammals have been exposed to similar noise and activities in the past, they may become habituated to a familiar disturbance. Large vessels traveling at more than 14 knots are the principal source of ship strike mortalities in whales whereas serious injuries to whales are likely infrequent when vessel speeds are less than 7.2 m/s (14 knots), and rare when vessel speeds are less than 5 m/s (10 knots). High speed container ships are considered to be potentially one of the greatest threats to blue whales.

Of the 11 species known to have been victims of vessel collision, fin whales are struck the most frequently; right whales, humpback whales, sperm whales and gray whales are also commonly struck (Laist et al. 2001). However, when these frequencies are corrected for the species population size, the North Atlantic right whale is struck most frequently per capita followed by the southern right whale

(Vanderlann and Taggart 2007), which is more a function of the right whale's tendency to linger at the surface than other species.

However, if particular individuals frequent the area, they may become habituated to vessels, which will increase the risk of collision. Fin whales, for example, have demonstrated habituation to tour boats after several years of exposure (Watkins 1986).

Marine Turtle Species at Risk

There have been no collisions between leatherbacks and boats documented in Atlantic Canada, but collisions have been known to occur in some areas of the U.S (ALTRT 2006). The risk of collision between Project vessels and the leatherback sea turtle is minimized because of the reduced speed of working vessels in the area.

Marine Fish Species at Risk

Collisions between marine fish species at risk and vessels are not expected.

Marine Bird Species at Risk

Collisions between marine bird species (e.g. Ivory Gull) at risk and vessels are not expected.

6.6.3.4 Effects of Waste and Wastewater

Wastewater discharge is managed in accordance with OWTG. All drilling and production chemicals that may interact with the marine environment are screened in accordance with the OCMS to minimize potential toxicity. Routine discharges from the wellsite/geohazard survey vessel will include domestic waste and ballast water (bilge water is not permitted to be discharged). All routine discharges will be in accordance with the *Pollution Prevention Regulations* of the *Canada Shipping Act*.

Minimal, if any, produced water will be discharged during development drilling. Produced water will be treated to reduce the oil content such that the 30 day volume weighted rolling average is 30 mg/L or less and 24 hour averages do not exceed 60 mg/l. Produced hydrocarbons will be separated from produced water on the rig. Small volumes of oil (approximately 0.14 L) are typically released in 30 bbl (~4,800L) of produced water. Unlike produced water discharges during production phases, which are continuous, long-term events, well testing would produce a small volume of discharge over a short period of time. Please see Section 2.7 for a description of all Project related waste and wastewater.

Marine Mammal Species at Risk

All discharges are subject to environmental compliance monitoring to ensure regulated waste streams are discharged in accordance with the OWTG. For this Project discharges are of limited duration and frequency and therefore are expected to have little effect on marine mammal species at risk.

Marine Turtle Species at Risk

All discharges are subject to environmental compliance monitoring to ensure regulated waste streams are discharged in accordance with the OWTG. For this Project, discharges are of limited duration and frequency and therefore are expected to have little effect on sea turtle species at risk.

Marine Fish Species at Risk

All discharges are subject to environmental compliance monitoring to ensure regulated waste streams are discharged in accordance with the OWTG. For this Project, discharges are of limited duration and frequency and therefore are expected to have little effect on marine fish species at risk.

Marine Bird Species at Risk

All discharges are subject to environmental compliance monitoring to ensure regulated waste streams are discharged in accordance with the OWTG. However, the Ivory Gull is more at risk of being attracted by waste and food particle discharge and is more sensitive to hydrocarbons in the environment than are fish and mammals. A sheen of oil on the surface of the water has some potential to oil seabirds. Produced water, if released at all, will be discharged within limits specified in the OWTG and the occurrence of the Ivory Gull in the Project Area is predicted to be rare.

6.6.3.5 Effects of Dredging and Disposal

Each drill centre will require a glory hole to protect the well from iceberg impacts. The excavation of the glory hole may be completed by a suction hopper dredge or alternate technology (e.g. clam shell). The potential environmental effects of each technology are similar, but they may differ in extent. The clam shell dredge will side cast the material during glory hole excavation, which will confine sediment dispersion and the disposal pile footprint to near the excavation site.

Sediments suspended during dredging of the glory hole(s) and disposed of thereafter, will result in increased turbidity within the water column. At the dredge site, disturbed material will remain near the seafloor. However, at the dredge spoils disposal site, material will be discharged from near surface, so turbidity will be affected through the water column. Observed sediments within the area to be dredged are comprised predominantly of sands and gravels with limited fine material, which will increase the rate of settlement.

Marine Mammal Species at Risk

Marine mammal species at risk may avoid the area of active dredging or disposal, due to noise or if the habitat quality becomes unsuitable due to turbidity. The Affected Area is not known to be of any more significance in terms of habitat or feeding areas for mammal species at risk than other areas of the Grand Banks.

Marine Turtle Species at Risk

As with marine mammals, sea turtle species at risk may also avoid the noise within the Affected Area, thereby avoiding any implications of the increase in turbidity. The Affected Areas are also not expected to be preferred areas for leatherback feeding.

Marine Fish Species at Risk

If elevated levels of suspended solids are sustained from dredging operations before or during a plankton bloom, a decrease in primary productivity may result within the Affected Area. In turn, the food supply for pelagic species and life stages may be diminished. This may have localized effect on prey selection in some fish species, including juvenile Atlantic cod. Wolffish species are not likely to be affected by dredging operations since the area impacted would be so confined compared to the available feeding area (Kulka et al. 2007).

Eggs and larvae of finfish and shellfish are generally more prone to physical damage from increased levels of suspended sediment because they are passive drifters and cannot avoid the Affected Area like the post-settlement life stages. Suspended sediment levels of 1,000 mg/L have caused mechanical damage to herring larvae (Boehlert and Yoklavich 1984). Sublethal effects in several fish species have been reported after several days of exposure to suspended sediment concentrations of approximately 650 mg/L or greater (Appleby and Scarratt 1989).

The sediment chemistry at the glory hole is considered to be at background levels for the Project Area, so there is no risk of contamination during disposal within the Project Area.

DFO has determined that the glory hole(s) dredging and dredge spoils disposal will result in a HADD. The total area of the HADD has yet to be determined, but HMDC will comply with the DFO policy of no net loss of the productive capacity of fish habitat from this Project.

Marine Bird Species at Risk

The occurrence of the Ivory Gull in the Project Area is unlikely, however, should it occur, it is most likely to arrive in late winter or early spring. Dredging operations would likely be a summer activity, so there is no opportunity for an interaction with this Project activity.

6.6.3.6 Presence of Structures, Lights and Flares

The presence of structures may create an artificial reef effect that could alter the local abundance and distribution of fish, thus concentrating a potential food source for some species. Some species may also be attracted by lights and flares from the Project.

Marine Mammal Species at Risk

The marine mammal species at risk with the most potential to occur within the Affected Area are the harbour porpoise, fin, blue and right whales each of which are plankton and/or small schooling fish feeders and therefore will not likely be attracted to subsea structures by any potential reef effect. In fact, avoidance of sub-sea structures may result if the mammals are deterred by noise from nearby activities. These mammal species at risk are not expected to be affected by the lights or flares from the Project.

Marine Turtle Species at Risk

As with the marine mammal species at risk, the marine turtle species at risk may actually be deterred from direct interaction with structures, lights or flares from the project, since they are more likely to be deterred by the noise from Project activities.

Marine Fish Species at Risk

The placement of physical structures on or in the bottom substrate/water column could affect wolffish habitat although in a very spatially limited manner compared to the widespread distribution of wolffish (Kulka et al. 2007). Wolffish and cod may be attracted by the habitat complexity introduced by subsea structures like flowlines and rock piles, but the attraction may be offset by avoidance at other subsea structures during drilling and dredging activities due to noise. If wolfish or cod are attracted to any of the structures, the safety zones around each structure (minimum of 500 m) will eliminate the chance of the individuals being caught in commercial by–catch, while they remain in the area. Since wolffish and cod are benthic species, they are not expected to be attracted to the surface by increased illumination at the surface from rig and vessel lights or flares. During Hibernia's annual ROV inspection of the OLS, small numbers of cod are regularly observed in open spaces within the riser base structure (R.Dunphy, pers comm.).

Marine Bird Species at Risk

The presence of structures, lights and flares have the potential to attract marine birds generally, but the probability of an interaction with the Ivory Gull is limited by the spatial and temporal overlap between the two. Furthermore, Ivory Gulls are scavengers, feeding on the carcasses of dead fish and marine mammals, so are not prone to feeding on plankton and schooling fish near a Project structure. There are no reports of Ivory Gulls being attracted to lights and flares.

6.6.4 Mitigations

Based on the potential interactions identified above and existing knowledge regarding these interactions, the following technically and economically feasible mitigation measures to reduce or eliminate potential adverse effects of routine Project activities on Species at Risk have been identified:

- use of water-based drilling muds wherever possible;
- use of non-toxic or low toxicity chemicals and muds, and treating synthetic oil-contaminated cuttings as per the OWTG;
- all wastewater discharges to comply with the OWTG and ship operations will adhere to Annex I of the *International Convention for the Prevention of Pollution from Ships* (MARPOL 73/78);
- use of the OCMS to screen chemicals for the Project;
- solid waste transported to shore and recycled where possible;
- adherence to DFO's Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment;
- all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently;
- operators of vessels will be instructed to reduce speed and alter coarse to avoid collision when marine mammals and sea turtles at risk are observed and on a collision course; and
- release of stranded birds as per CWS permit requirements.

HMDC acknowledges the rarity of the species at risk and will continue to exercise due caution to minimize impacts. HMDC will monitor *SARA* developments and if a new species is added that may occur in the Study Area and may potentially interact with the Project, existing mitigation measures will be reviewed to ensure that they are appropriate/sufficient. Additional mitigation will be added if required. Updates to the SARA lists are communicated to operators by DFO through CAPP and to HMDC through Imperial Oil.

6.6.5 Residual Environmental Effects Significance Criteria

The criteria to evaluate the significance threshold for adverse environmental effects to species at risk are defined as follows:

- A significant, adverse residual effect is one that, after application of all feasible mitigation and consideration of all reasonable Project alternatives, will jeopardize the achievement of selfsustaining population objectives or recovery goals; is not consistent with applicable allowable harm assessments; will result in permanent loss of critical habitat as defined in a recovery plan or an action strategy; and/or for which an incidental harm permit would not likely be issued. Due to the sensitive nature of species at risk, residual adverse effects on one individual may be considered significant.

- A non significant, adverse residual effect is one that, after application of all feasible mitigation and consideration of all reasonable Project alternatives, results in effects to individuals, residences or critical habitat of listed species that does not jeopardize the survival or recovery of the species; is consistent with applicable allowable harm assessments; does not result in permanent loss of critical habitat; and/or for which an incidental harm permit would likely be issued.

6.6.6 Environmental Effects Assessment

6.6.6.1 Effects assessment of Marine Fish Species at Risk

Potential effects from the discharge of drilling waste on marine species at risk include avoidance of the area of deposition and the smothering of potential prey for these species. These interactions occur at such a small scale compared to the remaining available habitat for marine species at risk, that the potential effects from the discharge of drilling waste are considered non-significant.

Most available literature indicates that the effects of noise on marine fish species (including those at risk) are transitory, short-lived and if outside a critical period, are expected not to translate into biological or physical effects. In most cases, it appears that behavioural effects on marine fish as a result of noise should result in negligible effects on individuals and populations. The issue of primary concern is the potential for interactions during particularly sensitive periods such as spawning. There is limited potential for marine fish species at risk to spawn within the Affected Area, so potential effects are non-significant.

Marine fish species at risk are not at risk of collision with vessels, so potential effects are non-significant.

The discharge of waste and wastewater from Project vessels, drill rig and production operations has the potential to attract marine fish species at risk. However, the potential is limited given that these species are largely benthic dwellers and the discharge occurs below the surface after maceration. All discharges of waste and wastewater are in compliance with the OWTG which are intended to reduce potential harm to the marine environment and therefore are expected to have non-significant effects on the marine fish species at risk.

The primary concern with dredging operations and its potential effects on marine fish species at risk is that the increase in turbidity in the water column can cause physiological problems for larval stages. However the limited potential for marine species at risk to spawn within the Affected Area, reduces the potential for larval stages of those species, therefore the potential for an interaction is low between these Project activities and marine species at risk. Furthermore, the effects of dredging operations are spatially and temporally limited which further lessens the probability of an interaction with marine fish species at risk, making any potential effects, non-significant.

The presence of structures introduces habitat complexity and may create a reef effect, which may attract potential prey of the wolffish and cod. However, the potential attraction of these marine species at risk may be offset by the avoidance of noise emitted during drilling and dredging activities. Lights and flares are not expected to attract marine species at risk. The presence of structure lights and flares are expected to have a non-significant effect on marine fish species at risk.

Overall, Project activities during construction, operation and decommissioning are expected to have a non-significant residual environmental effect on marine fish species at risk. Effects, where they occur are localized and short-term.

6.6.6.2 Effects assessment of Marine Mammal Species at Risk

Potential effects from the discharge of drilling waste on marine mammal species at risk are non significant given the limited potential for interaction. The pelagic food supply of the marine mammal species at risk will not be affected and the marine mammals themselves will likely avoid the area of drilling waste discharge due to the noise created by the activity.

A potential effect of Project noise on marine mammal species at risk is avoidance. Any avoidance would be temporary as construction activity does not inhibit marine mammal species at risk from returning to an area once the activity ceases (Davis et al. 1987). The implications of temporary avoidance are few as the Affected Area offers no unique habitat or feeding areas for marine mammal species at risk. Similar alternate habitats are available in the immediate area, so the normal functioning of any species of marine mammal species at risk will not be affected in any way that will substantially alter feeding or behavioral patterns. These species are opportunistic feeders and have adapted to the variability in prey abundance, so are not reliant on any single location for food.

Behavioral avoidance due to ramp-up procedures during VSP surveys would reduce the likelihood of marine mammal species at risk experiencing threshold shifts or other physical effects. Richardson et al. (1995) hypothesized that a permanent threshold shift (PTS) of marine mammal hearing would not likely occur with prolonged exposure to continuous anthropogenic sound of approximately 200 dB re 1 µPa-m. Prolonged continuous exposure to sounds of this level is not expected from this project, so PTS in marine mammal species at risk is not likely.

Noise generated from Project vessels will be at similar frequencies as those used by baleen whales for communication. Therefore, communication masking of marine mammal species at risk may occur throughout the Affected Area. The biological relevance of these effects are unknown, but animals would have to be “repeatedly disturbed during important behaviour (e.g., nursing, mating, foraging) or be permanently scared away from critical habitat” (Erbe 2003) for masking to be biologically important. If feeding efficiency is diminished as a result of masking, any effect will be temporary and of limited spatial extent. Therefore, the potential effects of noise from the Project are considered non-significant.

Large vessels traveling at more than 14 knots are the principal sources of ship strike mortalities in whales whereas serious injuries to whales are likely infrequent when vessel speeds are less than 14 knots. Under normal operations, vessels are not expected to exceed this speed within the Project area, so the potential effects are considered unlikely and non-significant.

Marine mammals may avoid the area of dredging or disposal due to noise or if the habitat quality becomes unsuitable due to turbidity. Neither the Project Area nor the dredge and disposal areas are known to be of any more significance in terms of habitat or feeding areas for mammals than other areas of the Grand Banks. Given the temporary nature of the disturbance, any effects from dredging and disposal on marine mammals are considered non-significant.

The environmental effect of waste and wastewater from the construction, operation and abandonment phases of this Project on marine mammal species at risk is considered non-significant.

The potential interaction between the presence of structures, lights and flares and marine mammal species at risk is limited. The structures are not expected to present any physical obstruction since mammals and turtles will avoid collision with stationary structures. Since there is some potential for mammal prey congregation around physical structures due to the reef effect, there is potential for mammals to feed near these structures. However, the scale of the potential attraction is so small, compared to the available feeding area for mammals, the potential effects are considered non-significant.

Overall, Project activities during construction, operation and decommissioning are considered to have a non-significant residual environmental effect on marine mammal species at risk. Effects, should they occur, will be short-term and localized.

6.6.6.3 Effects Assessment of Sea Turtle Species at Risk

There is limited potential for interaction between sea turtle species at risk and the discharge of drilling waste. The primary food supply of the sea turtle species at risk will not be affected, and the sea turtles themselves will likely avoid the area of drilling waste discharge due to the noise created by the activity. Potential effects from the discharge of drilling waste on sea turtles species at risk are considered non-significant.

Sea turtles are likely to avoid underwater noise (McCauley et al. 2000), which means they may be temporarily deterred from entering the Affected Area. Avoidance is not expected to affect them biologically however, as the Affected Area is not considered a feeding ground for sea turtles, although their primary prey, the jellyfish, may occur there. Jellyfish are transitory, with distributions changing within and between years, so there is no more reason to expect jellyfish within the Affected Area than any other area of the Grand Banks.

Avoidance in fact may reduce the risk of potential physiological effects of noise exposure. Sea turtles are not believed to use hearing for prey detection or navigation, therefore, masking is unlikely to be an important issue for sea turtles exposed to pulsed sounds. Therefore, the potential effects of noise from the Project on sea turtles are considered non-significant

The risk of a vessel collision with a sea turtle species at risk is reduced when vessel speeds are less than 14 knots. Under normal operations, vessels are not expected to exceed this speed within the Project area, so the potential effects are considered non-significant.

Sea turtles may avoid the area of dredging or disposal, due to noise or if the habitat quality becomes unsuitable due to turbidity. Neither the Project Area nor the dredge and disposal areas are known to be of any more significance in terms of habitat or feeding areas for mammals or turtles than other areas of the Grand Banks. Given the temporary nature of the disturbance, any effects from dredging and disposal on marine mammals are expected to be non-significant.

The environmental effect of waste and wastewater from the construction, operation and abandonment phases of this Project on sea turtles species at risk is considered non-significant.

The potential interaction between the presence of structures, lights and flares and sea turtle species at risk is limited since they are more likely to be deterred by the noise from Project activities.

Overall, Project activities during construction, operation and decommissioning are considered to have a non-significant residual adverse effect on sea turtle species at risk. Effects, should they occur, will be short-term and localized.

6.6.6.4 Effects Assessment of Marine Bird Species at Risk

Ivory Gulls are not anticipated to interact with disposal of drilling waste, noise from the Project or vessel collisions.

Given the limited potential for temporal overlap, the effects of dredging and disposal activities from this Project on the Ivory Gull are considered non significant.

The discharge of waste and wastewater will be conducted in compliance with the OWTG and Ivory gulls are considered to be rare in the Project Area. The discharge of waste and wastewater is considered non-significant.

Ivory Gulls are not expected to be attracted to structures by any increase in prey availability and there are no reports of Ivory Gulls being attracted by lights and flares; their residual environmental effects are therefore considered non significant.

6.6.6.5 Abandonment

The disturbance associated with decommissioning and abandonment activities (primarily associated with noise generated during removal of the wellhead and other infrastructure) will be of short duration and will mostly occur directly at the wellsite. The activities required for abandonment will comply with applicable regulations of the day. The likely residual adverse environmental effects of decommissioning and abandonment on Species at Risk are considered non significant.

6.6.7 Follow-up

The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate.

Pursuant to the OWTG, compliance monitoring all effluent discharges will be conducted.

A fish habitat compensation monitoring program will also be implemented to ensure no net loss of productive capacity in marine habitat as a result of this Project.

6.6.8 Summary of Residual Environmental Effects

Potential adverse environmental effects from routine Project activities on species at risk will be unlikely because of planned monitoring and mitigation measures. In addition, species at risk are expected to show some avoidance of the area of highest received levels of seismic sounds. Therefore, there is not likely to be a significant residual adverse environment effect on species at risk. The construction, operation and decommissioning of the Project is therefore not expected to contravene the prohibitions of *SARA* (Sections 32 (1), 33, 58(1)).

A summary of residual environmental effects is provided in Table 6.8.

Table 6.8 Summary of Environmental Assessment for Species at Risk

Interactions	
♦ effects associated with discharge of drill mud and cuttings; ♦ effects of noise from all routine activities; ♦ collisions with vessels; ♦ effects associated with the discharge of waste and wastewater; ♦ effects associated with dredging and ocean disposal; and ♦ effects associated with the presence of structures, lights and flares.	
Mitigation	
♦ use of water-based drilling muds wherever possible; ♦ use of non-toxic or low toxicity chemicals and muds, and treating synthetic oil-contaminated cuttings as per the OWTG; ♦ all wastewater discharges to comply with the OWTG (NEB et al. 2002) and ship operations will adhere to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78);use of the OCMS to screen chemicals for the Project; ♦ solid waste transported to shore and recycled where possible; ♦ adherence to DFO's Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment; ♦ all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently; ♦ operators of vessels will be instructed to reduce speed and alter coarse to avoid collision when marine mammals and sea turtles at risk are observed and on a collision course; and ♦ release of stranded seabirds as per the CWS seabird handling permit.	
Significance	
Likelihood of occurrence	Will occur
Geographic extent	• Drilling muds and cuttings: < 1km • Noise: < 10 km • Waste and wastewater: < 1km • Dredging and disposal: <10 km • Presence of structures and lights: <1 km
Frequency of occurrence (over 27 years or longer)	• Drilling muds and cutting: 1- 3 wells per year; • Noise: 1-3 wells per year; 1-2 glory holes per year; 1 VSP survey per well; one geohazards survey per drill centre; 1-2 mainifolds per drill centre; • Waste and wastewater: continuous during each well, glory hole and subsea installation; valve control fluid venting approx 15 times per well per year. • Dredging and disposal: 1-2 glory holes per year; and • Presence of structures and lights: continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment, for the life of the project. .
Duration of impact (over 27 years or longer)	• Drilling muds and cutting: 128 days each, up to 66 wells in total; • Noise: drilling - 128 days each, up to 66 wells in total; glory hole - 45 days each, up to 6 in total; 1 VSP survey per well, 1-3 days each; 1 geohazards survey per glory hole; 1-2 manifolds per drill centre, 30-40 days each; • Waste and wastewater: continuous during each well, glory hole and subsea installation; • Dredging and disposal: 45 days per year, up to 6 glory holes; • Presence of structures and lights: continuous during drilling and dredging operations (128 and 45 days, respectively). Subsea equipment, for the life of the project.
Magnitude of impact	Low (avoidance will be temporary, localized and of little biological consequence; physical effects are unlikely)
Permanence/reversibility	Reversible
Significance	**Non significant**
Confidence	High
Follow-up and monitoring	
▪ The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate. ▪ Pursuant to the OWTG, compliance monitoring all effluent discharges will be conducted. ▪ A habitat compensation monitoring program will also be implemented to ensure no net loss of productive capacity in habitat as a result of this Project.	

7.0 CUMULATIVE EFFECTS

Section 16(1)(a) of the *CEA Act* requires that the factors to be considered in an assessment of the "cumulative environmental effects that are likely to result from the project in combination with other projects or activities that have been or will be carried out". Cumulative effects analysis is based on residual effects that are predicted to remain after implementation of the mitigation measures (i.e., post-mitigation). A critical step in any EA is determining what other projects or activities are likely to proceed and therefore included as required by the *CEA Act* in the cumulative effects assessment.

It is helpful to consider the clarification provided by the Joint Review Panel for the Express Pipeline Project in Alberta. Following an analysis of subsection 16(1)(a) of *CEA Act*, the Joint Review Panel determined that certain requirements must be met for the Panel to consider cumulative environmental effects:

- there must be a measurable environmental effect of the project being proposed;
- environmental effects from the project must be demonstrated to interact cumulatively with the environmental effects from other projects or activities; and
- it must be known that the other projects or activities have been, or will be, carried out and are not hypothetical (NEB and CEA Agency 1996).

Furthermore, the Joint Review Panel indicated that it is an additional requirement that the cumulative environmental effect is likely to occur, that is, there must be some probability, rather than a mere possibility, that the cumulative environmental effect will occur. These criteria were used to guide the assessment of cumulative environmental effects of this proposed Project.

For the purposes of the assessment, it is assumed that the existing status or condition of each VEC reflects the influence of other past and current projects and activities occurring within or outside of the Study Area. This includes the other existing offshore development projects, including the operation of the Hibernia platform. The assessment has therefore integrated the cumulative effects of these past and present projects and activities. This section focuses on the effects of on-going and other future projects and activities, as considered and assessed for each VEC. The method used in assessing cumulative effects for this Project follows current practice and is consistent with the *CEA Act* and informed by the assessment framework presented in the *Cumulative Effects Assessment Practitioners Guide* (CEA Agency 1999). The CEA Agency suggests that relevant environmental standards, guidelines, and objectives should be helpful in determining significance of cumulative environmental effects.

7.1 Other On-going and Future Activities

On-going and future activities that have the potential to interact cumulatively with the Project have been identified in the Project Scoping Document (Appendix A) and include:

- Ongoing oil and gas activities;
- Proposed oil and gas activities under EA review (listed on the C-NLOPB Public registry at www.cnlopb.nl.ca);
- Seismic activities;

- Fishing activities, including Aboriginal fisheries; and
- Marine transportation.

Figure 7.1 describes the location of some of these activities in relation to the proposed Project. Each of these activities are described in more detail below.

7.1.1 On-Going and Future Oil and Gas Activities (including Seismic Activities)

The mandate of the C-NLOPB is to interpret and apply the provisions of the Atlantic Accord and the Atlantic Accord Implementation Acts to all activities of operators in the Newfoundland and Labrador Offshore Area, and, to oversee operator compliance with those statutory provisions. In the implementation of its mandate, the role of the C-NLOPB is to facilitate the exploration for and development of the hydrocarbon resources in the Newfoundland and Labrador Offshore Area in a manner that conforms to the statutory provisions for:

- worker safety;
- environmental protection and safety;
- effective management of land tenure;
- maximum hydrocarbon recovery and value; and,
- Canada/Newfoundland & Labrador benefits.

While the legislation does not prioritize these mandates, worker safety and environmental protection will be paramount in all Board decisions (C-NLOPB website accessed October 2008). Therefore, it can be assumed that all on-going and future oil and gas activities will be subject to the same high safety and environmental standards as the Project being assessed.

The proposed or on-going oil and gas activities that have the potential to interact with the proposed Project and result in cumulative effects on Project VECs are provided in the following list and further described in the text below:

- The Terra Nova Project, located 350 kilometres east-southeast of St. John's, Newfoundland and Labrador. The field, located in the Jeanne d'Arc Basin consists of one reservoir: the Jeanne d'Arc. The field is being produced with a Floating, Production, Storage and Off-Loading vessel (FPSO) and is operated by Petro-Canada;
- The Hibernia Project, located in the Jeanne d'Arc Basin, consists of two principal reservoirs: the Hibernia and Ben Nevis-Avalon reservoirs. The Hibernia field is being produced using a GBS operated by HMDC;
- The White Rose Project located on the northeastern margin of the Jeanne d'Arc Basin, has one principal reservoir: the Ben Nevis-Avalon reservoir. The field is being produced with a FPSO and is operated by Husky Oil,
- StatoilHydro's proposal to drill a maximum of 27 single and/or dual side-track wells between 2008 and 2016;
- StatoilHydro's proposed 2-D, 3-D and potentially 4-D seismic program;

Figure 7.1 Jeanne d'Arc Basin Lease Areas

Source NOIA East Coast Map 2008.

- StatoilHydro/Husky's proposed exploration/delineation drilling program for the SDL 1040;
- Husky's proposal to develop four new drill centres at White Rose;
- Husky's proposed exploration/delineation drilling program;
- Husky's proposed 3-D seismic surveys and geohazard surveys of their offshore acreage in Jeanne d'Arc Basin;
- Petro-Canada's proposal to conduct a three-dimensional seismic program in the Jeanne d'Arc Basin;
- Petro-Canada's proposed VSP program in the Terra Nova field; and
- future Hebron Development Activities.

Exploration activity on the Grand Banks began in 1966 with Tors Cove D-52 exploration well. Exploration drilling continued throughout the late 1960s and 1970s and between 1966 and the discovery of Hibernia in 1979, a total of 40 exploration wells were drilled on the Grand Banks. Following the discovery of Hibernia and prior to the first production well in 1997, an additional 64 exploration and delineation wells were drilled. Included among these wells were the discovery of Hebron, Terra Nova and White Rose. To date, a total of 265 exploration, delineation and development/production wells have been drilled on the Grand Banks, including 96 exploration wells, 38 delineation wells, and 131 development/production wells. There are currently 45 Significant Discovery Licences (SDLs) and 26 Exploration Licences (ELs) active in the Grand Banks area of the Newfoundland and Labrador offshore. Seismic activity on the Grand Banks began in 1964, with total of 9195 km of data collected that year. Since then a total of 336,624 km of 2D seismic data and 919,618 CMP KM of 3D seismic data has been collected on the Grand Banks

After a lull of exploration activity in the early 2000s, there has been a slight increase in activity. In addition to ongoing development drilling at the White Rose field, additional delineation of the field is currently underway. Additionally, on August 20, 2008 an agreement was signed for the development of Hebron, which will result in additional drilling activity within the next six to ten years. Additional exploration drilling is also planned within the Orphan Basin, with at least one well planned for the 2008/2009 drilling season. StatoilHydro Canada E&P Inc, Husky Energy, and Petro-Canada have submitted Environmental Assessments related to seismic programs in the Jeanne D'Arc Basin while both StatoilHydro and Husky Energy have submitted additional Environmental Assessments for exploration activity in the Basin. These activities are planned for 2008-2017.

Given the timeframe of the proposed Project and the general level of activity on the Grand Banks, it is likely that Project activities will continue to interact with oil and gas exploration and production activities throughout the life of the Project. The actual potential for cumulative effects associated with drilling exploration and production activities will be based on a variety of factors, including but not necessarily limited to the location of the exploration and/or production activities, number, type and durations of seismic surveys; number, type and duration of exploratory and/or production drilling activities; type of exploration and/or production platform and other factors intrinsic to the region.

7.1.2 Commercial and Aboriginal Fisheries

For this assessment, commercial fisheries have been included as a VEC as it is a valued socio-economic activity/resource that has the potential to be adversely affected by the proposed Project (see assessment in Section 6.3). It has also been scoped into the cumulative assessment as both a VEC and as an on-going and future activity that has the potential to contribute to cumulative effects on other biological resources including marine fish habitat, marine fish and shellfish, marine birds, marine mammals and species at risk.

The proposed Project lies within the NAFO fisheries management areas 3Lt. Although the Grand Banks has traditionally been commercially exploited for various fish species, there has been little commercial exploitation within the Project Area since the implementation of the groundfish moratorium. There are no aboriginal fisheries within the Project Area and as such will not be further discussed. The Study Area may serve as routing for commercial vessels to and from Newfoundland and Labrador ports to currently commercially exploited areas. There may in the future be increased commercial exploitation within or near Project and Study Areas should groundfish and other stocks rebound to a commercially sustainable level. Current fishery activity employing mobile gear (trawls) is conducted in the northeast portion of the 3Lt beyond the 200 m isobaths (primarily for shrimp). See Section 4.2 for a further description of existing commercial fisheries activities within the Project and Study Area.

7.1.3 Marine Transportation and Vessel Traffic

Marine transportation activity in the vicinity of the Project involves vessels travelling to, from ports, and to other ports in the province and vessels that are travelling through the zone to and from ports internationally, accessing the St. Lawrence Seaway and as a route to the Canadian High Arctic. Marine transportation is a year round activity. The Canadian Coast Guard operates Marine Communications and Traffic Services centre in St. John's, Newfoundland and Labrador that monitors in excess of 8,900 vessel movements on the east coast of the province. In addition, it processes in excess of 5,400 movements or requests from vessels intending to enter, leave, or proceed within Canadian waters. Vessels are governed by the *Canada Shipping Act* and *Regulations*, the *Marine Transportation and Security Act* and *Regulations*, the *Oceans Act*, the *Canada Marine Act* and *Regulations*, the *Pilotage Act* and *Regulations* and the *Coasting Trade Act*.

7.2 Cumulative Effects Assessment

The VECs identified for the environmental assessment of this Project are also considered appropriate for the cumulative effects assessment, as are the significance criteria previously identified. The assessment boundaries described in Section 5.6.1 for the various VECs are also considered appropriate for the cumulative effects assessment, although it is acknowledged that for migratory species or species with widespread distributions such as marine birds, marine mammals and marine turtles, there is potential for anthropogenic activities outside of the Project Areas and the Study Area to contribute to cumulative effects on these species. These issues are discussed as appropriate.

7.2.1 Marine Fish Habitat

Cumulative effects on Marine Fish Habitat could occur as a result of the proposed Project in combination with oil and gas activities (which can contribute to physical disturbance, contamination and smothering of benthic organisms and noise effects), commercial fisheries (which can contribute to physical disturbance and noise effects) and marine transportation (which can contribute to contamination and noise effects).

Drilling of exploratory and development wells, placing platforms and constructing pipelines, discharging muds and cuttings are all activities which have and will continue to impact marine fish habitat. The primary concern associated with the routine activities of production (and exploration) drilling relates to the deposition of drilling mud and cuttings on the seafloor around a well. For assessment purposes, it is assumed that the proposed Project could have a maximum of six drill centres each supporting up to 11 wells, resulting in the worst case scenario of 8.8 km^2 of seabed covered by a minimum of 1 cm of drill mud and cuttings (refer to Section 2.7.1.1 for more detail on mud and cuttings deposition). This assumes that there would be little or no overlap of mud and cuttings deposition for each well drilled from a glory hole. Such is most likely not to be the case and as the cumulative effected area of 8.8 km^2 is an overestimation. This cumulative area represents less than 1% of the Project Area.

It has been shown through environmental effects monitoring and compliance monitoring of the facilities offshore Newfoundland that mitigation measures being implemented by offshore operators with respect to marine fish habitat have been effective. It is generally accepted that the biological zone of influence from cuttings deposition is confined to within 500 m of the well (Hurley and Ellis 2004; Neff 2005). The changes to marine fish habitat as measured by benthic community changes have been primarily attributed to physical alterations in sediment texture, including smothering as opposed to toxic effects (Hurley and Ellis 2004). The effects and area affected will be influenced by environmental variables such as depth, current, wave regimes and substrate type, as well as the nature and volume of the discharges, including cuttings size and location of outfall within the water column. The data from current Canadian EEM programs suggest that benthic community change can be detected within 1000 m of the drill site with some habitat types and more sensitive species affected over greater distances, particularly along the axis of predominant current.

Studies have found that effects of drill mud and cuttings deposition in the area immediately adjacent to a well lessen considerably 1 to 2 years after drilling cessation (Kingston 1987; Gray et al 1990). Fish habitat, as measured by changes in benthic community structure around single exploration wells, returned to baseline conditions within one year after cessation of drilling (Hurley and Ellis 2004). At Hibernia, partial reinjection of SBM drill cuttings commenced in March 2000; when two drill rigs and a production facility were in operation (partial meaning the reinjection of coarse cuttings occurred while fine cuttings continued to be discharged). Full reinjection capacity was established in September 2002. In the 2002 EEM field study, which was conducted before full reinjection capacity was established, a substantial reduction in hydrocarbon concentrations in sediment was observed. The concentration of hydrocarbons was comparable to levels found in 1998 and concentrations of barium were comparable to 1999 levels; 1998 and 1999 concentration levels reflected 1 and 2 years of drilling and production operations respectively. Therefore, the biological effects of drilling are considered reversible.

There are currently three production facilities (Hibernia, White Rose and Terra Nova) as well as StatoilHydro’s proposal to drill a maximum of 27 single and/or dual side-track wells between 2008 and 2016, StatoilHydro/Husky’s proposed exploration/delineation drilling program for the SDL 1040, Husky’s proposal to develop four new drill centres at White Rose, Husky’s proposed exploration/delineation drilling program, future Hebron project activities and the proposed Project that have the potential to produce cumulative effects with respect to drill mud and cuttings deposition. While it is acknowledged that each production or exploration well is contributing to a cumulative impact on marine fish habitat, each of these projects is impacting a localized area and the effects are reversible. Each of these projects is also required to comply with the OWTG and related monitoring requirements.

For the assessment of StatoilHydro Canada Ltd’s proposed drilling program, LGL (2008b) calculated that between 2008 and 2017, as many as 45 exploration and appraisal/delineation wells could be drilled; 27 by StatoilHydro and 18 by Husky. They calculated the total area of seabed potentially covered by at least one centimetre of mud and cuttings to be approximately 45 x 0.8 km^2 or 36 km^2 (~ 0.034% of Project Area). The addition of the affected areas associated with Hibernia, Terra Nova and White Rose to the 36 km^2 calculated for all 45 wells does not account for a substantially greater proportion of the project area. They also determined that if a maximum of 54 wells is considered for the drilling phase of the Husky White Rose Development Project: New Drill Centre Construction and Operations Program, the total area potentially affected by drill mud and cuttings deposition without consideration of well ZOI overlap is 54 x 0.8 km^2 or 43.2 km^2. This area added to the 36 km^2 calculated above represents approximately 0.07% of the Project Area.

Currently the closest drill mud and cuttings deposition to the proposed Project is the Hibernia drilling and production platform (approximately 6.25 kms away) which releases WBM and cuttings only. Since 2002, greater than 95 percent of SBM cuttings generated on the GBS have been re-injected. The distance is such that there is expected to be little or no overlap in cumulative effects associated with drill mud and cuttings disposition based on currently know activities.

Given the distance of the proposed Project from any potential production and exploration drilling programs and current production programs and given that the predicted environmental effects on marine habitat are localized and reversible (with a high degree of confidence), the likely cumulative effects on marine habitat will be not significant.

While the proposed Project will result in impacts to marine benthos in the immediate vicinity of the well sites, this disturbance is reversible and localized. Assuming that all six drill centers are developed using a maximum of eleven wells each and using the conservative assumption that there is no overlap of deposition piles for wells within each glory hole, the total benthic area that could be affected would be 8.8 km^2. This is a relatively small area in comparison to fishing effort on the Grand Banks and is therefore not considered to contribute significantly to any cumulative effect.

All discharges from the proposed Project will be in compliance with the OWTG and any production discharges will be consistent with the level and nature currently associated with the Hibernia project. As general marine vessel discharges are also regulated, it is not predicted that any cumulative significant effects on marine fish habitat would result from the Project in combination with on-going or future marine transportation.

In summary, the Project in combination with other on-going and future projects and activities are not predicted to result in any significant adverse cumulative effects on marine fish habitat. No additional mitigation or follow-up, beyond that identified in Section 6.1.7 is considered necessary.

7.2.2 Marine Fish and Shellfish

Marine exploration, commercial fishery activity, marine transportation and existing production activity (e.g., White Rose, Hibernia, and Terra Nova) all have the potential to interact with fish and shellfish.

It is unlikely that routine activities associated with other marine exploration, marine transportation and existing production areas have much adverse direct impact on marine invertebrates and fish. While commercial fisheries can have an impact on marine invertebrates and fish, the current level of commercial exploitation within the Project Area is limited and DFO's fisheries management is intended to keep populations at sustainable levels.

Given that the predicted environmental effect of the proposed Project is not-significant and given that other oil and gas activities in the Project Area are likely to have similar effects on fish populations and given the limited nature of commercial fishing in the area, the cumulative effects of the Project on marine fish and shellfish are predicted to be non-significant. No additional mitigation or follow-up, beyond that identified in Section 6.2.7 is considered necessary.

7.2.3 Commercial Fisheries

As stated earlier, commercial fishing activity within the Project Area is limited. This is due to the limited biological availability of resources within the Project Area (largely associated with the cod moratorium), rather than existing oil and gas activity. While the Safety Zones to be established in association with the proposed Project will contribute to the fishery exclusion zones in the Project Area, only a small portion of potentially available fishing grounds for commercial exploitation are currently affected by the presence of oil and gas structures and support vessels. The implementation of a 500 m safety zone around the drill centres (approximately 4.7 km^2 if all six drill centres are constructed and in operation at the same time) and around the drill centre structures represents a small percent of the available area for commercial exploitation. Given the low abundance of target species, fishing activity in alternative locales adjacent to the exclusion zones could be used and as such the Project is not expected to represent an economic hardship to commercial fisheries. In addition, the Project would fall under Hibernia's existing policies with respect to compensation for any gear loss or damage.

Based on the above, the cumulative effects of the proposed Project in combination with other on-going and likely future projects on commercial fisheries are predicted to be non-significant. No additional mitigation or follow-up, beyond that identified in Section 6.3.7 is considered necessary.

7.2.4 Marine Mammals

Marine mammals may be vulnerable to cumulative effects from the Project in combination with marine transportation, commercial fishing and other oil and gas activities. The main effects of the Project on marine mammals are associated with noise disturbances, potential for injury and mortality due to vessel collisions and contamination or change in distribution of food source.

Routine offshore oil and gas activities that can affect marine mammals at risk include geophysical surveys, construction, and drilling and production activities. As discussed in previous sections, the major effects from these activities are noise and disturbance. While other seismic programs may occur in the Project Area, along with other drilling programs, geophysical (seismic, including 2-D, 3-D and VSP) activities will not overlap spatially, as this may interfere with data collection. It is possible that geophysical activities could overlap temporally (with appropriate distances between geophysical locations) as well, they may occur sequentially. Given the localized nature of the surveys associated with this Project, the zone of influence is spatially limited. In addition, all surveys conducted within the Project Area would be required to comply with both DFO's Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment and the C-NLOPB *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2008a), thereby reducing the potential for cumulative effects from this activity.

Marine mammal reaction to construction is likely temporary avoidance behaviour. Richardson *et al.* (1995) predicted a radius response to noise during development and production activities for baleen and odontocetes to be less than 100 m. Vessel traffic associated with the proposed Project would contribute to only a slight increase over current levels. No cumulative effects are expected with helicopter traffic due to the localized and temporary disturbance.

Marine mammals may be vulnerable to vessel collisions. Most marine mammal-vessel collisions occur near the surface where acoustical reflection and propagation can limit the ability of marine mammals to hear and locate approaching vessels (Gerstein et al. 2005). Injuries on stranded ship-struck marine mammals suggest that large vessels are the principal source of injury with most marine mammals not observed prior to the collision or at the last moment. Limited data suggest that vessels speeds below 26 km/hr (14 knots) may be beneficial in reducing marine mammal vessel collisions (Laist et al. 2001). The typical speed of vessels within the Project Area may assist in the avoidance of marine mammal collisions.

Based on the speed of the vessel movement associated with offshore activities and the limited incremental number of vessels associated with the Project, the predicted cumulative adverse effect on marine mammals is not significant. No additional mitigation or follow-up, beyond that identified in Section 6.4.7 is considered necessary.

7.2.5 Marine Birds

Marine bird distribution and abundance may be influenced by natural processes such as weather, food availability, and oceanographic variation, as well as by human activities such as fishing, vessel traffic, oil and gas exploration and production activities and pollution. Potential effects include disturbance from noise, the potential for attraction of birds to lights and resulting strandings, and potential contamination of prey or oiling of feathers as a result of oily vessel discharges. Seabirds may also be affected by projects and activities that occur outside the Project Area, but within their migratory ranges. As well, changes in prey and predator populations may affect marine bird populations.

Storm-petrels and other night flying birds could be attracted to vessel and platform lighting or flares, which could potentially result in disorientation (Wiese et al. 2001) and collision with the vessel lights, flares or infrastructure. Attraction could also result in continuous circling around the lights, using energy and delaying foraging or migration or being burned in flares (Wiese et al. 2001). Vessel lighting is essential since operations occur on a 24-hour basis and flaring should be limited to a short period during well testing.

However, with proper mitigation measures in place, most petrels can be released in good condition and are assumed to have survived stranding. Percentages of stranded Leach’s Storm-Petrels released and believed to survive based on data collected during the October-November 2005 and July-August 2006 Husky seismic programs in the Jeanne d’Arc Basin, were 69 percent (74 of 107) and 55 percent (6 of 11), respectively (Abgrall et al. 2007).

Lights from the proposed Project are not expected to act cumulatively with other offshore structures as the closest activity is about 6.25 km away from the HSE drill centre. As well, during production, all project infrastructure will be subsea, resulting in only the existing level of lighting at the Hibernia Platform and associated supply vessels. Designated personnel on the MODU, marine vessels or surveys vessels will handle stranded birds in accordance with requirements of CWS seabird handling permits.

Vessel traffic may affect marine birds through vessel lighting, oily discharges and noise. Chronic routine discharges, such as deck drainage and ballast and accidental releases of hydrocarbons, can expose seabirds to oil. Chronic releases may be equally or more important to long-term population dynamics of seabirds. All routine drilling platform discharges and supply vessel discharges will comply with the OWTG.

The proposed Project will temporally increase vessel traffic in the area, particularly during the construction phase. However as indicated above, the current numbers of vessel traffic (marine transportation, vessels related to offshore activities and commercial fisheries) traveling through the area is of such a volume that the addition of several vessels will not contribute significantly to the level of traffic. In addition, the level of vessel traffic associated with the production stage of the proposed Project is consistent with the current levels for the Hibernia project.

Given that the Project will result in only limited increases in vessel traffic, all Project discharges will comply with the OWTG and the Project is located far enough from other offshore structures to avoid cumulative effects with respect to attraction to lighting, the cumulative environmental effects of Project activities in combination with other on-going and future projects on Marine Birds within the Project Area are considered non significant. No additional mitigation or follow-up, beyond that identified in Section 6.5.7 is considered necessary.

7.2.6 Species at Risk

The marine mammal species at risk with the most potential to occur within the Affected Area are harbour porpoise, fin whales, blue whales and right whales. In addition, the leatherback sea turtle has some potential to occur within the Affected Area. The marine fish species at risk with the most potential to occur within the Affected Area are Atlantic cod, northern wolffish, spotted wolffish, and Atlantic wolfish. The Ivory Gull is the only marine bird species at risk having potential to occur within the Affected Area.

The potential for cumulative effects on these species is essentially the same as the potential cumulative effects on non-listed species, although it is acknowledged that due to the status of these populations, they may be more vulnerable to even limited Project effects compared to more stable populations. In general, the proposed Project's contribution to any cumulative effects is limited in comparison to the influences on these species throughout their range that have caused these species to reach their current population levels.

Marine mammal species at risk may be vulnerable to cumulative impacts from on-going and proposed oil and gas activities, tankering, commercial fishing, and shipping.

Routine offshore oil and gas activities that can affect marine mammals at risk include geophysical surveys, construction, and drilling and production activities. As discussed in previous sections, the major effects from these activities are noise and disturbance. As described above, all operators are required to comply with both DFO's *Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment*, thereby reducing the potential for cumulative effects from this activity. In addition, the seismic activities of the proposed Project will be localized and short-term (2-3 days) as compared to a 2-D or 3-D program.

Marine mammal reaction to construction is likely temporary avoidance behaviour. Richardson *et al.* (1995) predicted a radius response to noise during development and production activities for baleen and odontocetes to be less than 100 m. Collisions between support vessels and marine mammals at risk are not likely given the vessel speeds within the Project Area. No cumulative effects are expected with helicopter traffic due to the localized and temporary disturbance. The overall potential for cumulative effects of these projects and activities on marine mammal species at risk is considered non significant.

Potential sources of cumulative impacts for sea turtles at risk within the regional area include on-going and proposed oil and gas activities, tankering, commercial fishing, and shipping.

Routine offshore oil and gas activities that may result in impact to sea turtles include geophysical surveys, construction, drilling and production activities with associated support activities and the abandonment of wells. The major impact factors expected from these activities are noise and disturbance. Few studies have been undertaken on the effects of anthropogenic noise on sea turtles, however, it is assumed that noise from the various offshore sources could result in temporary disturbance to individuals. Although the effects of noise from this Project are not expected to be significant, it will add noise that sea turtles are exposed to within the Study Area. Sea turtles densities are low in the Project Area. There is no evidence to suggest that oil and gas activities and increased support vessel traffic result in adverse significant effects to sea turtles populations. Based on the effects criteria, the disturbance effects are considered non-significant and not to add measurably to cumulative impacts on sea turtles.

In offshore Newfoundland waters, leatherback turtles feeding in the area may be affected by entanglement in and ingestion of debris. Entanglements in fishing lines, lobster pot lines, nets and other fishing gear have been reported. Sea turtles either ingest baited hooks or become entangled or hooked externally or both (Witzell 1999; Smith 2001). There is no known directed take of sea turtles in Canadian waters. The take of sea turtles at sea or on nesting beaches in other areas is seen as a threat to all species of sea turtles.

For marine fish species at risk, overfishing, habitat degradation, pollution and natural variability of the population have caused adverse effects. Fishing pressure and subsequent bottom dragging techniques are significant stresses on some fish resources. Cod are designated endangered due to overfishing. Fishing pressures are expected to remain high to meet market demands which continue the decline or lack of recovery in some fish stocks. Bottom dragging fish gear impacts fish habitat by removing plants, corals, sessile food items, overturning rocks, leveling rock outcrops and re-suspending sediments, ultimately homogenizing the habitat. The proposed Project will represent a negligible incremental increase to the overall cumulative effects to fish species at risk as the impact to the seafloor will be localized, of short duration, and any affects on habitat are not expected to overlap between projects. Cumulative effects on marine fish species at risk are therefore considered non significant.

With respect to marine bird species at risk, the main projects and activities that would potentially result in cumulative effects include other oil and gas activities, tankering, shipping and commercial shipping. Effects of seismic activities on marine birds were considered to be negligible therefore, no significant cumulative adverse effects are predicted with respect to a spatial overlap of seismic programs within the Affected Area. As described above, the Project is a sufficient distance from other platforms in the region to not have a cumulative effect with respect to attraction of birds to lights and flares.

It is estimated that 300,000 seabirds die annually on Canada's east coast (*i.e.,* Grand Banks and Scotian Shelf). Any cumulative effects of oiling from illegal bilge pumping and chronic spills as a result of other vessel activities would be additive and density dependent. HMDC will manage operations responsibly to minimize the probability of Project-related spills and, in the unlikely event of a spill, implement appropriate spill response measures in an attempt to minimize effects.

In summary, the Project is not predicted to result in significant adverse cumulative effects on any of the species at risk that occur in the Affected Area. No additional mitigation or follow-up, beyond that identified in Section 6.6.7 is considered necessary.

8.0 ACCIDENTAL EVENTS

The primary accidental event associated with the proposed Project having environmental consequences of concern is the unintentional release of hydrocarbons either during development drilling or production operations. The hydrocarbon products subject to accidental release include crude oil, diesel oil, synthetic drilling mud, synthetic drill (base) fluid, lubricating oils and hydraulic oils. The main event of concern that can result in a hydrocarbon spill is a loss of well control (blow-out). Hydrocarbon spills may also occur as a result of human error or equipment failure during loading/unloading, storage tank overflows, hydraulic system failures, drains system faliures and others. An oil spill could occur at any time during the Project.

This chapter discusses the type and probability of spills (blowout (surface and subsea) and batch), oil spill trajectory on water and the potential environmental effects of an accidental event on each of the VECs.

8.1 Historical Data on Oil Spills

Oil spills are categorized as extremely large (greater than 150,000 barrels or 23,850 m^3), very large (greater than 10,000 barrels or 1,599 m^3), large (greater than 1,000 barrels or 159 m^3), medium (50 to 999 barrels or 7.95 to 158.9 m^3) and small (1 to 49 barrels or 0.16 to 7.94 m^3). It should be noted that the extremely large, very large and large categories are cumulative, with very large spills including extremely large spills and large spills including very large and extremely large spills. The primary source of large amounts of oil being accidently released into the environment is blowouts.

8.1.1 Extremely Large, Very Large and Large Oil Spills

Five extremely large oil spills (> 150 kbbls) have occurred in the history of oil and gas exploration and production, one during exploration drilling, two during development drilling and two during production operations (Table 8.1). The largest oil spill recorded during drilling activities was a result of procedures not practiced in Canadian (or US) waters and contrary to accepted international industrial practices. Only two extremely large spills have occurred during the drilling of 75,000 development wells (2/75,000), resulting in a spill frequency of 2.66 x 10^{-5} spills per development well drilled. Thirteen very large spills (> 10 kbbls) have been recorded during the history of oil and gas exploration and production (Table 8.1). Only four very large spills have occurred during the drilling of 75,000 development wells (4/75,000), resulting in a spill frequency of 5.33 x 10^{-5} spills per development well drilled.

Historical information on large spills is lacking, with no blowout spills of this size occurring in the US Gulf of Mexico Outer Continental Shelf since 1972 (Table 8.2). It could be assumed that large spills are occurring with more regularity than a very large spill, however, only one large spill from a blowout occurred worldwide between 1994 to 1999 (years for which data are available (Oil Spill Intelligence Report, in LGL 2007a). This results in a 5.0 x 10^{-5} spills per exploration and development well drilled (based on an estimated 20,000 wells drilled from 1994 to 1999). Because of incompleteness of data and uncertainties associated with the database, large spills are not considered further in this environmental assessment.

Table 8.1 Historical Extremely Large (>150,000 barrels) and Very Large (>10,000 barrel) Oil Spills from Offshore Blowouts, 1970 to Present

Area	Date	Spill Size (bbl (L))	Type of Operation
Santa Barbara, USA	1969	77,000 (12,242,000)	Production
S. Timbalier 26, USA	1970	53,000 (8,426,300)	?
Main Pass 41, USA	1970	30,000 (4,769,600)	Production
Trinidad	1973	10,000 (317,974,600)	Development Drilling
Dubai	1973	2,000,000 (1,589,900)	Development Drilling
North Sea/Norway	1977	158,000 (25,120,000)	Work-over
Mexico (*Ixtoc 1*)	1979	3,000,000 (476,961,900)	Exploratory Drilling
Saudi Arabia	1980	60,000 (9,539,200)	Exploratory Drilling
Nigeria	1980	200,000 (31,797,500)	Development Drilling
Iran	1980	100,000 (15,898,700)	Development Drilling
Iran[A]	1983	Unknown	Production
Mexico	1986	247,000 (39,269,900)	Work-over
Mexico	1987	56,000 (9,903,300)	Exploratory Drilling
Timbalier Bay/Greenhill, USA	1992	11,500 (1,828,400)	Production

Source: Gulf Canada 1981, updated by reference to the Oil Spill Intelligence Report
[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 Iran/Iraq war.

Table 8.2 Blowouts and Spills from United States Federal Offshore Wells, 1972 to 2005

Year	Well Starts	Development Drilling Blowouts		Non-drilling Blowouts									
				Production		Work-over		Completion		Total Blowouts		OCS[D] Production
		No	bbl	No	bbl	No	bbl	No	bbl	No	bbl	MMbbl
1972	845	2	0	1	0	0	0	0	0	5	0	396.0
1973	820	1	0	0	0	0	0	0	0	3	0	384.0
1974	816	1	0	4	275	0	0	0	0	6	275	354.9
1975	372	1	0	0	0	1	0	1	0	7	0	325.3
1976	1,038	4	0	1	0	0	0	0	0	6	0	314.5
1977	1,064	1	0	1	0	3	0	1	0	9	0	296.0
1978	980	4	0	0	0	3	0	1	0	11	0	288.0
1979	1,149	1	0	0	0	0	0	0	0	5	0	274.2
1980	1,307	1	0	2	1	1	0	1	0	8	1	274.7
1981	1,284	2	0	1	0	3	64	3	0	10	64	282.9
1982	1,035	4	0	0	0	4	0	0	0	9	0	314.5
1983	1,151	5	0	0	0	2	0	0	0	12	0	350.8
1984	1,386	1	0	0	0	1	0	0	0	5	0	385.1
1985	1,000	1	0	0	0	2	40	0	0	6	40	380.0
1986	1,538	1	0	0	0	1	0	0	0	2	0	384.3
1987	772	0	0	3	0	1	0	2	60	8	60	358.8
1988	1,007	1	0	0	0	1	0	0	0	3	0	332.7
1989	911	5[A]	0	0	0	1	0	0	0	11	0	313.7
1990	987	1	0	0	0	3	9	1	0	6	9	304.5
1991	667	3[A]	0	0	0	0	0	0	0	6	0	326.4
1992	943	0	0	0	0	0	0	0	0	3	100	337.9
1993	717[B]	2	0	0	0	0	0	0	0	3	0	352.7
1994	717[B]	0	0	0	0	1	0	0	0	1	0	370.4
1995	717[B]	0	0	0	0	0	0	0	0	1	0	429.2
1996	921	1	0	0	0	0	0	2	0	4	0	433.1

Year	Well Starts	Development Drilling Blowouts		Non-drilling Blowouts								
				Production		Work-over		Completion		Total Blowouts		OCS[D] Production
		No	bbl	No	bbl	No	bbl	No	bbl	No	bbl	MMbbl
1997	1,333	3	0	0	0	0	0	1	0	5	0	466.0
1998	1,325	1	0	2	0	3	0	0	0	7	2	490.5
1999	364	2	0	0	0	1	0	0	0	5	0	534.6
2000	1,061	4	0	0	0	0	0	0	0	9	200	551.6
2001	1,007	4	1	2	0	2	0	1	0	10	1	591.5
2002	828	2	0	2	350	1	0	0	0	6	351	602.1
2003	835	1	0	2	1	1	10	0	0	5	11	594.7
2004	861	0	0	0	0	2	1	0	0	4	17	567.0
2005	859[C]	1	0	0	0	0	0	0	0	4	0	557.3[C]
Total	32,617	91	1	24	627	38	125	14	60	205	1,131	13,520.7

Source: LGL 2007a
[A] Two of the drilling blowouts occurred during drilling for sulphur
[B] Estimated: cumulative total correct
[C] Forecast
[D] outer continental shelf

Since 2005, the MMS has recorded 20 spills greater than 50 barrels in the US Gulf of Mexico Outer Continental Shelf (Table 8.3), with a total of 4,690.9 barrels of synthetic base fluid, crude oil/condensate or refined petroleum product (e.g., diesel or mineral oil) released during the spills (MMS 2008). The bulk of the crude oil/condensate released in 2006 was residual seepage from the effects of hurricanes Katrina and Rita in 2005 (MMS 2008).

Table 8.3 US Gulf of Mexico Outer Continental Shelf Spills (>50 barrels)

Spill Type	2006		2007		2008	
	Spills	Barrels	Spills	Barrels	Spills	Barrels
Synthetic Oil Fluids	6	906.8	2	1,518	1	131.3
Crude Oil/Condensate	7	1,834.8	1	187.5	1	50.6
Refined Petroleum (e.g., diesel, mineral oil)	2	62	0	0	0	0
Total	**15**	**2,803.6**	**3**	**1,705.5**	**2**	**181.8**

Source: MMS 2008

8.2 Spills in the Newfoundland and Labrador Offshore Area

Spill frequency and volume data associated with drilling and production in the Newfoundland and Labrador Offshore Area are presented in Table 8.4. Only one large spill has been recorded in the Newfoundland and Labrador Offshore Area. This occurred in November 2004 at the Terra Nova field due to a malfunction in the production platform’s produced water separation facilities during which approximately 165 m^3 of crude was spilled. A small spill of approximately 4.8 m^3 occurred in September 2008 at the White Rose field due to the implementation of emergency disconnect procedures to disconnect a crude loading hose on the SeaRose FPSO from the cargo tanker.

Table 8.4 Spill Frequency and Volume during Exploration and Development Drilling and Production in the NL Offshore Area, 1997-2007

Date	Synthetic-based Drilling Fluid		All Other Hydrocarbons	
	Number	**Volume (M^3)**	**Number**	**Volume (M^3)**
1997	0	0	11	1.7
1998	2	2.0	26	3.8
1999	9	7.4	38	2.9
2000	5	4.7	5	0.22
2001	2	5.6	15	0.13
2002	2	12.3	24	0.03
2003	5	31.0	20	0.39
2004	6	108.1	50	165.9
2005	2	4.0	38	0.20
2006	6	3.63	32	0.6
2007	2	75.1	37	0.1
Total 1997-2007	**41**	**253.8**	**296**	**176**
Source: Source: C-NLOPB website accessed 2008				

Oil spill frequency, oil type and volume (>1 L) data in the Newfoundland and Labrador Offshore Area are provided in Table 8.5. In the past 12 years of oil and gas activity in the Newfoundland and Labrador Offshore Area: 173.7 m^3 of crude oil were spilled during 46 events; 4.8 m^3 of diesel were spilled during 26 events; 1.4 m^3 of hydraulic oil were spilled during 37 events; and 1.8 m^3 of other oil types were spilled during 35 events. SBM accounted for the largest spilled volume with 253 m^3 spilled over 26 events.

Table 8.5 Oil Spills Greater than One Litre in the Newfoundland and Labrador Offshore Area, 1997-2008 (all offshore activity under C-NLOPB jurisdiction).

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008 Nov 18
Number of Spills by Oil Type												
Crude	2	7	12	2	0	2	2	8	4	3	0	6
Diesel	6	8	7	0	2	1	1	1	0	0	0	0
Hydraulic	2	0	4	0	4	0	8	9	6	4	0	0
SBM	0	2	8	5	2	2	4	5	1	4	2	1
Other[A]	1	8	7	1	1	2	1	3	1	0	3	7
Total	**11**	**25**	**38**	**8**	**9**	**7**	**16**	**26**	**12**	**11**	**5**	**14**
Volume of Spills by Oil Type (m^3)												
Crude	1.0	0.38	0.98	0.22	0.00	0.005	0.01	165.8	0.02	0.61	0	4.62
Diesel	0.48	3.31	0.92	0.00	0.005	0.01	0.10	0.003	0.00	0.00	0	0.00
Hydraulic	0.21	0.00	0.69	0.00	0.12	0.00	0.28	0.07	0.02	0.018	0	0.00
SBM	0.00	2.01	7.37	4.70	5.60	12.25	30.1	108.1	4.03	3.63	75.1	0.10
Other[A]	0.04	0.10	0.27	0.002	0.003	0.011	0.93	0.01	0.14	0.00	0.093	0.18
Total	**1.7**	**5.8**	**10.2**	**4.9**	**5.7**	**12.3**	**31.4**	**274**	**4.2**	**4.3**	**75.2**	**4.9**

Source: C-NLOPB website accessed 2008
[A] includes mixed oil, condensate, well bore fluids, unidentified oil, jet fuel, lubricating oil, oily water

The C-NLOPB requires operators to report all spills regardless of size. The total number of spills of any size recorded since 1997 is 369, approximately 51% were less than 1 liter. Oil spills of 1 L or less in the Newfoundland and Labrador Offshore Area are provided in Table 8.6. A total of 53.6 L have been spilled over the past 12 years in 187 recorded events, for an average 0.28 L spilled per event.

Table 8.6 Oil Spills One Litre or Less in the Newfoundland and Labrador Offshore Area, 1997-2008

Year	Number of Spills	Total Spill Volume (L)
1997	0	0
1998	3	1.6
1999	9	4.7
2000	2	1.1
2001	8	4.2
2002	19	5.2
2003	9	2.5
2004	30	9.0
2005	28	9.0
2006	27	9.2
2007	34	4.3
2008	18	2.8
Source: C-NLOPB website 2008		

Based on the data presented in Table 8.4, the NL offshore area experiences approximately 31 spills/year. This includes spills of all volumes and hydrocarbons of all types spilled during all types of offshore oil and gas activity including; exploration drilling, development drilling, oil and gas production operations, subsea ROV inspections, construction activity, marine vessel operations, seismic vessel operations, etc. Annual spill frequencies by volume are presented in Table 8.7.

Table 8.7 Spills Frequency by Volume in the Newfoundland and Labrador Offshore Area

Spill Volume	**Frequency** (number per year)
Less than 1 litre (1)	16.4
1 Litre to 1 bbl (2)	12
Small (1–49 bbls) (2)	3.4
Medium (50-999 bbls) (2)	0.4
Large (>1000 bbls) (2)	0.09
Very Large (>10,000 bbls) (2)	0
Extremely Large (>150,000 bbls) (2)	0
Note 1: Based on Table 8.4 Note 2: Based on C-NLOPB website, spills >1 liter by Operator	

The highest oil spill frequencies are for the smaller, operational spills. As noted previously, of the total number of spills recorded since 1997, approximately 51% were less than 1 liter and 88% were less than 1 bbl (159 liters). Thus about half of the spills reported in the NL offshore in 12 years are over 1 liter and only 12% were over a barrel.

When comparing drilling operations spills to production operations over the same time period, drilling accounts for 60% of the number of spills, whereas production activities account for 40%. In terms of spill volumes, drilling activity accounts for 54% compared to production at 46%. The spill volume data is dominated by two key events that occurred in 2004; one in drilling and one in production. If these two events are removed, the spill volume distribution changes to 78% and 22% in drilling and production, respectively.

8.3 Well Blow-Out Probabilities

The absence of shallow gas deposits and Hibernia's drilling experience and understanding of the reservoir characteristics developed over the past 12 years in the drilling of over 60 wells, supports the unlikelihood of blowouts occurring during the Project. Development drilling differs substantially from exploration drilling in that during development drilling, you have the benefit of the knowledge and understanding of the reservoir characteristics (i.e., pressures and factures) gained during the initial exploration well(s) drilling. In exploration drilling, these characteristics are predicted and drill well planning is therefore based on predictions and related assumptions. Exploration drilling is a higher risk activity compared to development drilling.

Based on US Gulf of Mexico Outer Continental Shelf spill frequencies, spill probabilities for the drilling of the maximum of 66 wells associated with the Project were calculated and are provided in Table 8.8.

Table 8.8 Predicted Number of Blowouts and Spills for Drilling Phase of Project

Event	Historical Frequency[A]	No. of Events (66-well drilling phase)	Probability
Gas blowout during Development Drilling	3.45×10^{-3}/well drilled	2.27×10^{-1}	1 in 4.5
Development Drilling Blowout with Oil Spill >150,000 barrels	2.66×10^{-5}/well drilled	1.76×10^{-3}	1 in 570
Development Drilling Blowout with Oil Spill >10,000 barrels	5.33×10^{-5}/well drilled	3.52×10^{-3}	1 in 284
Development Drilling Blowout with Oil Spill >1,000 barrels	5.0×10^{-5}/well drilled	3.3×10^{-3}	1 in 303
Platform-based oil spill, 50 to 999 barrels	3.6×10^{-3}/well drilled	2.38×10^{-1}	1 in 4
Platform-based oil spill, 1 to 49 barrels	7.7×10^{-2}/well drilled	5.08	1 in 0.2
[A] The US Gulf of Mexico			

Approximately 20,000 development wells were drilled in the US Gulf of Mexico Outer Continental Shelf between 1972 and 2005 (LGL 2007a), with 91 blowouts from development wells during the same period. This results in a blowout frequency of one in 220 wells drilled (4.55×10^{-3}). As only 1 of the 91 development well blowouts resulted in oil being spilled (1 barrel), the probability of oil being spilled during development drilling is 5.0×10^{-5}. Therefore, the probability of having an oil spill associated with a development well blowout in the Project Area is 3.3×10^{-3}, or 1 in 303 development wells drilled.

8.4 Characteristics and Behaviour of Spilled Material

8.4.1 Hibernia Crude

The properties of Hibernia crude compared to other Grand Banks oil fields, are listed in Table 8.9. Compared to others, the Hibernia crude has a lower density and similar or lower pour point (the temperature below which the oil will not flow).

For many years Hibernia crude was believed to be waxy, highly emulsifiable and undispersible. Recent studies by SL Ross have concluded the oil is relatively light, it will not immediately emulsify and it will keep relatively non-viscous for many hours depending on spill and environment conditions (SL Ross 2003). Hibernia oil is now classified as a light-to-medium gravity oil having a density of about 0.850 g/cm^3 $^($API gravity = 35^o). The viscosity of the fresh oil is 30 cP at 15^{o}C and 110 at 1^{o}C, approximately the same as kerosene. The oil's pour point or the temperature at which an oil sample being cooled will no longer flow, was measured to be -6°C. (SL Ross 1999).

Since the 1999 SL Ross report, similar data collected by Hibernia as part of its regular quality control procedures continues to confirm the above referenced values with the exception of pour point. Data collected in 2006 and up to October in 2007 on the Platform revealed an API range of 34.2 to 35.7 (average of 34.9) and pour point range of -9 to 15 °C (average 8.4).

In November 2006 SL Ross Environmental Research Ltd. issued a report titled *Spill Related Properties of Hibernia Crude Oil 2006*. This 2006 report classified Hibernia oil as light-to-medium having a density of 0.837 g/cm^3 (API = 38°) at 15.5 °C. The viscosity of the fresh oil was 70 cP at 15 °C and 2659 cP at 1°C. Pour point was recorded at 12 °C.

Trajectory modeling conducted for the Hibernia EIS generally demonstrated that under prevailing winds and currents, oil on the water would tend to move offshore to the east and northeast. Only during four months of the year (November, December, January, and March) is there any chance of shoreline contact. The probability of this happening was predicted to be <0.6% (Mobil Oil 1985). However, given that the recent crude characteristic data differs from that used in the original trajectory modeling work, it is reasonable to conclude that the actual probability of shoreline impact is less and the survival time of the slick on the water surface is also less that originally predicted. Using the original Hibernia spill modeling results in this assessment is now viewed as a more conservative approach in terms of impact predictions.

In the event of a spill, dissolution data for Hibernia crude indicate that only a small portion of the total oil in the water column is likely to be in the dissolved form. Concentrations of 0.2 to 0.5 mg/L oil-in-water, immediately adjacent to the site of a spill may be expected. Short term evaporation losses from a spill could range from 10 to 40 percent at temperatures of 0°C and 15°C, respectively (Mobil Oil 1985).

Table 8.9 NL Offshore Crude Oil Properties

Crude Property	Hibernia[A]			Terra Nova[B]	White Rose[C]
	1984	1999	2006		
API Gravity	30.4	35.0	Not measured by SL Ross Platform range is 34.2 to 35.7	32.5	33
Density (kg/m^3 @ 15°C)	874	850	837	862	859
Viscosity (mm^2/s @ 25°C)	25	30	84 at 15°C	18.2	38
Air/Oil Interfacial Tension (mN/M)	27.2	28.8	26.6 at 0°C	29	30
Oil/Seawater Interfacial Tension (mN/m)	21	9.2	29.2 at 0°C	29.6	25
Pour Point (°C)	9	-6	12	12	18
Flash Point (°C)	14	12.5	<-5	<21	<0
Emulsion Formation Tendency and Stability @ 1°C and 15°C	Very stable	Not stable	Likely/entrained	Very Stable	Very Stable
Aqueous Solubility (g/m^3) in Seawater @ 22°C	17	Not measured	Not measured	18.778	Not measured

Source: Adapted from LGL 2006.
[A] Hibernia as produced (SL Ross 1984,1999 and 2006).
[B] SL Ross 1985
[C] SL Ross 2000

8.4.2 Diesel Fuel

Spills from platforms and vessels associated from the Project could be diesel fuel used for marine engines, rig generators or rig cranes. The United States Coast Guard (2005) has published a fact sheet on small diesel fuel spills (2.7 to 27.2 m^3). It indicates that diesel fuel is a light, refined petroleum product that when spilled on water will evaporate or naturally disperse within a few days or less. When spilled on water, diesel oil spreads very quickly to a thin film. Even when the oil is described as a heavy sheen, it is 0.01 mm thick and contains about 5,448 litres per square nautical mile of continuous coverage. Diesel has a very low viscosity and is readily dispersed into the water column when winds reach 5 to 7 knots or sea conditions are 0.6 to 1.2 m.

Diesel oil is much lighter than water (specific gravity is about 0.85, compared to 1.03 for seawater), and will therefore not sink and accumulate on the seafloor as pooled or free oil. It is possible for the oil to be physically mixed into the water column by wave action, forming small droplets that are carried and kept in suspension by the currents. Oil dispersed in the water column can adhere to fine-grained suspended sediments, which then settle out and get deposited on the seafloor. This process is more likely to occur near river mouths where fine-grained sediment is carried in by rivers. It is less likely to occur in open marine settings. This process is not likely to result in measurable sediment contamination for small spills.

Diesel oil is not very sticky or viscous, compared to black oils. When small spills do strand on the shoreline, the oil tends to penetrate porous sediments quickly, but also tends to be washed off quickly by waves and tidal flushing. Thus, shoreline cleanup is usually not needed. Diesel oil is readily and completely degraded by naturally occurring microbes, under time frames of one to two months (United States Coast Guard 2005).

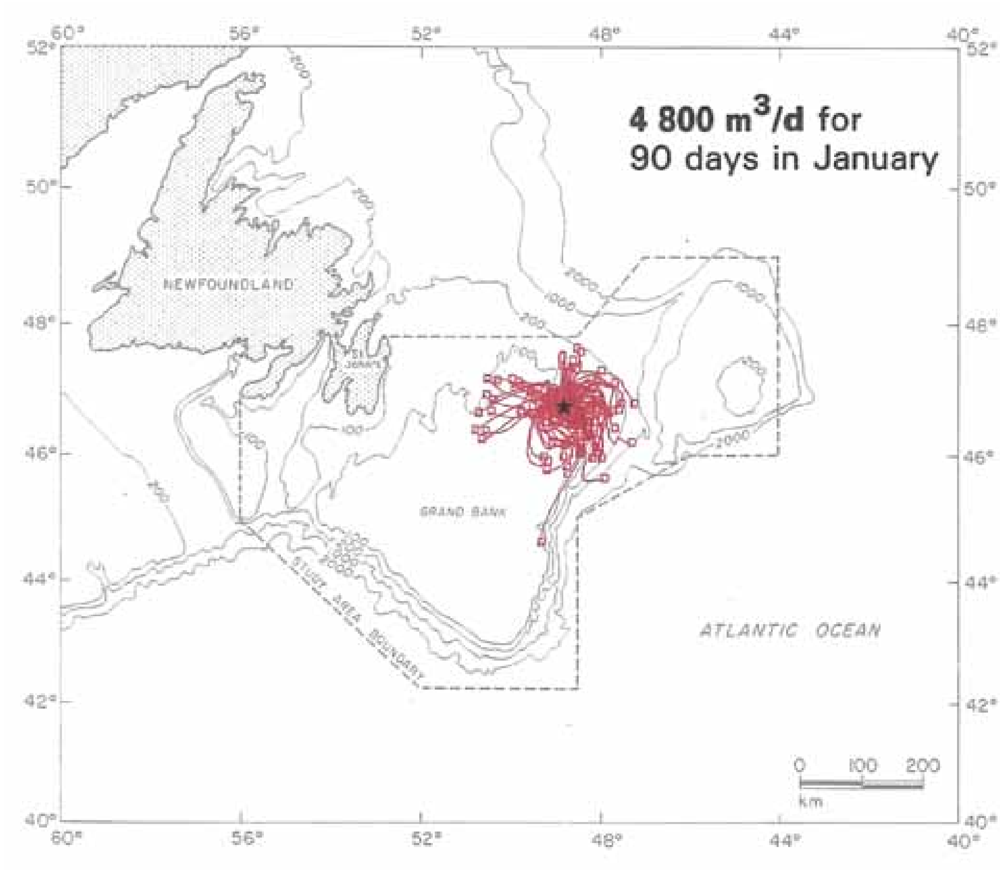
8.5 Oil Spill Trajectory

A review of oil spill trajectory modelling to date in the Jeanne d'Arc Basin is presented in the Husky New Drill Centre Construction and Operations Program EA (LGL 2006a; Sections 8.3.1 and 8.3.2). There it was noted that the quality of trajectory model data input improved for the Terra Nova project EA, in comparison to the Hibernia project EA, and again improved with the White Rose project EA. Even though the input data improved, the model results were essentially similar without substantive differences. The probability of oil reaching land was extremely low or zero and the oil moved generally eastward out to sea. The oil spill trajectory modelling completed for the original Hibernia project (Mobil Oil 1985) is generally centered in the Project Area and is close enough to the proposed drill centres to remain valid for this assessment. We also consider the more recent modelling results used in the SDL 1040 EA (Husky and Norsk Hydro 2006) since the spill trajectory model was run from a site 17.8 nm from Hibernia Southern Extension.

8.5.1 Subsea Blowouts

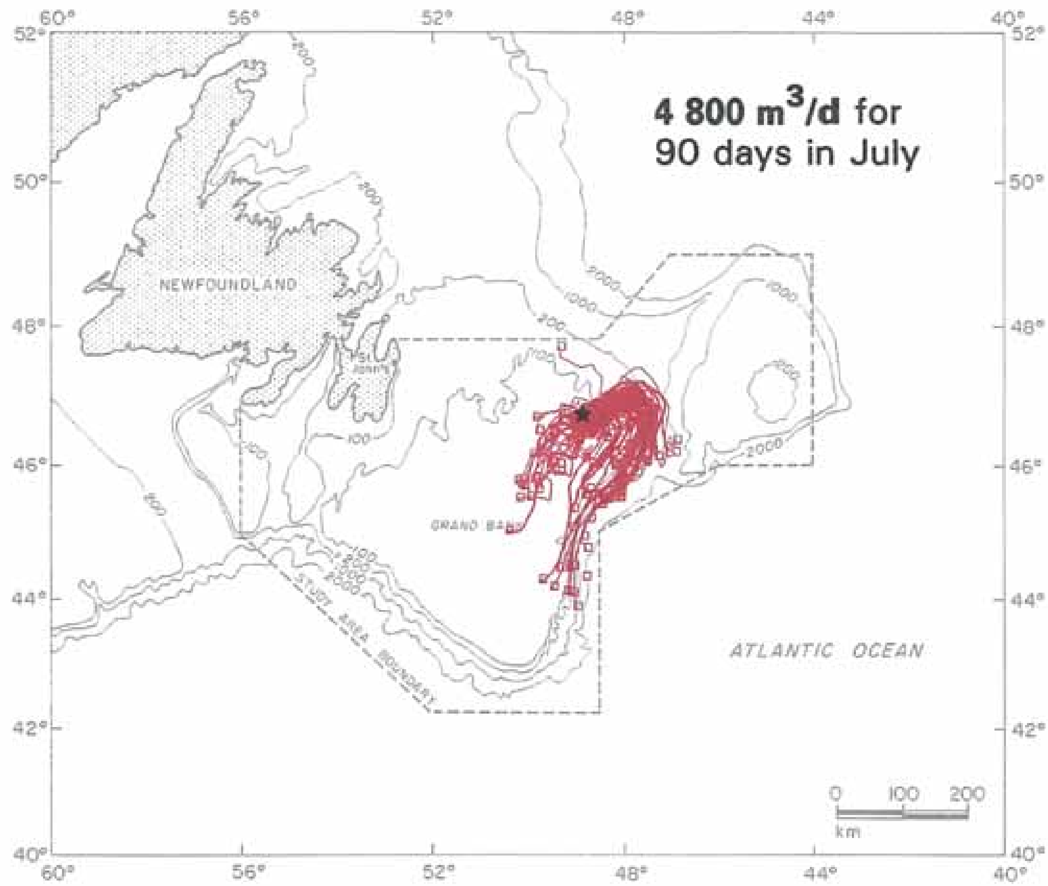
When emulsification, evaporation and dispersion are considered, a worst-case subsea blow out of 4,800 m^3 creates a slick lasting for four days in the winter and eight days during the summer (Figures 8.1 and 8.2). Trajectory modelling indicates that under prevailing wind and current conditions, slicks would tend to move offshore, to the east and northeast of the Project Area. The probability of any oil reaching the shores of Newfoundland is 0.6 percent.

Figure 8.1 January Subsea Blowout (worst case (4,800 m^3/day for 90 days)



Source: Seaconsult 1984

Figure 8.2 July Subsea Blowout (worst case (4,800 m^3/day for 90 days))



Source: Seaconsult 1984

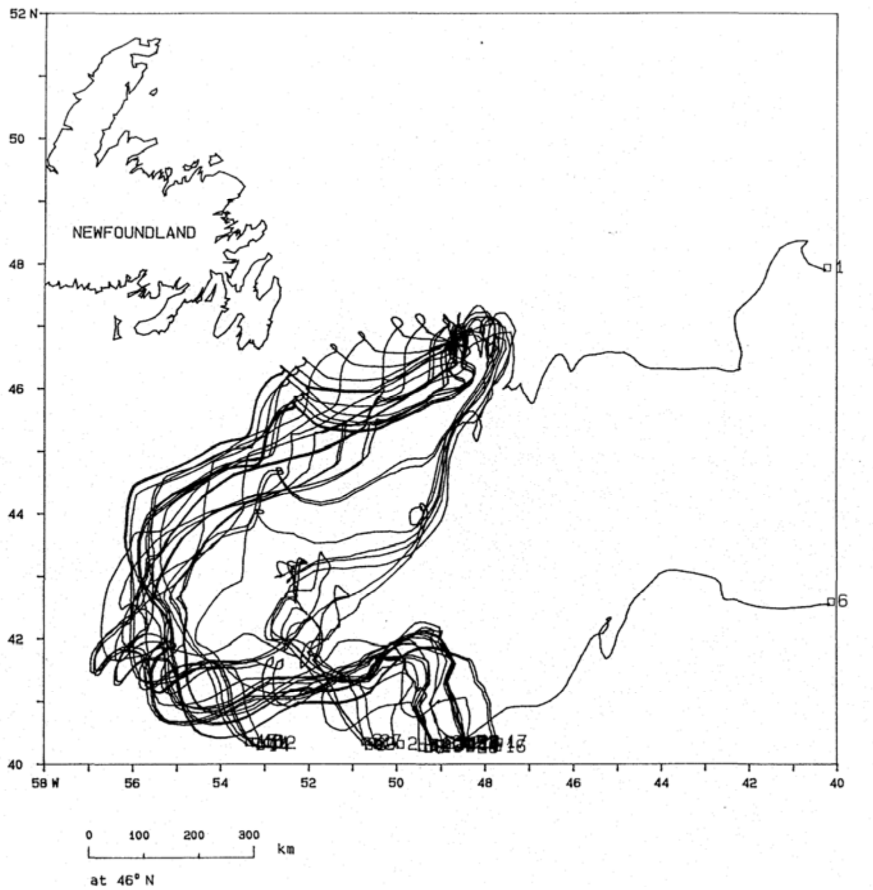
8.5.2 Surface Blowouts

Each oil spill distribution map for surface blowouts per month illustrates trajectory motion that is directed either to the southwest or to the sector east through northeast. The geographical distribution of approximately 90 percent of all trajectories is similar in all months, except during summer, when wind speeds are lightest and when wind directional variability is less extreme than in winter. During summer a greater portion of trajectories are effectively controlled by the strong Labrador Current core flowing southward along the offshore edge of the Grand Banks; the trajectories reveal a general movement to the south and/or west of the Hibernia P-15 site. In winter, the more extreme wind climate accounts for a broad and generally eastward directed distribution of trajectories throughout much of the southern model grid.

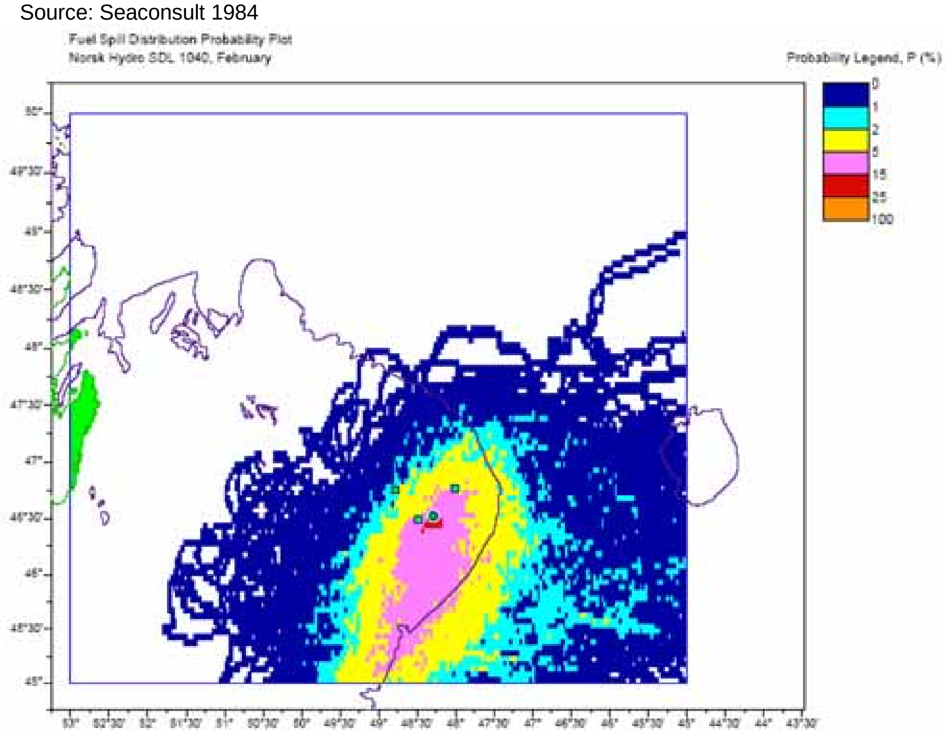
The original Hibernia modelling results reflect more recent oil spill trajectory modelling completed for SDL 1040 EA (Husky and Norsk Hydro 2006). Figures 8.3 and 8.4 illustrate the similarities in spill trajectories between the two sites in February and August, respectively.

Predictions of coastal impact on Newfoundland are few, being 0.56 percent in November, 0.11 percent in December, 0.43 percent in January and 0.22 percent in March. A total of only 12 predicted shore impacts sites were realized from almost 11,000 trajectories modelled.

Figure 8.3 February Surface Blowout (worst case)

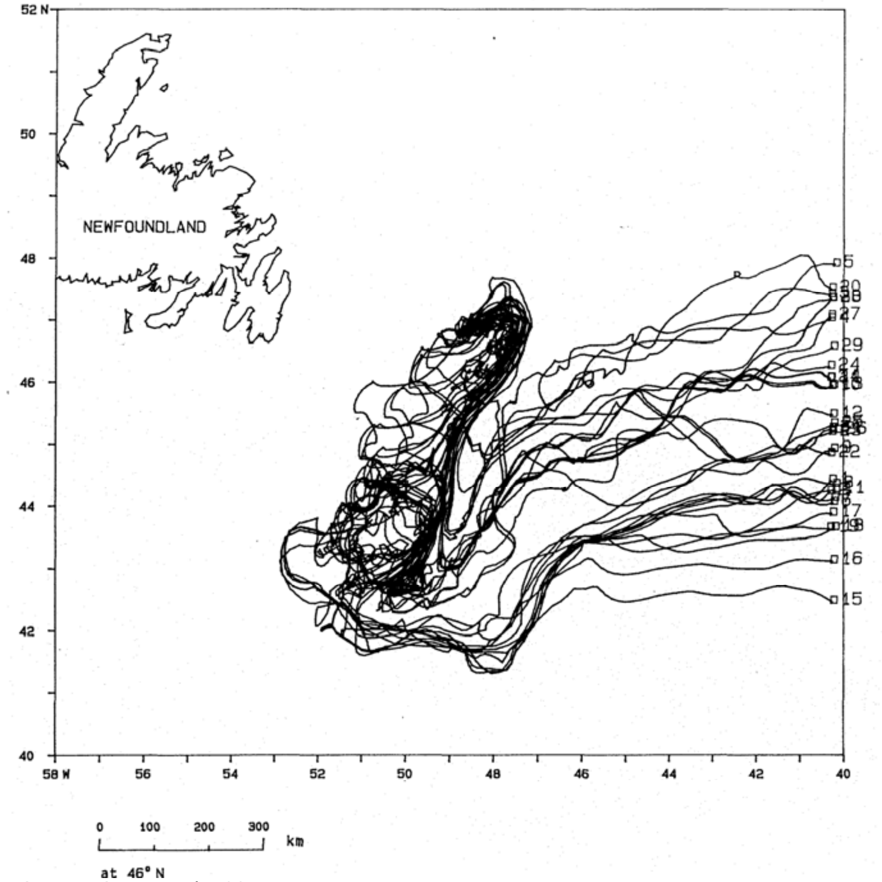


Source: Seaconsult 1984

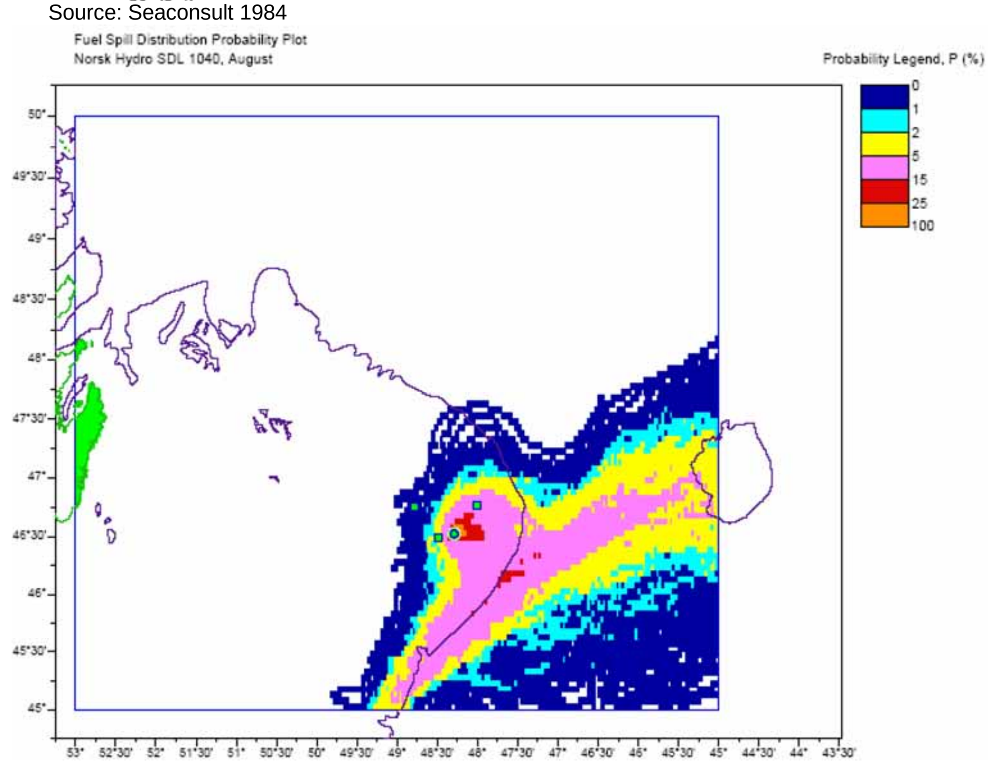


Source: Husky and Norsk Hydro 2006

Figure 8.4 August Surface Blowout (worst case)



Source: Seaconsult 1984



Source: JWL 2006

8.5.3 Batch Spills

Batch spills are an accidental spill that releases the oil within a specific time frame (i.e., there is a start and stop time to the release). The original EIS (Mobil Oil 1985) assumed a batch spill from a pipeline would release 3000 m^3 for one hour. The other potential source of a batch spill could be the drilling vessel or support/standby vessel.

8.6 Response to an Accidental Release

The response strategy to an accidental release as a result of the Project will be dependent upon the environmental conditions at the time of the release (e.g., visibility, wave height, winds) and the equipment and vessels available at the time. Hibernia's Oil Spill Response Plan (Appendix A of the Emergency Response Plan) and the Mutual Aid Agreement between operators will be utilized to manage releases occurring during this Project.

8.6.1 Containment and Collection of Spilled Oil

Oil spill containment booms may be deployed in the event of a spill. These booms are deployed downcurrent/downwind as close as is safely possible (and practical) to contain the oil for collection with an oil recovery skimmer. Recovered oil is pumped into an available tank on the supply vessel or other temporary storage unit. Any containment and collection technology must take slick characteristics into consideration (i.e., a subsea blowout usually results in a wider slick than a surface blowout). The technology must take into consideration that a blowout will result in a continuous slick until the release can be stopped, as opposed to a batch spill, which results in a one-time release.

The time available to contain and recover spilled oil is dependent on environmental conditions (e.g., wave height, visibility). Ideal clean up conditions occur in daylight with wave heights less than 1 m or in wave heights between 1 to 2 m with periods of 6 seconds or greater; visibility is greater than 0.5 km. The frequency that these conditions occur in the Newfoundland and Labrador Offshore Area is 0.24 in summer and 0.04 in winter or 0.13 on average (LGL 2006a).

8.6.2 Other Cleanup Methods

Other potential cleanup methods include *in situ* burning and the use of dispersants. *In situ* burning also requires the collection of the spilled oil, using fire-resistant booms. As with the use of conventional containment, it is dependent on environmental conditions. Once contained, the slick is ignited and burned in place; this is effective only when the oil has not emulsified. Dispersants, specially-formulated chemicals that cause the breakdown of the slick (allowing the slick to be dispersed through the water column), can be used to treat large areas without the need to store both the containment and recovery equipment, but also the recovered oil. It also reduces the size of the slick on the sea surface, minimizing the interaction with marine birds. However, dispersants can only be used on surface slicks and must also be applied before the oil emulsifies. A net environmental benefits analysis should be conducted prior to using dispersants to ensure the negative impacts on the water column are outweighed by the positive impacts gained via the protection of seabirds.

8.7 Analysis of the Environmental Effects of an Accidental Oil Spill

An accidental release of oil could affect marine birds (especially a surface blowout or batch spill), marine fish habitat (especially a subsea blowout or pipeline rupture), marine fish and shellfish (and the resulting affect on commercial fisheries), marine mammals and sea turtles that come into contact with a slick (although they can usually avoid a slick) and species at risk.

Areas along major shipping routes are more likely to experience accidents than others. These areas are also subject to chronic oiling from bilge pumping and de-ballasting by vessel traffic. The spatial and temporal effect of an accidental event in an area of chronic oiling may be extended since the resident biota may have accumulated hydrocarbons before the accidental event. Resident (non-migratory) species within an area affected by a spill would be benthic for the most part (e.g. scallop, clams, sculpins) and the least likely to have accumulated hydrocarbons from chronic oil pollution.

The following assessment assumes that the Affected Area for each of the VECs would be equivalent to the cumulative predicted zones of influence (ZOI) from the spill scenarios described in Section 8.5.

8.7.1 Marine Fish Habitat

Marine fish habitat includes the infauna and micro- and macrobenthos that live in and on the seafloor and in the water column (e.g., plankton).

8.7.1.1 Potential Interactions and Existing Knowledge

Plankton

The effects of oil on phytoplankton in the natural environment remain poorly understood (Howarth 1991). Toxicity is closely related to the amount of dissolved, nonvolatile components of the oil (Ostgaard 1994). Microcosm experiments provide the most useful information of the ecological effects of oil (Howarth 1989), particularly for low-level chronic contamination of species composition of plankton communities. Diatoms are one of the dominant phytoplankton algal groups and have undergone a number of laboratory studies; a review of which indicated that oil could be lethal or reduce photosynthesis and growth in phytoplankton, although it could stimulate phytoplankton growth at low concentrations (Capuzzo 1987). Effects from experiments vary from death to growth stimulation, depending on the amount and type of oil, and the species of phytoplankton (Ostgaard et al. 1984; Morales-Loos and Goutx 1990). Fluctuations in the natural environment make predicting the environmental effects of oil on phytoplankton hard to identify (Howarth 1989), resulting in limited evidence of long-term oil effects to phytoplankton in the natural environment (Ostgaard 1994). It is likely that phytoplankton in enclosed near-shore areas are more vulnerable to oil.

The most important biological event occurring after the *Prestige* oil spill was the spring bloom (Varela et al. 2006); the recruitment of many important shellfish and pelagic fishes depends on the normal development of this bloom. No significant differences in phytoplankton biomass and primary production rates were detected during the spring bloom, nor were any observed changes in the dominance of the main phytoplankton groups (Varela et al. 2006). Major effects on the phytoplankton community after the *Torrey Canyon* (Nelson-Smith 1970), the *Santa Barbara* (Straughan 1972), the *Argo Merchant* (Kühnhold 1978), the *Tsesis* (Linden et al. 1979; Johansson et al. 1980) or the *Aegean Sea* (Varela et al. 2006) could not be demonstrated. The results for the *Prestige* oil spills are comparable with those reported by Reid (1986) in the area of North Sea oil platforms or Batten et al. (1998) after the *Empress* oil spill, using long data series.

There is limited information on the environmental effects of oil on zooplankton communities; the structure of planktonic communities largely defines the environmental effect of oil. The generally held belief is that plankton are not likely to suffer long-term environmental effects from an oil spill as a result of rapid dilution and dispersion within the water column (Suchanek 1993). Johansson et al. (1980) found that zooplankton densities declined near a spill but rebounded within five days. Data from the *Prestige* oil spill do not reveal any significant shifts in zooplankton biomass during the spring bloom after the spill (Varela et al. 2006). Calanoid copepods were the dominant group of zooplankton in 2003, as they were in previous years (Varela et al. 2006).

Studies carried out over the last few years have demonstrated the existence of oil sedimentation on the sea floor due to planktonic organisms. Zooplankton are able to feed on oil particles (Johansson et al. 1980); these particles are incorporated to faecal pellets. Sedimentation could be accelerated by the high sinking rates of pellets, especially at low water temperatures (Honjo and Roman 1978). Zooplankton pellets could remove up to 30 percent of hydrocarbons from surface waters (Sleeter and Butler 1982).

The capability of both phytoplankton and zooplankton to metabolize hydrocarbons may reduce the environmental effects on the pelagic system (Varela et al. 2006). Studies have demonstrated that there are limited effects and a fast recovery of growth rates (after a short lag period) following exposure to fuel, even at concentrations of one order of magnitude higher than those reported for the *Prestige* spill (Herbert and Poulet 1980; Thomas et al. 1981). This ability of the plankton would result in an additional decrease in the concentration of hydrocarbons in the water.

Microbiota

Bacteria have an active role in the degradation processes of oil, which may explain the low concentrations of hydrocarbons in the water and, consequently, their reduced environmental effects (Varela et al. 2006). Bacteria can degrade up to 60 to 80 percent of crude oil under optimal conditions (Gutnick and Rosenberg 1977).

Invertebrates

The environmental effects of a fuel spill on invertebrates and invertebrate habitat are determined by factors such as species and life history stage, type of habitat, weather and time of year. Hydrocarbons can be detectable in sediments for several years if they are not physically or biologically disturbed (Sanders et al. 1980). Low levels of hydrocarbons in the substrate can have sublethal effects on nearby invertebrates, resulting in possible histopathological damage

Sublethal toxic effects of contaminants in marine organisms also include impairment of physiological processes, which may alter the energy available for growth and reproduction (Capuzzo 1987; Capuzzo et al. 1988). A consequence of chronic exposure to chemical contaminants is alteration in reproductive and developmental potential of populations of marine organisms; this in turn can result in possible changes in population structure and dynamics.

Egg and larval stages are more subject to harmful physiological effects from a fuel spill as they cannot actively avoid the spill nor have they developed any detoxification mechanisms. Environmental effects to eggs and larvae can include morphological malfunctions, genetic damage, reduced growth or localized mortality.

Oil from surface blowouts can reach the seafloor (thereby affecting the benthic invertebrate community) through weathering, losing buoyancy and eventually sinking or by associating with particulate matter suspended in the water and eventually sinking (Elmgren et al. 1983). Crustaceans appear to be the most sensitive organisms in benthic communities. Most oil spills have resulted in major environmental effects on crustacean fauna (Elmgren et al. 1980; Sanders et al. 1980; Dauvin and Gentil 1990; Jewett et al. 1999).

8.7.1.2 Environmental Effects Assessment

Environmental effects of oil spills on plankton are short-lived, while zooplankton are more sensitive than phytoplankton. Phytoplankton production may be inhibited by oil concentrations under a slick, but standing crop and species composition of the phytoplankton may be unaffected (Johansson et al. 1980). Zooplankton accumulate hydrocarbons in their bodies, but accumulated hydrocarbons are depurated within a few days after exposure has ended (Trudel 1985).

The oil spill model indicates that in the event of a spill, it is unlikely that oil will reach the shoreline. Any potential spill associated with an offshore blowout would rise to the surface and would not likely interact with benthic organisms or benthic habitat. 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. The environmental effect of an accidental oil spill on marine fish habitat is considered not significant (Table 8.10).

Table 8.10 Summary of Environmental Effects Assessment from an Oil Spill on Marine Fish Habitat

Interactions	
▪ Mortality of benthos ▪ Contamination of marine fish habitat from oil spill.	
Mitigation	
▪ Maintenance and inspection programs for subsea pipelines, and fluid transfer equipment (ex, hoses, pumps, valves). ▪ Procedures and checklists, similar to what is in place for the existing Hibernia drill rigs, in place for transferring product to/from MODU with supply vessel. ▪ Hibernia Ice Mgmt Plan to be amended as required to ensure protection from icebergs. New procedures will be developed as needed for subsea pipeline flushing similar to that in place for Hibernia's OLS. ▪ Blowout prevention measures include; o Blow out prevention equipment will be installed which would include at a minimum an annular preventer and a series of RAMS, o Pit volume monitoring will be used for influx detection, o Surface pressure monitoring will be used for influx detection, o Mud weight will be designed to provide overbalance to the reservoir - reducing the probability of an influx significantly, o There will be well control procedures in place to deal with the kick if there is an influx, o Key drilling personnel are trained and certified in well control. ▪ Hibernia's Oil Spill Response Plan will be in effect for the Project.	
Significance	
Confidence	High
Geographic extent	Localized (pipeline rupture and sub-sea blowout) to Study Area (surface blowout)
Frequency of occurrence	As per Table 8.7
Duration of impact	Several days to several years depending on nature of event
Magnitude of impact	High
Permanence/reversibility	Reversible
Significance	**Non-Significant**
Likelihood of occurrence	Only considered in the event of significant residual effect
Follow-up and Monitoring	
▪ HMDC's Oil Spill Response Plan includes the implementation of an Oil Spill EEM when necessary ▪ HMDC's existing EEM will provide some pre-spill condition information.	

8.7.2 Marine Fish and Shellfish

Marine fish and shellfish are an important component of the ecosystem and the basis of the commercial fisheries on the Grand Banks.

8.7.2.1 Potential Interactions and Existing Knowledge

While a hydrocarbon spill can affect local abundance and availability of phytoplankton and zooplankton to fish, fish are not expected to remain within an area affected by a spill. Accumulated hydrocarbons would be depurated from zooplankton that survive exposure within a few days after exposure has ended (Trudel 1985). Hydrocarbons will accumulate in fish that eat contaminated zooplankton, but fish are able to metabolize hydrocarbons, therefore, there is no potential for bioaccumulation.

All fish and shellfish past the egg and larval stage should be able to actively avoid an oil spill (Irwin 1998). Given the high rate of natural mortality of eggs and larvae, the environmental effects of a localized spill would be undetectable, and recruitment to a population would not be affected unless more than 50 percent of the larvae in a large portion of a spawning area were lost (Rice 1985). No environmental effect was detected (at the population level) when herring larvae survival was reduced by 58 percent due to the *Exxon Valdez* spill (Hose et al. 1996).

Embryo mortality of pink salmon was reported with laboratory exposure to aqueous total PAH concentrations as low as 1 ppb total PAH (derived from artificially weathered Alaska North Slope crude oil) Heintz et al. (1999). This laboratory result is consistent with the field observations of mortality of pink salmon embryos in streams traversing oiled beaches following the spill from the *Exxon Valdez* (Bue et al. 1998***)***. Fish eggs generally appear to be highly sensitive to oil contamination at certain stages and then become less sensitive just prior to larval hatching (Kühnhold 1978; Rice 1985). Rice et al. (1986) reported that larval sensitivity varies with yolk sac stage and feeding conditions, with eggs and larvae exposed to high concentrations of oil exhibiting morphological malformations, genetic damage and reduced growth. Embryo damage may not be apparent until the larvae hatch. Kühnhold (1974) observed that although Atlantic cod eggs survived oiling, the hatched larvae were deformed and unable to swim. Behavioural abnormalities such as initial increased swimming activity followed by low activity, narcosis and death have been exhibited in Atlantic herring larvae exposed to oil (Kühnhold 1972).

Persistent oil fractions and species-specific individual responses to specific compounds could result in chronic toxicity of petroleum hydrocarbons after an oil spill. Exposure to petroleum hydrocarbons resulted in alterations in bioenergetics and growth of bivalve mollusks, related to tissue burdens of specific aromatic compounds (Gilfillan et al. 1977; Widdows et al. 1982, 1987; Donkin et al. 1990). A negative correlation was demonstrated between cellular and physiological stress indices and tissue concentrations of aromatic hydrocarbons with long-term exposure of *Mytilus edulis* to low concentrations of North Sea crude oil (Widdows et al. 1982). Depuration of aromatic hydrocarbons resulted in the recovery of mussels following long-term exposure to low concentrations of diesel oil (Widdows et al. 1987). The accumulation of two- and three-ring aromatic hydrocarbons resulted in reductions in scope for growth in *Mytilus edulis*, as these compounds induced a narcotizing effect on ciliary feeding mechanisms (Donkin et al. 1990).

Long-term reductions in recruitment and over-wintering mortality in the fiddler crab (*Uca pugnax)* were observed for seven years following the spill of No. 2 fuel oil from the barge *Florida* ***(***Krebs and Burns 1977***)***. The disappearance of naphthalenes and alkylated naphthalenes from contaminated sediments correlated with crab population recovery. Amphipod (*Ampelisca abdita*) toxicity and chemistry of spilled No. 2 fuel oil in subtidal sediment samples was compared for nine months following the spill from the barge *North Cape* **(**Ho et al. 1999); toxicity to the amphipods decreased as the PAH concentration in sediments decreased over the first six months post-spill.

American lobster larvae had a 24-h LC50 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). Millions of American lobsters were killed due to the 1996 *North Cape* oil spill (over 800,000 US gallons of home heating oil); their deaths were attributed to the toxic effects of oil (McCay 2001).

Tested post-larval brown shrimp were less sensitive than adult invertebrate species to a variety of crude and refined oils (Anderson et al. 1974). Moulting larvae appear to be more sensitive than intermoult larvae to oil (Mecklenburg et al. 1977).

Physiological effects from oil have been reported on fish and include abnormal gill function (Sanders et al. 1981), increased liver enzyme activity (Koning 1987; Payne et al. 1987), decreased growth (Moles and Norcross 1998), organ damage (Rice 1985) and increased disease or parasites loads (Brown et al. 1973; Carls et al. 1998; Marty et al. 1999). Fish may suffer environmental effects when exposed to oil, ranging from direct physical effects (e.g., coating of gills and suffocation) to more subtle physiological and behavioural effects. Actual environmental effects depend on factors such as species and life stage, lifestyle, fish condition, the amount and type of oil, environmental conditions, degree of confinement of experimental subjects and others. Laboratory toxicity studies indicated that pelagic fish are more sensitive than either benthic or intertidal fish species (Rice et al. 1979).

Exposure of fish to the oil could potentially be of longer duration, however, juvenile and adult finfish are mobile and can avoid the contaminated areas. Less mobile invertebrates could not so easily avoid the oil. Contamination of shoreline habitats that are particularly important to fish with specific habitat requirements could potentially result in more adverse effects on the fish.

With respect to diesel fuel spills, diesel is considered to be one of the most acutely toxic oil types. Fish, invertebrates and seaweed that come in direct contact with a diesel spill may be killed. However, small spills in open water are so rapidly diluted that fish kills have never been reported. Fish kills have been reported for small spills in confined, shallow water.

8.7.2.2 Environmental Effects Assessment

The worst case scenario would be from an oil spill associated with a well blowout. It is highly unlikely that a spill of this type will occur (based on the Gulf of Mexico data - one in 303 probability over the 66 wells drilled for spills greater than 1,000 barrels).

Environmental effects of large spills are predicted to be greater in coastal zones and enclosed seas than in open ocean pelagic areas (Patin 1999, in Hurley and Ellis 2004). Any potential spill associated with an offshore blowout would rise to the surface and would not likely interact with benthic organisms or benthic habitat. Environmental effects of oil spills on plankton are short-lived, with zooplankton being more sensitive than phytoplankton. Zooplankton can accumulate hydrocarbons in their bodies, but these are depurated within a few days after exposure has ended (Trudel 1985). All motile fish and shellfish past the egg and larval stage will likely actively avoid a hydrocarbon spill (Irwin et al. 1998). Fish will accumulate hydrocarbons if they eat contaminated zooplankton, but they are also able to metabolize hydrocarbons, so there is no potential for biomagnification. However, fish eggs and larvae cannot actively avoid the spill and have not developed any detoxification mechanisms, thus are at increased risk to the harmful physiological effects of a fuel spill. Recruitment to a population would not be affected unless more than 50 percent of the larvae in a large portion of the spawning area were lost (Rice 1985). Thus, the effect of a localized spill on egg and larval survival would likely be undetectable from the high rate of natural mortality. The environmental effects of an accidental oil spill on fish and fish habitat is therefore considered non significant (Table 8.11).

Table 8.11 Summary of Environmental Effects Assessment from an Oil Spill on Marine Fish and Shellfish

Interactions	
▪ Injury/mortality of marine fish and shellfish ▪ Contamination food source of marine fish and shell fish from oil spill. ▪ Avoidance of area	
Mitigation	
▪ Maintenance & inspection programs for subsea pipelines and fluid transfer equipment (ex, hoses, pumps, valves). ▪ Procedures and checklists, similar to what is in place for the existing Hibernia drill rigs, in place for transferring product to/from MODU with supply vessel. ▪ Hibernia Ice Mgmt Plan to be amended as required to ensure protection from icebergs. New procedures will be developed as needed for subsea pipeline flushing similar to that in pace for Hibernia's OLS. ▪ Blowout prevention measures include; o Blow out prevention equipment will be installed which would include at a minimum an annular preventer and a series of RAMS, o Pit volume monitoring will be used for influx detection, o Surface pressure monitoring will be used for influx detection, o Mud weight will be designed to provide overbalance to the reservoir - reducing the probability of an influx significantly, o There will be well control procedures in place to deal with the kick if there is an influx, o Key drilling personnel are trained and certified in well control. ▪ Hibernia's Oil Spill Response Plan will be in effect for the Project.	
Significance	
Confidence	High
Geographic extent	Localized (pipeline rupture and sub-sea blowout) to Study Area (surface blowout)
Frequency of occurrence	As per Table 8.7
Duration of impact	Short-term
Magnitude of impact	High
Permanence/reversibility	Reversible
Significance	**Non significant**
Likelihood of occurrence	Only considered in the event of significant residual effect
Follow-up and Monitoring	
▪ HMDC's Oil Spill Response Plan includes the implementation of an Oil Spill EEM when necessary ▪ HMDC's existing EEM will provide some pre-spill condition information.	

8.7.3 Commercial Fisheries

With the collapse of groundfish stocks, shellfish have become an important component of the commercial fishery in the Affected Area.

8.7.3.1 Potential Interactions and Existing Knowledge

While the physical effects on fish from a spill may be assessed as non significant (refer to Section 6.1), the economic affects could be considerable as a result of: a fishers inability to access fishing grounds (because of areas temporarily excluded during the spill or spill clean-up); damage to fishing gear (through oiling); or a negative effect on the marketability of fish products (because of perceived tainting, even without organic or organoleptic evidence). An economic effect could also result from an interruption due to reduced catches, or extra costs associated with having to relocate harvesting effort. Economic effects due to market perceptions of poor product quality (i.e., tainted flesh) are more difficult to predict, as the actual (physical) effects of the spill might have little to do with these perceptions. In the past, areas around oil spills and blowouts have been closed without any evidence of taint. For example, a no-fishing zone was established during the 1984 blowout at the *Uniacke* well site near Sable Island, even though taste tests on cod, halibut and haddock sampled in the area did not indicate taint (Zitko et al. 1984). Similarly, inspection officers rejected lobster with any traces of external oil and no proof of internal contamination during the *Kurdistan* oil spill in 1979 (Tidmarsh et al. 1986). Shellfish prices and sales declined dramatically after the *Torry Canyon* spill in 1967, even though much of the shellfish catch was from other waters (LGL Limited et al. 2000).

Small spills (less than 50 barrels bbl) can also result in damage to fishing vessels and gear, as can materials lost from drill units. Damages are expected to occur infrequently; the C-NLOPB reported that (on average) there are two fishing gear conflicts per year from seismic activities in the Newfoundland and Labrador Offshore Area (C-NLOPB 2003).

In general, fixed gear poses a much greater potential for conflicts (or fouling) with oil (surface or water column) than towed gear, since it may be set out over long distances in the water and left for days at a time.

8.7.3.2 Environmental Effects Assessment

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 non significant (Table 8.12).

Table 8.12 Summary of Environmental Effects Assessment from an Oil Spill on Commercial Fisheries

Interactions	
▪ Potential contamination of commercial marine fish and shellfish from oil spill. ▪ Fouling of fishing gear and vessels ▪ Perceived taint of fish species	
Mitigation	
▪ Compensate for economic losses directly attributable to the Project and deemed reasonable ▪ Procedures and checklists, similar to what is in place for the existing Hibernia drill rigs, in place for transferring product to/from MODU with supply vessel. ▪ Hibernia Ice Mgmt Plan to be amended as required to ensure protection from icebergs. New procedures will be developed as needed for subsea pipeline flushing similar to that in pace for Hibernia's OLS. ▪ Blowout prevention measures include; o Blow out prevention equipment will be installed which would include at a minimum an annular preventer and a series of RAMS, o Pit volume monitoring will be used for influx detection, o Surface pressure monitoring will be used for influx detection, o Mud weight will be designed to provide overbalance to the reservoir - reducing the probability of an influx significantly, o There will be well control procedures in place to deal with the kick if there is an influx, o Key drilling personnel are trained and certified in well control. ▪ Hibernia's Oil Spill Response Plan will be in effect for the Project.	
Significance	
Confidence	High
Geographic extent	Localized (pipeline rupture and sub-sea blowout) to Study Area (surface blowout)
Frequency of occurrence	As per Table 8.7
Duration of impact	Short-term (perception of taint may last longer)
Magnitude of impact	High
Permanence/reversibility	Reversible
Significance	**Non significant**
Likelihood of occurrence	Only considered in the event of significant residual effect
Follow-up and Monitoring	
▪ HMDC's Oil Spill Response Plan includes the implementation of an oil spill EEM when necessary ▪ HMDC's existing EEM will provide some pre-spill condition information.	

8.7.4 Marine Birds

Marine birds that spend much of their time swimming and diving at the water surface are most at risk from oil spills and blowouts. There is no clear correlation between the size of an oil spill and numbers of seabirds killed (Burger 1993). The environmental effects of an accidental release of oil on marine birds are influenced by factors including the species of birds present, weather conditions, time of year, and size or duration of the spill or blowout (Wiese et al. 2001), as well as bird density in a spill area, wind velocity and direction, wave action and distance to shore (Burger 1993).

8.7.4.1 Potential Interactions and Existing Knowledge

Whether or not oil pollution has major long-term effects on bird productivity or population dynamics is dependent upon the scientific evidence. Some studies indicate that oil pollution is unlikely to have major long-term effects on bird productivity or population dynamics (Clark 1984; Boersma et al. 1995; Wiens 1995; Butler et al. 1998) while others indicate the opposite (Piatt et al. 1990; Walton et al. 1997).

The detrimental effects of an oil spill on marine birds have been clearly demonstrated (Camphuysen and Heubeck 2001). Major accidents still lead to mortality of marine birds; this has been demonstrated by spills from the *Erika* off the coast of France in 1999 (Cadiou et al. 2004; Riffault et al. 2005), the *Treasure* off Africa in 2001 and the *Prestige* off France and Spain in 2002 (Camphuysen et al. 2002).

Direct exposure to oil mats feathers, thereby effectively destroying the thermal insulation and buoyancy provided by air trapped by the feathers. This leads to hypothermia and/or drowning, particularly in cold water environments (Clark 1984; Hartung 1995).

Long-term physiological changes may result in eventual death for those birds that may survive initial oiling (Ainley et al. 1981; Williams 1985; Frink and White 1990; Fry 1990). Behavioural changes may result that may affect an individual's ability to find food, which could result in starvation (Burger 1997). Starvation could also result from an increase in metabolic rates due to the loss of insulation (Hartung 1967; McEwan and Koelink 1973).

Oil can also produce non-lethal effects in oiled birds, such as decreased fertility of adults as a result of physiological and behavioural changes brought on by oil exposure or direct mortality of young who are exposed to oil brought to the nest by oiled adults (Holmes et al. 1978; Hartung 1965; Ainley et al. 1995), both of which impair reproductive success.

Marine birds have increased chances of becoming oiled, in that they spend most of their lives at the air-water or land-water interfaces where floating oil accumulates (Wiens 1995). The ecological niches of some species make them especially susceptible to oil. Marine birds become fouled when oil is present as they must frequently pass through the water's surface. As such, diving species (such as murres, Atlantic Puffins, and Dovekies) are considered the most susceptible to the immediate effects of surface slicks (Leighton et al. 1985; Chardine 1995; Wiese and Ryan 1999, 2003). Alcids (often with the highest oiling rate) showed an annual increase over a 13-year period (2.7 percent) in the proportion of oiled birds recovered from beaches along the south and east coasts of the Avalon Peninsula, Newfoundland, (Wiese and Ryan 1999, 2003). This family is known to be extremely vulnerable to small increases in adult mortality.

Thick-billed Murres (and other auks) are most sensitive to oiling on the Grand Banks (Wiese and Ryan 2003), comprising (with Common Murres and Dovekies) over 80 percent of the oiled birds recorded during winter beached bird surveys on the Avalon Peninsula (Environment Canada 2002).

Shearwaters, gulls, terns, Northern Fulmar, and Storm-Petrels are also vulnerable to oiling because they travel over large distances and frequently come into contact with the water surface while feeding.

Most marine bird losses occur during the initial spill when floating oil can interact with large numbers of birds (Hartung 1995). It was estimated that the total kill of marine birds from the *Exxon Valdez* spill in 1989 was 100,000 to 300,000 (Piatt et al. 1990). Murres comprised 74 percent of the birds retrieved, and a colony of 129,000 murres at the Barren Islands was devastated (Piatt et al. 1990). Those birds that do not die as a direct result of hypothermia and/or drowning often seek refuge ashore, where they try to get rid of the oil on their feathers through abnormally excessive preening (Hunt 1957, in Hartung 1995). This results in ingestion of considerable quantities of oil that can cause lethal effects (although the oil is partially absorbed (McEwan and Whitehead 1980)). Emaciation, renal tubular degeneration, necrosis of the duodenum and liver, anemia and electrolytic imbalance have been noted in Common Murres and Thick-billed Murres oiled off Newfoundland's south coast (Khan and Ryan 1991).

Oil may be transferred to eggs of nesting seabirds from their plumage and feet (Albers and Szaro 1978). Small quantities of oil (1 to 20 µL) on eggs have been demonstrated to produce 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 hatching and fledging success of young from oiled eggs 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. The first half of incubation is the most sensitive period for exposure to oil for embryos (Albers 1977; 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). Ducklings that ingest oil directly also exhibit similar effects (Miller et al. 1978; Peakall et al. 1980; Szaro et al. 1981).

Abandonment of nesting burrows by oiled adult Leach's Storm-Petrels may have contributed to reproductive failure in that population (Butler et al. 1998), an indication of indirect reproductive failure caused by oil pollution.

Ingesting oil or oil-contaminated prey may also lead to immuno-suppression and Heinz-body hemolytic anemia, which compromises the ability of the blood to carry oxygen (Leighton et al. 1983; Fry and Addiego 1987), with effects persisting long after the birds appear to have recovered from the initial exposure (Fry and Addiego 1987). Species of marine birds that obtain their food by pursuing prey underwater can be affected by their blood's diminished oxygen carrying-capacity. The resulting stress from handling during cleaning could exacerbate any direct and indirect effects (Briggs et al. 1996), as an increased vulnerability to stress due to physiological impairment is a potential sublethal effects of oil on marine birds (Briggs et al. 1996).

Irons et al. (2000) conducted a long-term study of effects from the *Exxon Valdez* oil spill, which indicated that 9 of 14 taxa studied showed a negative oil spill effect that may have been caused by greater ingestion of oil by birds living in the area studied, and a decrease in abundance of high quality prey (i.e., sand lance, Pacific herring, and capelin) for a number of years after the spill (compared to pre-spill abundance).

The environmental effect will be much greater if a spill occurs when birds are aggregated during breeding or migration, than if they are widely dispersed at sea. A small spill around marine bird habitat with large breeding populations may have a disproportionately large effect and it is likely that the cumulative effect of numerous "small" spills and chronic pollution in such areas has had a greater effect on marine bird populations than the rarer large spills. As an example, an estimated 30,000 oiled seabirds washed up along the coasts of the Skagerrak following a small release of oil from one or two ships (Mead and Baillie 1981), while less than 5,000 birds died as a result of the wreck of the *Amoco Cadiz* off the coast of Brittany, France, which released 230,000 tonnes of crude oil into coastal waters (Hope-Jones et al. 1978).

The accepted method to estimate seabird mortalities in chronically polluted near shore areas is the beached bird survey (Camphuysen and Heubeck 2001). However, beached bird surveys were not an option for monitoring the environmental effects of the Terra Nova FPSO spill which resulted in the release of approximately 1,000 barrels of crude oil in 2004. No direct data were available on marine bird mortality due to winds blowing westward, so carcasses would not drift to shore and live birds would have to fly a long distance into a headwind. The probability of a deceased oiled seabid reaching land in Newfoundland is likely of the same order of magnitude of the probability spilled oil reaching land. However, an estimate was prepared by Wilhelm et al. (2007) using typical seabird densities for the area, published mortality estimates from oiling and event probabilities. Wilhelm et al. (2007) estimated that up to 10,000 murres and Dovekies could have died because of the spill. This event (in conjunction with other population stressors (i.e., chronic oil pollution, hunting, and fishery by-catch) was concluded to potentially further stress populations of marine birds (Wilhelm et al. 2007).

After the P*restige* oil spill off France and Spain in 2002, mortality was estimated using capture-recapture methods, and resulted in a mortality estimate of 11 times the number of beached birds collected on the coasts. Guillemots were the most affected species. A study on the nonlethal effects of the *Prestige* spill on Yellow-legged Gulls concluded that physiology of marine birds could be negatively affected due to ingestion of polycyclic aromatic hydrocarbons from oil spills (Alonso-Alvarez et al. 2007).

8.7.4.2 Environmental Effects Assessment

It is the timing and location of spills that primarily influence bird mortality rates, as there is no direct relationship between the volume of oil spilled and bird mortality (Wiese et al. 2001). The environmental effect of an oil spill will depend on factors such as time of year, sea conditions, volume and type of oil spilled and type of spill (i.e., surface or subsurface) and whether or not marine birds have aggregated in the area. However, if marine birds are within the zone of influence of the spill, the environmental effect of an accidental oil spill on pelagic birds could be considerable. The environmental effect of an accidental oil spill on marine birds is therefore considered potentially significant (Table 8.13). While any environmental effect to marine birds would be irreversible on an individual level, a population-level environmental effect is likely reversible, so the population of marine birds will be able to meet the needs of future resource users.

Table 8.13 Summary of Environmental Effects Assessment from an Oil Spill on Marine Birds

<table>
<tr><th colspan="2">Interactions</th></tr>
<tr><td colspan="2">▪ Mortality due to hypothermia from reduction in insulating factor of feathers
▪ Health effects due to ingestion of oil from feathers.
▪ Potential contamination of food sources from oil spill.</td></tr>
<tr><th colspan="2">Mitigation</th></tr>
<tr><td colspan="2">▪ Maintenance & inspection programs for subsea pipelines and fluid transfer equipment (ex, hoses, pumps, valves).
▪ Procedures and checklists, similar to what is in place for the existing Hibernia drill rigs, in place for transferring product to/from MODU with supply vessel.
▪ Hibernia Ice Mgmt Plan to be amended as required to ensure protection from icebergs. New procedures will be developed as needed for subsea pipeline flushing similar to that in place for Hibernia's OLS.
▪ Blowout prevention measures include;
o Blow out prevention equipment will be installed which would include at a minimum an annular preventer and a series of RAMS,
o Pit volume monitoring will be used for influx detection,
o Surface pressure monitoring will be used for influx detection,
o Mud weight will be designed to provide overbalance to the reservoir - reducing the probability of an influx significantly,
o There will be well control procedures in place to deal with the kick if there is an influx,
o Key drilling personnel are trained and certified in well control.
▪ Hibernia's Oil Spill Response Plan will be in effect for the Project.</td></tr>
<tr><th colspan="2">Significance</th></tr>
<tr><td>Confidence</td><td>High</td></tr>
<tr><td>Geographic extent</td><td>Localized (pipeline rupture and sub-sea blowout) to Study Area (surface blowout)</td></tr>
<tr><td>Frequency of occurrence</td><td>As per Table 8.7</td></tr>
<tr><td>Duration of impact</td><td>Long-term</td></tr>
<tr><td>Magnitude of impact</td><td>High</td></tr>
<tr><td>Permanence/reversibility</td><td>Reversible</td></tr>
<tr><td>Significance</td><td>Significant</td></tr>
<tr><td>Likelihood of occurrence</td><td>Large spills are unlikely</td></tr>
<tr><th colspan="2">Follow-up and Monitoring</th></tr>
<tr><td colspan="2">▪ HMDC's Oil Spill Response Plan includes the implementation of an Oil Spill EEM when necessary
▪ HMDC's existing EEM will provide some pre-spill condition information.</td></tr>
</table>

8.7.5 Marine Mammals

Marine mammals and sea turtles can be affected by an oil spill if they come in direct contact with oil however, most marine mammals have been observed avoiding or attempting to avoid spill areas. Direct exposure of marine mammals and sea turtle to oil should be brief, if it occurs at all. Whales are not considered at high risk to the effects of oil exposure. Most marine mammals can withstand some oiling without toxic or hypothermic effects.

8.7.5.1 Potential Interactions and Existing Knowledge

Whales present in the area of an oil spill could suffer sublethal effects if they swim through a slick (oiling of mucous membranes or the eyes) (Geraci and Smith 1976; Geraci 1990), however, these effects are reversible and would not cause permanent damage to the animals.

Whales, seals and turtles use blubber to maintain core body temperature and are therefore not affected by a covering of oil. However, since it takes several months to build up a blubber layer sufficient to maintain body heat, young seal pups can become hypothermic if they are covered in oil.

There is a possibility that the baleen of whales could be contaminated with oil, thereby reducing filtration efficiency (Geraci 1990). As well, oil can be ingested via contaminated prey. For example, this may be the cause of the decline of the Alaskan killer whale population following the *Exxon Valdez* oil spill, where up to 22 individuals died, including a high number of females (with calves) (*Exxon Valdez* Oil Spill Trustees 1992; Miller 1999). However, oil is not usually bioaccummulated in marine mammals (although some oil can be absorbed (see LGL et al. 2000)). Vapourized hydrocarbons can also be absorbed into the blood stream if marine mammals breathe near the water's surface during a blowout event.

Seals appear to be more adversely affected by oil spills than are whales. As a result of the *Exxon Valdez* oil spill, approximately 300 harbour seals died (most of those were exposed at contaminated haul out sites), and the population declined 35 percent between 1989 and 1997 (compared to 13 percent at uncontaminated sites) (*Exxon Valdez* Oil Spill Trustees 1992; Miller 1999). Concentrations of petroleum hydrocarbons in bilge were up to six times higher than in seals from uncontaminated sites (*Exxon Valdez* Oil Spill Trustees 1992).

8.7.5.2 Environmental Effects Assessment

Oil will settle on the sea surface in the unlikely event of an oil spill at the surface or subsea, where it could potentially come in contact with marine mammals in the area. Marine mammals can be affected by an oil spill if they come in direct contact with oil, but most marine mammals have been observed avoiding or attempting to avoid spills. Oil does not affect the ability to maintain body temperature with the exception of young seal pups, however, there will be no spatial interaction with the Project. Marine mammal and sea turtle direct exposure to oil should therefore be brief, if it occurs at all. Feeding on oiled prey may also result in temporary exposure however, no long-term effects on marine mammals from external exposure, ingestion or bioaccumulation have ever been demonstrated from an oil spill (LGL et al. 2000).

Spills and blowouts are considered unlikely from development drilling activities, and HMDC's Oil Spill Response Plan will be implemented in an attempt mitigate impacts. Therefore, the environmental effect of an accidental oil spill on marine mammals is predicted to be non significant (Table 8.14).

Table 8.14 Summary of Environmental Effects Assessment from an Oil Spill on Marine Mammals

Interactions	
▪ Disturbance of marine mammals from the presence of oil spill response vessels, ▪ Potential contamination of food sources of marine mammals from oil spill. ▪ Avoidance of area	
Mitigation	
▪ Maintenance & inspection programs for subsea pipelines and fluid transfer equipment (ex, hoses, pumps, valves). ▪ Procedures and checklists, similar to what is in place for the existing Hibernia drill rigs, in place for transferring product to/from MODU with supply vessel. ▪ Hibernia Ice Mgmt Plan to be amended as required to ensure protection from icebergs. New procedures will be developed as needed for subsea pipeline flushing similar to that in place for Hibernia's OLS. ▪ Blowout prevention measures include; o Blow out prevention equipment will be installed which would include at a minimum an annular preventer and a series of RAMS, o Pit volume monitoring will be used for influx detection, o Surface pressure monitoring will be used for influx detection, o Mud weight will be designed to provide overbalance to the reservoir - reducing the probability of an influx significantly, o There will be well control procedures in place to deal with the kick if there is an influx, o Key drilling personnel are trained and certified in well control. ▪ Hibernia's Oil Spill Response Plan will be in effect for the Project. ▪ Collision avoidance practices, including constant speed and course maintained by all Project vessels (including oil spill response vessels).	
Significance	
Confidence	High
Geographic extent	Localized (pipeline rupture and sub-sea blowout) to Study Area (surface blowout)
Frequency of occurrence	As per Table 8.7
Duration of impact	Short-term
Magnitude of impact	Low
Permanence/reversibility	Reversible
Significance	**Non significant**
Likelihood of occurrence	Only considered in the event of significant residual effect
Follow-up and Monitoring	
▪ HMDC's Oil Spill Response Plan includes the implementation of an Oil Spill EEM when necessary ▪ HMDC's existing EEM will provide some pre-spill condition information.	

8.7.6 Species at Risk

Species at risk in the Project Area that could be affected by an accidental release of oil are cod and the three species of wolffish, Ivory Gull, blue, fin and right whales and harbour porpoise and leatherback turtle.

8.7.6.1 Potential Interactions and Existing Knowledge

All identified species at risk have the potential to interact with all types of oil spills. The environmental effects of an oil spill on marine fish and shellfish are applicable to cod and the three species of wolffish (Section 8.7.2.1).

The environmental effects of an oil spill on marine mammals and sea turtles are applicable to blue, fin and right whales and harbour porpoise (Section 8.7.5.1).

The environmental effects of an oil spill on marine birds are applicable to Ivory Gull (Section 8.7.4.1), except that the Ivory Gull is considered a rare migrant to the Project Area. The Ivory Gull is closely associated with pack ice and pack ice has only occurred twice within the Hibernia ice monitoring zone since the start of operations in 1997. The Ivory Gull has not been recorded near the Project Area.

8.7.6.2 Environmental Effects Assessment

Rationale for the environmental effects assessment on cod and northern, spotted and Atlantic wolffish is provided in Section 8.7.2.2, where the environmental effects of an accidental oil spill on marine fish and shellfish are discussed.

Rationale for the environmental effects assessment on blue, fin and right whales is provided in Section 8.7.5.2, where the environmental effects of an accidental oil spill on marine mammals are discussed.

Sea turtles have developed lesions and skin irritations when exposed to oil. Lutcavage et al. (1995) studied the physiological and clinic pathological effects of oil on loggerhead sea turtles (approximately 15 to 18 months old) in a controlled setting. They suggest that because sea turtles show no avoidance behavior when they encounter an oil slick, all post-hatch life stages are vulnerable to oil affects and tar ingestion. Turtles indiscriminately eat anything that registers as being an appropriate size for food, including tar balls. Lutcavage et al. (1995) showed that both chronic and acute exposures (adversely affect the loggerhead sea turtles' major physiological systems. The soft pliable skin of the neck and flippers of exposed turtles sloughed off in layers, continuing for one to two weeks into the recovery period. Recovery took up to 21 days, which increased the turtle's susceptibility to infection.

Since a keen sense of smell plays an important role in navigation and orientation, olfactory impairment from chemical contamination could represent a substantial indirect effect in sea turtles (as impairing its ability to properly orient itself can result in a population effect) (Frazier 1980, in NOAA 2003).

Sea turtles show no avoidance behavior when they encounter an oil slick (Lutcavage et al. 1995).

Rationale for the environmental effects assessment on the Ivory Gull is provided in Section 8.7.4.2, where the environmental effects of an accidental oil spill on marine birds are discussed. However, the Ivory Gull is rarely found far from drifting pack ice and pack ice has been recorded within the Hibernia ice monitoring zone in 2 of the 11 years since operations began, so the probability of the Ivory Gull occurring within the Project Area is low. If it were to occur, it would be on the scale of individuals and not groups of birds.

Large spills and blowouts are considered unlikely from development drilling activities, and HMDC's Oil Spill Response Plan will be implemented in an attempt mitigate impacts.. Therefore, the environmental effect of an accidental oil spill on species at risk, is predicted to be non significant (Table 8.15).

Table 8.15 Summary of Environmental Effects Assessment from an Oil Spill on Species at Risk

Interactions	
▪ Mortality of marine fish and marine birds species at risk ▪ Health effects from contamination of marine fish and marine birds species at risk ▪ Disturbance of marine mammals and sea turtles species at risk from the presence of oil spill response vessels, particularly collisions with marine mammal and turtle species at risk. ▪ Potential contamination of food sources of species at risk from oil spill. ▪ Avoidance of area	
Mitigation	
▪ Maintenance & inspection programs for subsea pipelines and fluid transfer equipment (ex, hoses, pumps, valves). ▪ Procedures and checklists, similar to what is in place for the existing Hibernia drill rigs, in place for transferring product to/from MODU with supply vessel. ▪ Hibernia Ice Mgmt Plan to be amended as required to ensure protection from icebergs. New procedures will be developed as needed for subsea pipeline flushing similar to that in place for Hibernia's OLS. ▪ Blowout prevention measures include; o Blow out prevention equipment will be installed which would include at a minimum an annular preventer and a series of RAMS, o Pit volume monitoring will be used for influx detection, o Surface pressure monitoring will be used for influx detection, o Mud weight will be designed to provide overbalance to the reservoir - reducing the probability of an influx significantly, o There will be well control procedures in place to deal with the kick if there is an influx, o Key drilling personnel are trained and certified in well control. ▪ Hibernia's Oil Spill Response Plan will be in effect for the Project. ▪ Collision avoidance practices, including constant speed and course maintained by all Project vessels (including oil spill response vessels).	
Significance	
Confidence	High
Geographic extent	Localized (pipeline rupture and sub-sea blowout) to Study Area (surface blowout)
Frequency of occurrence	As per Table 8.7
Duration of impact	Short-term
Magnitude of impact	High
Permanence/reversibility	Reversible
Significance	**Non significant**
Likelihood of occurrence	Only considered in the event of significant residual effect
Follow-up and Monitoring	
▪ HMDC's Oil Spill Response Plan includes the implementation of an Oil Spill EEM when necessary ▪ HMDC's existing EEM will provide some pre-spill condition information.	

9.0 EFFECTS OF THE ENVIRONMENT ON THE PROJECT

The definition of environmental effect under Section 2 (1) of the *CEA Act* includes “any change to the project that may be caused by the environment.” The key environmental factors that may affect the Project include wind, waves, ice and visibility. Weather, ice and icing, geohazards, currents, biofouling and wave conditions affect every project on the East Coast to some degree. It is anticipated that these effects will be mitigated by using rigs, vessels and equipment that are all certified by the appropriate authorities (e.g., Lloyds Register, Transport Canada, Coast Guard, and the C-NLOPB, and others) for use on the Grand Banks, by detailed project planning, by design in accordance with recognized and appropriate national and international standards, by operational scheduling, operating limits and by state of-the-art forecasting. Some delays to the Project are expected due to environmental factors along with damage to equipment and the possibility of accidents.

9.1 Visibility

As presented in Section 3.1.3, visibility is often limited in the summer months, which can greatly affect helicopter scheduling and platform staffing and supply. The average percent occurrence of fog is 8 percent in January and 40 percent in July (and can be as high as 80 percent).

9.2 Wind, Waves and Current Conditions

Operational limits related to winds and sea states will be put in place to ensure operations proceed safely in a manner that ensures an acceptable level of environmental protection. For a semi-submersible rig, currents will be a consideration for towing onto location and anchoring to the seabed. A semi-submersible may be more affected by surface currents and not by bottom type whereas equipment positioned on the seabed will be more affected by bottom currents and bottom substrate. Winds and sea states, both wave height and period, will also be a consideration during towing planning, and forecasted conditions will be within acceptable limits for the tow to proceed. Floating rig systems can also be affected by wave activity because they are subject to heaving. Periods of high winds will suspend crane operations and will limit the ability to transfer products from the supply boat to the MODU. Wind and seastate limits define operational weather windows and are key SHE control measures for various construction, operation and maintenance activities.

9.3 Structural Icing, Sea Ice and Icebergs

Freezing precipitation is of concern because it can affect personnel safety and structural integrity. Accumulations of ice may create slip and fall hazards and in extreme cases can affect vessel stability and aviation operations. Freezing precipitation in the Newfoundland and Labrador area is most likely to occur during March and April. Accumulations of ice on structures may be due to precipitation, condensation or sea spray and are highly related to air temperature, wind speed, diameter of surfaces, and other factors. HMDC will manage these risks through forecasting, close monitoring of conditions, effective communication with the POB, and adherence to documented and proven safety procedures. Ice accumulations (superstructure icing) may cause delays while operations are slowed or suspended and ice accumulation is avoided or removed. Any delays are anticipated to be relatively short-lived compared to the Project’s timeline.

To manage risks associated with sea ice and icebergs, HMDC has prepared an Ice Management Plan which enables a structured approach to ice threat assessment and response. Since ice conditions can vary greatly from area to area, and season to season, or year to year within an area, the ice management plan is tailored to the region, period and nature of the operation. Icebergs will be managed by surveillance, an early warning system, and by having support vessels apply deflection techniques that have been proven effective and safe over the past 12 years of operations. More details on ice management operations can be found in Section 3.3.

The effects of ice on the Project will be minimal as most of the Project Area is often free of sea ice and subject to relatively few icebergs most of the year. Given careful timing selection and good forecasting as well as implementation of the Ice Management Plan, there is expected to be little or minimal effect on the Project from sea ice or icebergs.

9.4 Seismic Activity

Seismic activity is of some risk on the east coast, but the risk is not high and is unlikely to be significant if a semi-submersible is used and the emergency shutdown system functions as designed. Other geohazards including steep slopes, slumping, shallow gas, etc., will be evaluated prior to drilling through dedicated geohazard surveys or further analysis of 3-D seismic data. This risks associated with seismic activity are subject to complex quantitative risk assessments which form the conceptual safety case required by the C-NLOPB for each production facility.

9.5 Biofouling

Effects of the biological environment on the Project are primarily those related to biofouling. Biofouling may affect rig stability and may increase corrosion rates on exposed support structures, vessel hulls and the interior of pipelines, pumps, tanks, and other colling system related equipment. Mud systems and annulur fluids can also become contaminated with bacteria. These effects will be minimized through regular inspections and cleaning and, where necessary, treatment with appropriate biocides, usually a chloride or gluteraldehyde based product. The use of biocides is described in detail in Hibernia's environmental protection plan.

Apart from corrosion and stability concerns, establishment of sulphur reducing bacteria can occur in systems having low oxygen concentrations in the presence of sulphur compounds. The formation of hydrogen sulphide (H_2S) has the potential to create significant human health and safety risks including the risk of explosions. The integrity of equipment may also be compromised if hydrogen sulphide develops in a system not originally designed for contact with H_2S.

9.6 Mitigation and Effects Analysis

Prior to obtaining an approval to drill a well, the MODU must be issued a certificate of fitness by an approved certifying authority. This process is regulated by the C-NLOPB and ensures that a drilling installation is designed, constructed, transported and installed in accordance with appropriate standards and is fit for the purpose for which it is to be used and can be operated safely without creating significant risks to the environment. This certification process addresses issues such as corrosion, icing, maximum loading, etc.

Severe or extreme environmental conditions can still occur and interrupt marine and aviation operations as well as drilling and production operations. Effects of the environment will be mitigated by state-of-the-art weather forecasting, ice surveillance and management procedures, operating limits, timing, selection of suitable rigs and vessels, properly designed equipment, risk assessment processes and personnel trained to work offshore safely and responsibly. Therefore, in consideration of the planned mitigation, all residual effects of the environment on the Project are predicted to be non significant.

10.0 SUMMARY AND CONCLUSION

Hibernia Management and Development Company Ltd. (HMDC), and the associated offshore land licence owners, are proposing the construction, installation, operation, maintenance, modification, decommissioning and abandonment of up to six drill centres within glory holes that contain the equipment necessary to support the extraction of petroleum resources. This includes subsea flowlines and associated infrastructure to enable flow to and from the existing gravity base structure (GBS). The six subsea developments and associated glory holes may be located at any point within Production Licence Areas (PLs) 1001 and 1005, Exploration Licence Areas (ELs) 1092 and 1093, and Significant Discovery Licence Areas (SDLs) 1001, 1002, 1003, 1004, 1005 and 1041 at any point in time over the life of the field which could be extended as new reserves are identified (Figure 1.1). Some of these developments remain subject to the identification of economically recoverable reserves, as well as commercial and contractual agreements between Hibernia's owners and the area license holders.

This EA Report has been prepared in order to satisfy the requirements of the DPA application review process under the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Act* and the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act* (Accord Acts). It also addresses the factors to be considered under Sections 16 (1) of the *CEAA* as part of a screening level assessment, and the specific requirements of the Scoping Document (Appendix A). In addition to the C-NLOPB, Environment Canada and DFO are also RAs for this assessment as the Project will require an ocean disposal permit and will result in a HADD.

10.1 Summary of Effects Assessment

The following Table 10.1 summarizes the residual environmental effects predicted for each of the VECs for each Project stage. Potentially significant adverse residual effects have only been predicted for Marine Birds from an accidental oil spill. However, a significant effect occurring is considered unlikely as a large spill would have to occur at a time when there were high concentrations of seabirds in the immediate area at the time of the spill and winds and seastates were such that rapid dispersion and degradation of the oil did not occur; a significant adverse effect could potentially occur.

Table 10.1 Summary of Residual Project Effects on VECs by Project Stage

VEC	Construction	Operation	Abandonment	Accidental Events
Marine Fish Habitat	Non significant	Non significant	Non significant	Non significant
Marine Fish and Shellfish	Non significant	Non significant	Non significant	Non significant
Commercial Fisheries	Non significant	Non significant	Non significant	Non significant
Marine Mammals	Non significant	Non significant	Non significant	Non significant
Marine Birds	Non significant	Non significant	Non significant	**Significant**
Species at Risk	Non significant	Non significant	Non significant	Non significant

10.2 Summary of Mitigation and Follow-Up

Mitigation and follow-up (including monitoring) have been proposed for each VEC to reduce or eliminate potentially significant adverse effects. Table 10.2 summarizes mitigation and follow-up commitments made by HMDC in this EA Report.

Table 10.2 VEC Specific Mitigation Measures

VEC	Mitigation Measures	Monitoring and Follow-Up
Marine Fish Habitat	♦ use of water-based drilling muds wherever possible; ♦ use of non-toxic or low toxicity chemicals and muds, and treating synthetic oil-contaminated cuttings as per the OWTG; ♦ all wastewater discharges to comply with the OWTG and ship operations will adhere to Annex I of the *International Convention for the Prevention of Pollution from Ships* (MARPOL 73/78); ♦ use of the OCMS to screen chemicals; ♦ solid waste transported to shore and recycled where possible; ♦ compliance with DFO's Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment; ♦ all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently.	♦ The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate. ♦ Pursuant to the OWTG, compliance monitoring of all effluent discharges will be conducted. ♦ A fish habitat compensation monitoring program will also be implemented to ensure no net loss of productive capacity in fish habitat as a result of this Project.
Marine Fish and Shellfish	♦ use of water-based drilling muds wherever possible; ♦ use of non-toxic or low toxicity chemicals and muds, and treating synthetic oil-contaminated cuttings as per the OWTG; ♦ all wastewater discharges will comply with the OWTG and ship operations will adhere to Annex I of the *International Convention for the Prevention of Pollution from Ships* (MARPOL 73/78); ♦ solid waste transported to shore and recycled where possible; ♦ compliance with DFO's Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment; ♦ use of OCMS for chemical selection; and ♦ all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently..	♦ The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate. ♦ Pursuant to the OWTG, compliance monitoring of all effluent discharges will be conducted. ♦ A fish habitat compensation monitoring program will also be implemented to ensure no net loss of productive capacity in fish habitat as a result of this Project.
Commercial Fisheries	♦ operational arrangements will be made to ensure that the operator and/or its survey contractor and the local fishing interests are informed of each other's planned activities. Communication throughout survey operations with fishing interests in the area should be maintained. ♦ Where feasible, a soft-start approach – a gradual ramp-up of airguns - will be implemented prior to survey. ♦ The operator should publish a Canadian Coast Guard "Notice to Mariners" and a "Notice to Fishers" via the CBC Radio program Fisheries Broadcast. ♦ Section 4.9 of the C-NLOPB's Guidelines Respecting Drilling Programs in the Newfoundland Offshore Area (C-NOPB 2000) state, "the operator should provide	♦ The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate. ♦ Pursuant to the OWTG, compliance monitoring of all effluent discharges will be conducted. ♦ A fish habitat compensation monitoring program will also be implemented to ensure no net loss of productive capacity in fish habitat as a result of this Project.

VEC	Mitigation Measures	Monitoring and Follow-Up
	for the advance notification of persons engaged in fishing activities in the proposed area of operations and the measures to be put in place to eliminate any potential mutual interference." ♦ The locations of the Project safety zones will be well publicized and communicated to fishers and DFO, and HMDC will continually communicate with fishers and DFO about fishing and survey activities in these areas during construction	
Marine Mammals	♦ use of non-toxic or low toxicity chemicals and muds, and treating synthetic oil-contaminated cuttings to meet the OWTG; ♦ discharges will comply with the OWTG and ship operations will adhere to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78); ♦ use of OCMS for screening chemicals to be used; ♦ helicopters will maximize flying altitude and are prohibited from flying over wildlife for passengers to view; ♦ Collision avoidance practices, including constant speed and course maintained by all Project vessels. Vessel traffic will be limited to routes between the MODU and the shorebase, survey areas around the well-site, to/from other platforms, ice surveillance routes; and ♦ Adherence to the Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment and the mitigations outlined in the Geophysical, Geological, Environmental and Geotechnical Program Guidelines (2008).	♦ HMDC will adhere to the *Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment* and *the Geophysical, Geological, Environmental and Geotechnical Program Guidelines.* ♦ Pursuant to the OWTG, compliance monitoring all effluent discharges will be conducted.
Marine Birds	♦ use of water-based drilling muds and low toxicity blowout preventer fluid & subsea valve control fluid; ♦ discharge of drilling muds, other fluids/solids, and food and sanitary waste below the surface; ♦ release of stranded seabirds in accordance with CWS permit; ♦ discharges will comply with the OWTG and ship operations will adhere to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78); ♦ adherence to the Statement of Canadian Practice on the Mitigation of Seismic Noise in the Marine Environment ♦ solid waste transported to shore and recycled where possible; ♦ all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently; ♦ avoidance of seabird colonies by aircraft and vessels.	♦ Seabird occurrence data will be collected in the area under CWS coordinated program. ♦ POB advised to notify SHE Lead when stranded birds found.
Species at Risk	♦ use of water-based drilling muds wherever possible; ♦ use of non-toxic or low toxicity chemicals and muds, and treating synethic oil-contaminated cuttings as per OWTG; ♦ all wastewater discharges to comply with the OWTG and ship operations will adhere to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78); ♦ use of the OCMS to screen chemicals;	♦ The current Hibernia EEM program will be amended to include the effects monitoring of the drill centres as spatially and temporally appropriate ♦ Pursuant to the OWTG, compliance monitoring all effluent discharges will be conducted. ♦ A fish habitat compensation

VEC	Mitigation Measures	Monitoring and Follow-Up
	♦ solid waste transported to shore and recycled where possible; ♦ adherence to DFO's Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment; ♦ all equipment designed to meet regulatory requirements for emissions and regular maintenance plans to ensure equipment operates efficiently.; ♦ operators of vessels will be instructed to reduce speed and alter coarse to avoid collision with marine mammals and sea turtles; and ♦ release of stranded seabirds in accordance with CWS permit.	monitoring program will also be implemented to ensure no net loss of productive capacity in fish habitat as a result of this Project.

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Taylor, B. Geotechnical Engineer; Jacques Whitford Limited

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APPENDIX A

Hibernia Drill Centres Construction and Operations Program Scoping Document

1 Purpose

This document provides scoping information for the environmental assessment (EA) of the proposed construction, operation, maintenance, modification, decommissioning, and abandonment of up to six drill centres and associated subsea equipment, drilling operations within these drill centres, and all other related works and activities (the Project) at the Hibernia field. The Hibernia South Extension (HSE) subsea development is the first planned subsea tie-back to the Hibernia GBS. Five additional drill centres may be constructed over the life of the project. The proposed Project is located on the Grand Banks offshore Newfoundland, approximately 320 km east-southeast of St. John's (Figure 1 in Project Description). Hibernia Management Development Corporation (HMDC) is the project Proponent.

Included in this document is a description of the scope of the project that will be assessed, the factors to be considered in the assessment, and the scope of those factors.

This Scoping Document has been developed by the C-NLOPB in consultation with the Department of Fisheries and Oceans, Environment Canada and other agencies in the Governments of Canada and Newfoundland and Labrador.

2 Canadian Environmental Assessment Act - Regulatory Considerations

In 1986, the Hibernia Development Project received Development Plan approval from the C-NLOPB. In addition, the Hibernia Development was subject to a panel review under the former Environmental Assessment and Review Process (EARP) and it was determined that the project was not likely to cause significant adverse environmental effects.

The Project, as outlined in the Project Description submitted by HMDC, is in support of production operations at the Hibernia platform. However, the proposed Project is outside the scope of the project previously assessed in the EARP panel review of the Hibernia Development Project and the location of the drill centre(s) is outside the original project area (as defined by the Hibernia Significant Discovery Area[1]).

The C-NLOPB has determined, in accordance with paragraph 3(1)(a) of the *Regulations Respecting the Coordination by Federal Authorities of Environmental Assessment Procedures and Requirements* (FCR), that an EA of the project under section 5 of the *Canadian Environmental Assessment Act* (CEA Act) is required.

[1] Hibernia Development Project Environmental Impact Statement Volume IIIa Biophysical Assessment. 1985. Mobil Oil Canada Ltd.

3 The Project will require authorizations pursuant to Section 138 (1)(b) of the *Canada-Newfoundland Atlantic Accord Implementation Act* and Section 134(1)(a) of the *Canada-Newfoundland and Labrador Atlantic Accord Implementation Newfoundland and Labrador Act.* Environment Canada has indicated that the proposed project will require an ocean disposal permit pursuant to the *Canadian Environmental Protection* Act (Schedule 1, Part 1, Paragraph 3, Section 127(1) (formerly Subsection 71 (1)). In addition, the Department of Fisheries and Oceans has indicated that an authorization pursuant to Section 35(2) of the *Fisheries* Act will be required. Pursuant to Section 5(1)(d) of the CEA Act, the C-NLOPB, Environment Canada, and the Department of Fisheries and Oceans are Responsible Authorities (RAs) and must undertake an EA of the Project**.** The project, as proposed, is described in the *Inclusion List Regulations* and therefore is subject to a screening level of assessment under the CEA Act.

Pursuant to Section 12.2 (2) of the CEA Act, the C-NLOPB will be assuming the role of the Federal Environmental Assessment Coordinator (FEAC) for this screening and in this role will be responsible for coordinating the review activities of the RAs and the expert government departments and agencies that participate in the review.

> ***The C-NLOPB, Environment Canada, and the Department of Fisheries and Oceans, as Responsible Authorities (RAs) intend that the environmental assessment submitted with any supporting documents as may be necessary, will fulfill the requirements for a Screening. The RAs therefore, pursuant to Section 17(1) of the CEA Act, formally delegate the responsibility for preparation of an acceptable Screening environmental assessment to HMDC, the project proponent. The RAs will prepare the Screening Report, which will include the determination of significance.***

4 Scope of the Project

The Project to be assessed consists of the following components:

3.1 Construction, installation, operation, maintenance, modification, decommissioning and abandonment of up to 6 drill centres, including seabed excavation and soil deposition;

3.2 Installation, operation, maintenance, modification, decommissioning and abandonment of subsea flowlines/umbilicals and associated equipment (inclusive of injection and production flowlines) tied back to the Hibernia GBS. Upgrades to the Hibernia GBS will be included, if required. This includes any associated seabed trenching, excavation, covering and/or soil deposition;

3.3 Drilling and workover of up to 11 wells per drill centre;

3.4 Vertical Seismic Profiling (VSP) and wellsite/geohazard surveys;

3.5 Operation of support craft associated with above activities, including but not limited to vessels for the excavation of glory holes, mobile offshore drilling units, supply/standby vessels, helicopters, and shuttle tanker activity that is incremental to that already in existence or expected to be in existence; and

3.6 Project activities are likely to be undertaken year-round, commencing in 2009 until end of project, currently estimated to be 2036. For the Hibernia South Extension (HSE), the following is a proposed project schedule, which is dependent on project approval.

- Geotechnical/Geophysical (wellsite surveys) investigations from summer to fall 2009;
- HSE glory hole excavation from summer to fall 2011
- subsea equipment installation activities from summer to fall of 2012;
- Drilling activities will likely occur year round, commencing in 2012, with possible completion by 2012;
- VSP surveys may occur year round from commencement of drilling activities through to end of production;
- Production operations are likely to commence in 2012 and will continue year round through to 2036. Abandonment will likely commence after 2036.

For the remaining five drill centres, it is assumed that project activities will require similar timelines for completion, with activities to commence at any time of the year throughout the life of the project.

4 Factors to be Considered

The environmental assessment shall include a consideration of the following factors in accordance with Section 16 of CEAA:

4.1 The purpose of the Project;

4.2 Alternative means of carrying out the project which are technically and economically feasible and the environmental effects of any such alternative means;

4.3 The environmental effects[2] of the Project, including those due to malfunctions or accidents that that may occur in connection with the Project and any change to the Project that may be caused by the environment;

4.4 Cumulative environmental effects of the Project that are likely to result from the project in combination with other projects or activities that have

[2] The term "environmental effects" is defined in Section 2 of the *CEA Act*, and Section 137 of the *Species at Risk Act*.

been or will be carried out, including all activities and ancillary activities for the construction, operation and maintenance of the drill centres;

4.5 The significance of the environmental effects described in 4.3 and 4.4;

4.6 Measures, including contingency and compensation measures as appropriate, that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the project;

4.7 The significance of adverse environmental effects following the employment of mitigative measures, including the feasibility of additional or augmented mitigative measures;

4.8 The need for, and the requirements of, any follow-up program in respect of the Project consistent with the requirements of the CEA Act and the SARA; and

4.9 Report on consultations undertaken by HMDC with interested parties who may be affected by program activities and/or the public respecting any of the matters described above.

5 Scope of the Factors to be Considered

Hibernia Management Development Corporation will prepare and submit to the C-NLOPB, as lead RA, an EA for the above described physical works and activities, and those described in the project description "*Hibernia Drill Centres Construction and Operations Program Project Description*" (HMDC,2008). The EA will address the factors listed above; the issues identified in Section 5.2, and document any issues and concerns that may be identified by the proponent through regulatory, stakeholder, and public consultation**.**

Program activities are proposed for the Jeanne d'Arc Basin, an area that has been studied extensively in a number of recent EAs. For the purposes of this assessment, the information provided in previous EA documents for offshore oil and gas activities in the Jeanne d'Arc Basin area can be used, where applicable, in support of the EA for the proposed Project. Where new or updated information (i.e., modelling, new field data) is not included, justification for the use of older information must be provided.

If the "valued ecosystem component" (VEC) approach is used to focus its analysis, a definition of each VEC (including components or subsets thereof) identified for the purposes of EA, and the rationale for its selection, shall be provided.

The scope of the factors to be considered in the EA includes the components identified in Section 5.2 “Summary of Potential Issues” setting out the specific matters to be considered in assessing the environmental effects of the project and in developing environmental plans for the project and the defined “Boundaries” (see below). Considerations relating to definition of “significance” of environmental effects are provided in the following sections.

Discussion of the biological and physiological environments should consider the data available for the project and study areas. Where data gaps exist, the EA should clearly identify the lack of data available.

5.1. Boundaries

The EA will consider the potential effects of the proposed physical works and physical activities within spatial and temporal boundaries that encompass the periods and areas during and within which the project may potentially interact with, and have an effect on, one or more VEC. These boundaries may vary with each VEC and the factors considered, and should reflect a consideration of:

- The proposed schedule/timing of the construction, operation, maintenance, and decommissioning phases of the proposed physical works and/or physical activities;
- The natural variation of a VEC or subset thereof;
- The timing of sensitive life cycle phases in relation to the scheduling of proposed physical works and/or physical activities;
- Interrelationships/interactions between and within VECs;
- The time required for recovery from an effect and/or return to a pre-effect condition, including the estimated proportion, level, or amount of recovery;
- The area within which a VEC functions and within which a project effect may be felt.

The proponent shall clearly define, and provide the rationale for the spatial and temporal boundaries that are used in its EA. The EA report shall clearly describe the spatial boundaries (i.e. Study Area, Project Area), and shall be clearly defined by illustration in figures and maps. The corner-point coordinates should be included.

Boundaries should be flexible and adaptive to enable adjustment or alteration based on field data and/or modeling results. The Study Area and associated boundaries will be described based on consideration of potential areas of effects as determined by modeling (e.g., spill trajectory and cuttings dispersion), the scientific literature, and project-environment interactions (including transportation corridors). A suggested categorization of spatial boundaries follows.

5.1.1 Spatial Boundaries

Project Area — The areas in which Project activities are to occur.

Affected Area — The area that could potentially be affected by Project activities beyond the "Project Area".

Regional Area — The area extending beyond the "Affected Area" boundary. The "Regional Area" boundary will also vary with the component being considered (e.g., boundaries suggested by bathymetric and/or oceanographic considerations).

5.1.2 Temporal Boundaries

The temporal scope should describe the timing of project activities. Scheduling of project activities should consider the timing of sensitive life cycle phases of the VECs in relation to physical activities.

5.2 Summary of Potential Issues

The EA report for the proposed program should contain descriptions of the physical and biological environments, as identified below. Where applicable, information may be summarized from existing environmental assessment reports for the Jeanne d'Arc Basin. However, where new information is available for any of the following factors, the new data and/or information must be provided. If information is not updated, justification must be provided. Where information is summarized from existing EA reports, it should be properly referenced, with specific reference to those sections of the existing EA report summarized.

The EA should contain descriptions and definitions of EA methodologies employed in the assessment of effects. Effects of relevant Project activities on those Valued Ecosystem Components (VECs) most likely to be in the Study Area will be assessed. Discussion of cumulative effects within the Project and with other relevant marine projects will be included. Issues to be considered in the EA will include, but not be limited, to the following.

5.2.1 Physical Environment

Provide a summary description of the following:

- Meteorological and oceanographic characteristics in the Study Area, including extreme conditions;
- Site-specific sea ice and iceberg conditions, including iceberg scour of the seabed;
- Overview of physical environmental monitoring, observation and forecasting programs that will be in place for all phases of the project ;
- Ice management/mitigation procedures to be implemented, including criteria respecting disconnection of project installations and assessment of

the efficiency of detection and deflection techniques, and any change to the Project that may be caused by the environment; and

- Effects of the environment on the Project, including cumulative effects. The effects assessment should pay specific attention to effects of environmental factors on mobile drilling units, and mitigations that may be implemented to reduce these effects.

Marine Resources

Characterization, including quantification to the degree possible, of the spatial area of seabed that is predicted to be affected by the following activities should be provided: dredging, trenching and dredge spoil disposal; stitching and dumping; drill cuttings and other discharges

5.2.2 Marine and/or Migratory Birds using the Study Area

Provide a summary description of the following:

- Spatial and temporal species distributions in the Study Area (observation/monitoring data collected during ongoing petroleum activities should be included);
- Species habitat, feeding, breeding, and migratory characteristics of relevance to the Study Area;
- Physical displacement as a result of vessel presence (e.g. disruption of foraging activities);
- Effects of hydrocarbon spills from accidental events;
- Attraction of birds to vessel lighting and flares;
- Procedures for handling birds that may become stranded on offshore structures (e.g., rigs, supply vessels, construction vessels);
- Means by which bird mortalities associated with project operations may be documented and assessed;
- Means by which potentially significant effects upon birds may be mitigated through design and/or operational procedures; and
- Environmental effects due to the Project, including cumulative effects.

5.2.3 Marine Fish and Shellfish

Provide a summary description of the following:

- Characterization of existing environment in the Study Area;
- Distribution and abundance of species utilizing the Study Area with consideration of critical life stages (e.g., spawning areas, overwintering, juvenile distribution, migration);
- Description, to the extent possible, of location, type, diversity and areal extent of marine fish habitat in the Study Area, in particular those indirectly

or directly supporting traditional, aboriginal, historical, present or potential fishing activity, and including any essential/critical (e.g. spawning, feeding, overwintering) habitats;

- Means by which potentially significant effects upon fish (including critical life stages) may be mitigated through design, scheduling, and/or operational procedures; and
- Environmental effects due to the Project, including cumulative effects.

5.2.4 Marine Mammals and Sea Turtles

Provide a summary description of the following:

- Spatial and temporal distribution and abundance of species utilizing the Study Area (observation and monitoring data collected during exploration and development activities operated by Hibernia should be discussed). Data from other recent operations, if available, within the Jeanne d'Arc Basin should also be included;
- Description of marine mammal and sea turtle lifestyles/life histories relevant to Study Area;
- Means by which potentially significant effects upon marine mammals/sea turtles (including critical life stages) may be mitigated through design, scheduling, and/or operational procedures; and
- Environmental effects due to the Project, including cumulative effects.

5.2.5 Species at Risk (SAR)

Provide a summary description of the following:

- A description, to the extent possible, of species at risk as listed in Schedule 1 of the *Species at Risk Act (SARA)*, and those under consideration by COSEWIC in the Study Area, including fish, marine mammals, sea turtles and seabird species;
- A description of critical habitat (as defined under SARA), if applicable, relevant to the Study Area;
- Means by which adverse effects upon SAR and their critical habitat may be mitigated through design, scheduling, and/or operational procedures;
- Monitoring and mitigation, consistent with recovery strategies/action plans (endangered/threatened) and management plans (special concern);
- Assessment of effects (adverse and significant) on species and critical habitat, including cumulative effects;
- The means by which the Proponent intends to ensure that relevant changes or updates to SARA listed species, including recovery strategies

and management plans, are tracked throughout the project life and incorporated into its environmental planning; and

- A summary statement stating whether project effects are expected to contravene the prohibitions of SARA (Sections 32 (1), 33, 58(1)).

5.2.6 “Sensitive” Areas

Information should include:

- A description, to the extent possible, of any ‘Sensitive” areas in the Study Area such as important or essential habitat to support any of the marine resources identified;
- Environmental effects due to the project, including cumulative effects, on those “Sensitive” areas identified;
- Means by which adverse effects upon “Sensitive” areas may be mitigated through design, scheduling, and/or operational procedures; and
- Environmental effects due to the Project, including cumulative effects, on those sensitive areas identified.

Marine Use

5.2.7 Noise/Acoustic Environment

Provide a description of the following:

- Noise and acoustic issues in the marine environment that may be generated from construction activities (e.g., drill centre excavation); drilling operations (e.g., drill rig, thruster-equipped vessels), VSP geohazard/wellsite survey programs and abandonment (wellhead severance);
- Disturbance/displacement of VECs and SAR associated with the above activities;
- Means by which potentially significant effects may be mitigated through design and/or operational procedures; and
- Assessment of effects of noise/disturbance on the VECs and SAR, including cumulative effects.

5.2.8 Presence of Structures and/or Operations

Provide a description of the following:

- Size and location of temporary or project-life exclusion zones;
- Description of project-related traffic, including routings, volumes, scheduling and vessel types;
- Means by which adverse effects upon marine use may be mitigated through design, scheduling and/or operational procedures; and

- Effects of physical presence of structures upon access to fishing grounds, fish research surveys and upon general marine traffic/navigation, including cumulative effects.

5.2.9 The EA should describe the relationship of the existing Hibernia production project, with the proposed Project. For example, the EA should address whether the produced water discharge rate is likely to change or whether any elements of that project, other than the drilling of the wells and subsea construction/installation are additional or supplementary to the project already assessed.

5.2.10 Discharges and Emissions

Provide a description of planned project discharges to the marine environment, including:

- Dredge spoil, drilling muds, fluids and cuttings, produced water, bilge water, grey water, black water, cooling water, deck drainage, blow out preventer fluid; ballast water; etc.;
- Characterization, quantification and modelling of expected discharges (e.g., cuttings dispersion; concentration of metals, nutrients, hydrocarbons, biocides) and the timing of discharges, including a description of the models employed;
- Means for reduction, re-use and recovery of wastes beyond those specified in regulations and guidelines, including a description of "best available/practicable technology"; and
- Environmental effects of discharges, with consideration of EEM data from Hibernia and other Grand Banks production operations, including cumulative effects.

5.2.11 Air Quality

Provide a description of the following:

- Annual estimates of rates and quantities of emissions (e.g., as reported through the OWTG, NPRI, and Environment Canada's GHG Facility Reporting), and a description of potential means for their reduction and reporting;
- Implications for health and safety of workers that may be exposed to them;
- Mitigation and monitoring; and
- Assessment of effects, including cumulative effects.

5.2.12 Commercial Fisheries

Provide a description of commercial fisheries in the Jeanne d'Arc Basin area including the most recent data available. The information should include:

- Description of fisheries in the Study Area (including traditional, existing and potential commercial, recreational and aboriginal/subsistence and foreign fisheries, where practicable);
- Traditional historical fishing activity – abundance data for certain species in this area, prior to the severe decline of many fish species (e.g., an overview of survey results and fishing patterns in the survey areas for the last 20 years);
- Consideration of underutilized species that may be found in the Study Area as determined by analyses of past DFO research surveys and Industry GEAC survey data, with emphasis on those species being considered for future potential fisheries, and species under moratoria;
- Fisheries liaison/interaction policies and procedures;
- Program(s) for compensation of affected parties, including fisheries interests, for accidental damage resulting from project activities;
- Means by which adverse effects upon commercial fisheries may be mitigated through design and/or operational procedures; and
- Environmental effects of the Project, including cumulative effects.

5.2.13 <u>Accidental Events</u>

The discussion should not be limited to crude oil, but should consider accidental releases of drilling fluids, drilling muds, other hydrocarbons, and/or chemicals that may be spilled. An update to the information presented in previous environmental assessments should be provided. The information should include:

- Quantification of blowout risk;
- Quantification of risk of hydrocarbon/chemical spills of all volumes, from all facilities associated with the project (hydrocarbons should not be limited to crude and or diesel, but shall include synthetic based muds and fluids, and other hydrocarbons);
- Discussion of the potential for spill events from drilling and production activities to enter the marine environment;
- Modelled physical fate of oil spills, including descriptions of models and/or analyses that are employed and the physical data upon which they are based;
- Description of the marine area likely to be affected by hydrocarbons from a spill event that enters the marine environment;
- Fate of hydrocarbons in the marine environment, as determined by spill trajectory analysis;
- Mitigation measures to be employed to reduce or prevent such events from occurring;

- Contingency plans to be implemented in the event of an accidental release;
- Environmental effects of petroleum or chemical spills on all VECs identified, including losses from streamers (VSP and geohazard surveys) and drilling muds/fluids/cuttings, with consideration of effectiveness of spill countermeasures; and
- Cumulative effects in consideration of "chronic" oil pollution on the Grand Banks (e.g. spills from other offshore operations, bilge dumping and other discharges from vessels).

5.2.14 **Environmental Management**
Provide a general overall description of Hibernia Management and Development Company Limited's environmental management system and its components, including, but not limited to:

- Pollution prevention policies and procedures;
- Environmental compliance monitoring;
- Provisions or management system auditing;
- Chemical selection and management procedures;
- Fisheries liaison/interaction policies and procedures;
- Program(s) for compensation of affected parties, including fisheries interests, for accidental damage resulting from project activities; and
- Emergency response plan(s).

Biological and Follow-up Monitoring

5.2.15 Discuss the need for and requirements of a follow-up program (as defined in Section 2 of CEAA) and pursuant to the SARA. The discussion should also include any requirement for compensation monitoring (compensation is considered mitigation). Modifications to existing follow-up programs to accommodate project modifications should be addressed, including compensation monitoring (Section 35(2) HADD authorization), EEM design and implementation, and the need for baseline information in support of these programs.

5.2.16 Provision of an acceptable fish habitat compensation strategy, including options considered, in accordance with the Department of Fisheries and Oceans "*Policy for the Management of Fish Habitat*".

5.2.17 Detailed description of monitoring and observations procedures to be implemented regarding marine mammals, sea turtles, and seabirds (observation protocols should be consistent with the "*Geophysical, Geological, Environmental and Geotechnical Program Guidelines*" (C-NLOPB 2008)).

5.2.18 Abandonment/Decommissioning

Plans for abandonment and/or decommissioning of the project area and associated facilities following termination of production, including any anticipated requirement for post-abandonment monitoring.

5.3 Significance of Adverse Environmental Effects

The Proponent shall clearly describe the criteria by which it proposes to define the "significance" of any residual adverse effects (i.e., following the employment of mitigative measures) that are predicted by the EA. This definition should be consistent with the November 1994 CEAA reference guide "*Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects"*, and be relevant to consideration of each VEC (including components or subsets thereof) that is identified. SARA species shall be assessed independent of non-SARA species. The effects assessment methodology should clearly describe how data gaps are considered in the determination of significance of effects.

5.4 Cumulative Effects

The assessment of cumulative environmental effects should be consistent with the principles described in the February 1999 CEAA "*Cumulative Effects Assessment Practitioners Guide*" and in the March 1999 CEAA operational policy statement "*Addressing Cumulative Environmental Effects under the Canadian Environmental Assessment Act*". It should include a consideration of environmental effects that are likely to result from the proposed project in combination with other projects or activities that have been or will be carried out. These include, but are not limited to:

- Ongoing oil and gas activities;
- Proposed oil and gas activities under EA review (listed on the C-NLOPB Public registry at www.cnlopb.nl.ca);
- Seismic activities;
- Fishing activities, including Aboriginal fisheries; and
- Marine transportation.

6 Projected Timelines for the Environmental Assessment Process

The following are estimated timelines for completing the EA process. The timelines are offered based on experience with recent environmental assessments of similar project activities.

ACTIVITY	TARGET	RESPONSIBILITY
Submission of EA upon receipt of Scoping Document	8 weeks	Proponent
Prepare for EA Review	~1 week	C-NLOPB
EA Review	6 weeks	C-NLOPB & Regulatory Agencies
Compile Comments on EA	1 week	C-NLOPB
Submission of EA Addendum/Response to EA Comments	4 weeks	Proponent
Review of EA Addendum/Response Document	3 weeks	C-NLOPB & Regulatory Agencies
Screening Report (Determination of Significance of Project Effects)	3 weeks	C-NLOPB
Total	26 weeks	

APPENDIX B

Physical Environment at Hibernia Southern Extension – Oceans Ltd. 2008

Physical Environment at Hibernia Southern Extension

Submitted To:
Jacques Whitford Environmental Ltd.
Torbay Road
St. John's, NL

October 2008

Physical Environment at
Hibernia Southern Extension

Submitted To:
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Submitted By;
Oceans Ltd.
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October 2008

1.0 Introduction

The physical environment at Hibernia and surrounding areas on the Grand Banks is being described in this report in support of activities at Hibernia Southern Extension.

The wind and wave climatology was prepared from the MSC50 hindcast data set using Grid Point 11028, from surface observations in the ICOADS data set, and from MANMAR observations on the Hibernia platform. The wind climatology for Hibernia South is presented through the use of wind roses and histograms showing the frequencies of wind speeds and directions by month and on an annual basis. Percentage exceedance diagrams for wind speeds are included. Statistics on air and sea surface temperatures, frequency distribution of the various types of precipitation, and the percentage occurrences of low visibility in specified ranges are presented and discussed.

The wave climatology is presented through the use of wave roses and histograms showing the wave heights and directions on a monthly and annual basis, plus significant wave height statistics, percent occurrence of specified wave periods, percentage exceedance diagrams, and scatter diagrams of the significant wave height versus spectral peak periods. The wave climatology presents the frequency of specific wave conditions and the sea state an operator would most likely encounter during each month of the year.

The climate section includes information on tropical systems affecting the area and climate variability to show trends in climate change.

The report contains an extremal analysis of the wind and wave conditions in the project area based on the same MSC50 grid point. The analysis used two different methods; a Gumbel distribution together with a sensitivity analysis to determine the appropriate number of storms to use in the analysis, and the joint probability method using a Weibull distribution for significant wave heights and a lognormal distribution of spectral peak periods.

The physical oceanography section consists of a description of the currents and water properties in the area. The current data base consists of moored current data collected during the Hibernia exploration phase, and data in the Bedford Institute of Oceanography archive plus surface currents measured by the MIROS radar.

A general description of currents is presented for the area from published literature and models together with information on the mean velocities and the mean and maximum current speeds on a monthly basis from current measurements. The water properties is described using published information, hydrographic contours from data collected by Fisheries and Oceans Canada, and temperature and salinity statistics and T-S diagrams produced from data archived by the Bedford Institute of Oceanography.

2.0 Climate

The Grand Banks of Newfoundland experiences weather conditions typical of a marine environment with the surrounding waters having a moderating effect on temperature. In general, marine climates experience cooler summers and milder winters than continental climates and have a much smaller annual temperature range. Furthermore, a marine climate tends to be fairly humid, resulting in reduced visibilities, low cloud heights, and receives significant amounts of precipitation.

The climate of the Grand Banks is very dynamic, being largely governed by the passage of high and low pressure circulation systems. These circulation systems are embedded in, and steered by, the prevailing westerly flow that typifies the upper levels of the atmosphere in the mid-latitudes, which arises because of the normal tropical to polar temperature gradient. The mean strength of the westerly flow is a function of the intensity of this gradient, and as a consequence is considerably stronger in the winter months than during the summer months, due to an increase in the south to north temperature gradient. [Meteorological convention defines seasons by quarters; e.g., winter is December, January, February, etc.]

At any given time, the upper level flow is a wave-like pattern of large and small amplitude ridges and troughs. These ridges and troughs tend to act as a steering mechanism for surface features and therefore their positions in the upper atmosphere determine the weather at the earth's surface. Upper ridges tend to support areas of high pressure at the surface, while upper troughs lend support to low pressure developments. The amplitude of the upper flow pattern tends to be higher in winter than summer, which is conducive to the development of more intense storm systems.

During the winter months, an upper level trough tends to lie over Central Canada and an upper ridge over the North Atlantic resulting in three main storm tracks affecting the Grand Banks: one from the Great Lakes Basin, one from Cape Hatteras, North Carolina and one from the Gulf of Mexico. These storm tracks, on average, bring eight low pressure systems per month over the area.

Frequently, intense low pressure systems become 'captured' and slow down or stall off the coast of Newfoundland and Labrador. This may result in an extended period of little change in conditions that may range, depending on the position, overall intensity and size of the system, from the relatively benign to heavy weather conditions.

Rapidly deepening storms are a problem south of Newfoundland in the vicinity of the warm water of the Gulf Stream. Sometimes these explosively deepening oceanic cyclones develop into a "weather bomb"; defined as a storm that undergoes central pressure falls greater than 24 mb over 24 hours. Hurricane force winds near the center, the outbreak of convective clouds to the north and east of the center during the explosive stage, and the presence of a clear area near the center in its mature stage (Rogers and Bosart, 1986) are typical of weather bombs. After development, these systems will either move across Newfoundland or near the southeast coast producing gale to storm force winds from the southwest to south over the project area.

There is a general warming of the atmosphere during spring due to increasing heat from the sun. This spring warming results in a decrease in the north-south temperature gradient. Due to this weaker temperature gradient during the summer, storms tend to be weaker and not as frequent. Furthermore, the weaker tropical-to-polar temperature gradient in the summer results in the storm tracks moving further north. With the low pressure systems passing to the north of the region, the prevailing wind direction during the summer months is from the southwest to south. As a result, the incidences of gale or storm force winds are relatively infrequent over Newfoundland during the summer.

2.1 Data Sources

Wind and wave climate statistics for the area were extracted from the MSC50 North Atlantic wind and wave climatology database compiled by Oceanweather Inc under contract to Environment Canada. The MSC50 database consists of continuous wind and wave hindcast data in 1-hour time steps from January 1954 to December 2005, on a 0.1° latitude by 0.1° longitude grid. Winds from the MSC50 data set are 1-hour averages of the effective neutral wind at a height of 10 metres. In this study, Grid Point 11028 located at 46.7°N; 48.7°W was considered to be most representative of conditions within the project area (Figure 2.1).

Air temperature, sea surface temperature, wind speed and direction, visibility, and wave statistics for the area were compiled using data from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). A subset of global marine surface observations from ships, drilling rigs, and buoys for the area 46.5°N to 47.0°N; 48.5°W to 49.0°W covering the period from January 1950 to December 2006 was used in this report. The ICOADS data set has certain inherent limitations in that the observations are not spatially or temporally consistent. In addition, even though the data used in this report were subjected to standard quality control procedures, the data set is somewhat prone to observation and coding errors, resulting in some erroneous observations within the data set. The errors were minimized by using the standard filtering system using source exclusion flags, composite QC flags and an outlier trimming level of 3.5 standard deviations. The ICOADS data set is also suspected to contain a fair-weather bias, due to the fact that ships tend to avoid severe weather or simply do not transmit weather observations during storm situations.

Wind direction and speed statistics were also compiled using MANMAR data from the Hibernia platform located at 46°45´01"N; 48°46´54"W. The data used in this report is from January 1999 to December 2001 and January 2003 to September 2008. Observational data from 2002 was not available at the time of this report. Since the ICOADS region includes the Hibernia platform, Hibernia MANMAR data is also included within the ICOADS dataset.

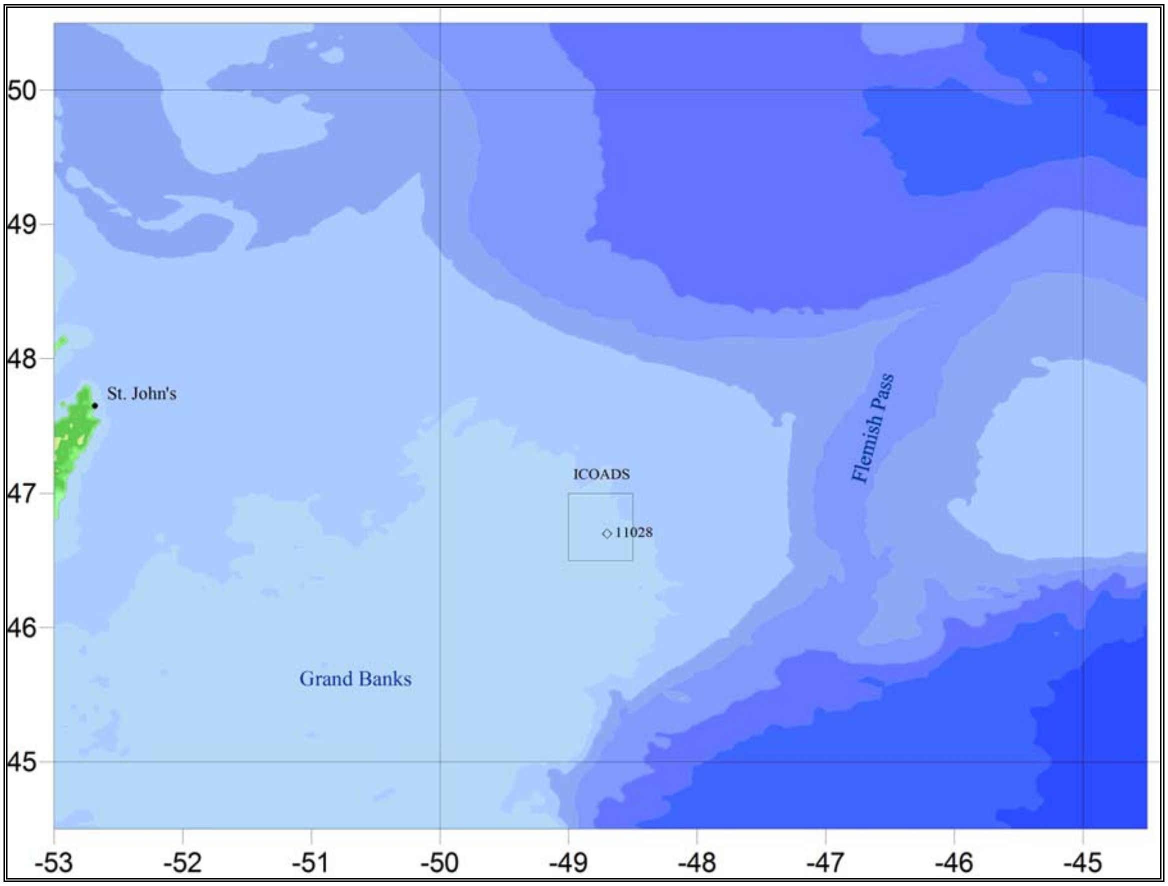

Figure 2.1 Locations of the Climate Data Sources

2.2 Wind Climatology

The Grand Banks experiences predominately southwest to west flow throughout the year. West to northwest winds which are prevalent during the winter months begin to shift counter-clockwise during March and April resulting in a predominant southwest wind by the summer months. As autumn approaches, the tropical-to-polar temperature gradient strengthens and the winds shift slightly, becoming predominately westerly again by late fall and into winter.

Low pressure systems crossing the area are more intense during the winter months. As a result, mean wind speeds tend to peak during this season. Mean wind speeds at grid point 11028, the ICOADS data set and the Hibernia MANMAR dataset peak during the month of January (Table 2.1). Grid 11028 had January and February mean wind speeds of 10.9 m/s, while the ICOADS dataset recorded the highest mean wind speed of 14.1 m/s for January. The Hibernia platform also had its highest mean wind speeds of 15.9 m/s during the month of January. Wind speeds from all three data sets are not directly comparable to each other due to their sampling period and the heights at which they were measured. Winds from the Hibernia dataset were 10-minute means, measured from an anemometer located 139 metres above sea level.

The wind speed is dependent on height since the wind speed increases at increasing heights above sea level. Methods to reduce wind speeds from anemometer level to 10 metres have proven ineffective due to atmospheric stability issues. As a result, wind speed data from the Hibernia platform is presented in its original form and not reduced to the reference 10 m height. Winds in the ICOADS data set were either estimated or measured by anemometers at various heights above sea level. Also, winds speeds from each of the data sources have different averaging periods. The MSC50 winds are 1-hour averages while the ICOADS winds are 10-minute average winds. The adjustment factor to convert from 1-hour mean values to 10-minute mean values is usually taken as 1.06 (U.S. Geological Survey, 1979).

Table 2.1 Mean Wind Speed (m/s) Statistics

	MSC50 Grid Point 11028		ICOADS		Hibernia MANMAR	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
January	10.9	4.6	14.1	6.7	15.9	7.6
February	10.9	4.5	13.8	6.3	15.3	7.4
March	9.9	4.3	12.4	5.9	14.4	6.7
April	8.4	3.9	11.2	5.6	13.4	6.8
May	7.0	3.5	10.1	4.7	11.8	5.9
June	6.5	3.1	9.7	4.8	11.5	5.6
July	6.1	2.9	9.8	4.6	11.1	5.9
August	6.4	3.0	9.1	4.3	10.5	5.6
September	7.5	3.6	9.9	4.9	11.2	5.9
October	8.8	3.9	11.8	5.3	13.0	6.4
November	9.5	4.2	12.3	5.9	13.3	6.8
December	10.6	4.5	13.3	6.1	15.2	7.3

A wind rose of the annual wind speed and histogram of the wind speed frequency from grid point 11028 is presented in Figure 2.2 and Figure 2.3. Monthly wind roses along with histograms of the frequency distributions of wind speeds for Grid Point 11028 can be found in Appendices 1 and 2, respectively. There is a marked increase in the occurrence of winds from the west to northwest in the winter months as opposed to the summer months, which is consistent with the wind climatology of the area.

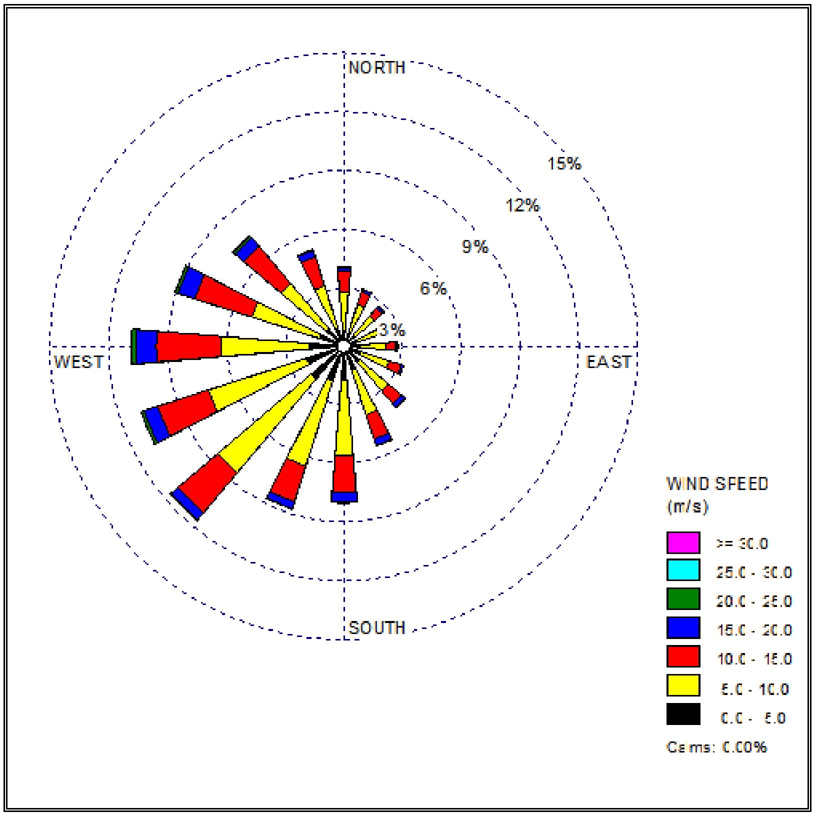

Figure 2.2 Annual Wind Rose for MSC50 Grid Point 11028 located near 46.7°N; 48.7°W. 1954 – 2005

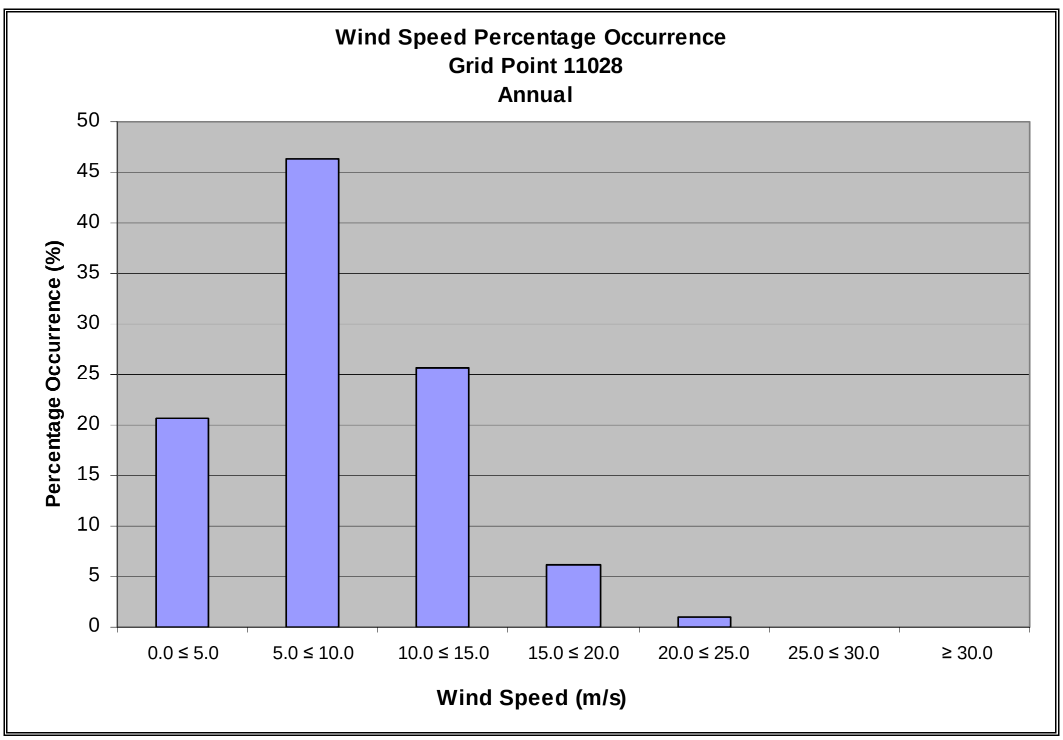

Figure 2.3 Annual Percentage Frequency of Wind Speeds for MSC50 Grid Point 11028 located near 46.7°N, 48.7°W; 1954 – 2005

The percentage exceedance of wind speeds at grid point 11028 is presented in Figure 2.4.

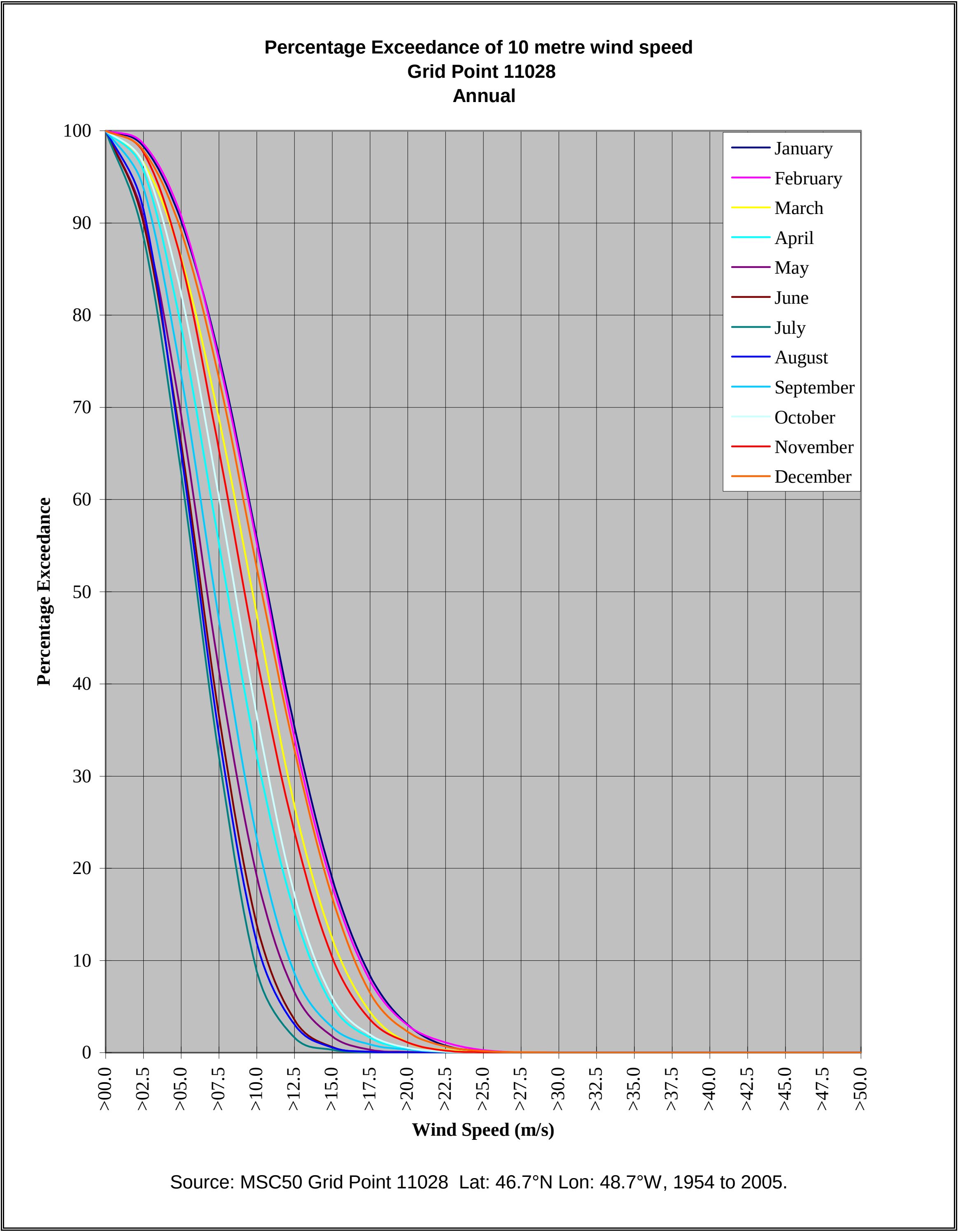

Figure 2.4 Percentage Exceedance of 10 metre wind speed at Grid Point 11028

Intense mid-latitude low pressure systems occur frequently from early autumn to late spring. In addition, remnants of tropical systems have passed near Newfoundland between spring and late fall. Therefore, while mean wind speeds tend to peak during the winter months, maximum wind speeds may occur at anytime during the year. A table of monthly maximum wind speeds for each of the data sets is presented in Table 2.2.

Rapidly deepening storm systems known as weather bombs frequently cross the Grand Banks. These storm systems typically develop in the warm waters of Cape Hatteras and move northeast across the Grand Banks. On February 11, 2003 wind speeds at Grid Point 11028 peaked at 29.9 m/s. Wind speeds of 49.4 m/s from the southwest were recorded at 18Z by the Hibernia Platform anemometer as this system passed. During this storm, a low pressure developing off Cape Hatteras on February 10th rapidly deepened to 949 mb as it tracked northeast across the Avalon Peninsula around 18Z on February 11th.

Another intense storm which developed south of the region passed east of the area on December 16, 1961. This storm resulted in wind speeds similar to that produced during the February 11th storm. During this event, grid point 11028 had wind speeds of 29.9 m/s. There were no observations from the ICOADS dataset recorded during this storm.

While mid-latitude low pressure systems account for the majority of the peak wind events on the Grand Banks, storms of tropical origin can also on occasion pass over the region. On August 22 1995, the remnants of Category 4 Hurricane Felix passed approximately 60 nm west of the region as a tropical storm with maximum sustained 1-minute wind speeds of 25.7 m/s and a central pressure of 985 mb. During this event, the 1-hour average wind speeds in the MSC50 data set peaked at 27.0 m/s from the south-southwest. No observations were recorded within the ICOADS dataset during this event.

Table 2.2 Maximum Wind Speeds (m/s) Statistics

	MSC50 Grid Point 11028	ICOADS	MANMAR
January	27.0	35.0	43.2
February	30.2	38.1	49.4
March	27.4	36.5	37.6
April	24.2	28.3	32.9
May	21.9	24.7	30.9
June	23.0	23.2	31.4
July	18.1	22.1	29.8
August	27.0	23.2	36.0
September	25.4	25.7	37.6
October	27.2	30.9	41.2
November	27.2	34.0	38.1
December	29.9	32.9	39.1

2.3 Wave Climatology

The main parameters for describing wave conditions are the significant wave height, the maximum wave height, the peak spectral period, and the characteristic period. The significant wave height is defined as the average height of the 1/3 highest waves, and its value roughly approximates the characteristic height observed visually. The maximum height is the greatest vertical distance between a wave crest and adjacent trough. The spectral peak period is the period of the waves with the largest energy levels, and the characteristic period is the period of the 1/3 highest waves. The characteristic period is the wave period reported in ship observations, and the spectral period is reported in the MSC50 data set.

A sea state may be composed of the wind wave alone, swell alone, or the wind wave in combination with one or more swell groups. A swell is a wave system not produced by the local wind blowing at the time of observation and may have been generated within the local weather system, or from within distant weather systems. The former situation typically arises when a front, trough, or ridge crosses the point of concern, resulting in a marked shift in wind direction. Swells generated in this manner are usually of low period. Swells generated by distant weather systems may propagate in the direction of the winds that originally formed to the vicinity of the observation area. These swells may travel for thousands of miles before dying away. As the swell advances, its crest becomes rounded and its surface smooth. As a result of the latter process, swell energy may propagate through a point from more than one direction at a particular time.

The wave climate of the Grand Banks is dominated by extra-tropical storms, primarily during October through March, however severe storms may, on occasion, occur outside these months. Storms of tropical origin may occur during the early summer and early winter, but most often from late August through October. Hurricanes are usually reduced to tropical storm strength or evolve into extra-tropical storms by the time they reach the area, however they are still capable of producing storm force winds and high waves.

Mean monthly ice statistics were used when calculating the wave heights in the MSC50 data. As a result, if the mean monthly ice coverage for a particular grid point is greater than 50% for a particular month, the whole month (from the 1st to the 31st) gets "iced out"; meaning that no forecast wave data has been generated for that month. This sometimes results in gaps in the wave data.

The annual wave rose from the MSC50 data for grid point 11028 is presented in Figure 2.5. The wave rose show that the majority of wave energy comes from the west-southwest to south-southwest, and accounts for 36.2% of the wave energy at grid point 11028. Waves were "iced out" for 1.31% of the time over the 50-year record; this value may be somewhat high since monthly ice files were used when generating the waves.

During autumn and winter, the dominate direction of the combined significant wave height is from the west. This corresponds with a higher frequency of occurrence of the wind wave during these months, suggesting that during the late fall and winter, the wind wave is the main contributor to the combined significant wave height. During the months of March and April, the wind wave remains predominately westerly, while the swell begins to back to southerly, resulting in the vector mean direction of the combined significant wave heights backing to southwesterly. A mean southwesterly direction for the combined significant wave heights during the summer months is a result of a mainly southwesterly wind wave and a southwesterly swell. As winter approaches again, during the months of September and October, the wind wave will veer to the westerly and become the more dominant component of the combined significant wave height. This will result in the frequency of occurrence of the combined significant wave heights veering to westerly once again.

The annual percentage frequency of significant wave height is presented in Figure 2.6. This histogram shows that the majority of significant wave heights are between 1.0 m and 5.0 m on the Grand Banks. There is a gradual decrease in frequency of wave heights above 4.0 m and only a small percentage of the wave heights exceed 8.0 m. Monthly wave roses along with histograms of the frequency distributions of wave heights for Grid Point 11028 can be found in Appendices 3 and 4, respectively.

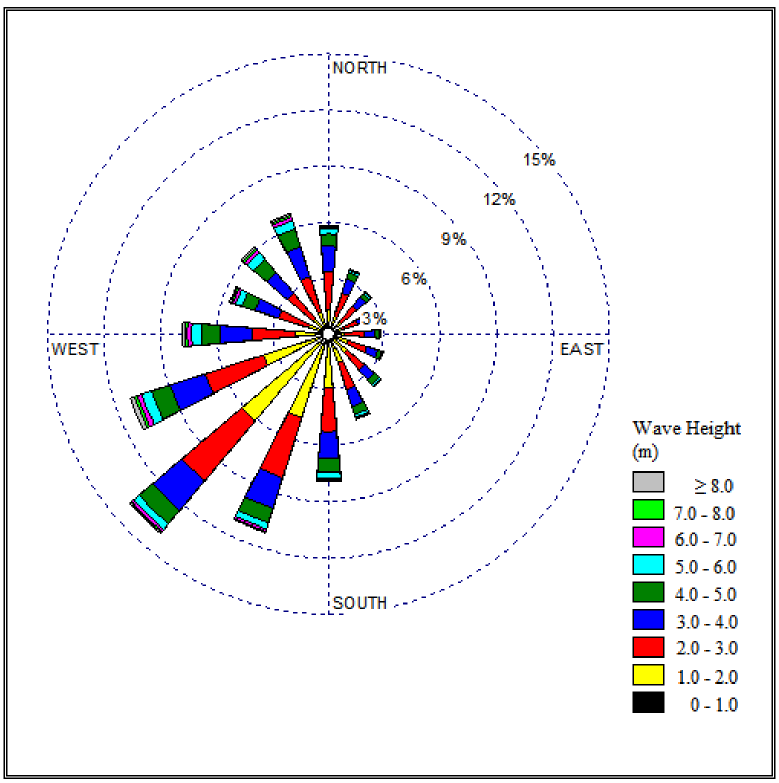

Figure 2.5 Annual Wave Rose for MSC50 Grid Point 11028 located near 46.7°N; 48.7°W

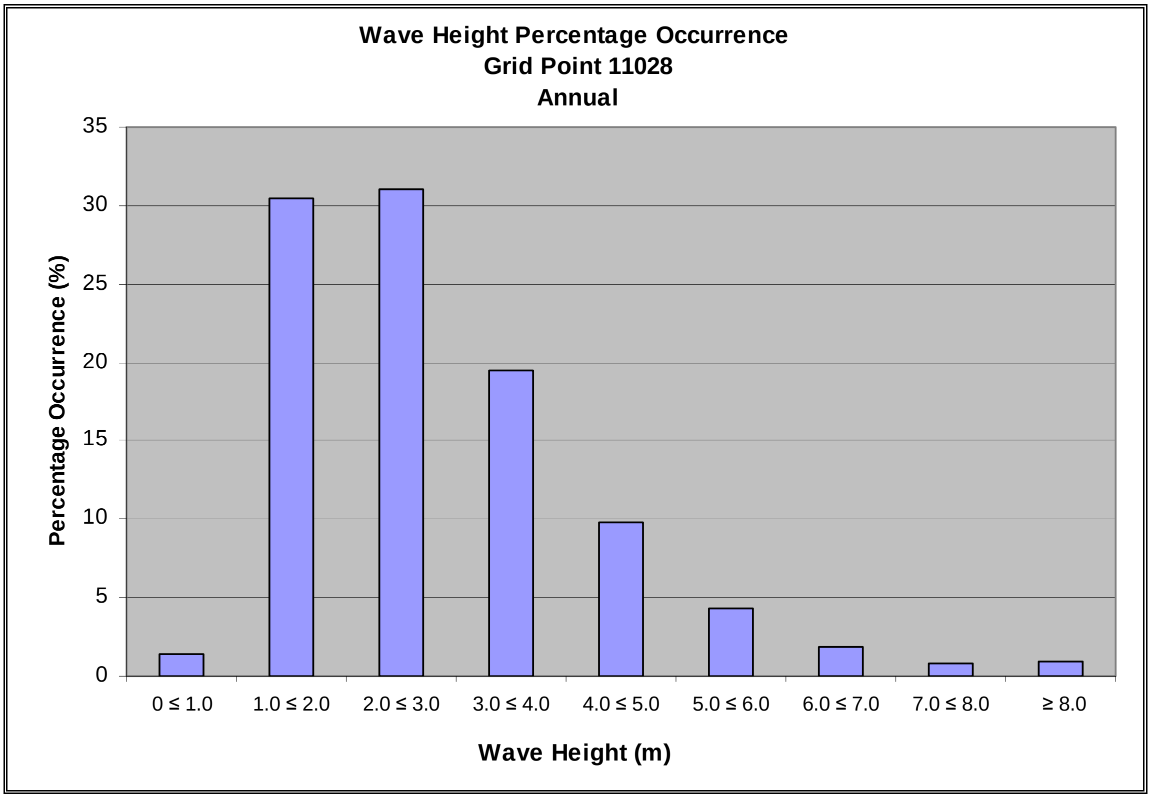

Figure 2.6 Annual Percentage Frequency of Wave Height for MSC50 Grid Point 11028 located near 46.7°N; 48.7°W. 1954 – 2005

Significant wave heights on the Grand Banks peak during the winter months with Grid Point 11028 having a mean monthly significant wave height of 3.9 metres. The lowest significant wave heights occur in the summer with July having a mean monthly significant wave height of only 1.7 m (Table 2.3).

Table 2.3 Combined Significant Wave Height Statistics (m) for the MSC50 data set

	Mean	Standard Deviation	Maximum
January	3.9	1.7	12.6
February	3.7	1.7	13.6
March	3.1	1.6	10.8
April	2.6	1.3	10.6
May	2.2	0.9	9.9
June	1.9	0.7	9.7
July	1.7	0.6	6.2
August	1.8	0.7	8.5
September	2.4	1.0	10.6
October	2.9	1.2	11.4
November	3.3	1.4	11.2
December	3.9	1.5	13.0

Combined significant wave heights of 10.5 metres or more occurred in each month between September and April, with the highest waves occurring during the month of February. The highest combined significant wave heights of 13.6 m occurred during the February 11, 2003 storm as discussed earlier. While maximum significant wave heights tend to peak during the winter months, a tropical system could pass through the area and produce wave heights during any month.

Figure 2.7 shows percentage exceedance curves of significant wave heights for grid point 11028. For the months of January through April the percentage exceedance curves do not reach 100% because of the presence of ice on the Grand Banks during these months.

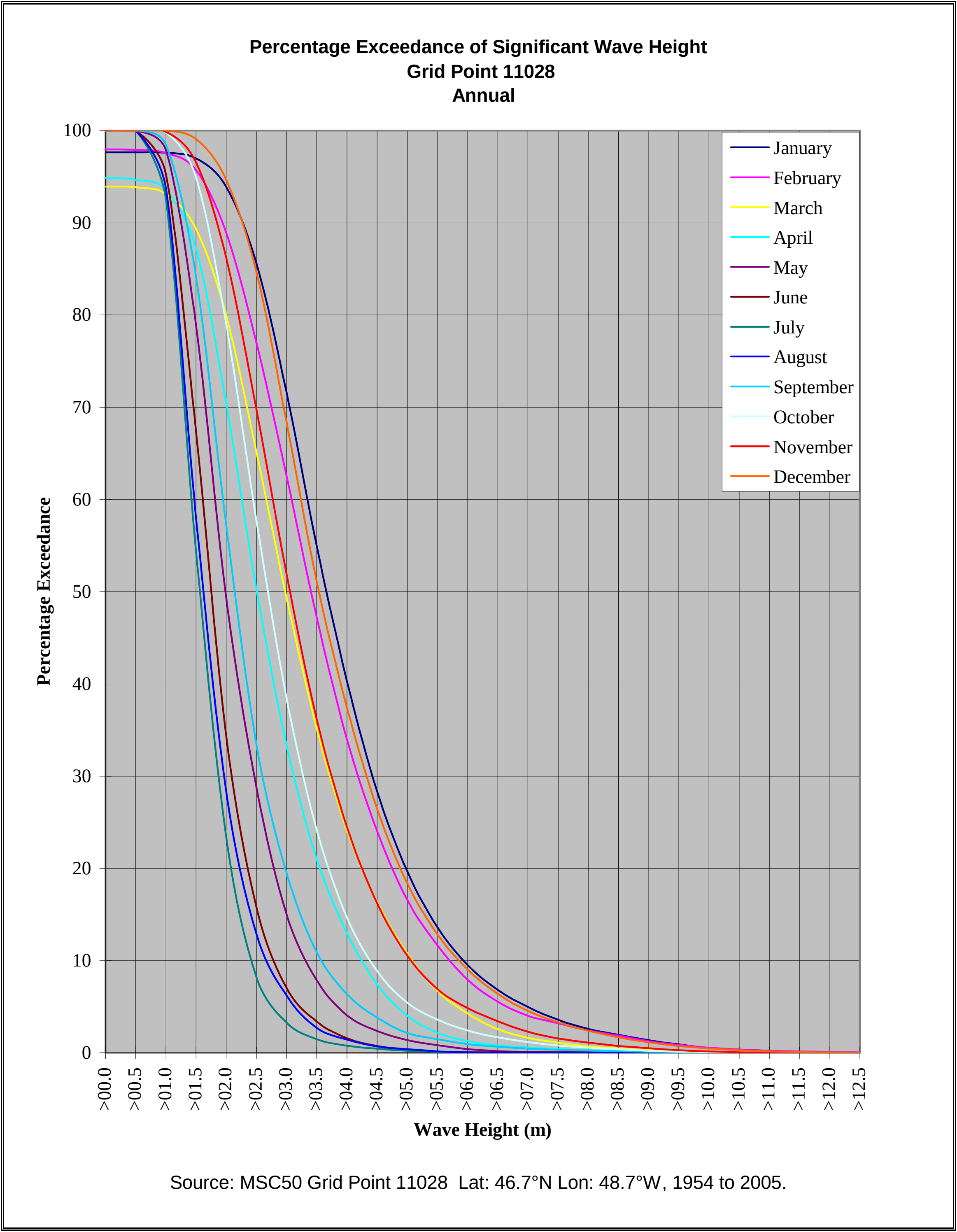

Figure 2.7 Percentage Exceedance of Significant Wave Height at Grid Point 11028

The spectral peak period of waves vary with season with the most common period varying from 7 seconds in July and August to 11 seconds in January and February. Annually, the most common spectral peak period is 9 seconds, occurring 18.90% of the time. Periods above 12 seconds occur more frequently during the winter months; though they may occur at anytime during the year. The percentage occurrence of spectral peak period for each month is shown in Table 2.4 and in Figure 2.8.

Table 2.4 Percentage Occurrence of Spectral Peak Period of the Total Spectrum at Grid Point 11028

	Peak Spectral Period (seconds)															
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
January	0.0	0.0	0.0	0.0	0.3	1.5	5.6	9.1	15.9	19.2	**21.3**	12.2	9.6	4.5	0.6	0.1
February	0.0	0.0	0.0	0.2	1.4	3.3	7.9	10.1	16.6	18.2	**18.8**	12.1	7.1	3.4	0.6	0.2
March	0.0	0.0	0.0	0.3	1.6	4.1	9.6	12.1	17.7	**19.1**	16.7	10.2	4.9	3.2	0.2	0.2
April	0.0	0.0	0.0	0.3	1.3	4.3	9.1	15.1	**24.7**	20.1	13.3	7.2	2.8	1.4	0.2	0.0
May	0.0	0.0	0.0	0.1	1.8	7.2	16.2	**25.8**	23.3	14.1	6.1	3.7	1.2	0.3	0.0	0.0
June	0.0	0.0	0.0	0.3	3.8	11.1	24.6	**27.9**	19.7	8.1	2.2	1.3	1.0	0.1	0.0	0.0
July	0.0	0.0	0.0	0.4	4.7	14.7	**30.3**	27.8	13.3	5.9	1.2	0.4	0.9	0.1	0.1	0.2
August	0.0	0.0	0.0	0.5	5.5	13.7	**29.6**	25.8	14.0	5.2	2.5	1.8	1.1	0.3	0.1	0.0
September	0.0	0.0	0.0	0.1	2.1	6.9	17.8	**21.6**	20.5	10.4	8.4	6.6	3.7	1.3	0.2	0.3
October	0.0	0.0	0.0	0.1	0.9	3.9	11.8	17.8	**22.9**	16.2	12.2	7.8	4.3	1.7	0.3	0.2
November	0.0	0.0	0.0	0.0	0.6	3.0	8.3	12.2	20.9	**21.1**	15.6	8.9	6.6	2.3	0.2	0.2
December	0.0	0.0	0.0	0.0	0.3	1.6	5.2	9.3	17.6	**22.4**	19.7	11.6	8.6	3.2	0.5	0.2
Winter	0.0	0.0	0.0	0.1	0.7	2.1	6.2	9.5	16.7	19.9	**20.0**	11.9	8.4	3.7	0.6	0.2
Spring	0.0	0.0	0.0	0.3	1.6	5.2	11.7	17.6	**21.9**	17.8	12.0	7.0	3.0	1.7	0.1	0.1
Summer	0.0	0.0	0.0	0.4	4.7	13.2	**28.2**	27.2	15.7	6.4	2.0	1.2	1.0	0.2	0.1	0.1
Autumn	0.0	0.0	0.0	0.1	1.2	4.6	12.6	17.2	**21.5**	15.9	12.1	7.8	4.9	1.8	0.2	0.2
Annual	0.0	0.0	0.0	0.2	2.0	6.3	14.7	17.9	**18.9**	15.0	11.5	7.0	4.3	1.8	0.3	0.1

Source: MSC50 Grid Point 11028 Lat: 46.7°N Lon: 48.7°W, 1954 to 2005.

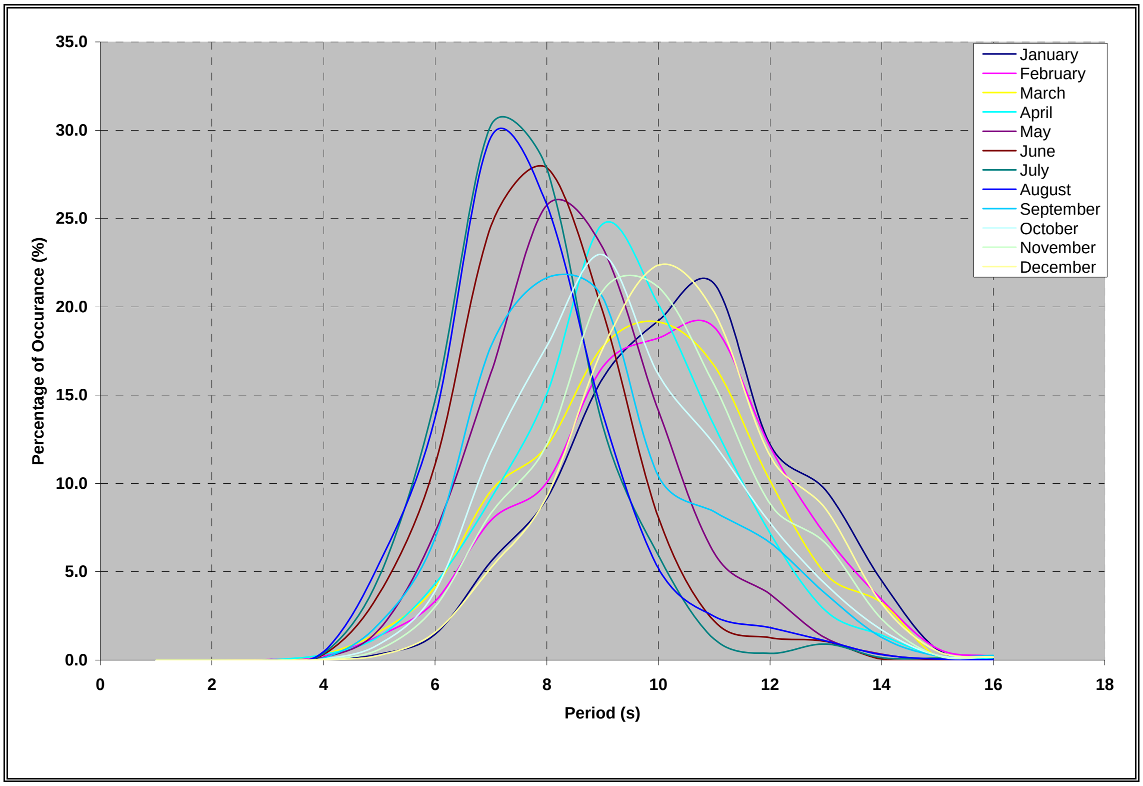

Figure 2.8 Percentage of Occurrence of Peak Wave Period at Grid Point 11028

A scatter diagram of the significant wave height versus spectral peak period is presented in Table 2.5. From this table it can be seen that the most common wave is 2 metres with a peak spectral period of 9 seconds, and the second most common wave being 2 metres and a peak spectral period of 8 seconds. Note that wave heights in these tables have been rounded to the nearest whole number. Therefore, the 1 metre wave bin would include all waves from 0.51 metres to 1.49 metres.

Table 2.5 Percent Frequency of Occurrence of Significant Combined Wave Height and Spectral Peak Period at Grid Point 11028

		Wave Height (m)														Total
		<1	1	2	3	4	5	6	7	8	9	10	11	12	13	
Period(s)	0	1.30														1.30
	1	0.00														0.00
	2	0.00														0.00
	3	0.00	0.00													0.00
	4	0.00	0.16	0.04	0.00											0.20
	5	0.00	1.13	0.83	0.04	0.00										2.01
	6	0.00	1.66	4.15	0.42	0.02	0.00									6.25
	7		4.58	6.05	3.65	0.30	0.01									14.59
	8	0.01	4.60	6.41	4.54	2.06	0.14	0.00	0.00							17.75
	9	0.00	1.76	8.14	4.01	3.55	1.14	0.07	0.00							18.67
	10	0.01	0.65	4.62	4.20	2.36	2.20	0.65	0.05	0.00						14.74
	11	0.00	0.22	2.15	3.99	2.04	1.24	1.07	0.45	0.08	0.01					11.24
	12	0.00	0.20	1.35	2.01	1.34	0.61	0.45	0.40	0.30	0.14	0.01	0.00			6.82
	13		0.18	0.58	1.01	1.06	0.54	0.25	0.16	0.15	0.17	0.12	0.01	0.00		4.24
	14		0.03	0.13	0.41	0.54	0.32	0.13	0.06	0.03	0.03	0.05	0.05	0.01	0.00	1.79
	15		0.01	0.02	0.04	0.07	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.25
	16		0.02	0.03	0.03	0.03	0.01	0.01	0.00	0.00		0.00		0.00	0.00	0.12
	17		0.00	0.01	0.00	0.00	0.00									0.03
	18		0.00				0.00									0.00
		1.32	15.20	34.50	24.36	13.36	6.28	2.65	1.14	0.57	0.34	0.18	0.06	0.02	0.01	100.00

2.4 Air and Sea Temperature

The moderating influence of the ocean serves to limit both the diurnal and the annual temperature variation on the Grand Banks. Diurnal temperature variations due to the day/night cycles are very small. Short-term, random temperature changes are due mainly to a change of air mass following a warm or cold frontal passage. In general, air mass temperature contrasts across frontal zones are greater during the winter than during the summer season.

Air and sea surface temperatures for the area were extracted from the ICOADS data set. A monthly plot of air temperature versus sea surface temperature is presented in Figure 2.9. Temperature statistics presented in Table 2.6 show that the atmosphere is coldest in February with a mean temperature of –0.6°C, and warmest in August with a mean temperature of 14.1°C. The sea surface temperature is warmest in August with a mean temperature of 14.0°C and coldest in February and March with a mean temperature of 0.5°C. The mean sea surface temperature is in the range of 0.1 to 1.5°C colder than the mean air temperature from March to August, with the greatest difference occurring in the month of July. From September to February, sea surface temperatures are in the range of 0.0 to 1.1°C warmer than the mean air temperature. The colder sea surface temperatures from March to August have a cooling effect on the atmosphere, while relatively warmer sea surface temperatures from September to February tends to warm the overlying atmosphere.

Table 2.6 Air and Sea Surface Temperature Statistics

	Air Temperature (°C)			Sea Surface Temperature (°C)		
	Mean	**Maximum**	**Minimum**	**Mean**	**Maximum**	**Minimum**
January	0.1	10.4	-9.4	1.1	9.0	-1.9
February	-0.6	10.4	-10.5	0.5	9.0	-2.2
March	0.5	11.1	-8.2	0.6	9.0	-2.2
April	1.9	10.7	-5.0	1.0	9.2	-2.8
May	4.6	13.4	-2.2	3.5	11.4	-2.2
June	7.4	16.6	-0.1	6.3	14.4	0.0
July	12.0	20.3	3.8	10.5	18.3	4.0
August	14.1	20.2	7.0	14.0	19.0	7.8
September	12.6	20.0	4.9	13.4	19.1	7.0
October	9.4	18.3	0.6	10.3	16.1	2.0
November	5.4	15.6	-3.3	6.3	15.0	0.0
December	2.4	13.0	-7.2	3.4	12.0	-1.8
Winter	0.6	11.3	-9.0	1.7	10.0	-2.0
Spring	2.3	11.7	-5.1	1.7	9.9	-2.4
Summer	11.1	19.0	3.6	10.3	17.2	3.9
Autumn	9.1	18.0	0.7	10.0	16.7	3.0

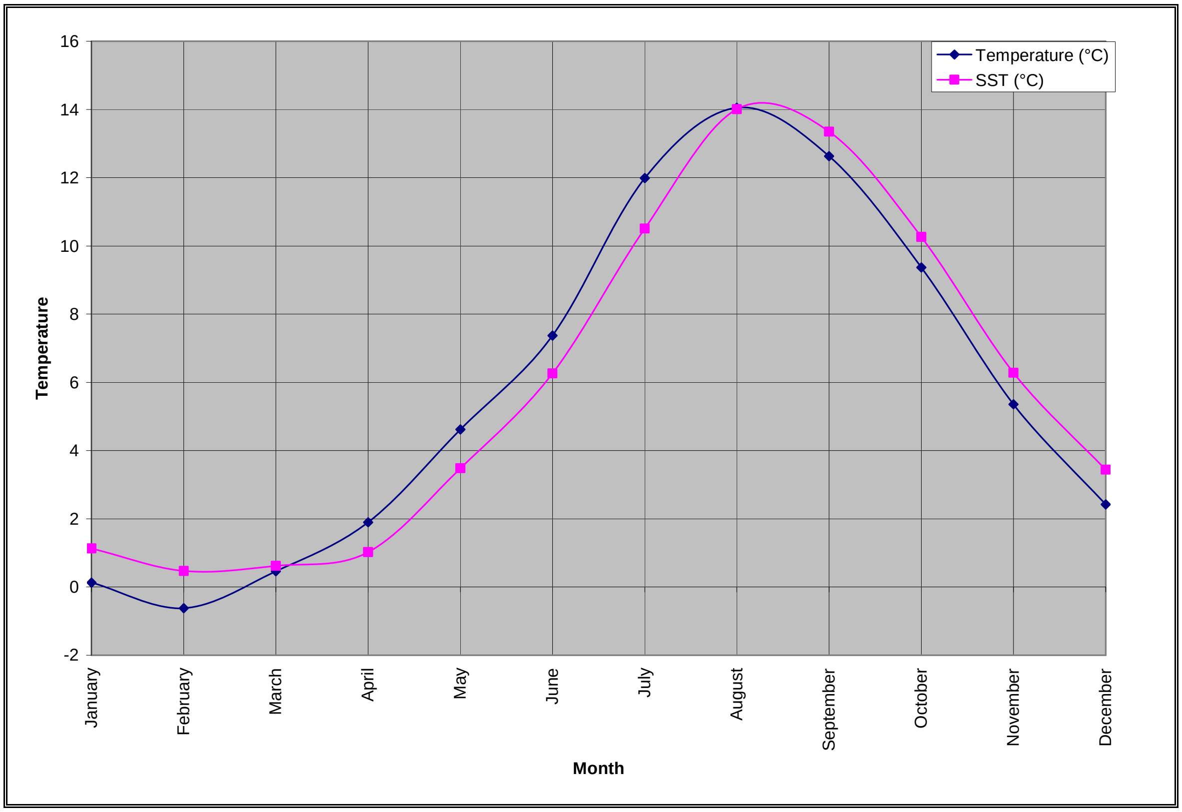

Figure 2.9 Monthly Mean Air and Sea Surface Temperature

2.5 Precipitation

Precipitation can come in three forms and are classified as liquid, freezing or frozen. Included in the three classifications are

Liquid Precipitation
- Drizzle
- Rain

Freezing Precipitation
- Freezing Drizzle
- Freezing Rain

Frozen Precipitation
- Snow
- Snow Pellets
- Snow Grains
- Ice Pellets
- Hail
- Ice Crystals
-

The frequency of precipitation type for each region was calculated using data from the ICOADS data set, with each occurrence counting as one event. Precipitation statistics for these regions may be low due to a fair weather bias. That is, ships tend to either avoid regions of inclement weather, or simply do not report during these events.

The frequency of precipitation type (Table 2.7) shows that annually, precipitation occurs 23.9% of the time. Winter has the highest frequency of precipitation with 37.6% of the observations reporting precipitation. Snow accounts for the majority of precipitation during the winter months, accounting for 58.0% of the occurrences of winter precipitation. Summer has the lowest frequency of precipitation with a total frequency of occurrence of 14.3%. Snow has been reported in each month from October to May.

Table 2.7 Percentage Frequency (%) Distribution of Precipitation.

	Rain / Drizzle	Freezing Rain / Drizzle	Rain / Snow Mixed	Snow	Hail	Total
January	14.9	0.4	0.7	26.6	0.2	42.7
February	10.3	1.2	0.4	25.2	0.1	37.1
March	11.6	1.4	0.4	13.7	0.0	27.1
April	12.3	0.2	0.1	5.8	0.1	18.5
May	16.3	0.0	0.0	0.8	0.0	17.2
June	15.4	0.0	0.0	0.0	0.0	15.4
July	12.9	0.0	0.0	0.0	0.0	12.9
August	14.7	0.0	0.0	0.0	0.0	14.7
September	18.8	0.0	0.0	0.0	0.0	18.8
October	23.2	0.0	0.0	1.1	0.2	24.5
November	22.5	0.0	0.4	5.0	0.2	28.2
December	17.2	0.1	1.0	14.8	0.3	33.4
Winter	14.3	0.5	0.7	21.8	0.2	37.6
Spring	13.6	0.5	0.2	6.3	0.0	20.6
Summer	14.3	0.0	0.0	0.0	0.0	14.3
Autumn	21.7	0.0	0.1	2.2	0.1	24.2
Total	15.9	0.3	0.2	7.4	0.1	23.9

2.6 Visibility

Visibility is defined as the greatest distance at which objects of suitable dimensions can be seen and identified. Horizontal visibility may be reduced by any of the following phenomena, either alone or in combination:

- Fog
- Mist
- Haze
- Smoke
- Liquid Precipitation (e.g., Drizzle)
- Freezing Precipitation (e.g., Freezing Rain)
- Frozen Precipitation (e.g., Snow)
- Blowing Snow

A plot of the frequency distribution of visibility from the ICOADS data set is presented in Figure 2.10. Figure 2.10 shows that obstructions to vision can occur in any month. Annually, 37.9% of the recorded observations had reduced visibilities. During the winter months, the main obstruction is snow; however, mist and fog may also reduce visibilities at times. As spring approaches, the amount of visibility reduction attributed to snow decreases. As the air temperature increases, so does the occurrence of advection fog. Advection fog forms when warm moist air moves over the cooler waters of the Labrador Current. By March, the sea surface temperature on the Grand Banks is cooler than the surrounding air. As warm moist air moves over the colder sea surface, the air cools and its ability to hold moisture decreases. The air will continue to cool until it becomes saturated and the moisture condenses to form fog. The presence of advection fog increases from April through July. July month has the highest percentage (63.8%) of obscuration to visibility, most of which is in the form of advection fog, although frontal fog can also contribute to the reduction in visibility. On average, fog reduces visibility below 1 kilometre 47.6% of the time in July. In August the temperature difference between the air and the sea begins to narrow and by September, the air temperature begins to fall below the sea surface temperature. As the air temperature drops, the occurrence of fog decreases. Reduction in visibility during autumn and winter is relatively low and is mainly attributed to the passage of low-pressure systems. Fog is mainly the cause of the reduced visibilities in autumn and snow is the cause of reduced visibilities in the winter. October has the lowest occurrence of reduced visibility (21.7%) since the air temperature has, on average, decreased below the sea surface temperature and it is not yet cold enough for snow.

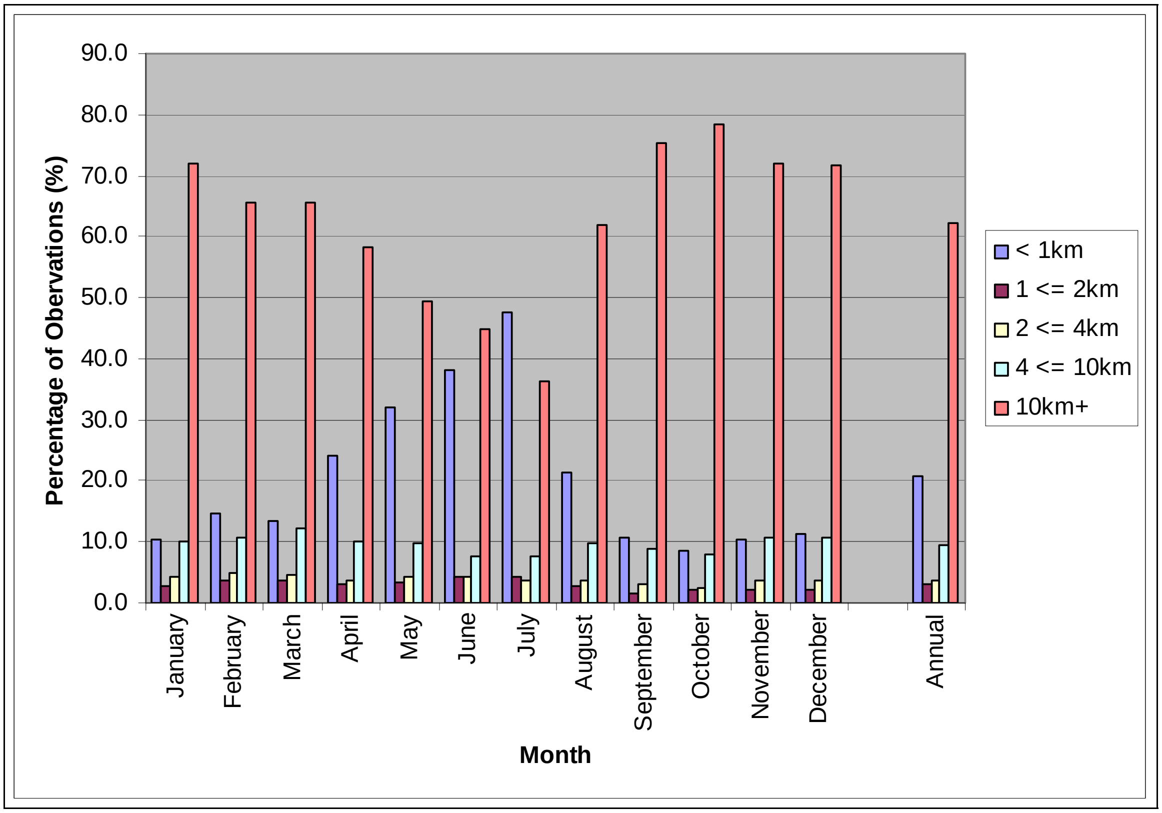

Figure 2.10 Monthly and Annual Percentage Occurrence of Visibility
Source: ICOADS Data set (1950-2006)

2.7 Tropical Systems

The hurricane season in the North Atlantic basin normally extends from June through November, although tropical storm systems occasionally occur outside this period. While the strongest winds typically occur during the winter months and are associated with mid-latitude low pressure systems, storm force winds may occur at any time of the year as a result of tropical systems. Once formed, a tropical storm or hurricane will maintain its energy as long as a sufficient supply of warm, moist air is available. Tropical storms and hurricanes obtain their energy from the latent heat of vapourization that is released during the condensation process. These systems typically move east to west over the warm water of the tropics, however, some of these systems turn northward and make their way towards Newfoundland and the Grand Banks. Since the capacity of the air to hold water vapour is dependent on temperature, as the hurricanes move northward over the colder ocean waters, they begin to lose their tropical characteristics. By the time these weakening cyclones reach Newfoundland, they are usually embedded into a mid-latitude low and their tropical characteristics are usually lost.

Since 1995 the number of Hurricanes that have developed within the Atlantic Basin has been increasing as shown in Figure 2.11. This increase in activity has been attributed to naturally occurring cycles in tropical climate patterns near the equator called the tropical multi-decadal signal and typically lasts 20 to 30 years (Bell, 2006). As a result of the increase in tropical activity in the Atlantic Basin, there has also been an increase in tropical storms or their remnants entering the Canadian Hurricane Centre Response zone, and consequently, a slight increase in the number of tropical storms entering the study area. It should be noted that the number of storms in 2006 and 2007 have shown a decrease with only 10 tropical storms developing in the Atlantic Basin in 2006 and 17 tropical storms in 2007. This time period is not of sufficient length however to determine whether this decrease will continue.

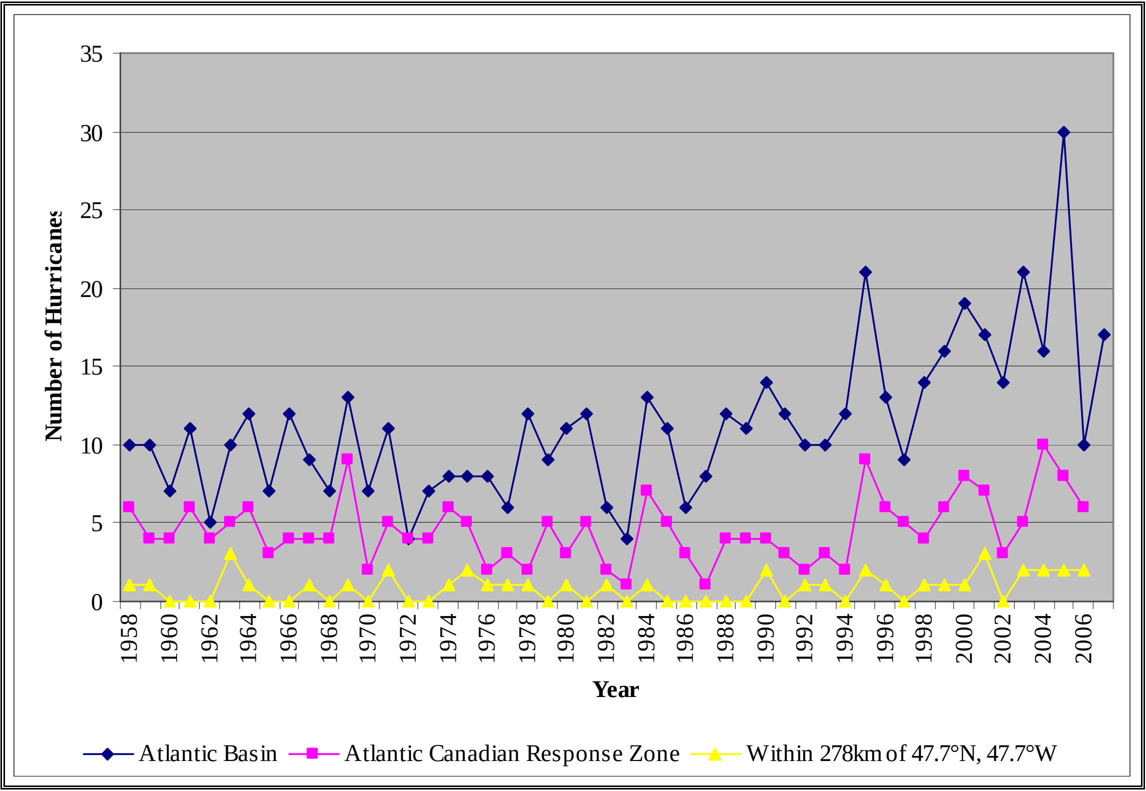

Figure 2.11 Frequency of Tropical Storm Development in the Atlantic Basin 1958 – 2007

Since 1950, 46 tropical systems have passed within 278 km of 46.7°N; 48.7°W. The names are given in Table 2.8 and the tracks over the Grand Banks are shown in Figure 2.12. It must be noted that the values in the table are the maximum 1-minute mean winds speeds occurring within the tropical system at the 10-metre reference level as it passed within 278 km of the location.

On occasion, these systems still maintain their tropical characteristics when they reach Newfoundland. On October 02, 1975, Hurricane Gladys, a Category 4 Hurricane as it passed east of Cape Hatteras tracked northeast towards the Grand Banks. Gladys, still a Category 2 Hurricane with 43.7 m/s winds and a central pressure of 960 mb on October 03 moved northeast across the Grand Banks and maintained Hurricane strength until it moved north of 50° latitude when it weakened to a post-tropical storm. As this system passed over the region, the MSC50 data set has peak winds speeds of 26.7 m/s and wave heights of 7.5 m.

Table 2.8 Tropical Systems Passing within 278 km of 46.7°N; 48.7°W, 1950 to 2006

Year	Month	Day	Hour	Name	Lat	Long	Wind (m/s)	Pressure (mb)	Category
1950	10	5	1200Z	Georges	47.0	-51.9	30.9	N/A	Post-Tropical
1952	9	8	1200Z	Baker	47.8	-49.3	30.9	N/A	Post-Tropical
1954	9	3	1200Z	Dolly	46.8	-47.4	25.7	N/A	Post-Tropical
1955	8	21	1200Z	Diane	45.0	-49.3	18.0	N/A	Post-Tropical
1958	8	20	0000Z	Cleo	44.8	-47.1	38.6	N/A	Category 1 Hurricane
1959	6	21	1200Z	NotNamed	47.3	-53.7	23.1	N/A	Post-Tropical
1963	8	11	0000Z	Arlene	42.5	-52.0	33.4	N/A	Post-Tropical
1963	8	28	0000Z	Beulah	45.8	-48.3	36.0	N/A	Category 1 Hurricane
1963	10	12	1800Z	Flora	45.2	-47.5	38.6	N/A	Post-Tropical
1964	9	4	1800Z	Cleo	46.9	-49.8	36.0	N/A	Category 1 Hurricane
1967	9	4	0600Z	Arlene	45.8	-48.6	30.9	N/A	Tropical Storm
1969	8	13	0000Z	Blance	47.1	-49.0	25.7	N/A	Post-Tropical
1971	7	7	1800Z	Arlene	46.5	-53.0	23.1	N/A	Post-Tropical
1971	8	6	1200Z	NotNamed	46.0	-49.0	38.6	974	Category 1 Hurricane
1974	7	20	0600Z	SubTropical	46.7	-48.0	20.6	N/A	Post-Tropical
1975	7	4	0600Z	Amy	44.5	-51.6	25.7	986	Tropical Storm
1975	10	3	1200Z	Gladys	46.6	-50.6	43.7	960	Category 2 Hurricane
1976	8	24	0000Z	Candice	45.9	-48.7	41.2	N/A	Category 1 Hurricane
1977	9	30	0000Z	Dorothy	47.0	-51.0	25.7	995	Post-Tropical
1978	9	5	0600Z	Ella	47.2	-50.2	41.2	975	Category 1 Hurricane
1980	9	8	1200Z	Georges	45.6	-51.1	35.0	993	Category 1 Hurricane
1982	9	19	0600Z	Debby	47.0	-50.5	38.6	979	Category 1 Hurricane
1984	9	2	1200Z	Cesar	46.0	-50.4	25.7	994	Tropical Storm
1990	9	3	0000Z	Gustav	46.0	-46.5	28.3	993	Tropical Storm
1990	10	15	0600Z	Lili	46.6	-56.4	20.6	994	Post-Tropical
1992	10	26	1800Z	Frances	46.0	-46.9	28.3	988	Tropical Storm
1993	9	10	0600Z	Floyd	45.4	-48.3	33.4	990	Category 1 Hurricane
1995	7	20	1800Z	Chantal	45.4	-48.8	25.7	1000	Post-Tropical
1995	8	22	1200Z	Felix	46.8	-50.8	25.7	985	Tropical Storm
1996	9	16	0000Z	Hortense	46.0	-54.0	20.6	998	Post-Tropical
1998	9	4	0000Z	Danielle	44.8	-48.5	33.4	975	Post-Tropical
1999	10	19	1200Z	Irene	48.0	-48.0	41.2	968	Post-Tropical
2000	9	25	1200Z	Helene	44.0	-55.5	28.3	988	Tropical Storm
2001	8	29	0000Z	Dean	47.0	-48.5	23.1	999	Post-Tropical
2001	9	20	0000Z	Gabrielle	48.5	-48.5	30.9	988	Post-Tropical
2001	11	6	1200Z	Noel	43.0	-48.5	25.7	996	Post-Tropical
2003	9	8	0000Z	Fabian	44.3	-47.9	36.0	975	Category 1 Hurricane
2003	10	7	1800Z	Kate	47.5	-47.2	30.9	980	Tropical Storm
2004	8	6	0000Z	Alex	44.5	-49.3	38.6	978	Category 1 Hurricane
2004	9	2	0000Z	Gaston	47.0	-50.0	23.1	997	Post-Tropical
2005	7	30	1800Z	Franklin	46.4	-48.8	20.6	1006	Post-Tropical
2005	9	19	0600Z	Ophelia	49.0	-48.8	23.1	1001	Post-Tropical
2006	9	14	0000Z	Florence	47.6	-51.3	33.4	965	Post-Tropical
2006	10	3	0000Z	Isaac	47.6	-51.0	28.3	996	Post-Tropical
2007	8	1	1800Z	Chantal	49.0	-49.5	30.9	988	Post-Tropical

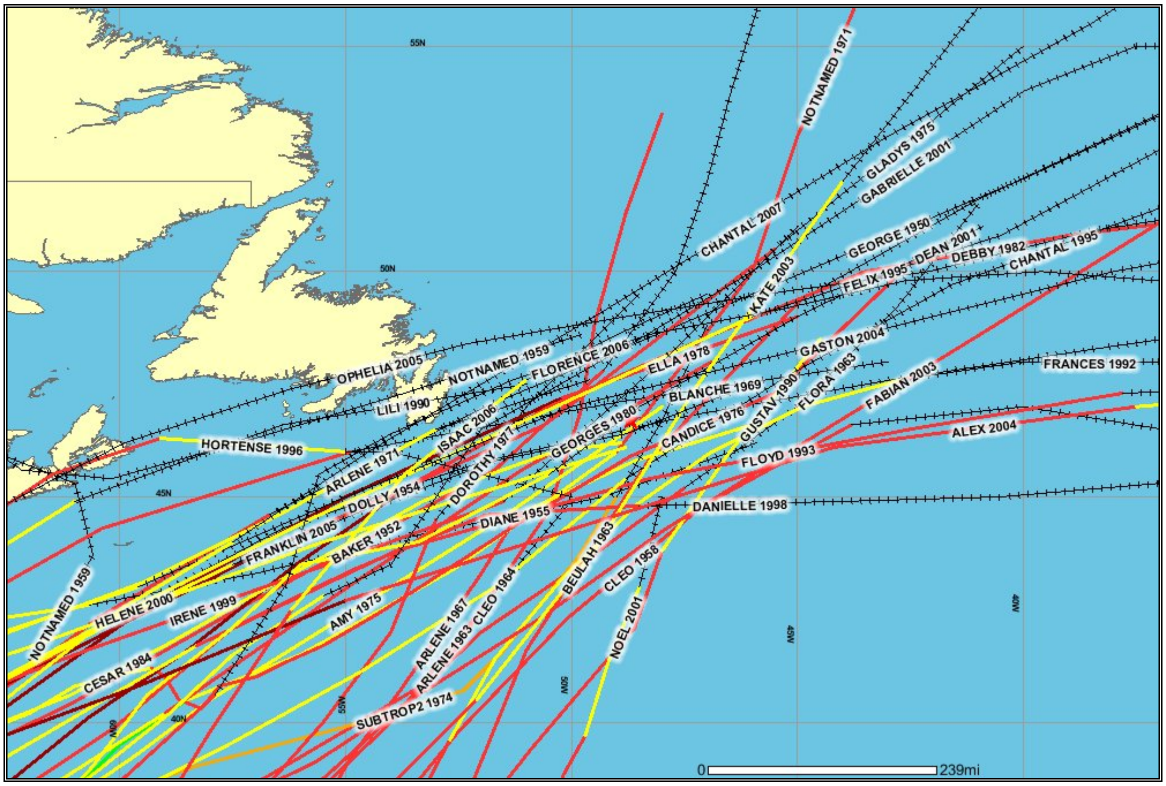

Figure 2.12 Storm Tracks of Tropical Systems Passing within 278 km of 46.7°N; 48.7°W, 1950 to 2006

2.8 Climate Variability

Climate is naturally variable and can change over a range of time scales from the very short term, to seasonally, and to longer time periods in response to small and large-scale changes of atmospheric circulation patterns. Short-term meteorological variations are largely a consequence of the passage of synoptic scale weather systems: low pressure systems, high pressure systems, troughs and ridges. The energetics of these features varies seasonally in accordance with the changes in the strength of the mean tropical - polar temperature gradient. Long-term changes occur in response to small and large-scale changes of atmospheric circulation patterns and in the past in the Northern Hemisphere were the mainly result of changes in the North Atlantic Oscillation (NAO). While the NAO still has an effect on climate patterns, there is a general consensus amongst the scientific community that Greenhouse Gas emissions have played a significant role in the climate during the last 50 years. However, the high degree of climate variation naturally experienced makes it difficult to identify, with any degree of certainty, trends that are a direct result of climate change. (Environment Canada, 1997)

The dominate features of the mean sea level pressure pattern in the North Atlantic Ocean are the semi-permanent area of relatively low pressure in the vicinity of Iceland and the sub-tropical high pressure region near the Azores. The relative strengths of these two systems control the strength and direction of westerly winds and storm tracks in the North Atlantic and therefore play a significant role in the climate of the North Atlantic. The fluctuating pressure difference between these two features is known as the North Atlantic Oscillation (NAO).

A measure of the North Atlantic Oscillation is the NAO Index, which is the normalized difference in pressure between the Icelandic low and the Azores high. A large difference in pressure results in a positive NAO Index and can be the result of a stronger than normal subtropical high, a deeper than normal sub-polar low, or a combination of both. A time-series of the Winter (DJF) North Atlantic Oscillation Index is presented in Figure 2.13 and shows that during the period of 1950 – 2006 there is a general trend towards increasing NAO Index indicating that in recent years either the Icelandic low is deeper or the Azores high is stronger than on average. This trend is also present in the Summer North Atlantic Oscillation index, albeit significantly weaker.

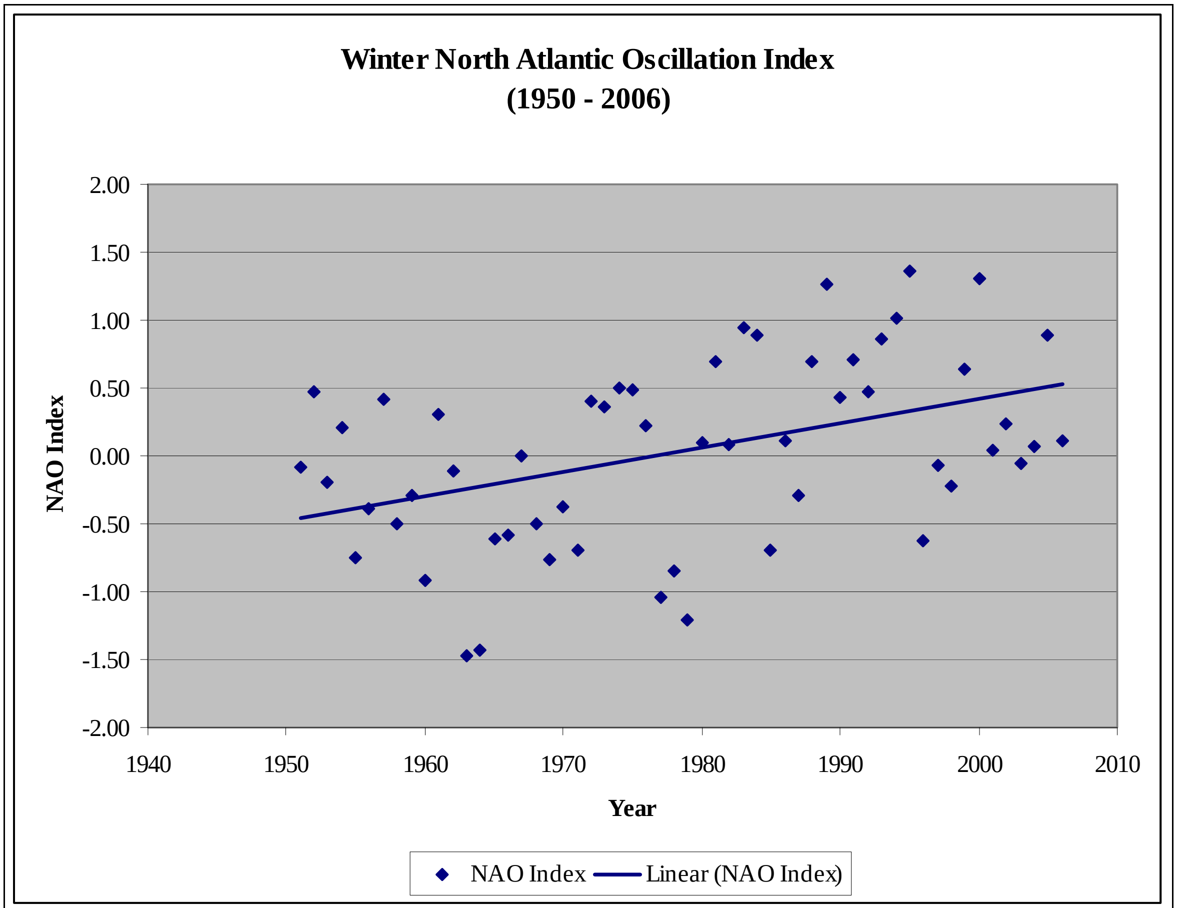

Figure 2.13 Winter North Atlantic Oscillation Index (1950 - 2006)

In general, over the Northwest Atlantic during the winter season, a positive NAO index brings with it an increase in frequency and strength of westerly winds in the upper atmosphere, which tends to steer storm systems in a more west to east direction. As a result, a positive NAO index results in an increase in storm systems coming off of the continent resulting in colder temperatures, increased precipitation, and relatively stronger winds. Due to the weaker trend in NAO index and other atmospheric patterns, conclusions could not be drawn about correlations between summer NAO indices and temperature, precipitation and winds during the summer months.

Figure 2.14 depicts the seasonally averaged winter NAO Index against mean wind speed for each of the grid points analyzed in this study. Linear trend lines are also presented in the plots. This figure shows that mean wind speeds increase with increasing NAO index in accordance with general expectations.

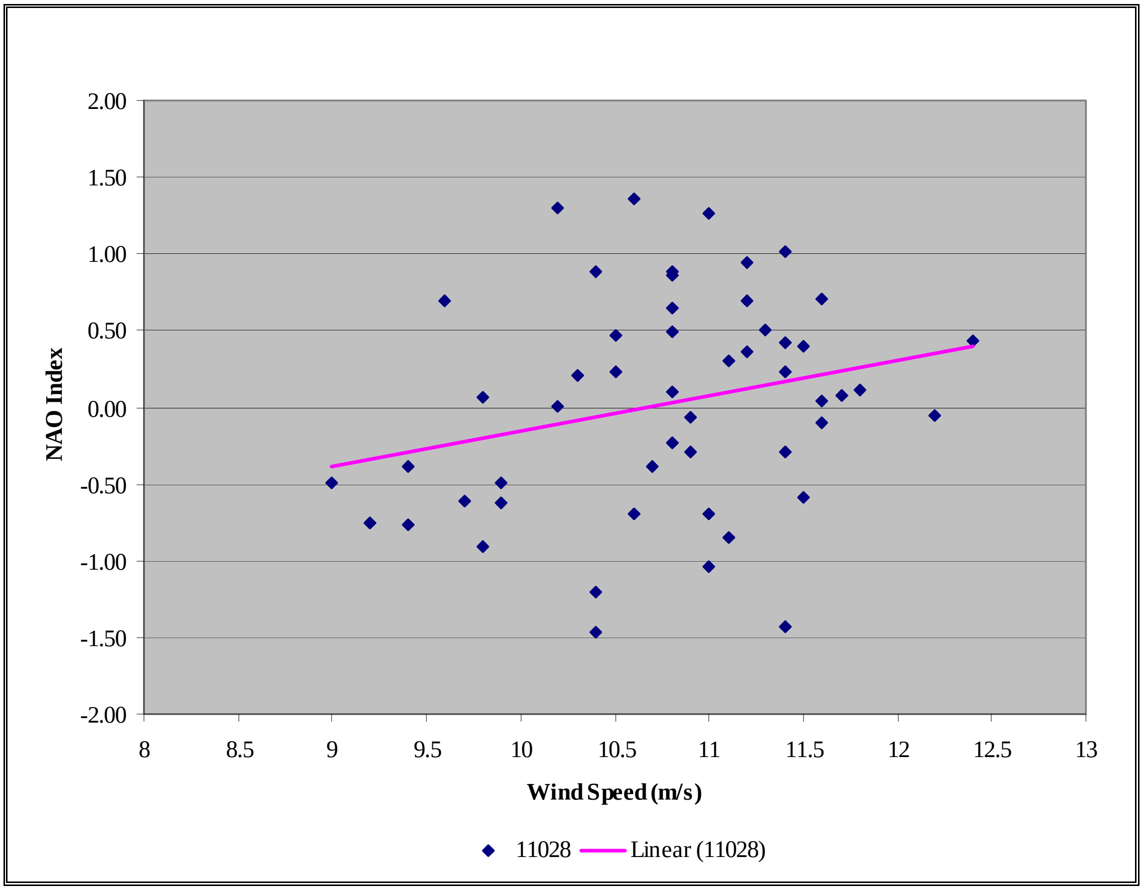

Figure 2.14 Scatterplot of Seasonally Averaged NAO Index against Wind Speed at Grid Point 11028 (Winter 1954 – 2004)

With a positive correlation in wind speed against NAO index, it would be expected that significant wave heights would also be positively correlated. A scatterplot of seasonally averaged NAO Index against wave height (Figure 2.15) shows little or no correlation between wave height and the winter NAO index. These results are typical of other studies done in the waters surrounding Newfoundland (Swail, 1996 and Swail et al., 1999).

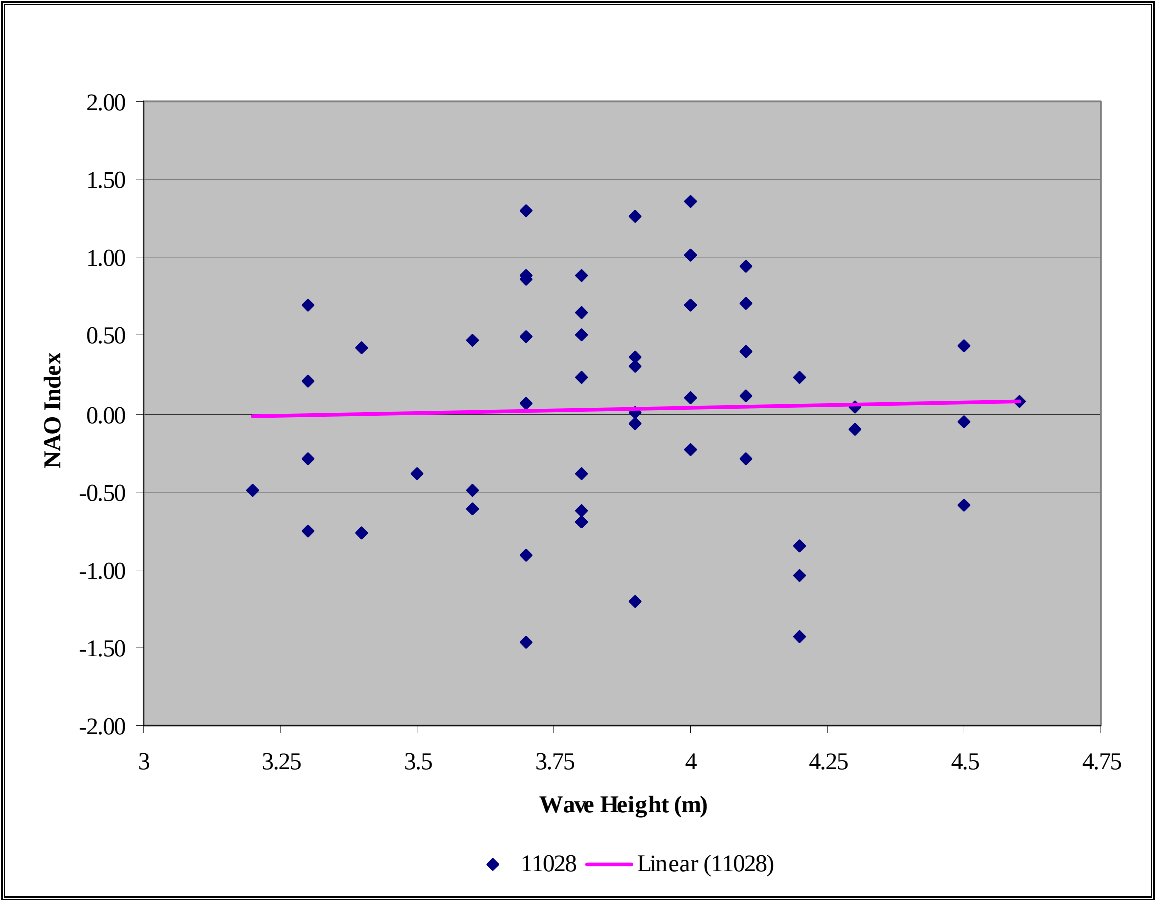

Figure 2.15 Scatterplot of Seasonally Averaged NAO Index against Wave Height at Grid Point 11028 (Winter 1954 – 2004)

During the summer months, the NAO index has a less direct effect on the climate of Eastern Canada; however studies have shown that the NAO has an effect on the track of hurricanes in the North Atlantic. During seasons with a negative NAO index, hurricanes tend to favour a track that parallels lines of latitude often ending up in the Gulf of Mexico and the Caribbean (Elsner, 2003), while during seasons with a positive NAO index, hurricanes tend to curve northward (Elsner & Bosak, 2004) along the United States Eastern Seaboard. An analysis of the number of tropical storms entering the Canadian Hurricane Centre Response Zone however shows that tropical storm frequency decreases with increasing summer NAO index (Figure 2.16). Likewise, the number of tropical storms coming within 278 km of the project area also decreases during summers with positive NAO index.

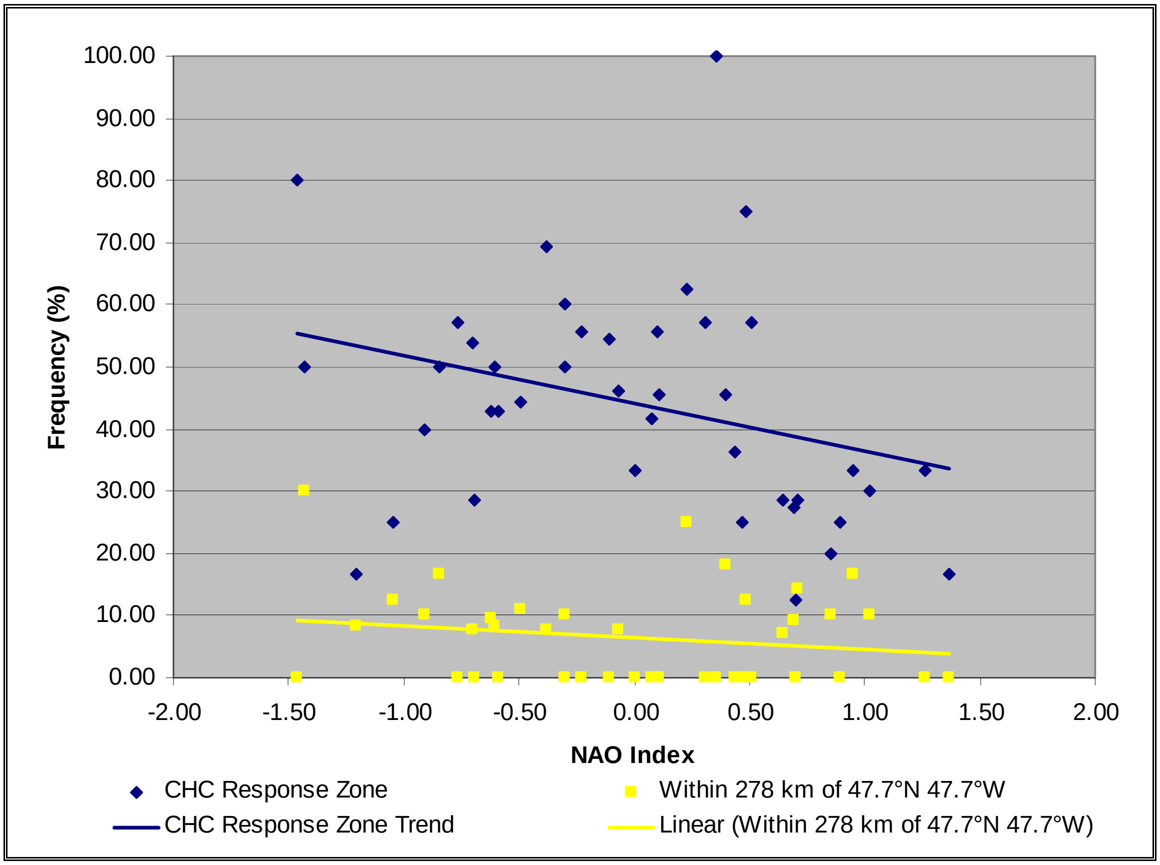

Figure 2.16 Frequency of Atlantic Basin Storms entering the Canadian Hurricane Centre Response Zone against Summer NAO Index

3.0 Wind and Wave Extreme Value Analysis

An analysis of extreme wind and waves was performed for each region using the MSC50 data set. This data set was determined to be the most representative of the available datasets, as it provides a continuous 52-year period of 1 hourly data for the study area. The extreme value analysis for wind speeds was carried out using the peak-over-threshold method. For the extreme wave analysis, two methods were used; the peak-over-threshold method and the joint probability method.

After considering four different distributions, the Gumbel distribution was chosen to be the most representative for the peak-over-threshold method as it provided the best fit to the data. Since extreme values can vary, depending on how well the data fits the distribution, a sensitivity analysis was carried out to determine how many storms to use in the analysis.

Grid Point 11028 located at 46.7°N; 48.7°W was deemed to give the most accurate depiction of conditions within region and was used in this analysis. Since extreme values can vary depending on how well the data fits the distribution, a sensitivity analysis was carried out to determine the number storms to use. The sensitivity analysis showed that the best fits occurs using 258 storms for winds and 270 storms for waves. This represented storms of 8 m waves and above and winds of 21.5 m/s and above. The 61 storms used in the monthly analysis corresponded to similar storm conditions during the winter months.

3.1 Extreme Value Estimates for Winds from the Gumbel Distribution

The extreme value estimates for wind were calculated using Oceanweather's Osmosis software program for the return periods of 1-year, 10-years, 25-years, 50-years and 100-years. The calculated annual and monthly values for 1-hour, 10-minutes and 1-minute are presented in Table 3.1 to Table 3.3. The analysis used hourly mean wind values for the reference height of 10-metres above sea level. These values were converted to 10-minute and 1-minute wind values using a constant ration of 1.06 and 1.22, respectively (U.S. Geological Survey 1979). The annual 100-year extreme 1-hour wind speed was determined to be 31.4 m/s for grid point 11028. The highest extreme winds are expected to occur during February.

A comparison of these values, with actual values measured by platforms on the Grand Banks was not possible. Logarithmic profiles for adjusting wind speeds from anemometer height to the surface are valid only in neutral or unstable conditions. Observations from platforms on the Grand Banks over the past ten years frequently show stable conditions in which the surface layer wind speed profiles are not valid. Using a logarithmic profile to adjust wind speeds between the 10-metre and anemometer level would therefore introduce an unnecessary source of error in the results.

Table 3.1 1-hr Extreme Wind Speed Estimates (m/s) for Return Periods of 1, 10, 25, 50 and 100 Years

	Grid Point #11028				
Month	**1**	**10**	**25**	**50**	**100**
January	22.1	25.7	26.8	27.6	28.4
February	21.8	27.0	28.6	29.7	30.9
March	19.8	24.8	26.3	27.5	28.6
April	17.8	22.2	23.5	24.5	25.5
May	15.2	19.3	20.6	21.5	22.5
June	14.1	18.0	19.2	20.1	21.0
July	13.0	16.8	18.0	18.8	19.7
August	13.5	19.7	21.6	23.0	24.4
September	16.4	22.3	24.2	25.5	26.9
October	17.6	23.7	25.5	26.9	28.3
November	19.5	24.4	26.0	27.1	28.2
December	21.2	26.2	27.8	28.9	30.0
Annual	24.8	28.2	29.4	30.4	31.4

Table 3.2 10-minute Extreme Wind Speed (m/s) Estimates for Return Periods of 1, 10, 25, 50 and 100 Years

	Grid Point #11028				
Month	**1**	**10**	**25**	**50**	**100**
January	23.4	27.2	28.4	29.2	30.1
February	23.1	28.6	30.3	31.5	32.8
March	21.0	26.3	27.9	29.1	30.3
April	18.9	23.5	24.9	26.0	27.0
May	16.1	20.5	21.8	22.8	23.8
June	14.9	19.1	20.4	21.3	22.3
July	13.8	17.8	19.0	19.9	20.9
August	14.3	20.9	22.9	24.4	25.9
September	17.4	23.7	25.6	27.1	28.5
October	18.6	25.1	27.1	28.5	30.0
November	20.7	25.9	27.5	28.7	29.9
December	22.5	27.8	29.4	30.6	31.8
Annual	26.3	29.8	31.2	32.2	33.2

Table 3.3 1-minute Extreme Wind Speed (m/s) Estimates for Return Periods of 1, 10, 25, 50 and 100 Years

	Grid Point #11028				
Month	**1**	**10**	**25**	**50**	**100**
January	26.9	31.3	32.6	33.6	34.6
February	26.6	32.9	34.8	36.3	37.7
March	24.2	30.2	32.1	33.5	34.9
April	21.8	27.0	28.7	29.9	31.1
May	18.5	23.6	25.1	26.3	27.4
June	17.2	22.0	23.4	24.5	25.6
July	15.9	20.5	21.9	22.9	24.0
August	16.5	24.0	26.4	28.1	29.8
September	20.0	27.3	29.5	31.1	32.8
October	21.4	28.9	31.2	32.9	34.5
November	23.8	29.8	31.7	33.0	34.4
December	25.9	32.0	33.9	35.3	36.6
Annual	30.3	34.4	35.9	37.1	38.3

3.2 Extreme Value Estimates for Waves from a Gumbel Distribution

The annual and monthly extreme value estimates for significant wave height for return periods of 1-year, 10-years, 25-years, 50-years and 100-years are given in Table 3.4. The annual 100-year extreme significant wave height was 14.5 metres at grid point 11028. This significant wave height corresponds with a significant wave height of 14.66 metres recorded over a 20-minute interval by a waverider buoy in the area on February 11, 2003. A storm with a return period of 100 years means that the calculated significant wave height will occur once every 100 years, averaged over a long period of time. The value recorded on February 11, 2003 was the highest recorded significant wave height in a near continuous waverider data set extending back to early 1999. The previous highest recorded value in this data set was 12.47 metres, which occurred on January 25, 2003. The maximum significant wave heights measured during the “Ocean Ranger” storm of 1982 was approximately 12 m. If more occurrences of an event of this magnitude were observed, the calculated statistics would consequently begin to increase.

Table 3.4 Extreme Significant Wave Height Estimates for Return Periods of 1, 10, 25, 50 and 100 Years

	Grid Point #11028				
Month	**1**	**10**	**25**	**50**	**100**
January	8.6	11.4	12.3	13.0	13.6
February	8.0	11.7	12.9	13.7	14.6
March	6.8	9.8	10.7	11.4	12.1
April	5.4	8.4	9.4	10.0	10.7
May	4.4	7.0	7.8	8.4	9.0
June	3.6	5.9	6.6	7.1	7.6
July	3.3	5.3	5.9	6.4	6.8
August	3.6	6.1	6.8	7.4	8.0
September	4.9	8.7	9.9	10.7	11.6
October	6.1	9.5	10.6	11.5	12.3
November	7.2	10.1	11.0	11.7	12.4
December	8.4	11.2	12.1	12.7	13.4
Annual	10.3	12.5	13.3	13.9	14.5

The maximum individual wave heights were calculated within Oceanweather's OSMOSIS software by evaluating the Borgman integral (Borgman 1973), which was derived from a Raleigh distribution function. The variant of this equation used in the software has the following form (Forristall, 1978):

$$\Pr\{H > h\} = \exp\left[-1.08311\left(\frac{h^2}{8M_0}\right)^{1.063}\right]; \quad T = \frac{M_0}{M_1}$$

where h is the significant wave height, T is the wave period, and M_0 and M_1 are the first and second spectral moments of the total spectrum. The associated peak periods are calculated by plotting the peak periods of the chosen storm peak values versus the corresponding significant wave heights. This plot is fitted to a power function ($y = ax^b$), and the resulting equation is used to calculate the peak periods associated with the extreme values of significant wave height. The maximum individual wave heights and extreme associated peak periods are presented in Table 3.5

Table 3.5 and Table 3.6. Maximum individual wave heights and the extreme associated peak periods peak during the month of February.

During a storm event on January 08, 2007 a maximum individual wave height of 22.63 metres was recorded by a waverider in the Terra Nova field. This is similar to the 25-year return period estimate of 22.7 metres. The significant wave height during this event was 9.72 metres.

Table 3.5 Extreme Maximum Wave Height Estimates for Return Periods of 1, 10, 25, 50 and 100 Years

	Grid Point #11028				
Month	**1**	**10**	**25**	**50**	**100**
January	15.8	21.1	22.7	23.9	25.1
February	15.0	21.6	23.6	25.2	26.7
March	12.6	18.1	19.8	21.1	22.4
April	10.2	15.5	17.2	18.4	19.6
May	8.1	14.1	16.0	17.4	18.7
June	6.9	10.8	12.0	12.9	13.8
July	6.3	9.9	11.0	11.9	12.7
August	6.8	10.9	12.2	13.1	14.1
September	9.4	15.9	17.9	19.4	20.8
October	11.7	17.6	19.6	21.1	22.6
November	13.4	18.8	20.5	21.7	23.0
December	15.5	20.8	22.4	23.6	24.8
Annual	19.1	23.0	24.6	25.7	26.8

Table 3.6 Extreme Associated Peak Period Estimates for Return Periods of 1, 10, 25, 50 and 100 Years

	Grid Point #11028				
Month	**1**	**10**	**25**	**50**	**100**
January	12.4	14.1	14.6	15.0	15.3
February	12.0	14.1	14.7	15.1	15.5
March	11.5	13.1	13.5	13.8	14.1
April	10.5	12.1	12.5	12.8	13.1
May	10.0	11.7	12.1	12.4	12.7
June	8.5	10.7	11.2	11.7	12.0
July	8.2	10.7	11.3	11.8	12.3
August	8.6	11.5	12.2	12.8	13.3
September	10.4	12.9	13.5	14.0	14.4
October	11.3	13.1	13.6	13.9	14.3
November	11.8	13.3	13.7	14.0	14.2
December	12.5	14.0	14.4	14.7	14.9
Annual	13.5	14.7	15.1	15.4	15.7

3.3 Joint Probability of Extreme wave Heights and Spectral Peak Period

In order to examine the period ranges of storm events, an environmental contour plot was produced showing the probability of the joint occurrence of significant wave heights and the spectral peak periods using the methodology of Winterstein et al. (1993). The wave heights were fitted to a Weibull Distribution and the peak periods to a lognormal distribution using data for every 3 hours over a 51 year period. The wave data was divided into bins of 1 metre for significant wave heights and 1 second for peak periods. Since the lower wave values were having too much of an impact on the wave extremes, the wave heights below 2 metres were modeled separately in a Weibull Distribution. The two Weibull curves were combined near 2 metres, the point where both functions had the same probability.

Three-parameter Weibull Distributions were used with a scaling parameter α, shape parameter β, and location parameter γ. The three parameters were solved by using a least square method, the maximum log likelihood, and the method of moments. The following equation was minimized to get the coefficients

$$LS(\alpha, \beta, \gamma) := \sum_{i=0}^{13} \left[\ln\left(-\ln\left(1 - FP_i\right)\right) - \beta \cdot \ln\left[\frac{\left(h_i - \gamma\right)}{\alpha} \right] \right]^2$$

where h_i is the endpoint of the height bin (0.5, 1.5, …) and FP_i is the cumulative probability of the height bin. Using a minimizing function the three parameters α, β and γ were calculated.

A lognormal distribution was fitted to the spectral peak periods in each wave height bin. The coefficient of the lognormal distribution was the calculated. Using the coefficients and the two distribution functions, the joint wave height and period combinations were calculated for the various return periods.

A lognormal distribution was fitted to the spectral peak periods in each wave height bin. The coefficient of the lognormal distribution was the calculated. Using the coefficients and the two distribution functions, the joint wave height and period combinations were calculated for the various return periods. A contour plot depicting these values for return periods of 1-year, 10-years, 25-years, 50-years and 100-years is presented in Figure 3.1. The annual values for the significant wave height estimates and the associated spectral peak periods are given in Table 3.7. The extreme wave height for all return periods, were higher using the Weibull Distribution when compared to the Gumbel Distribution. The 100-year extreme significant wave height was 16.3 metres using the Weibull Distribution as compared to 14.5 metres using the Gumbel Distribution. A 14.5 m wave corresponds to a 25-year return period using the Weibull Distribution.

Table 3.7 Annual Extreme Significant Wave Estimates and Spectral Peak Periods for Return Periods of 1, 10, 25, 50 and 100 Years

Return Period (years)	Combined Significant Wave Height (m)	Spectral Peak Period Median Value (s)
1	11.2	13.9
10	13.5	15.2
25	14.4	15.6
50	15.1	16.0
100	15.8	16.3

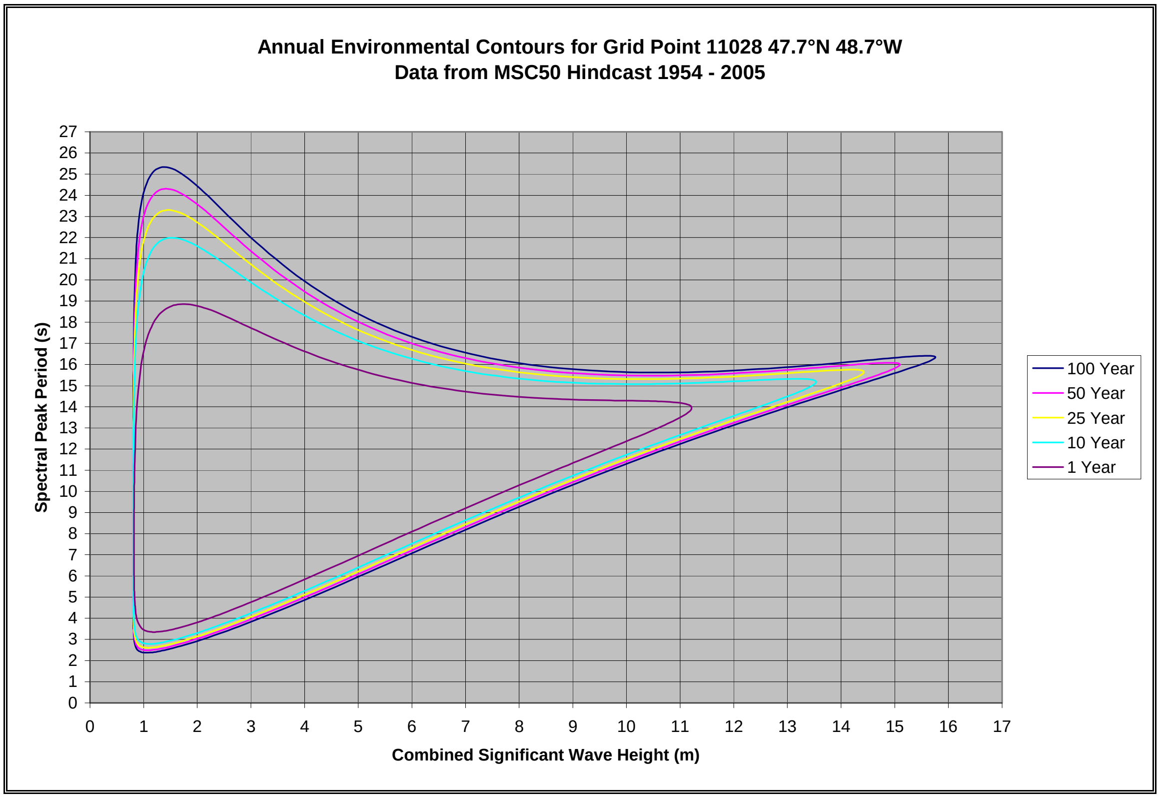

Figure 3.1 Environmental Contour Plot for Grid Point 11028 (46.7°N 48.7°W)

4.0 Physical Oceanography

4.1 General Description of the Major Currents

The large scale circulation offshore Newfoundland and Labrador is dominated by well established currents that flow along the margins of the Continental Shelf. The main circulatory feature near the study area is the Labrador Current, which transports sub-polar water to lower latitudes along the Continental Shelf of eastern Canada (Figure 4.1). Oceanographic studies show a strong western boundary current following the shelf break with relative low variability compared to the mean flow. Over the Grand Banks a weaker current system is observed where the variability often exceeds that of the mean flow (Colbourne, 2000).

The Labrador Current consists of two major branches. The inshore branch is located on the inner part of the shelf and its core is steered by the local underwater topography through the Avalon Channel. The stronger offshore branch flows along the shelf break over the upper portion of the Continental Slope. Lauzier and Wright (1993) found that the offshore branch of the Labrador Current offshore Labrador was located in a 50 km wide band between the 400 m and 1200 m isobaths. This branch of the Labrador Current divides between 48°W and 50°W, resulting in one sub-branch flowing to the east around Flemish Cap and the other flowing south around the eastern edge of the Grand Banks and through Flemish Pass. Characteristic current speeds on the Slope are in the order of 30 cm/sec to 50 cm/sec (Colbourne, 2000), while those in the central part of the Grand Banks are generally much lower, averaging between 5-15 cm/sec.

The outer branch of the Labrador Current exhibits a distinct seasonal variation in flow speeds (Lazier and Wright, 1993), in which the mean flows is a maximum in October and a minimum in March and April. This annual cycle is reported to be the result of the large annual variation in the steric height over the continental shelf in relation to the much less variable internal density characteristic of the adjoining deep waters. The additional freshwater in spring and summer is largely confined to the waters over the shelf. In summer, the difference in sea level between the shelf and open ocean is 0.09 m greater than in winter (Lazier and Wright, 1993). This difference produces a greater horizontal surface pressure gradient and hence stronger mean flows.

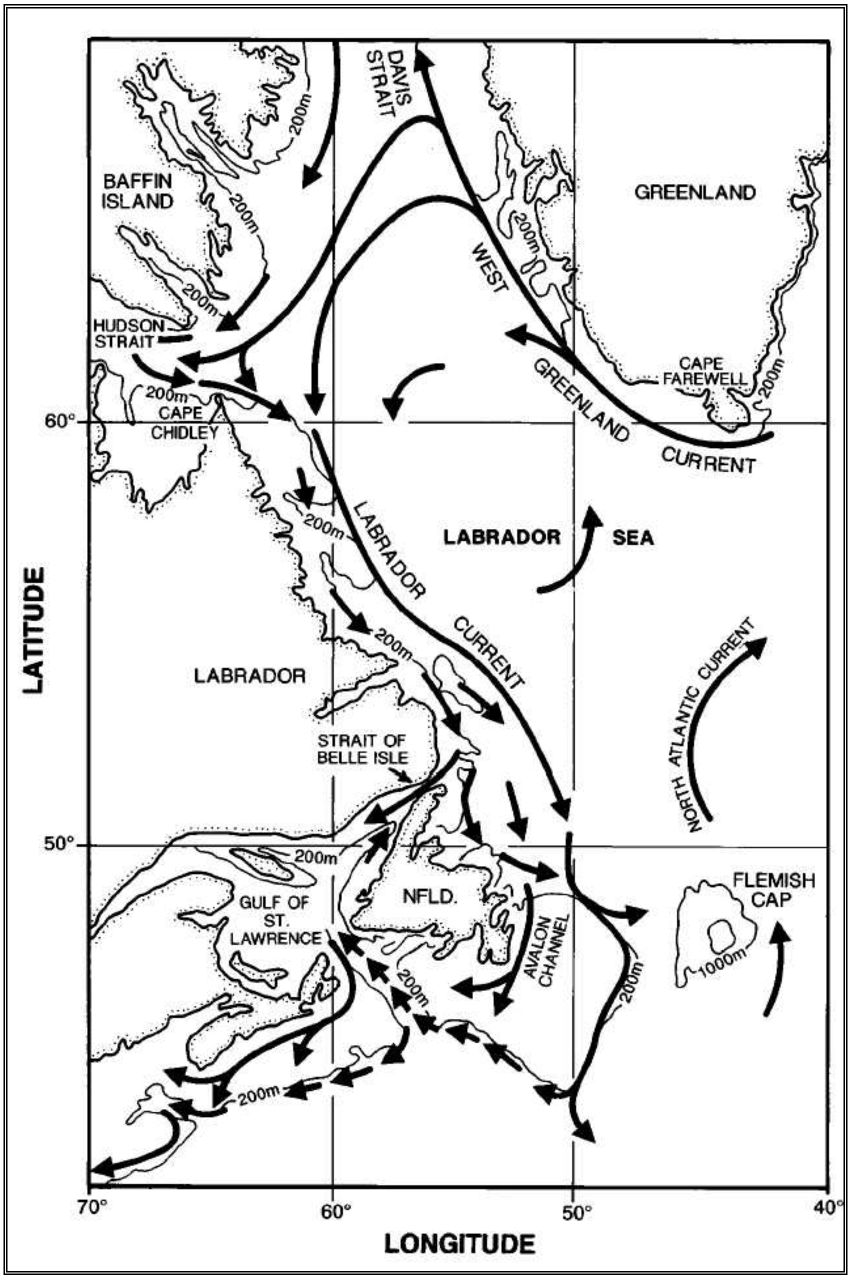

Figure 4.1 Mayor Ocean Circulation Features in the Northwest Atlantic
Source: Colbourne et al., 1997

Figure 4.2 shows the trajectories and mean current velocities calculated by Pepin and Helbig (1997) of 41 satellite tracked drifting buoys that were placed the Labrador Current near Hamilton Bank during 1992 and 1994. This figure illustrated the general pattern of the spatial distribution of the surface currents in the northeast sector of the Newfoundland Shelf.

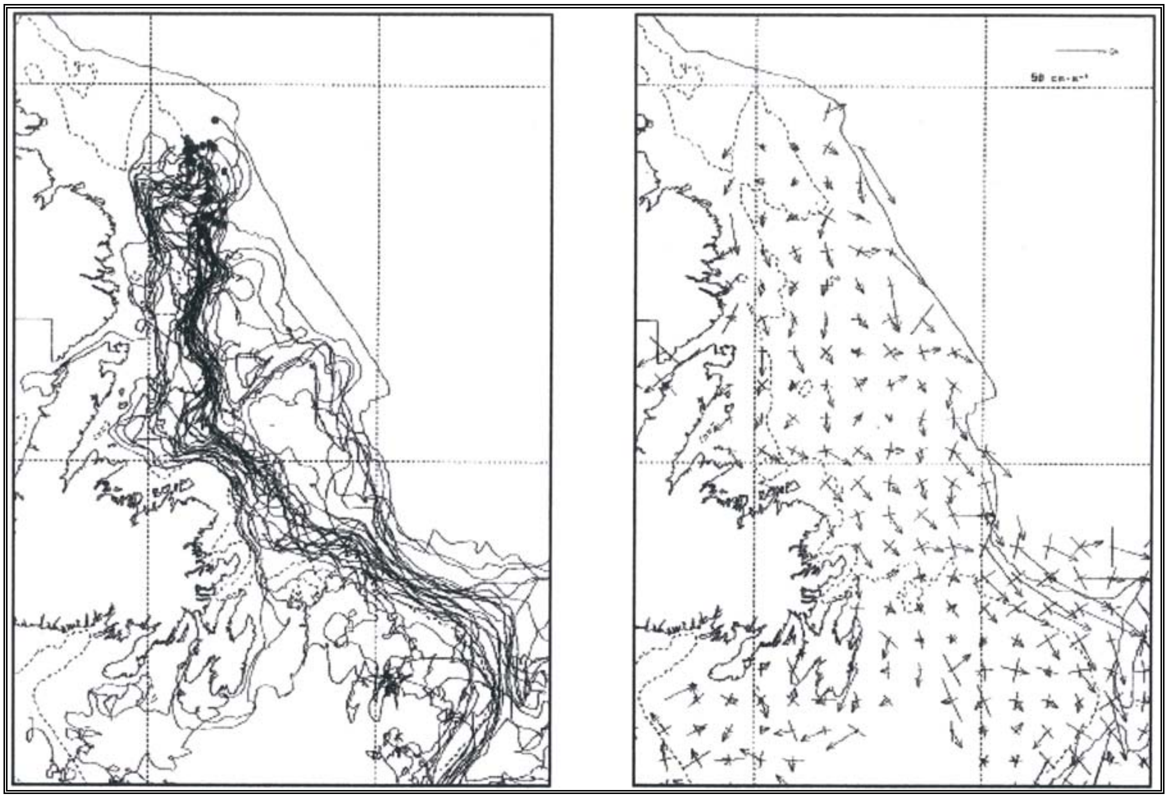

Figure 4.2 Currents on the northeast Newfoundland Shelf as inferred from 149 drifting buoys by Pepin and Helbig (1997)

Left Panel: Low-pass-filtered drifting buoys tracks. Drop locations are indicated by circles and terminal positions by asterisks.

Right Panel: Mean surface currents derived from spatial averages of all drifting buoy tracks. The principal axes of variation are indicated by crosses.

Another major current system is situated to the south of the Grand Banks. In the area of the Southeast Newfoundland Rise, the Gulf Stream branches into two streams. The southern branch continues east at approximately 40°N. The northern branch, known as the North Atlantic Current, turns north and flows along the Continental Slope southeast of the Grand Banks and continues north-eastward along the east side of Flemish Cap. This circulation pattern is captured in the nonlinear finite element model produced by Han and Wang (2005) and shown in Figure 4.3. Their model study supported a significant seasonal cycle in the current regime with strong flows during the fall/winter and weak flows in spring/summer. Figure 4.4 shows the climatological mean surface currents from the same model together with currents estimated from satellite drifter data (Han et al., 2008).

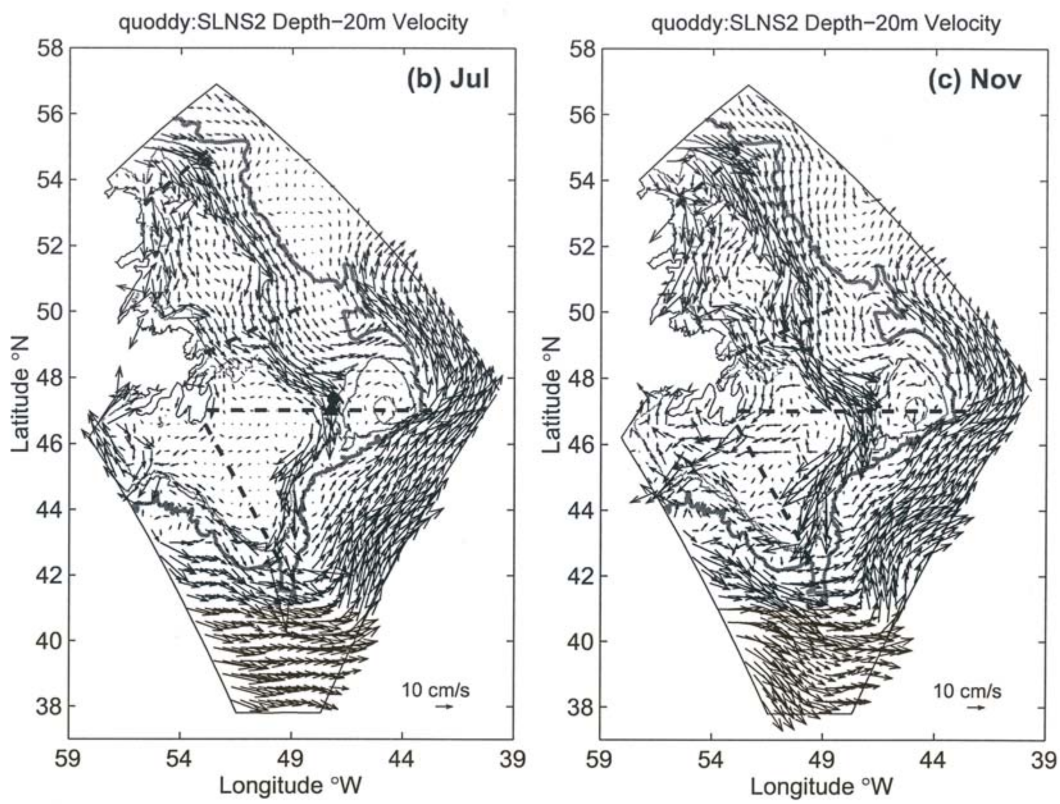

Figure 4.3 Model circulation fields at the 20 m depth for (2a) July and (b) November, representing the summer and fall respectively
(from Han and Wang, 2005)

Wind stress is an important driving force for the currents on the Continental Shelf, with a distinct annual cycle of comparatively strong winds in winter and weaker, more variable winds in summer. The analysis of an array of current meter data collected from January to May 1992 by De Tracey et al. (1996) shows that near-surface currents and local wind are highly coherent in the interior of the shallow region of the Grand Banks, which suggests that the currents have a strong wind driven component. In this area the currents are weak (a few centimetres per second) with a variability much larger (5 to 15 cm/s) than the mean velocities. Near the 200 m contour on the Northeast Newfoundland Shelf, the coherence between wind stress and the barotropic current was insignificant suggesting that local wind was not a major source contributing to the current flow. De Tracey et al. (1996) suggested that currents over the shelf edge are generated by mechanisms other than direct wind forcing and postulates that the major causes of the observed low-frequency currents may be meandering of the Labrador Current, eddy formation, and shelf wave propagations.

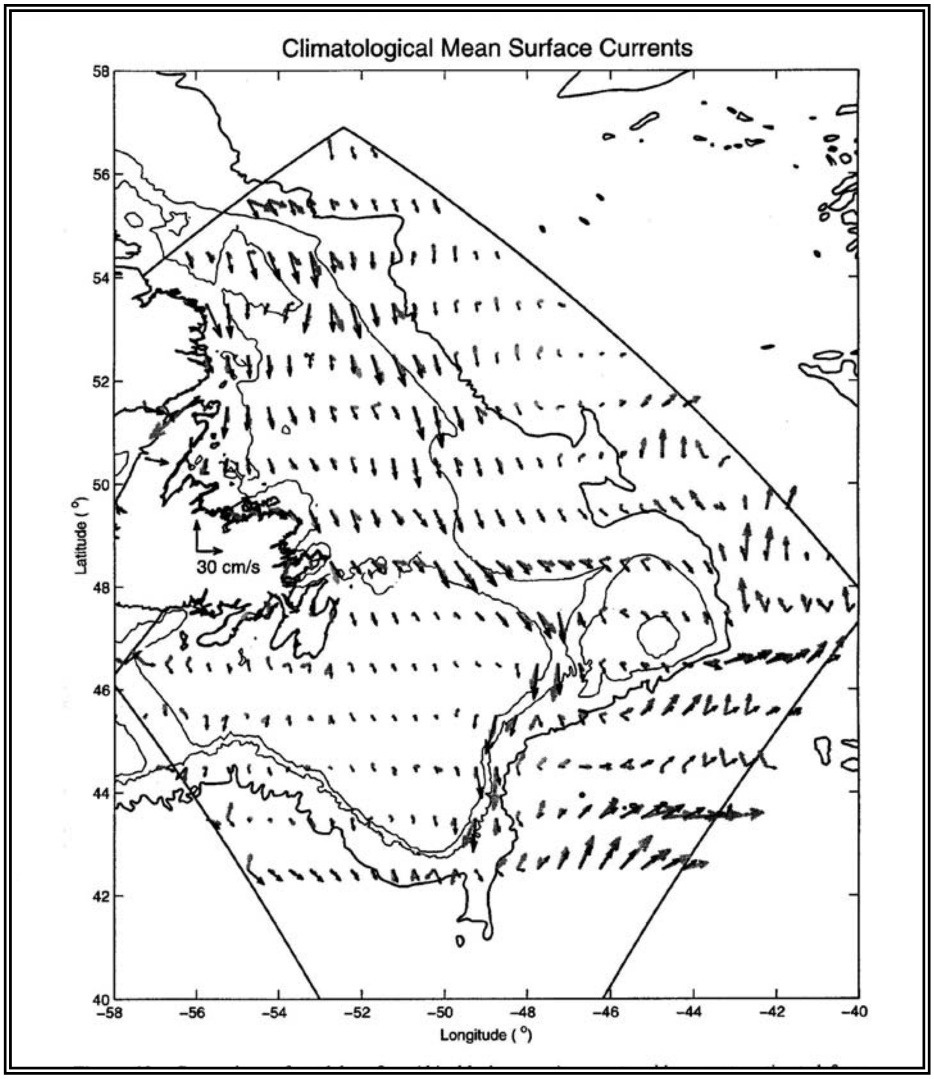

Figure 4.4 Comparison of model surface (thin black arrows) currents with currents estimated from drifter data (thick gray arrows). The 200, 1000, and 3000-m isobaths are also depicted

4.2 Currents in the Project Area

Hibernia and the project area are located on the shallow section of the Grand Banks where the water depth is less than 100 m (Figure 4.5). The majority of the moored current meter data at Hibernia are for the years 1980 to 1984 during the phase of exploration drilling. Five additional data sets obtained from the archive at the Bedford Institute of Oceanography were included. Surface currents are continuously measured at the Hibernia platform by a MIROS Directional Wave and Currents Radar. Information on surface currents for years 2003 to 2007 are included in this report.

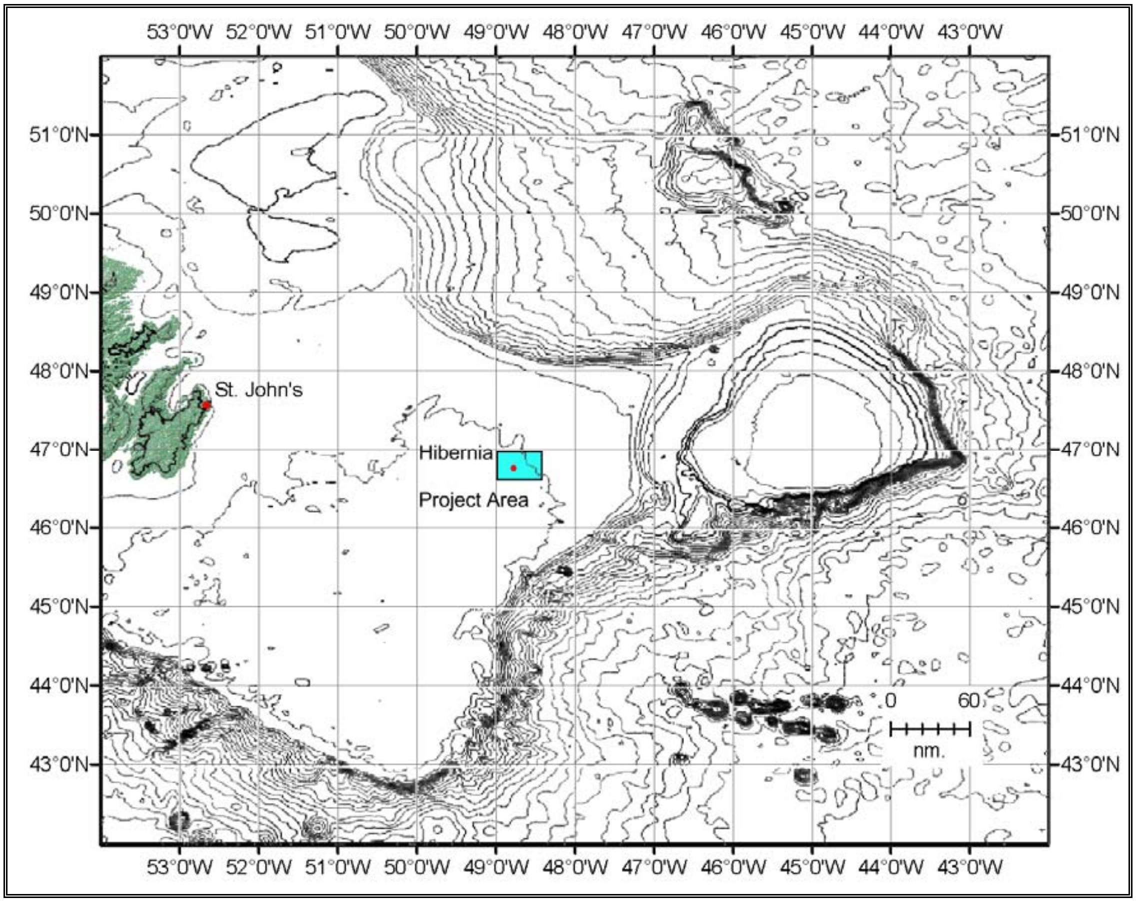

Figure 4.5 Project Area

Tides play a major role in the currents on the Grand Banks. The major tidal semidiurnal constituents are M_2 and S_2 and the major diurnal constituents are O_1 and K_1. The tidal currents are a significant portion of the flow on the Grand Banks. In the near surface waters, M_2, S_2, O_1, and K_1 can have values which range from 6 to 9 cm/s, 2 to 4 cm/s, 2 to 6 cm/s and 2 to 6 cm/s, respectively. At mid-depth, the tidal constituents of M_2, S_2, O_1, and K_1 have values of 6 to 7 cm/s, 1 to 3 cm/s, 2 to 3 cm/s, 2 to 4 cm/s. At 10 m above bottom the constituents of M_2, S_2, O_1, and K_1 have values 0 to 7 cm/s, 0 to 3 cm/s, 0 to 4 cm/s and 0 to 4 cm/s. The individual constituents have low values but the combination of all the tidal constituents contribute significantly to the overall flow.

The semi-diurnal tidal currents rotate through 360° twice per day in a clockwise direction. The diurnal tidal ellipses at Terra Nova are almost circular showing no preferred direction, and the semidiurnal tidal ellipses are slightly elongated in a northwest/southeast direction. Overall, the tidal currents at Terra Nova are responsible for about 30% of the variability near the surface and at mid-depth, and for 20% of the variability near the bottom.

Wind stress is another important driving force for the currents on the Grand Banks, with a distinct annual cycle of comparatively strong winds in winter and weaker more variable winds in summer.

The low frequency components are the most important contributor to the overall flow. The strongest currents have been observed to always occur during the passage of low pressure systems. Some of the flow can be attributed to direct effects of the wind stress upon the sea surface as indicated by an inertial period signal showing up in spectral analysis of the data. Spectral analysis shows that the low frequency components are in the period range of 4 to 7 days. The barotropic component appears to be the largest component of the strong flows.

Tables 4.1 to 4.3 present current values at Hibernia measured 20 m below the surface, at mid-depth, and at 10 m above the bottom. Tables 4.1 to 4.3 present mean speeds, mean velocities, and maximum speeds and directions for each month. The mean current speed varied between 13.5 cm/s to 21.0 cm/s near the surface, between 10.9 cm/s to 20.2 cm/s at mid-depth, and between 11.0 cm/s to 15.3 cm/s near bottom. The magnitude of the mean velocity was very low at all depths due to the high degree of variability. The mean velocity tends to be directed in a southerly direction between south and southwest at all depths. The maximum current speeds reached 127 cm/s in September in near surface waters, 119 cm/s in November at mid-depth, and 71 cm/s in November near the bottom.

The mean speeds and velocities at the surface from the data measured by the MIROS radar are summarized in Table 4.4. The mean surface speeds varied between 22.3 cm/s and 29.0 cm/s, and the mean velocities varied between 1.7 cm/s and 8.6 cm/s. There is a high degree of variability in the surface currents because the surface current tends to be in the same direction as the wind.

Table 4.1 Near-surface (20 m) currents at Hibernia (1980-1984)

Month	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction (°T)	Max Speed (cm/s)	Direction (°T)
January	21.05	6.16	SSW	67.00	193
February	18.05	4.76	SSW	59.00	179;199
March	14.63	0.62	SSW	47.00	312
April	14.55	0.67	NE	114.00	264
May	13.54	2.37	S	44.00	182
June	13.90	4.73	S	59.00	134
July	13.78	5.53	S	50.00	118
August	15.36	4.97	S	74.00	347
September	15.91	3.83	SSW	127.00	204
October	18.58	4.19	SSW	68.00	233;292
November	21.33	5.58	SSW	74.00	216
December	20.28	7.92	SSW	59.00	154;182

Table 4.2 Mid-depth currents at Hibernia (1980-1984)

Month	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction (°T)	Max Speed (cm/s)	Direction (°T)
January	18.04	4.99	SSW	48.00	199
February	15.75	3.94	SSW	61.00	314
March	13.17	0.97	SSW	54.00	220
April	13.59	1.19	NE	54.00	172
May	11.89	1.50	SSW	38.00	181
June	10.91	3.09	SSW	75.00	151
July	12.80	5.56	SW	44.00	237
August	12.66	3.44	SW	40.00	221
September	14.83	3.03	SW	59.00	217
October	16.54	3.67	SSW	57.00	213
November	19.01	4.71	SW	119.00	88
December	20.24	7.59	SSW	78.00	219;238

Table 4.3 Near-bottom currents at Hibernia (1960-1984)

Month	Mean Speed (cm/s)	Mean Velocity (cm/s)	Direction (°T)	Max Speed (cm/s)	Direction (°T)
January	14.17	4.12	SSW	39.00	222
February	14.33	3.66	SSW	57.00	181;315
March	12.79	0.73	SSW	46.00	265
April	11.88	0.11	SW	30.00	37
May	11.02	1.76	SW	32.00	229
June	11.32	3.46	SW	36.00	248
July	11.12	4.60	SW	36.00	240
August	11.00	3.35	SW	33.00	239
September	11.65	2.33	SW	56.00	307
October	13.06	2.35	SW	36.00	350
November	15.25	3.80	SW	72.00	199
December	15.18	5.98	SSW	57.00	137

Table 4.4 Surface Currents from MIROS Data (2003-2007)

Month	Mean Speed (cm/sec)	Mean Velocity (cm/sec)	Direction (°T)	Max Speed (cm/sec)	Direction (°T)
Jan	23.6	6.5	E	99.7	277
Feb	23.1	8.6	E	99.8	276
March	22.3	4.9	ESE	99.2	286
April	23.5	3.7	E	130	165
May	23.1	1.7	N	121	322
June	23.3	2.9	SE	100	114
July	26.1	4.6	SE	148	265
August	29.0	3.1	NE	157	093
Sept	27.0	3.7	SW	145	001
Oct	25.2	4.4	ESE	138	117
Nov	26.0	5.9	SE	159	256
Dec	26.2	5.3	SSE	153	260

4.3 Water Mass Structure

The water structure on the Grand Banks of Newfoundland is characterized by the presence of three identifiable features.

The first identifiable feature is the surface layer which is exposed to interaction with the atmosphere, and experiences temperature variations from sub zero values in January and February to above 15°C in summer and early fall. Salinity at this layer is strongly impacted by wave action and local precipitations. Considering that a water mass is a body of water which retains its well defined physical properties, over a long time period, the surface layer of variable temperature and salinity is usually left out of a water mass analysis for a particular region. During the summer, the stratified surface layer can extend to a depth of 40 m or more. In winter, the stratification in the surface layer disappears and becomes well mixed due to atmospheric cooling and intense mixing processes from wave action.

A second element of the thermohaline structure on the Grand Banks is the Cold Intermediate Layer (Petrie et al., 1988). In areas where the water is deep enough, this layer of cold water is trapped during summer between the seasonally heated upper layer and warmer slope water near the seabed (Colbourne, 2002). Its temperatures range from less than -1.5°C to 0°C (Petrie and al., 1988; Colbourne et al., 1996) and salinities vary within 32 and 33 psu. It can reach a maximum vertical extent of over 200 m (Colbourne, 2004). The Cold Intermediate Layer is the residual cold layer that occurs from late spring to fall and is composed of cold waters formed during the previous winter season. It becomes isolated from the sea surface by the formation of the warm surface layer during summer, and disappears again during late fall and winter due to the intense mixing processes that take place in the surface layer from strong winds, high waves and atmospheric cooling. In winter the two layer structure is replaced by a mixed cold body of water which occupies the entire water column.

Figure 4.5 shows average bottom temperature during the decade from 1991 to 2000. The figure shows that positive bottom temperatures are found south of 46°N. The blue area to the north of 46° N in Figure 4.5 corresponds to the average spread of the Cold Intermediate Layer. The variabilities in temperature and salinity in the area have been the subject of systematic research (Colbourne, 2004; Colbourne et al., 1997; Colbourne and Foote, 2000). These studies suggest that the water properties on the Grand Banks experience notable temporal variability. Colbourne (2004) explains that bottom temperatures ranged from near record lows during 1991 to very high values in the late 90's. The areal coverage of the Cold Intermediate Layer was highest on the Newfoundland Shelf during years 1972, 1984 and 1991 (Colbourne, 2004).

Bottom temperature and salinity maps were produced by Colbourne et al. (2007) by trawl-mounted CTD data from approximately 700 fishing tows during the fall of 2005. These maps are presented in Figure 4.6. Both Figures 4.5 and 4.6 shows that the Cold Intermediate Layer is still present near the bottom in the Project Area.

A third element is the sharp density boundary near the Shelf break which separates the water on the shelf from the warmer, more saline water of the Continental Slope. The water over the Slope is the Labrador Sea water which is formed in the Labrador Sea as a result of the deep convection processes that take place during severe winters. The Labrador Sea has temperatures between 2°C to 4°C and salinities between 34.8‰ to 35‰.

During the last 50 years there have been three warming periods in the Labrador Sea; 1960 to 1971, 1977 to 1983, and 1994 to present. In 1994, the Labrador Sea water filled the entire central part of the Labrador Sea basin within the depth range of 500-2400 m (Yashayaev and Clarke, 2006). The warming trend since 1994 has caused the water to become warmer, saltier, and more stratified; thus making it more difficult for winter renewal of Labrador Sea Water to take place. Unusual warming took place in 2004 believed to have originated from waters transported north and west by the North Atlantic Current and the Irminger Current (Yashayaev and Clarke, 2006).

The temperature and salinity boundary between the water on the Shelf and the water in Flemish Pass is shown in Figure 4.7 from CTD data collected during April 2007 along the routinely sampled Flemish Cap transect. The offshore branch of the Labrador Current flows along the Shelf break in the region of this strong density gradient. Only the outside edge of the Grand Banks and Flemish Pass was sampled in April 2008. A notable feature is that the water on the outside edge of the Grand Banks was slightly colder in 2008, having temperatures reaching -1°C whereas in 2007 the temperature was approximately 0°C in the same location. Figure 4.8 shows the hydrographic properties along the same transect in July 2008. In July the water is much warmer on the Grand Banks with a strong stratification in the upper 30 m. Below 50 m, the water was approximately 0°C along the transect to the Shelf break.

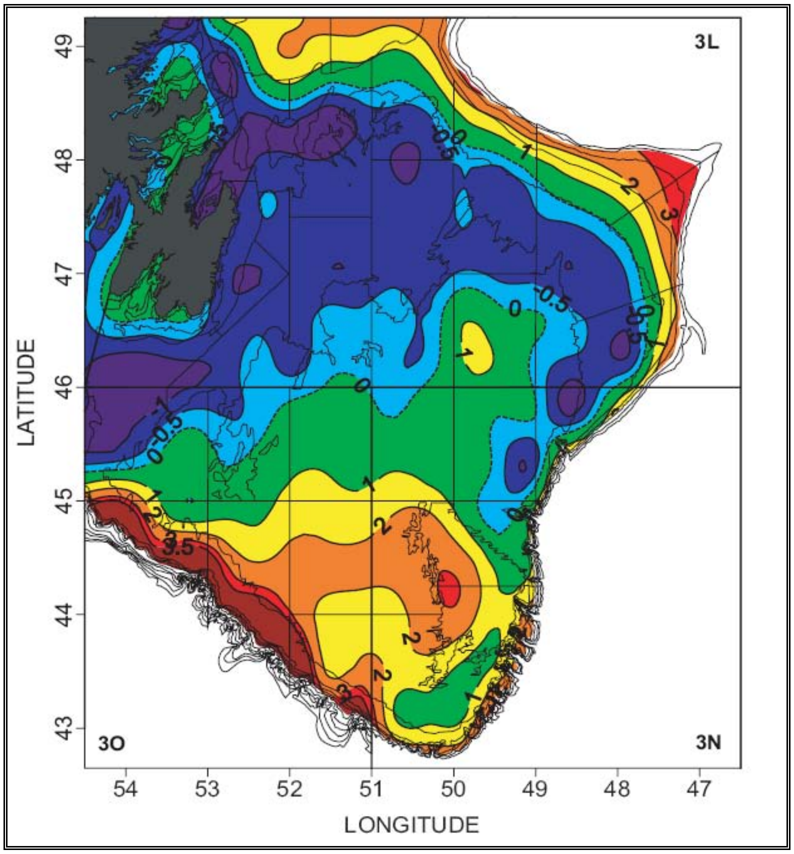

Figure 4.6 Average near bottom temperature during spring from all available data for the decade 1991-2000 (adapted from Colbourne, 2004)

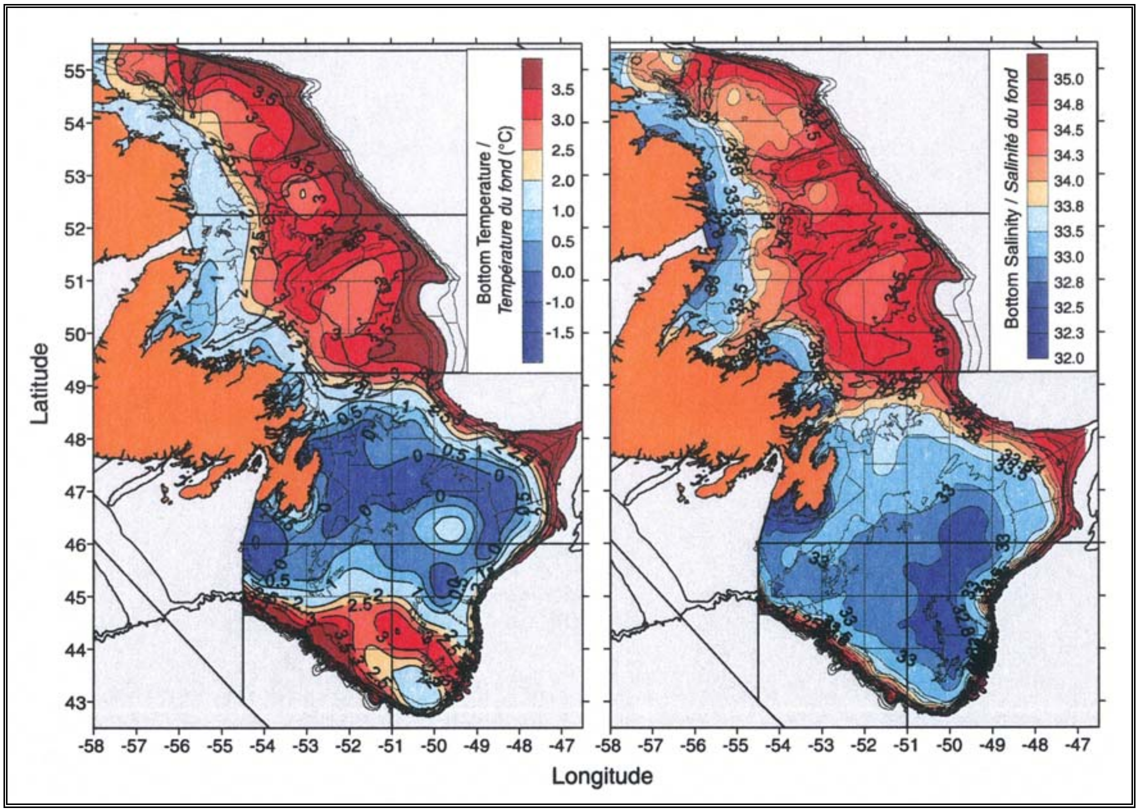

Figure 4.7 Bottom temperature and salinity maps derived for the trawl-mounted CTD data *(from Colbourne et al. 2007)*

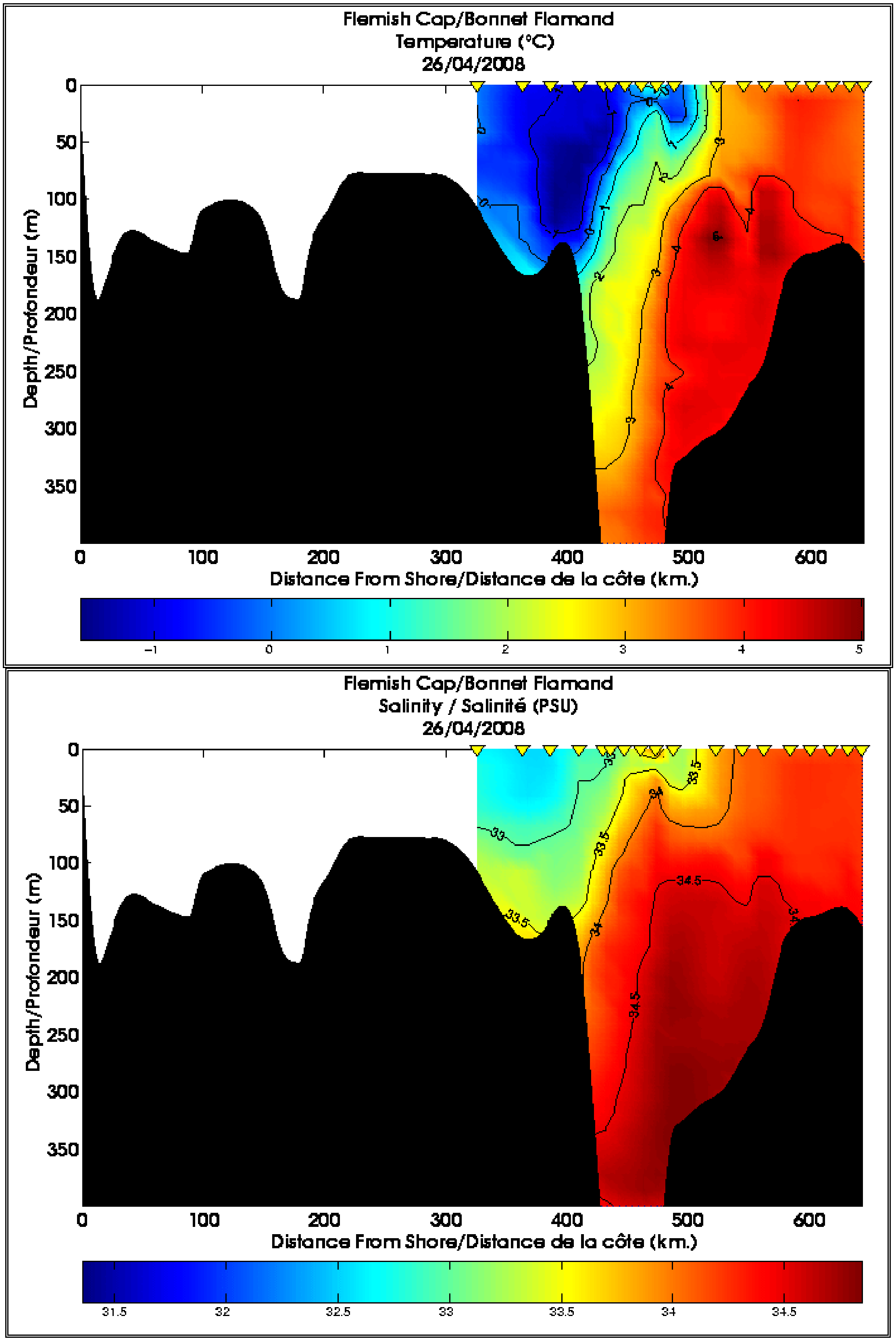

Figure 4.8 Hydrographic contours of the Flemish Cap transect during April 2008
(from DFO Marine Environmental Data Service Website)

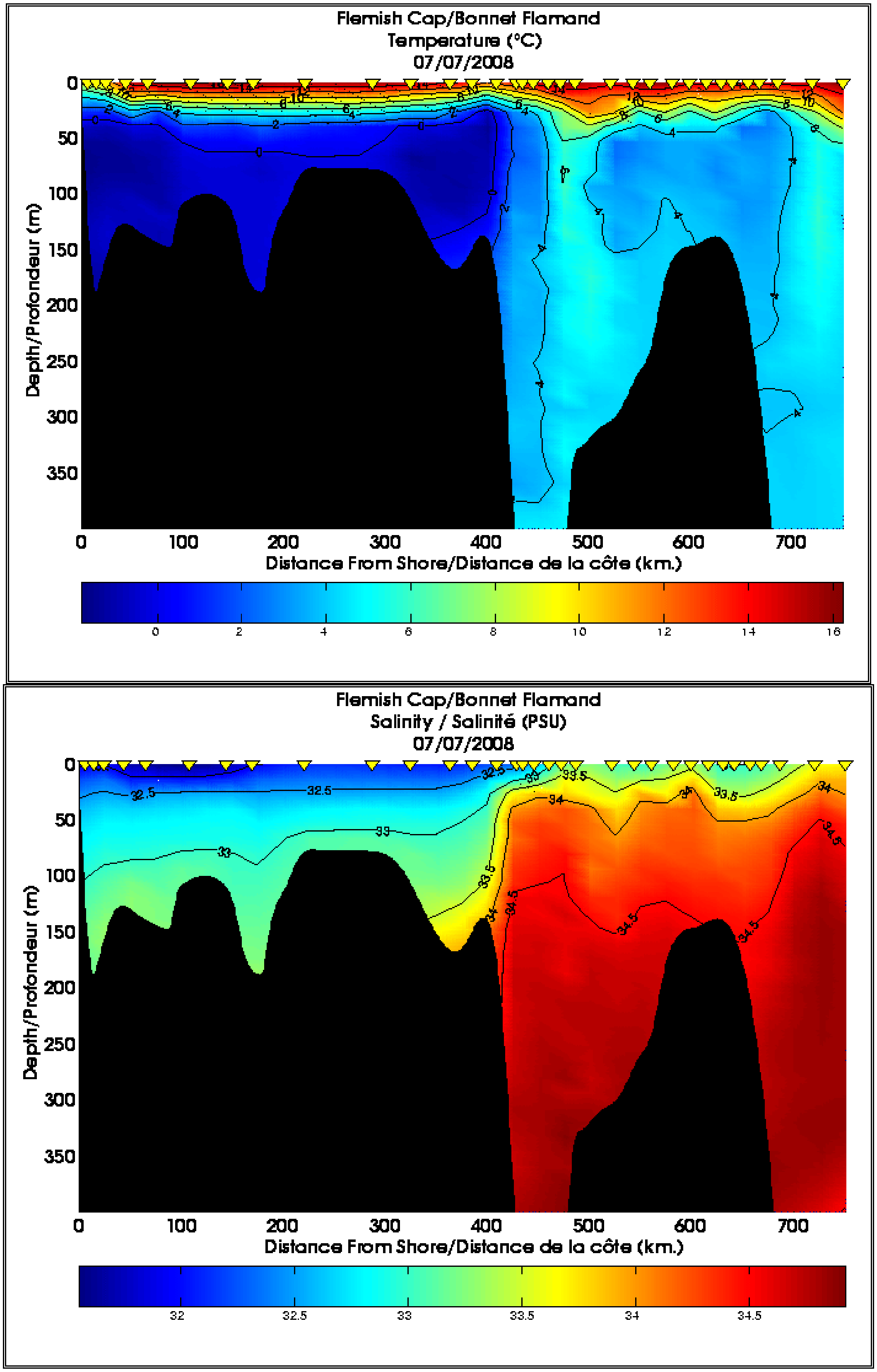

Figure 4.9 Hydrographic contours of the Flemish Cap transect during July 2007
(from DFO Marine Environmental Data Service Website)

4.4 Water Properties in the Project Area

Temperatures and salinity data for the project area was acquired form the Bedford Institute of Oceanography and used to produce statistics, T-S diagrams and contour plots. Tables 4.5 and 4.6 show the mean, minimum and maximum values for temperature and salinity, respectively, on a monthly basis for the surface waters and for depths of 50 m and 100 m. The majority of the data is for months of April to July and October to December. There is no data for January, February, and March and only a few observations for August and September.

The data in Table 4.5 shows that the warmest temperatures near the surface are between July and September with mean temperatures ranging between 10.3°C to 11.7°C. The coldest temperatures are normally in March on the Grand Banks. The mean salinities ranged between 31.9 psu in September and 32.8 psu in April.

At a depth of 50 m, the mean temperatures ranged between -0.6°C to 2.1°C in August. At a depth of 100 m, the mean temperatures were always negative ranging between -1.4°C in September to -0.3°C in July. The mean salinities varied between 32.7 psu in December to 32.9 psu in April and October at a depth of 50 m, and between 33.1 psu in May to 33.4 psu in December at a depth of 100 m.

Table 4.5 Temperature Statistics for the Surface and Depths of 50 m and 100 m

Month	Depth (m)	No. of observations	Minimum (°C)	Maximum (°C)	Mean (°C)
January	-	-	-	-	-
February	-	-	-	-	-
March	-	-	-	-	-
	0	58	-0.69	3.13	0.40
	50	144	-1.67	1.07	-0.23
April	100	52	-1.58	0.84	-0.34
	0	26	0.41	3.59	2.00
	50	286	-1.63	2.84	1.53
May	100	42	-1.52	-0.02	-0.84
	0	277	2.90	8.10	5.60
	50	810	-0.85	3.65	0.87
June	100	59	-1.34	0.40	-0.34
	0	192	5.05	14.21	10.26
	50	402	-1.47	3.95	0.61
July	100	208	-1.44	0.37	-0.28
	0	2	11.63	11.84	11.73
	50	11	-0.67	3.88	2.08
August	100	6	-0.85	-0.45	-0.74
	0	13	9.11	11.53	10.51
	50	17	-1.46	0.76	-0.61
September	100	5	-1.49	-1.34	-1.39
October	0	15	6.83	11.77	8.64

	50	240	-1.10	2.19	-0.50
	100	14	-1.33	-1.10	-1.16
	0	48	3.35	9.80	6.05
	50	108	-1.21	6.39	1.05
November	100	75	-1.06	0.51	-0.47
	0	30	1.27	4.06	2.46
	50	67	-0.93	4.97	1.54
December	100	26	-0.99	0.32	-0.33

Table 4.6 Salinity Statistics for the Surface and Depth of 50 m and 100m

	Depth (m)	No. of observations	Minimum (psu)	Maximum (psu)	Mean (psu)
January	-	-	-	-	-
February	-	-	-	-	-
March	-	-	-	-	-
	0	58	32.23	33.02	32.83
	50	144	32.71	33.28	32.90
April	100	52	32.92	33.66	33.25
	0	26	31.87	32.77	32.52
	50	286	32.66	33.97	32.77
May	100	42	32.91	33.24	33.11
	0	277	30.11	33.68	32.57
	50	810	32.50	33.89	32.82
June	100	59	32.84	33.44	33.21
	0	192	31.89	32.67	32.43
	50	402	32.46	33.93	32.89
July	100	208	32.93	33.42	33.22
	0	2	32.04	32.09	32.07
	50	11	32.62	32.99	32.71
August	100	6	33.03	33.31	33.13
	0	13	31.70	32.09	31.90
	50	17	32.60	33.12	32.87
September	100	5	33.04	33.42	33.27
	0	15	30.28	32.40	31.93
	50	240	32.55	33.06	32.90
October	100	14	33.03	33.24	33.17
	0	48	31.67	32.52	32.16
	50	108	32.11	33.35	32.84
November	100	75	32.95	33.81	33.27
	0	30	32.13	32.91	32.44
	50	67	32.02	33.33	32.70
December	100	26	33.16	33.62	33.43

Contour plots of the mean temperature and salinity with depth are shown in Figures 4.9 and 4.19 for months of April to December.

T-S diagrams in Figure 4.11 show how the water properties vary with season throughout the water column. In summer and fall the water is stratified to a depth of 50 m. Below 50 m the water is less stratified and shows negative temperatures at 100 m, within the core of the Cold Intermediate Layer. In winter and spring, the water between the surface and 50 m is less stratified than during summer and fall. Between 50 m and 100 m the water is more stratified during winter than during the other seasons.

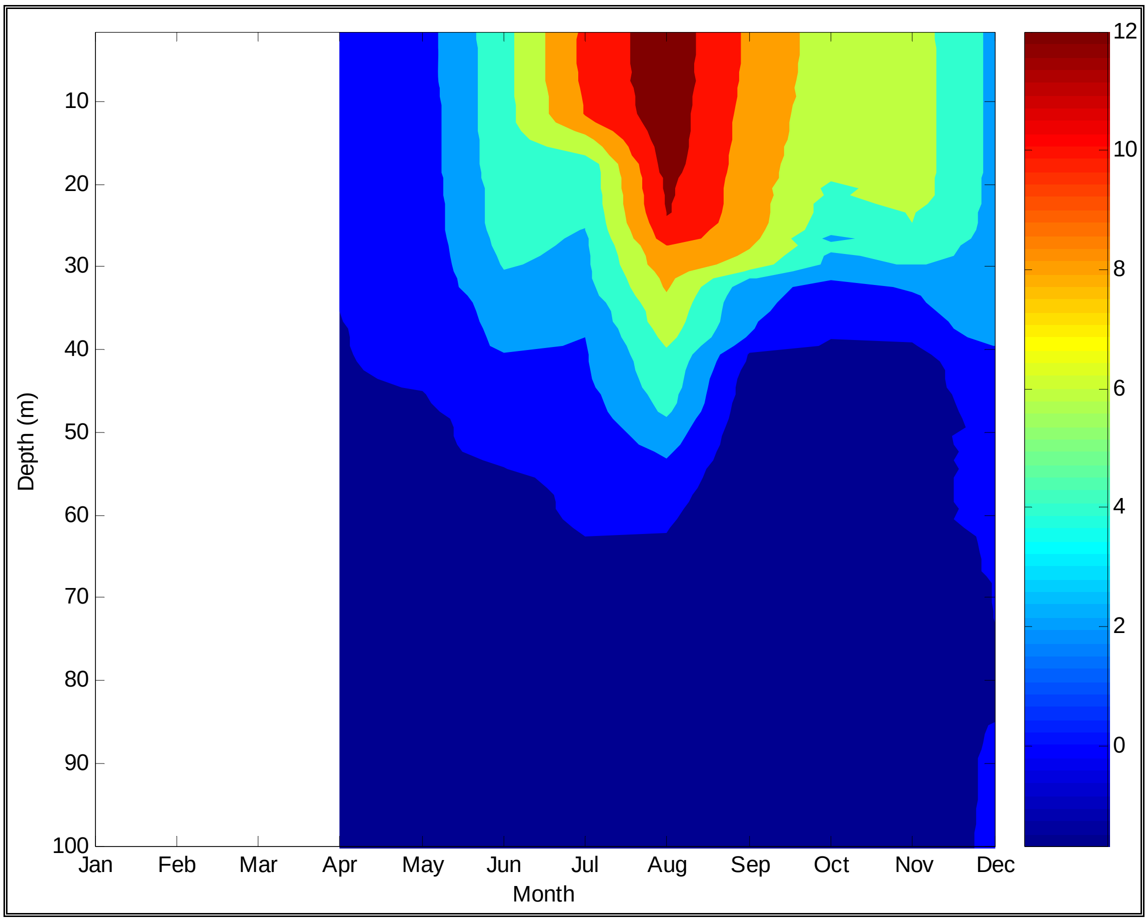

Figure 4.10 Contour Plot of Monthly Temperature Data at Hibernia

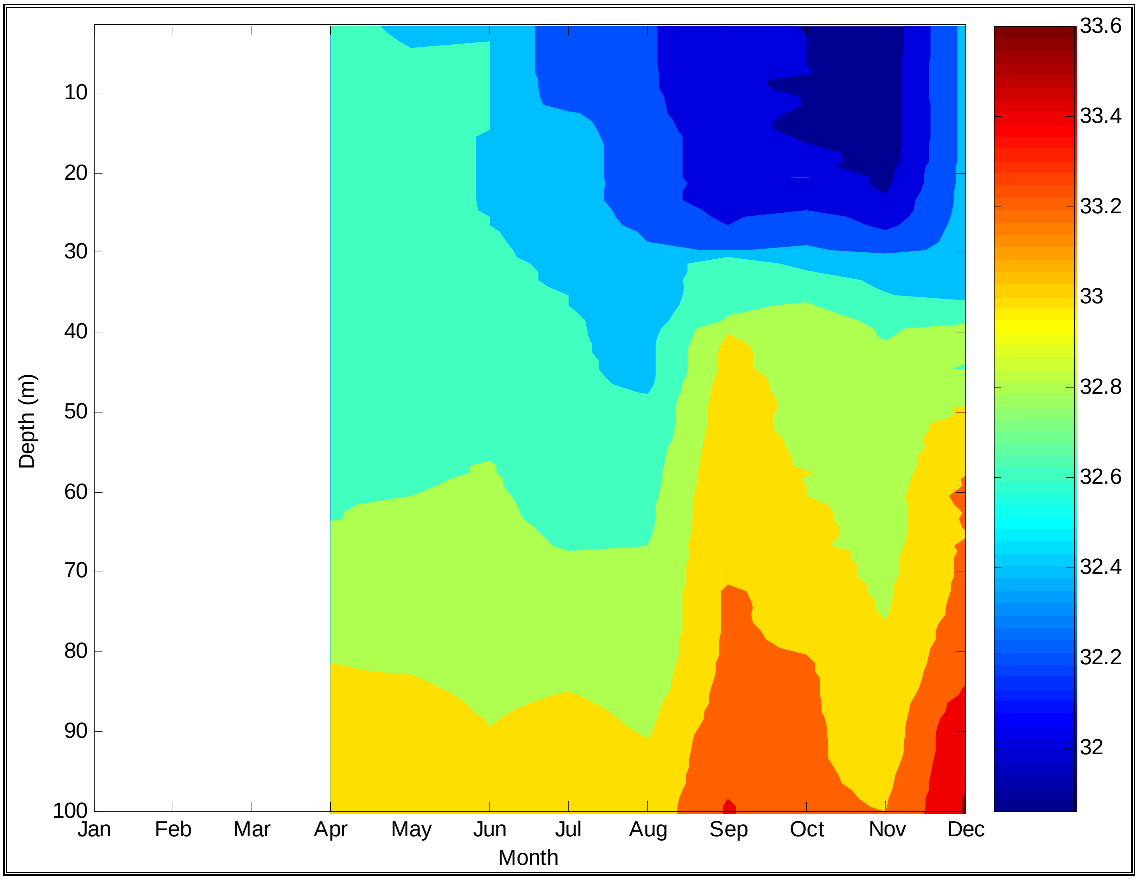

Figure 4.11 Contour Plot of Monthly Salinity Data

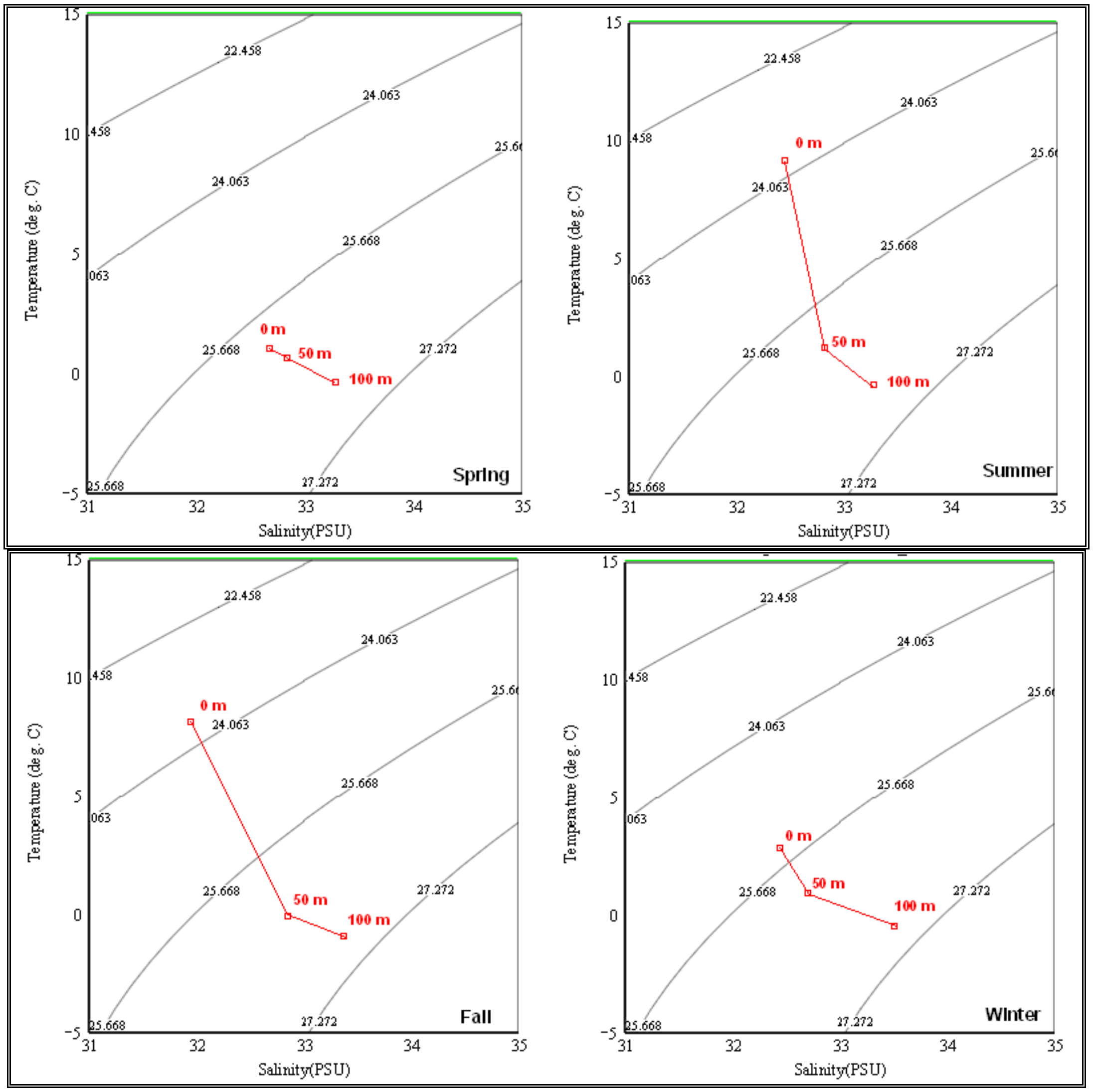

Figure 4.12 Seasonal T-S Diagrams for Hibernia
The numbers on the curves represent the depth in metres.

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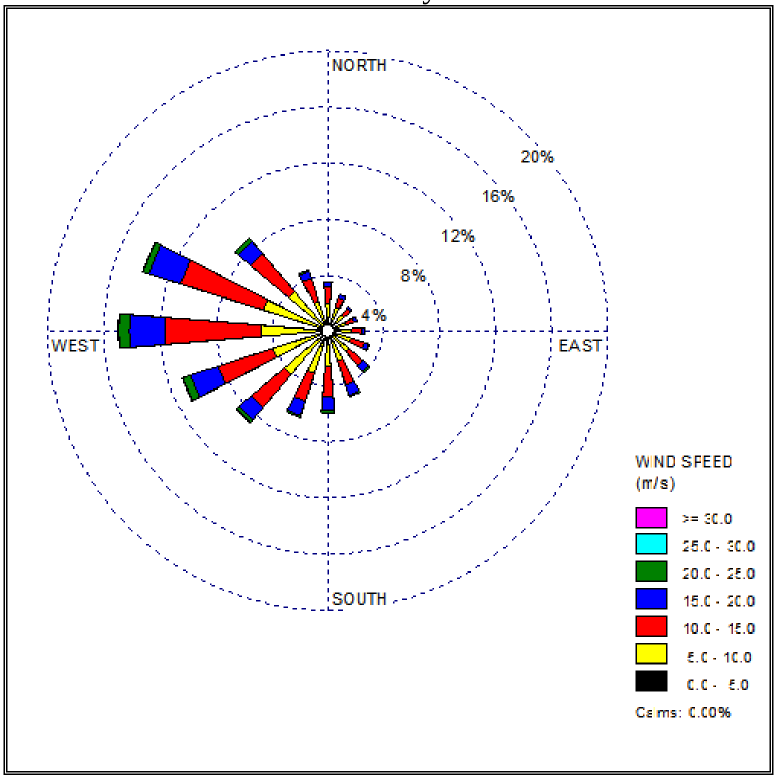
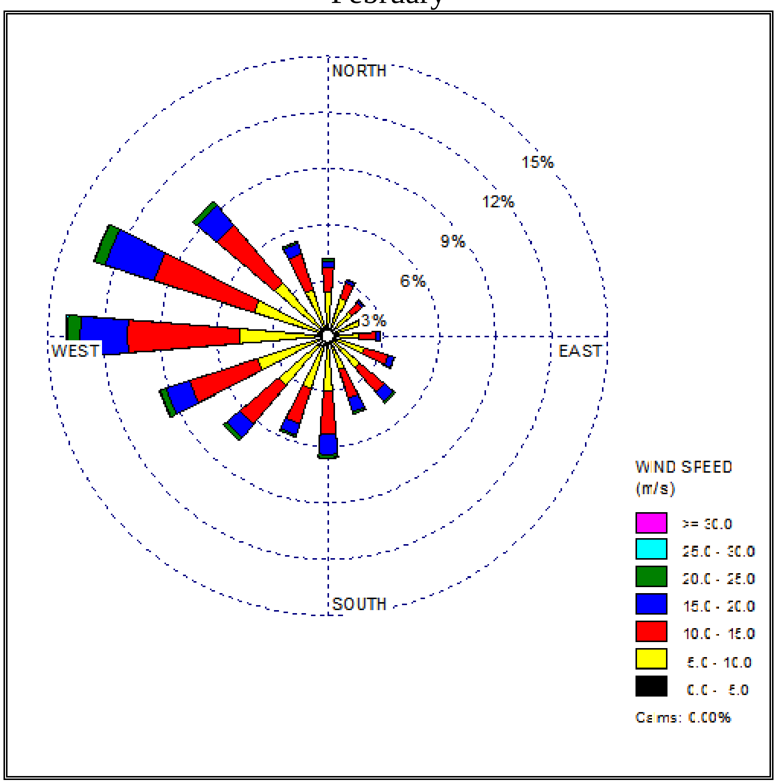
Appendix 1
Wind Roses
for MSC50 GridPoint 11028

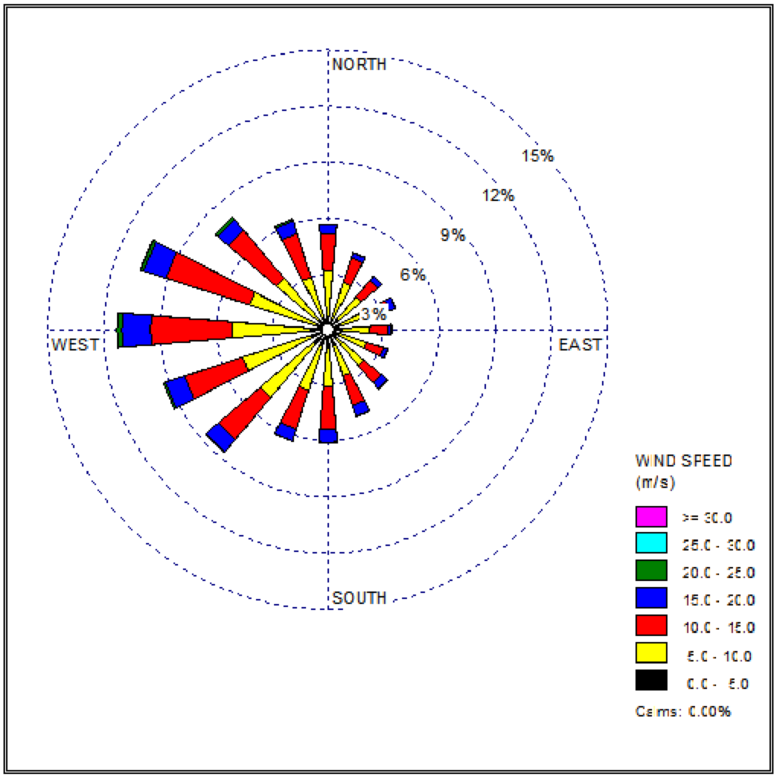
January



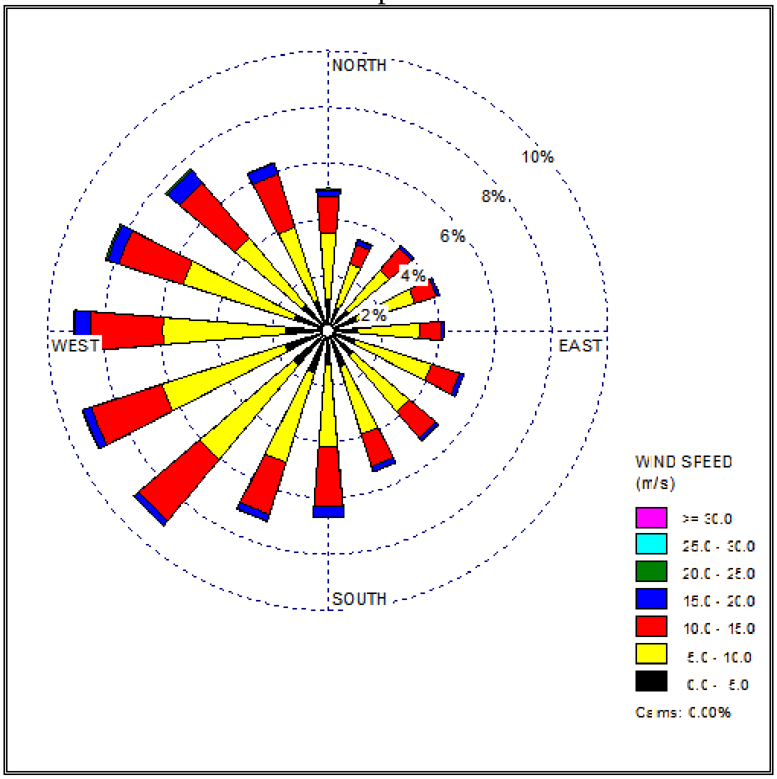
February



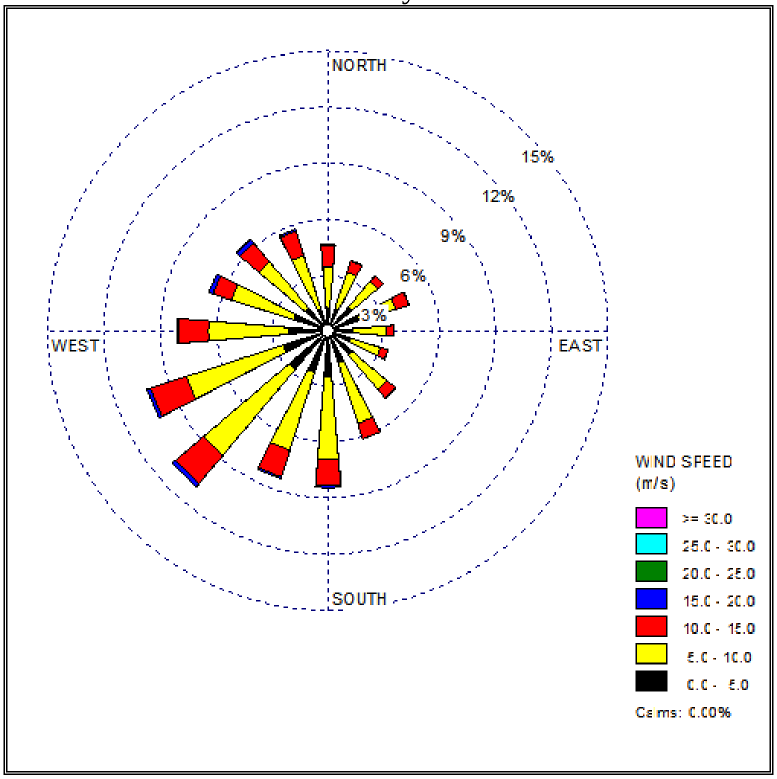
March


NORTH
SOUTH
WEST
EAST
3%
6%
9%
12%
15%
WIND SPEED
(m/s)
>= 30.0
25.0 - 30.0
20.0 - 25.0
15.0 - 20.0
10.0 - 15.0
5.0 - 10.0
0.0 - 5.0
Calms: 0.00%

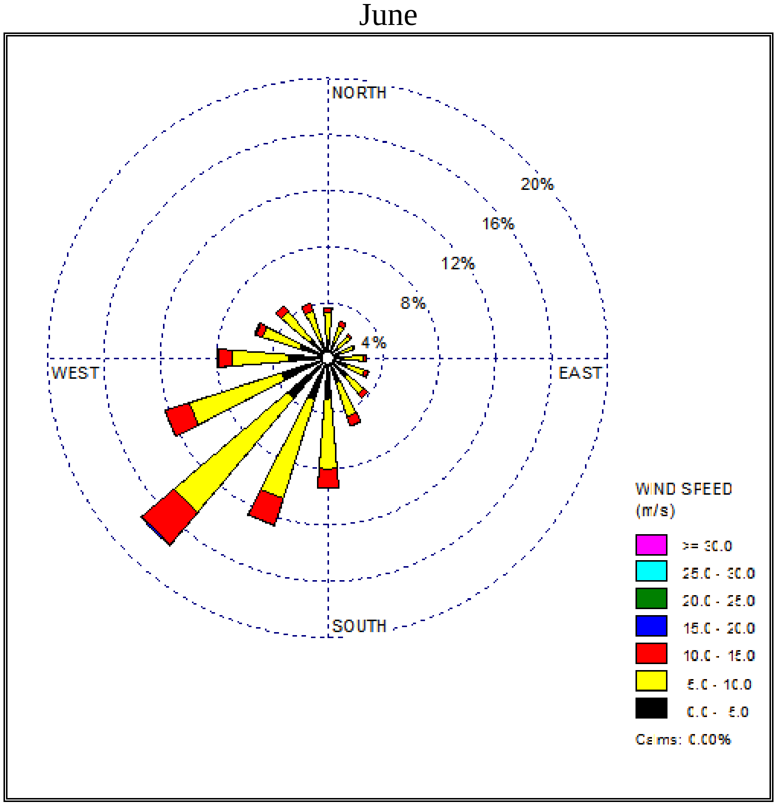
April


NORTH
SOUTH
WEST
EAST
2%
4%
6%
8%
10%
WIND SPEED
(m/s)
>= 30.0
25.0 - 30.0
20.0 - 25.0
15.0 - 20.0
10.0 - 15.0
5.0 - 10.0
0.0 - 5.0
Calms: 0.00%

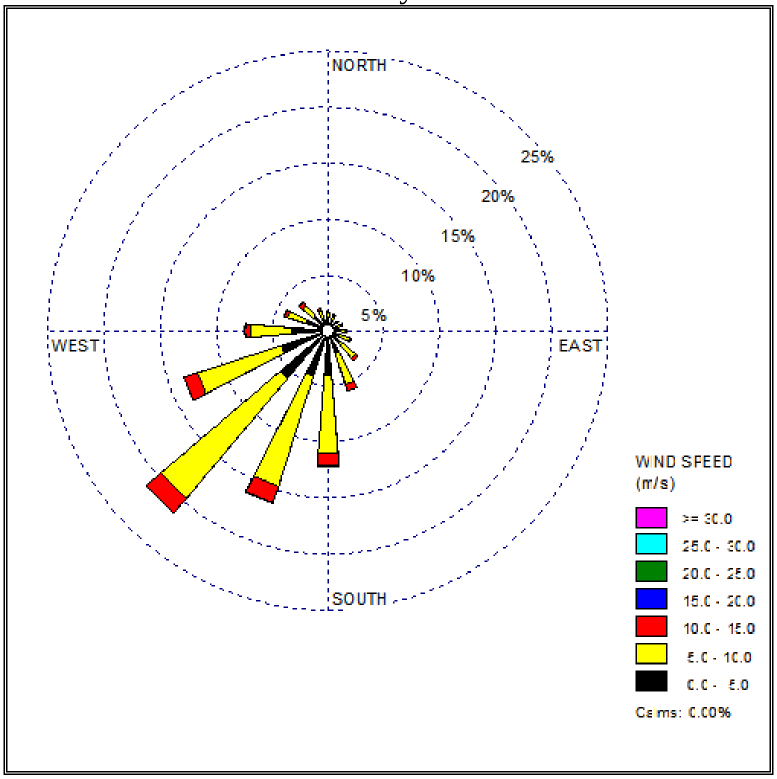
May


NORTH
SOUTH
WEST
EAST
3%
6%
9%
12%
15%
WIND SPEED
(m/s)
>= 30.0
25.0 - 30.0
20.0 - 25.0
15.0 - 20.0
10.0 - 15.0
5.0 - 10.0
0.0 - 5.0
Calms: 0.00%

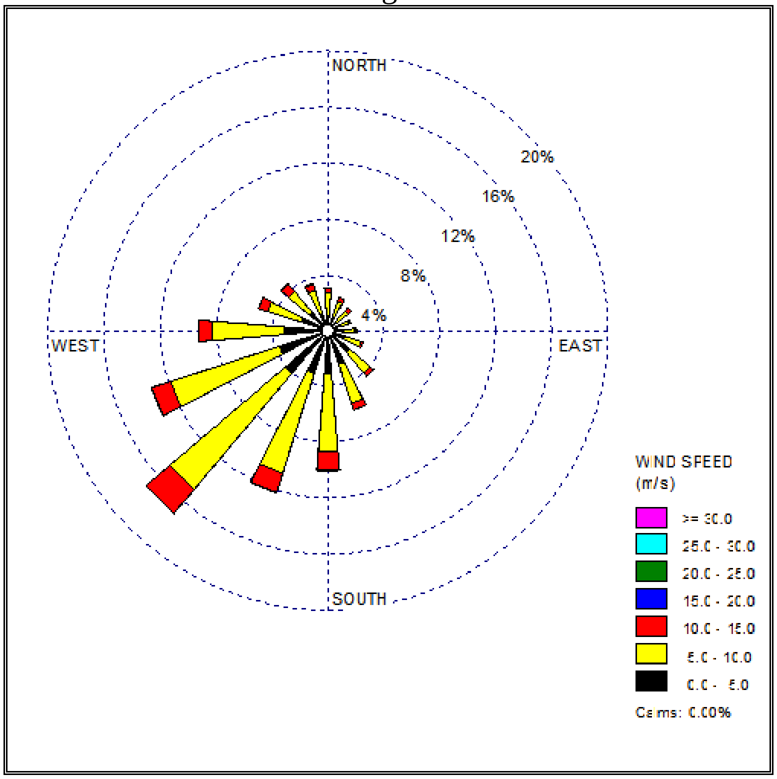
June


NORTH
SOUTH
WEST
EAST
4%
8%
12%
16%
20%
WIND SPEED
(m/s)
>= 30.0
25.0 - 30.0
20.0 - 25.0
15.0 - 20.0
10.0 - 15.0
5.0 - 10.0
0.0 - 5.0
Calms: 0.00%

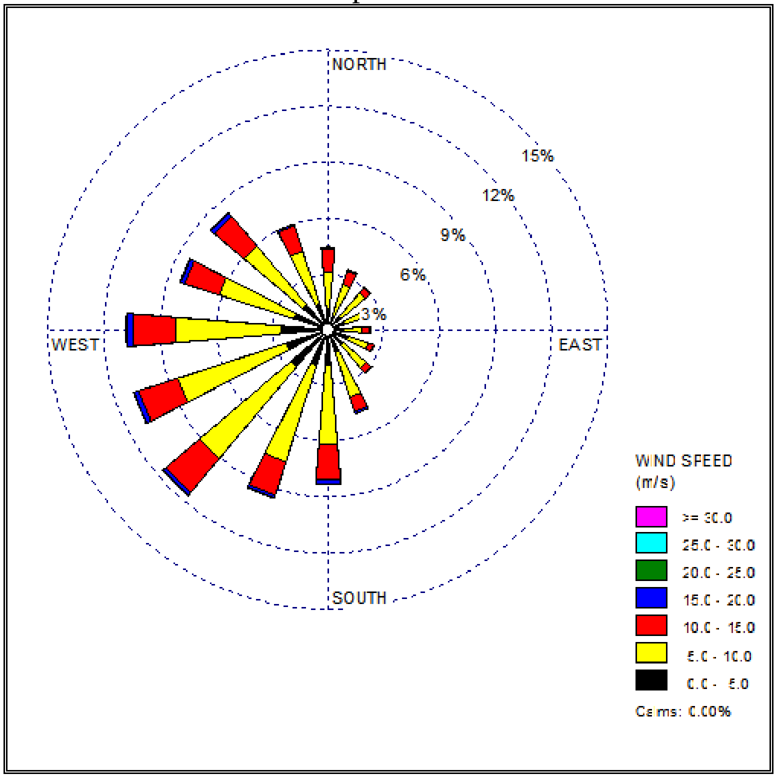
July


NORTH
SOUTH
WEST
EAST
5%
10%
15%
20%
25%
WIND SPEED
(m/s)
>= 30.0
25.0 - 30.0
20.0 - 25.0
15.0 - 20.0
10.0 - 15.0
5.0 - 10.0
0.0 - 5.0
Calms: 0.00%

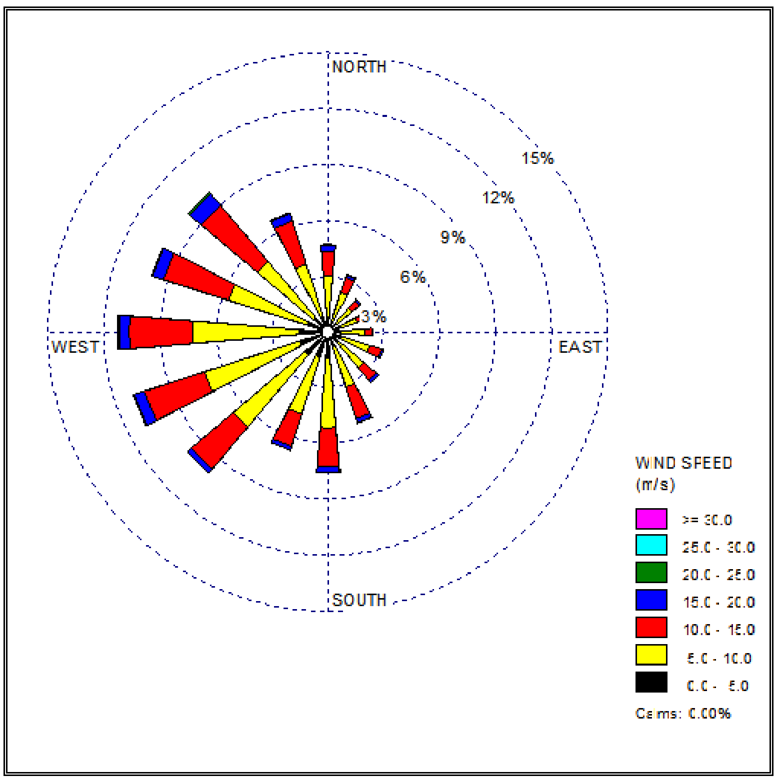
August


NORTH
SOUTH
WEST
EAST
4%
8%
12%
16%
20%
WIND SPEED
(m/s)
>= 30.0
25.0 - 30.0
20.0 - 25.0
15.0 - 20.0
10.0 - 15.0
5.0 - 10.0
0.0 - 5.0
Calms: 0.00%

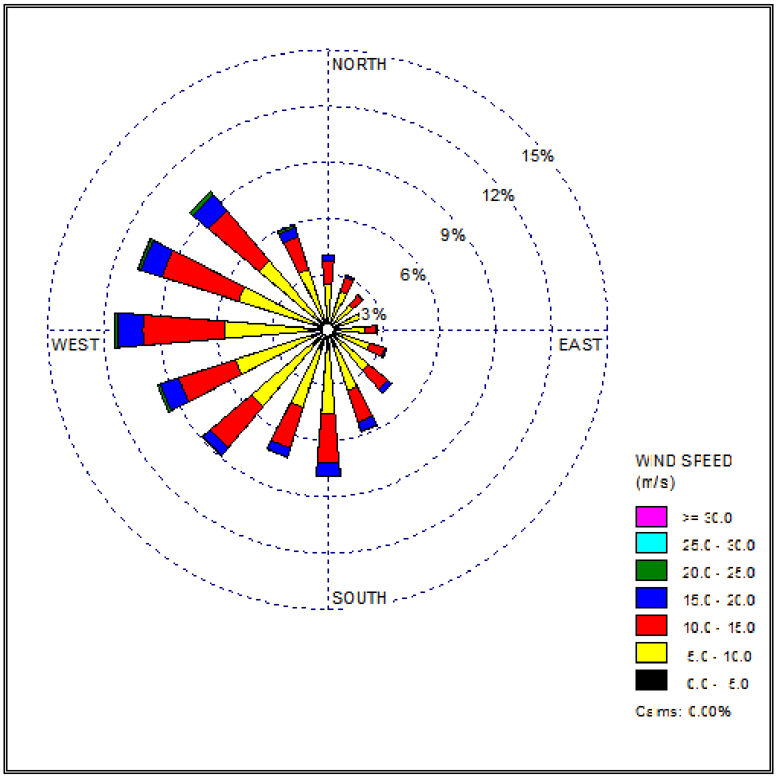
September



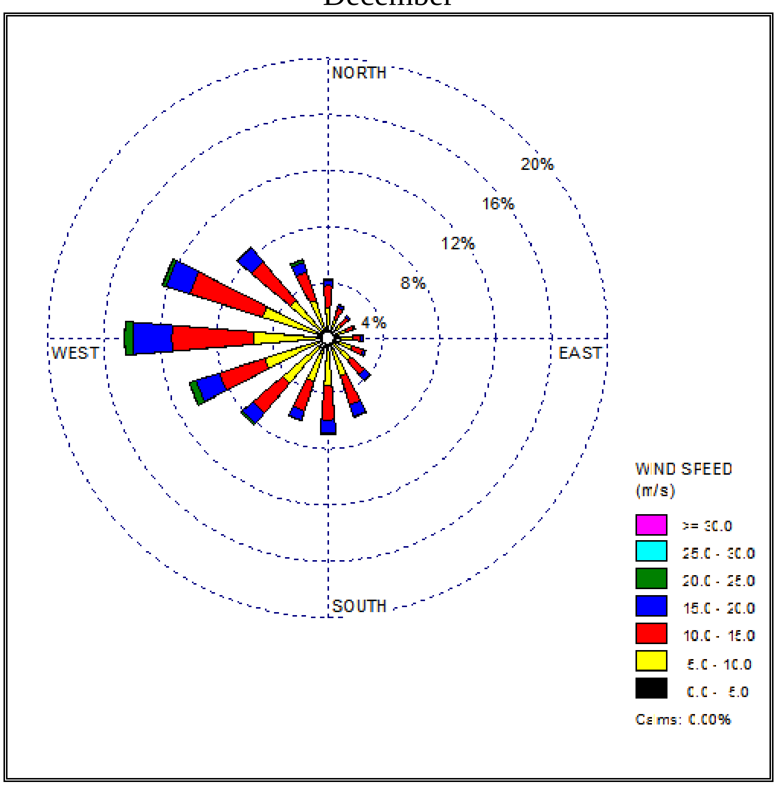
October



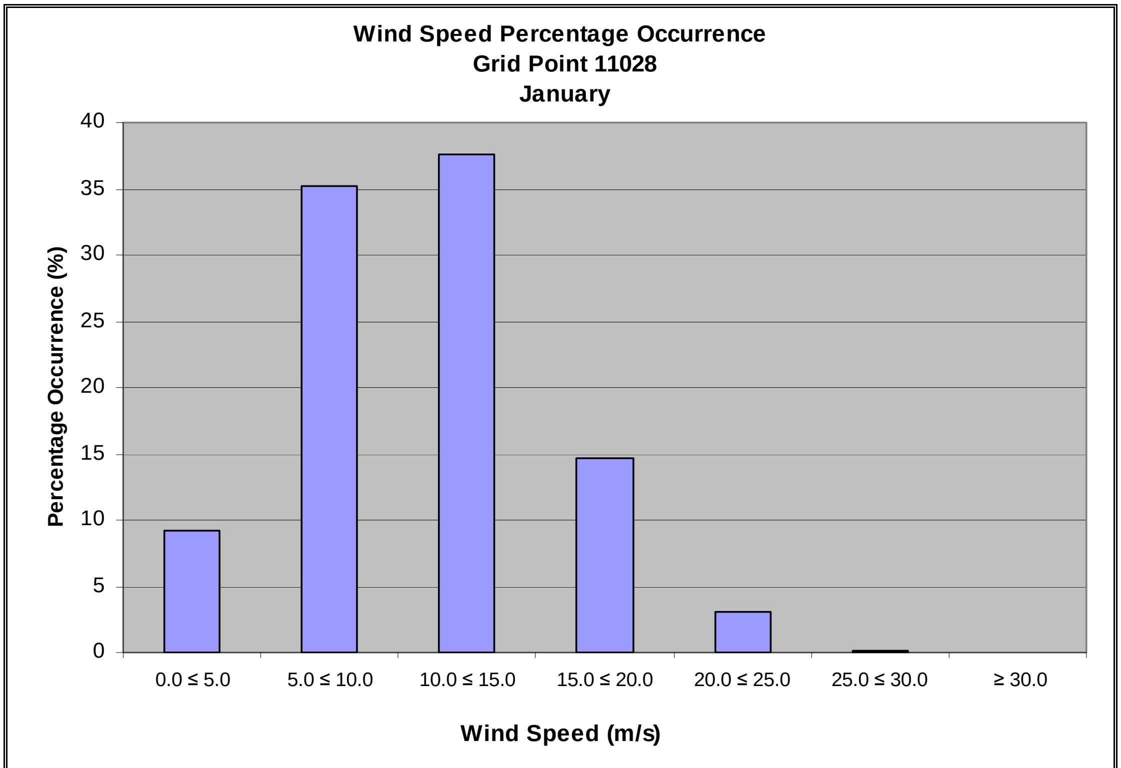
November

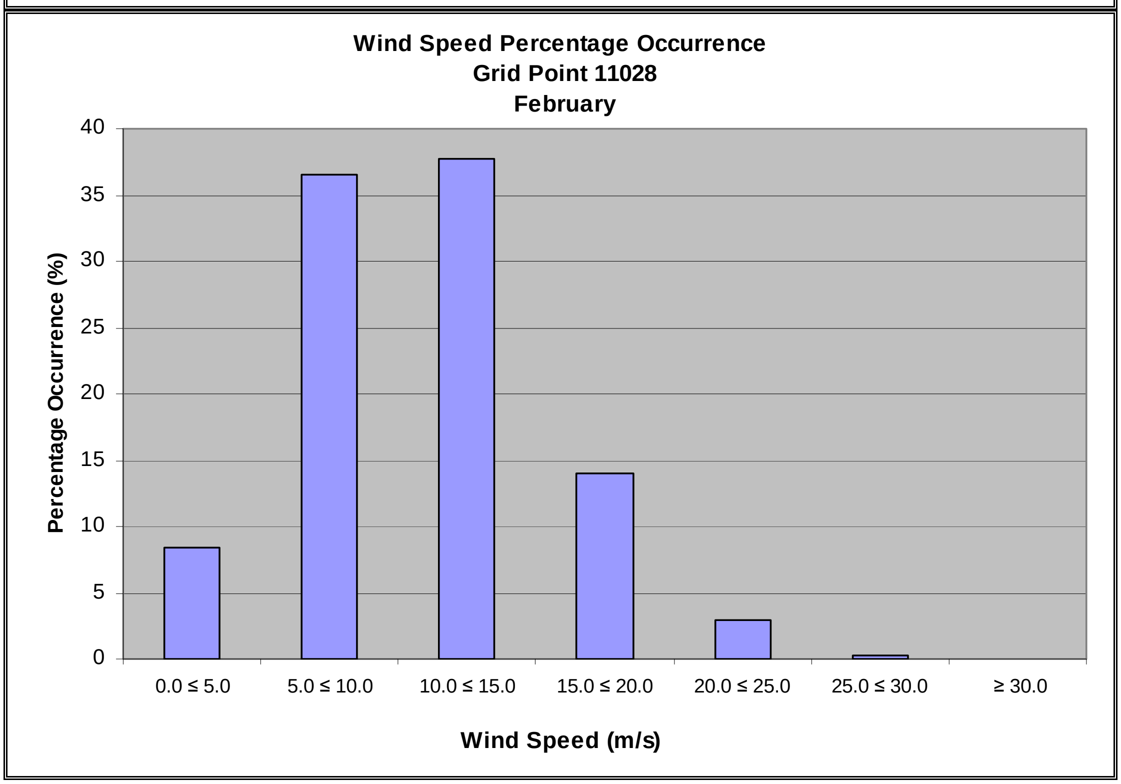


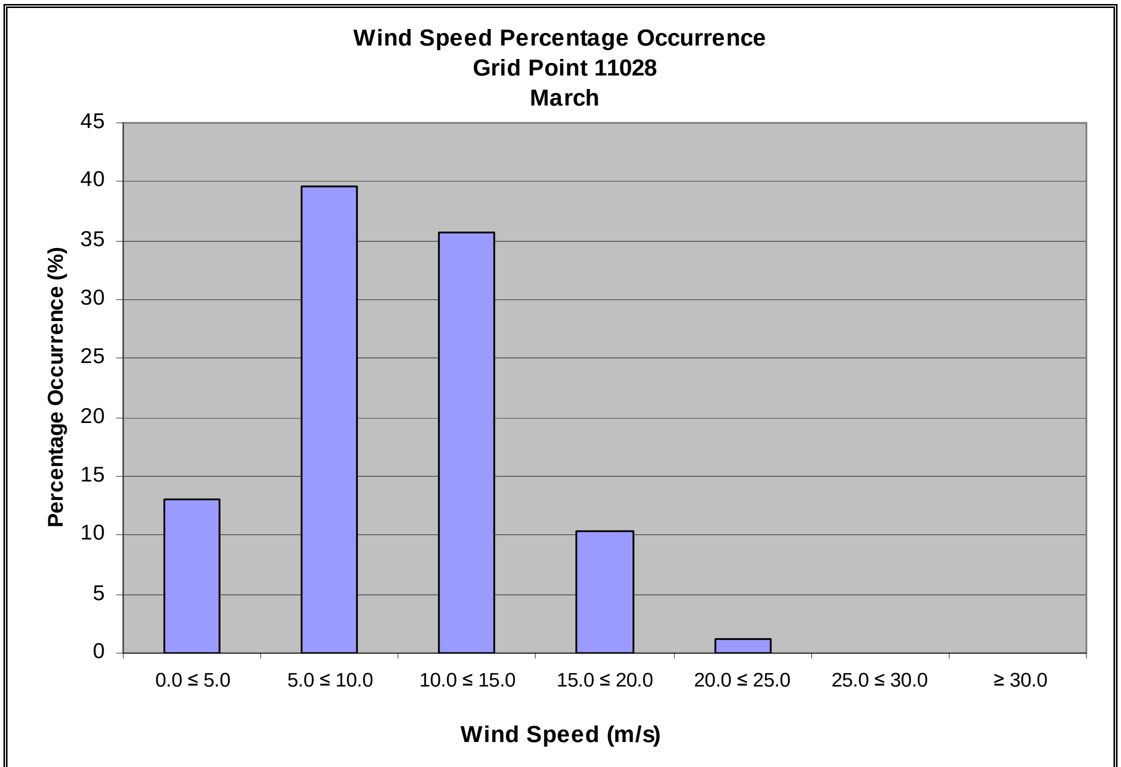
December

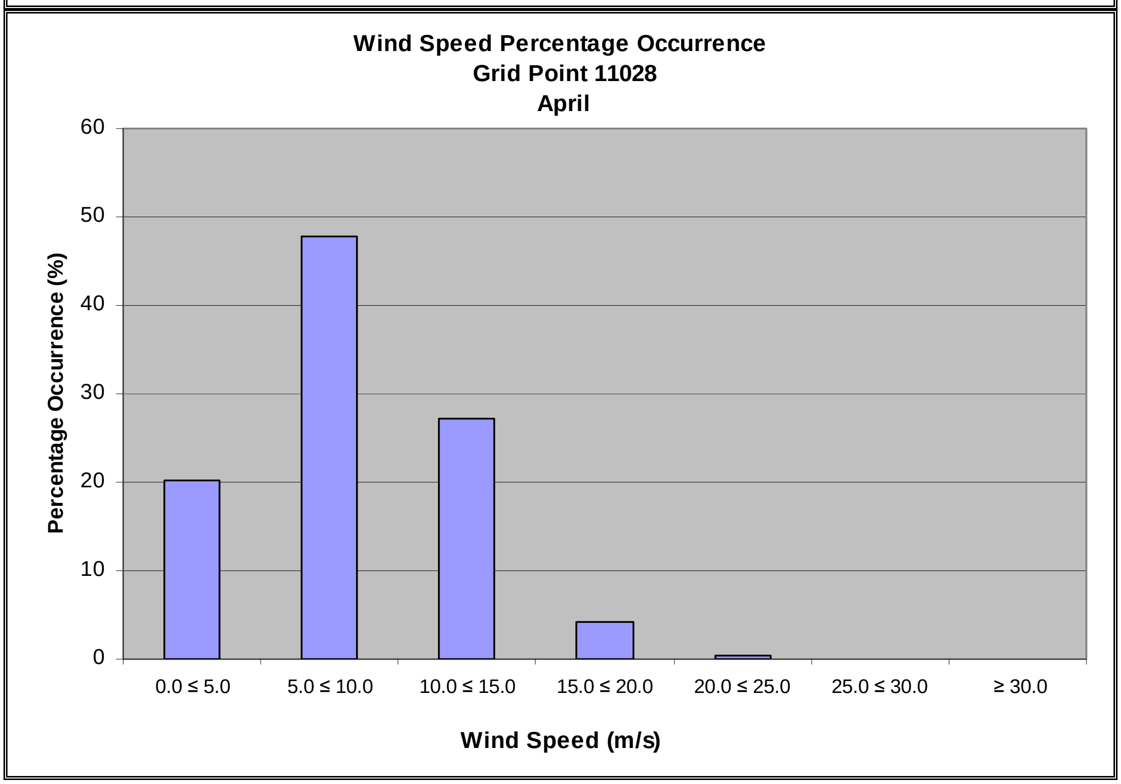


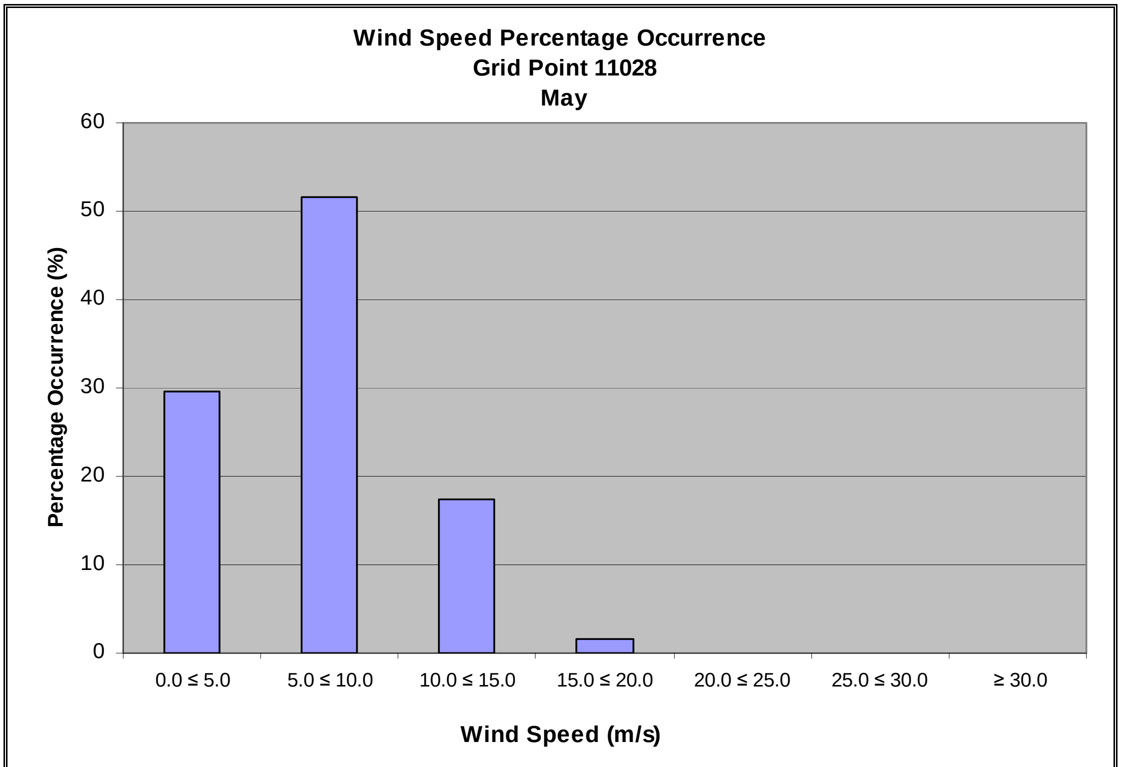
Appendix 2
Wind Speed Frequency Distributions
for MSC50 GridPoint 11028

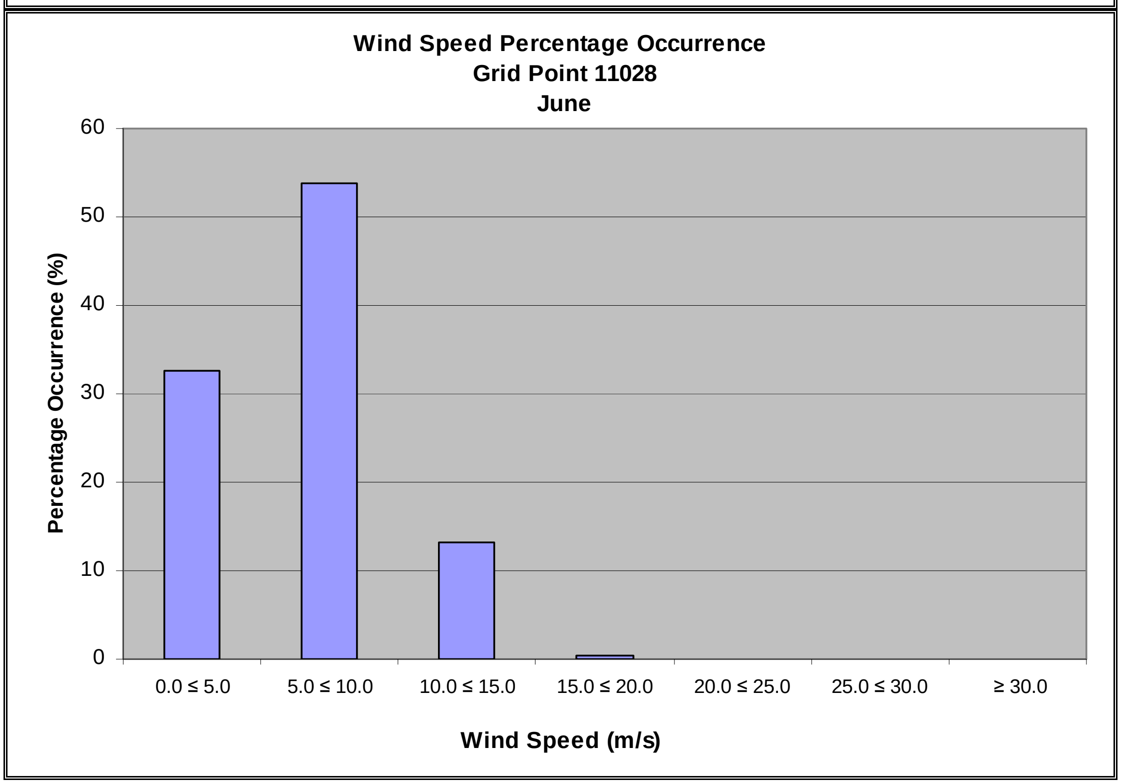

Wind Speed Percentage Occurrence
Grid Point 11028
January
40
35
30
25
20
15
10
5
0
Percentage Occurrence (%)
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)

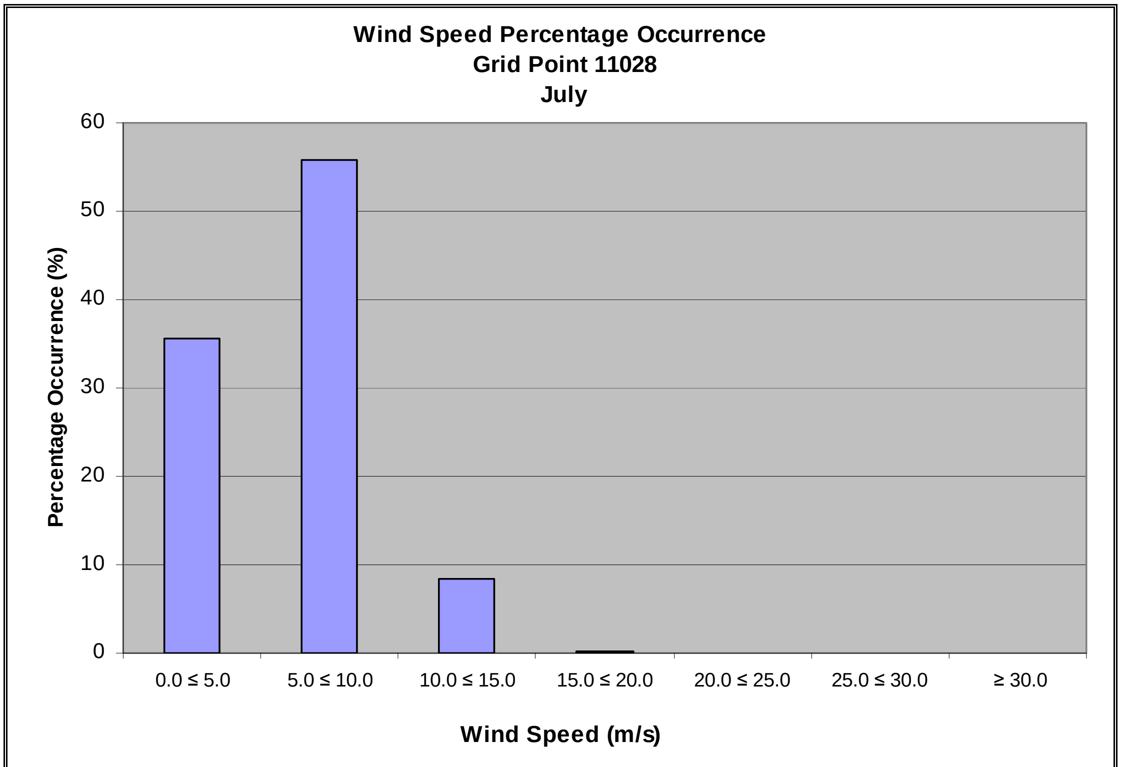

Wind Speed Percentage Occurrence
Grid Point 11028
February
40
35
30
25
20
15
10
5
0
Percentage Occurrence (%)
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)

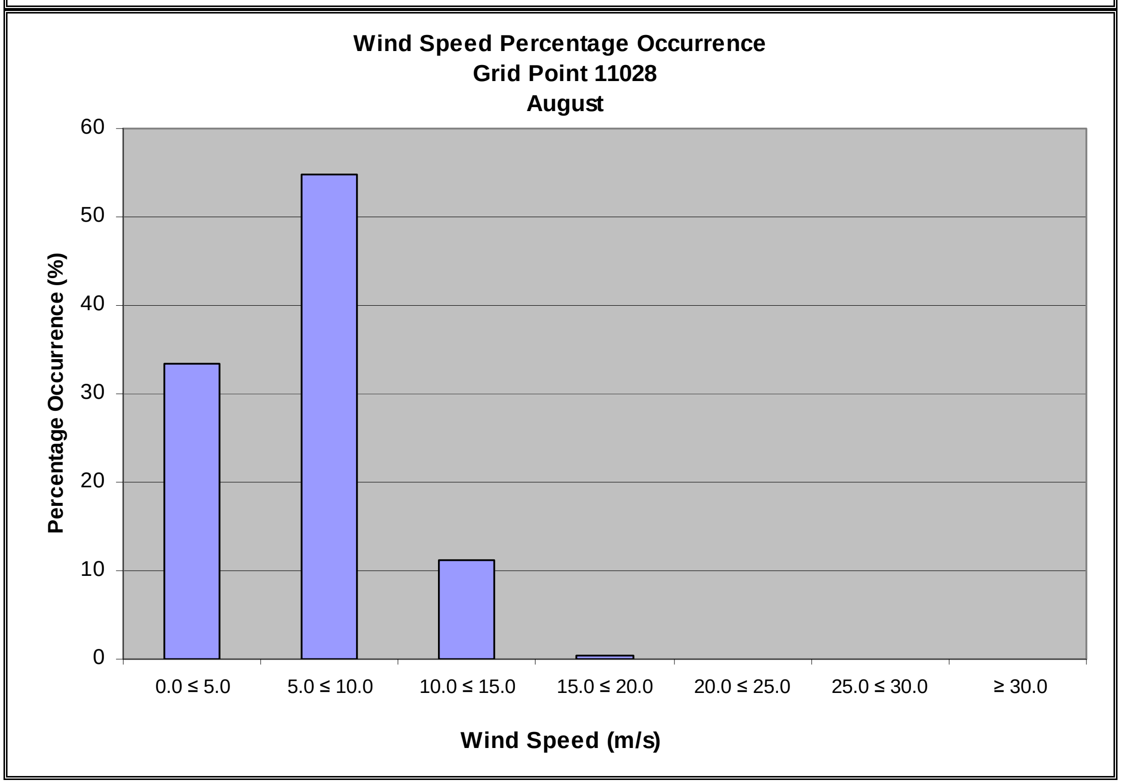

Wind Speed Percentage Occurrence
Grid Point 11028
March
Percentage Occurrence (%)
45
40
35
30
25
20
15
10
5
0
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)

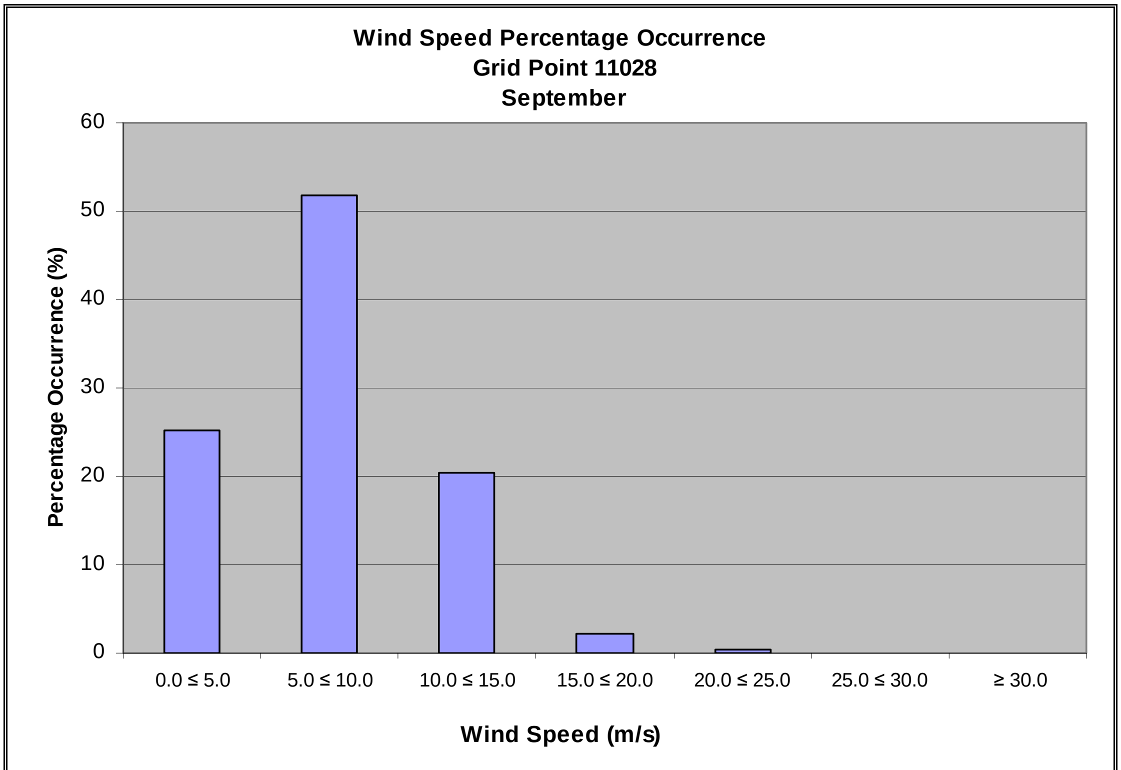

Wind Speed Percentage Occurrence
Grid Point 11028
April
Percentage Occurrence (%)
60
50
40
30
20
10
0
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)

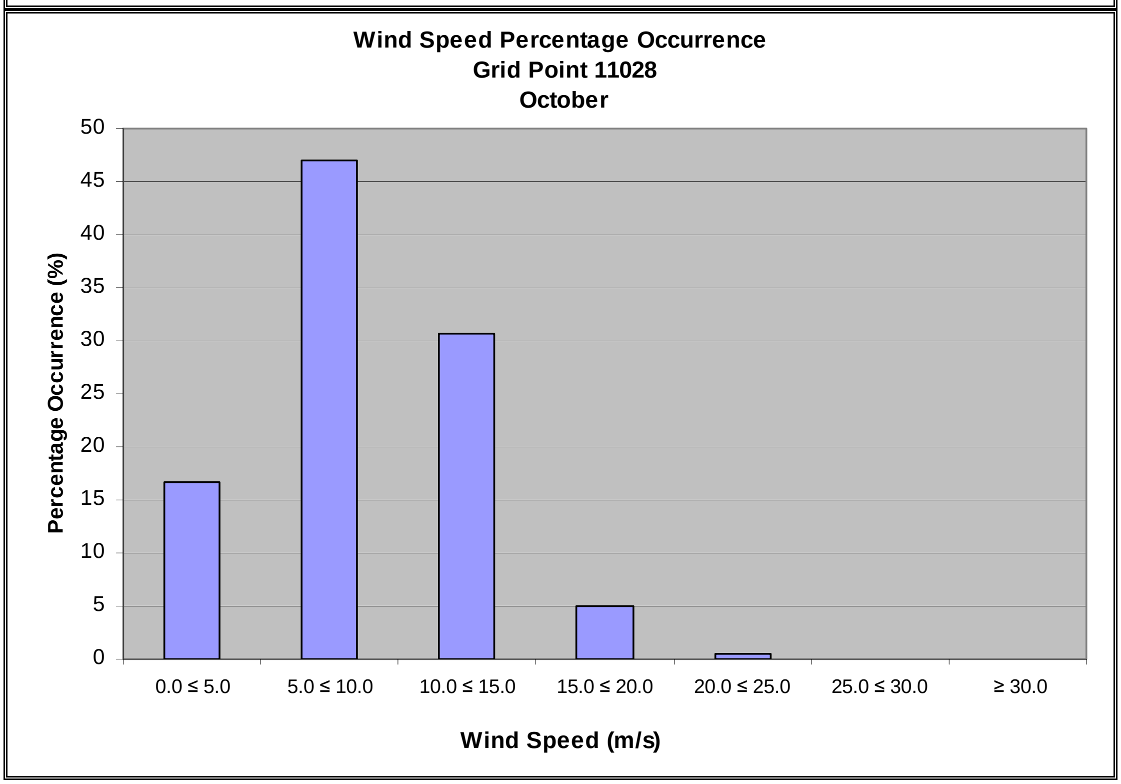

Wind Speed Percentage Occurrence
Grid Point 11028
May
Percentage Occurrence (%)
60
50
40
30
20
10
0
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)

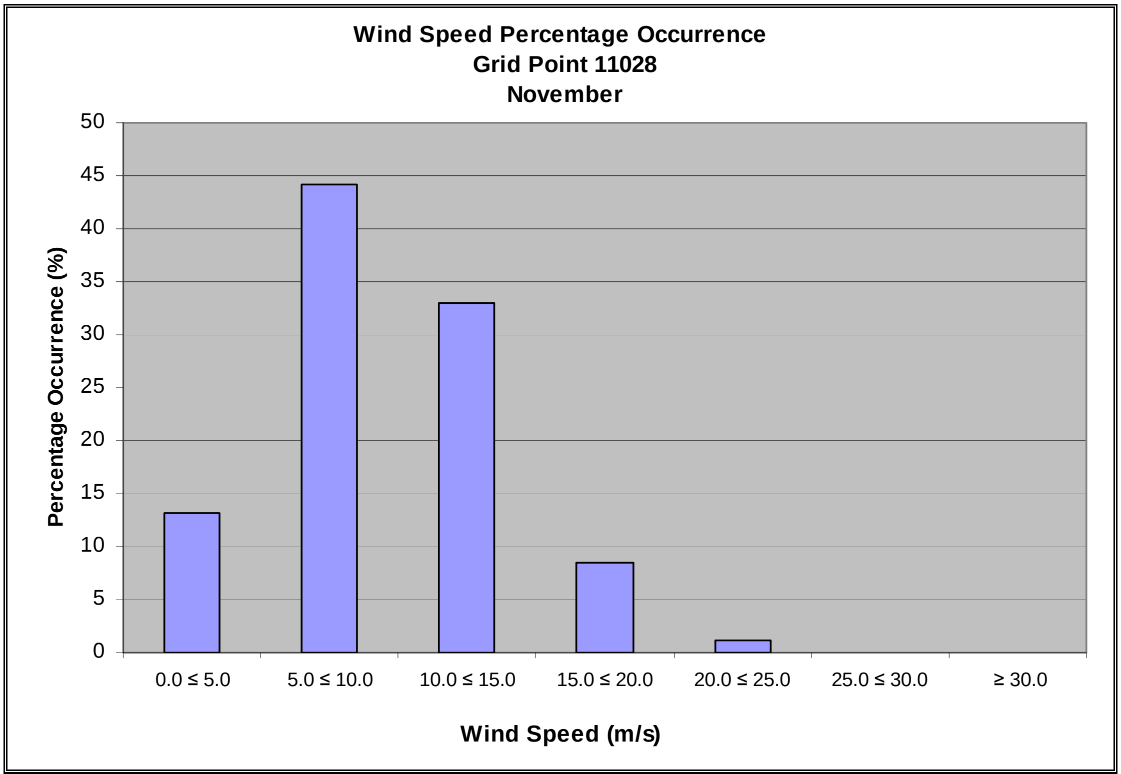

Wind Speed Percentage Occurrence
Grid Point 11028
June
Percentage Occurrence (%)
60
50
40
30
20
10
0
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)

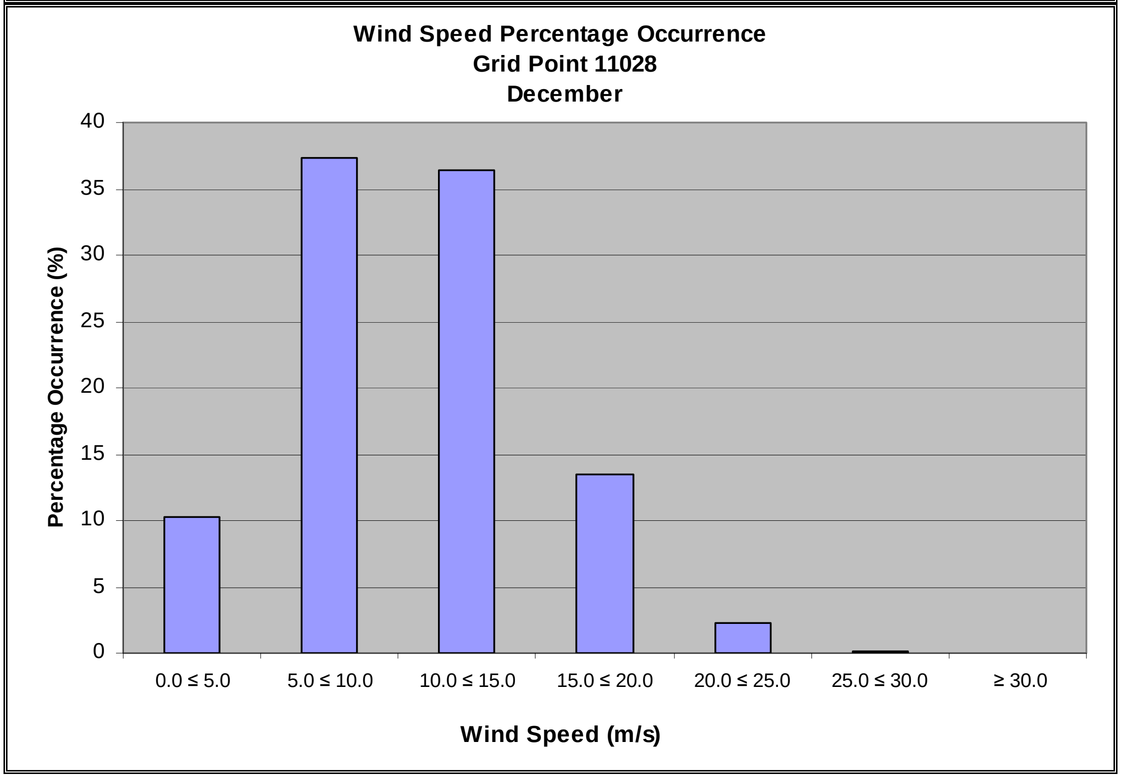

Wind Speed Percentage Occurrence
Grid Point 11028
July
Percentage Occurrence (%)
60
50
40
30
20
10
0
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)


Wind Speed Percentage Occurrence
Grid Point 11028
August
Percentage Occurrence (%)
60
50
40
30
20
10
0
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)


Wind Speed Percentage Occurrence
Grid Point 11028
September
60
50
40
30
20
10
0
Percentage Occurrence (%)
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)

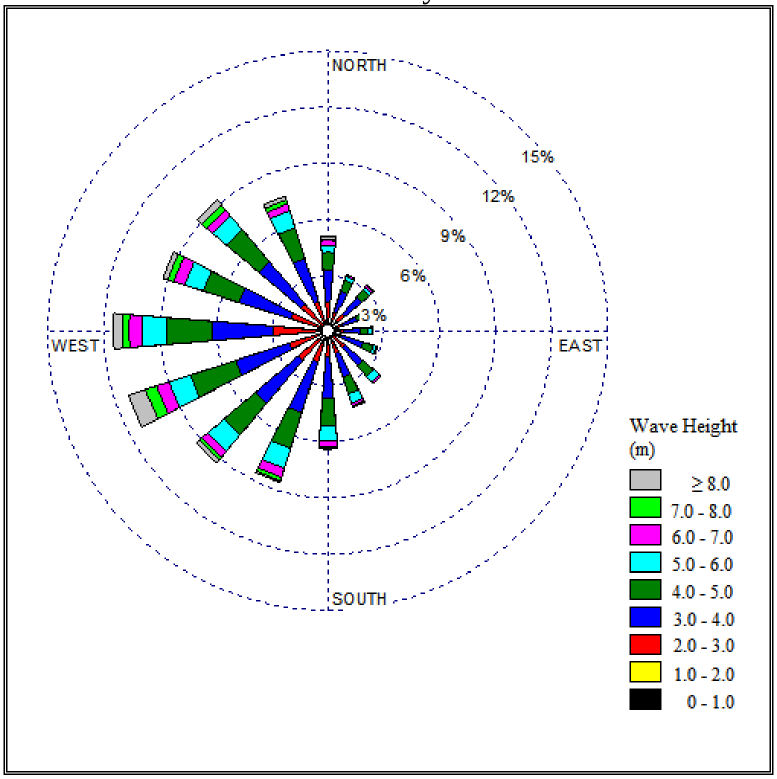

Wind Speed Percentage Occurrence
Grid Point 11028
October
50
45
40
35
30
25
20
15
10
5
0
Percentage Occurrence (%)
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)


Wind Speed Percentage Occurrence
Grid Point 11028
November
Percentage Occurrence (%)
50
45
40
35
30
25
20
15
10
5
0
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)

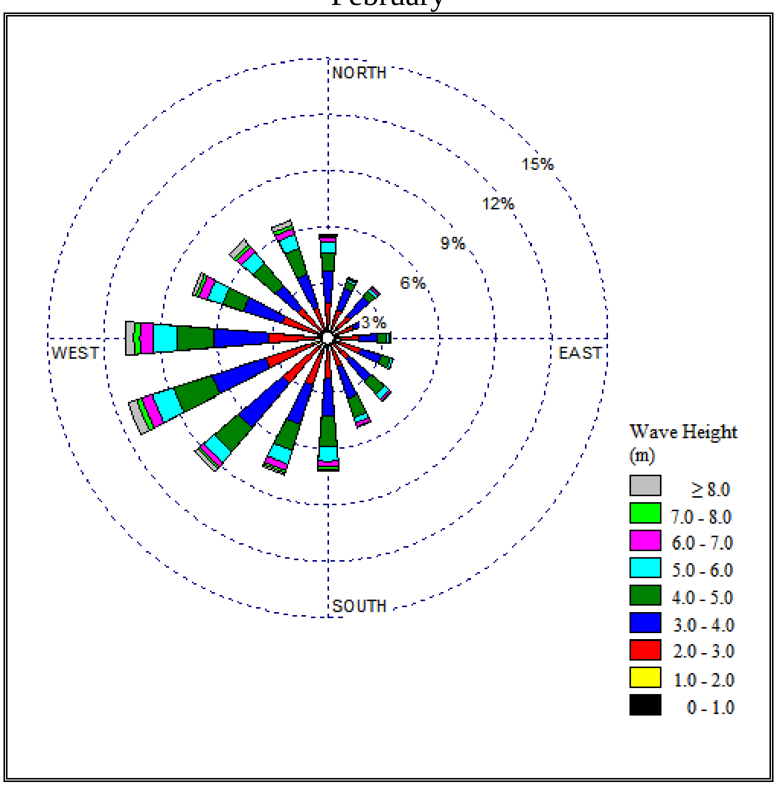

Wind Speed Percentage Occurrence
Grid Point 11028
December
Percentage Occurrence (%)
40
35
30
25
20
15
10
5
0
0.0 ≤ 5.0
5.0 ≤ 10.0
10.0 ≤ 15.0
15.0 ≤ 20.0
20.0 ≤ 25.0
25.0 ≤ 30.0
≥ 30.0
Wind Speed (m/s)

Appendix 3
Wave Roses
for MSC50 GridPoint 11028

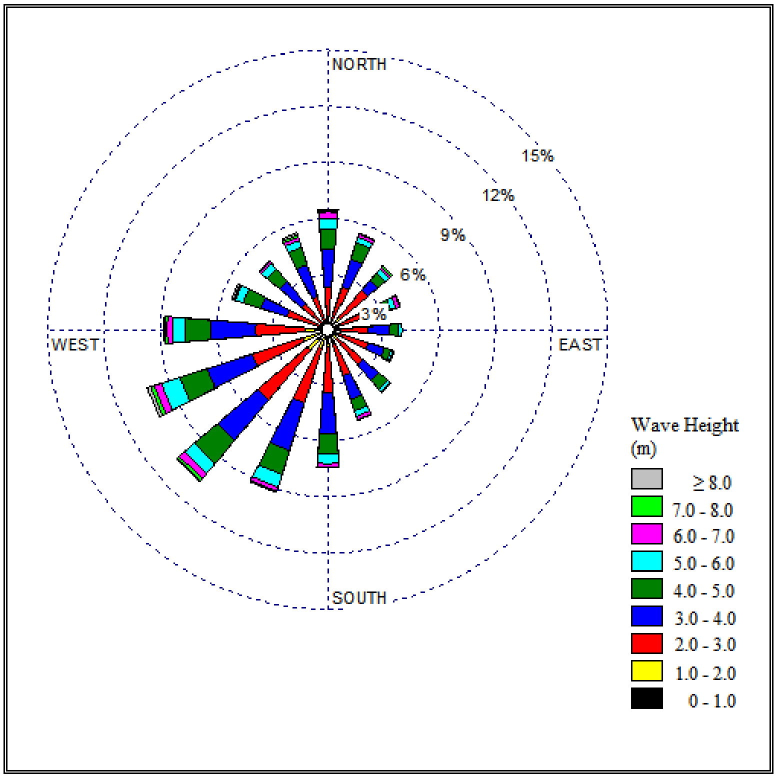
January



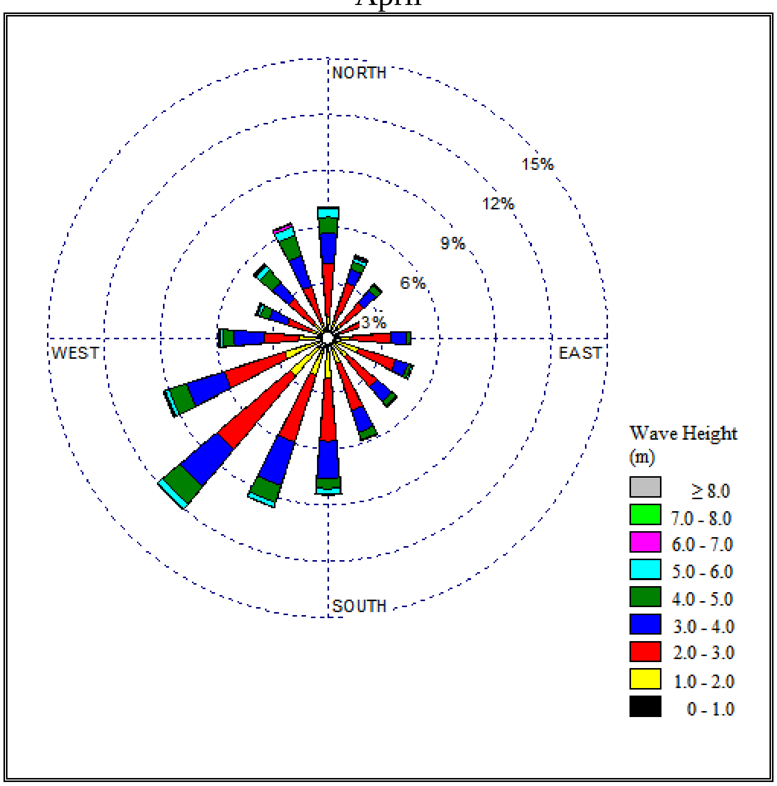
February



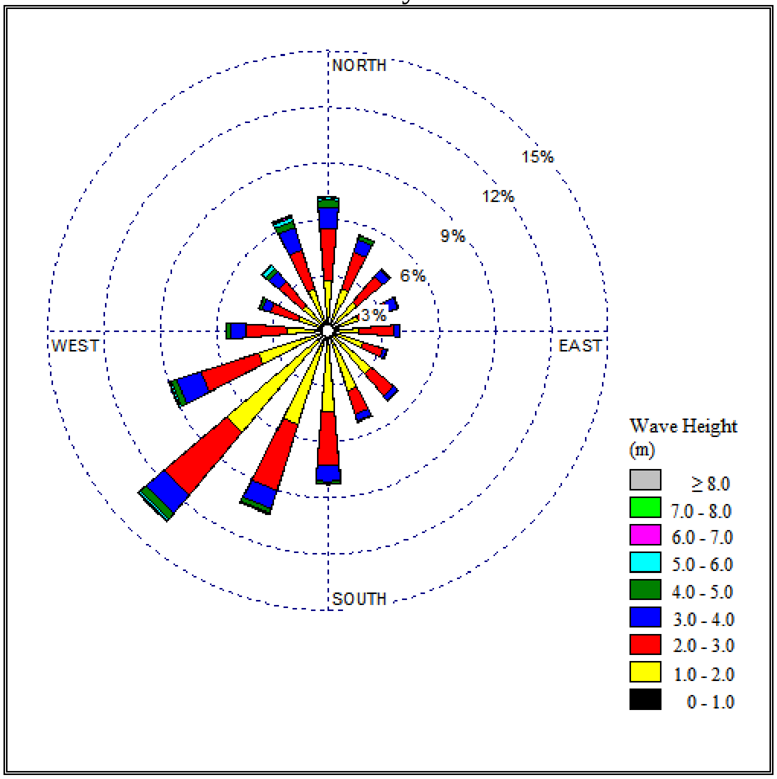
March


NORTH
SOUTH
WEST
EAST
3%
6%
9%
12%
15%
Wave Height
(m)
≥ 8.0
7.0 - 8.0
6.0 - 7.0
5.0 - 6.0
4.0 - 5.0
3.0 - 4.0
2.0 - 3.0
1.0 - 2.0
0 - 1.0

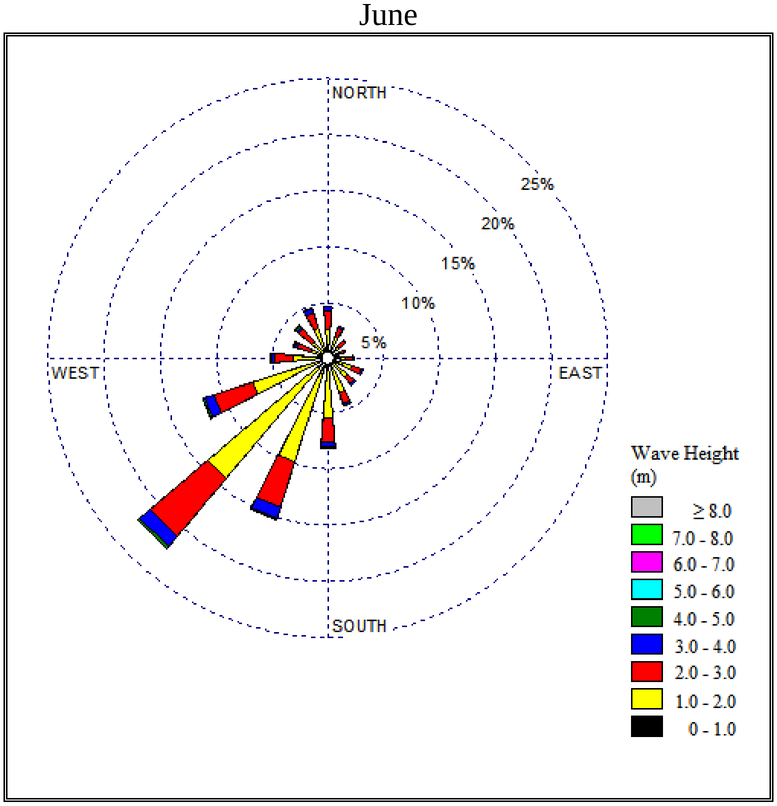
April


NORTH
SOUTH
WEST
EAST
3%
6%
9%
12%
15%
Wave Height
(m)
≥ 8.0
7.0 - 8.0
6.0 - 7.0
5.0 - 6.0
4.0 - 5.0
3.0 - 4.0
2.0 - 3.0
1.0 - 2.0
0 - 1.0

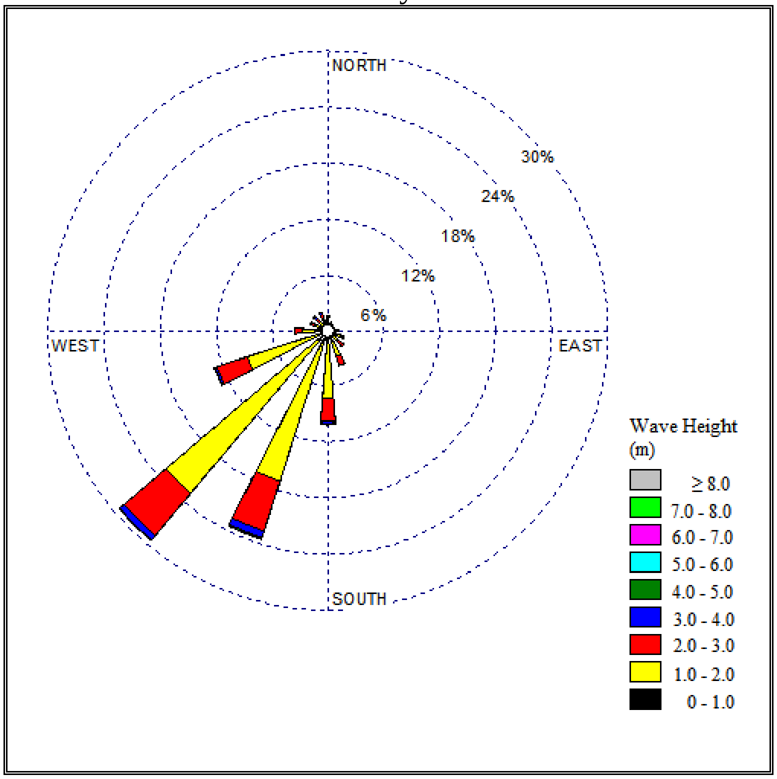
May


NORTH
SOUTH
WEST
EAST
3%
6%
9%
12%
15%
Wave Height
(m)
≥ 8.0
7.0 - 8.0
6.0 - 7.0
5.0 - 6.0
4.0 - 5.0
3.0 - 4.0
2.0 - 3.0
1.0 - 2.0
0 - 1.0

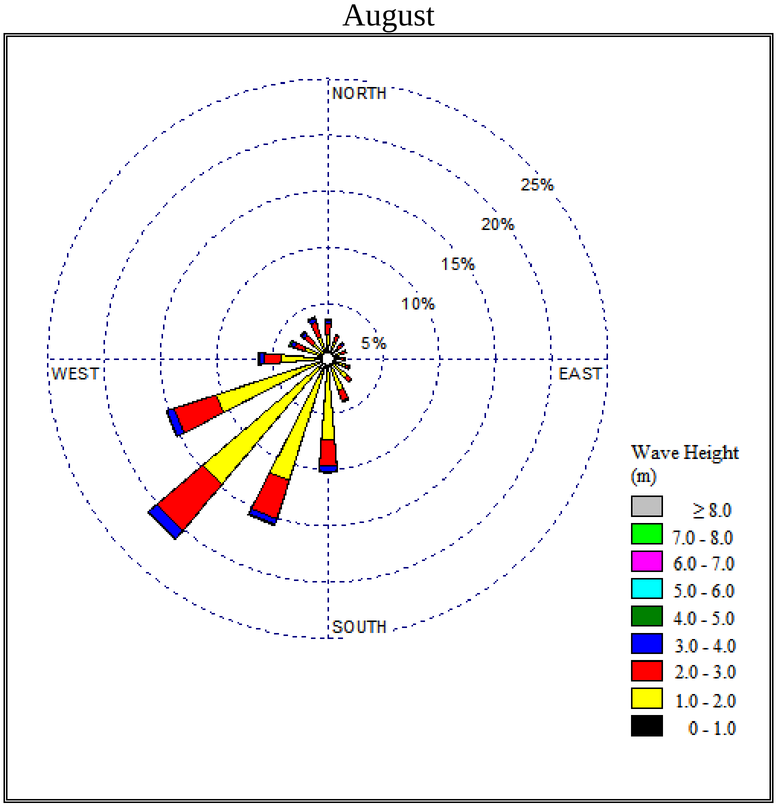
June


NORTH
SOUTH
WEST
EAST
5%
10%
15%
20%
25%
Wave Height
(m)
≥ 8.0
7.0 - 8.0
6.0 - 7.0
5.0 - 6.0
4.0 - 5.0
3.0 - 4.0
2.0 - 3.0
1.0 - 2.0
0 - 1.0

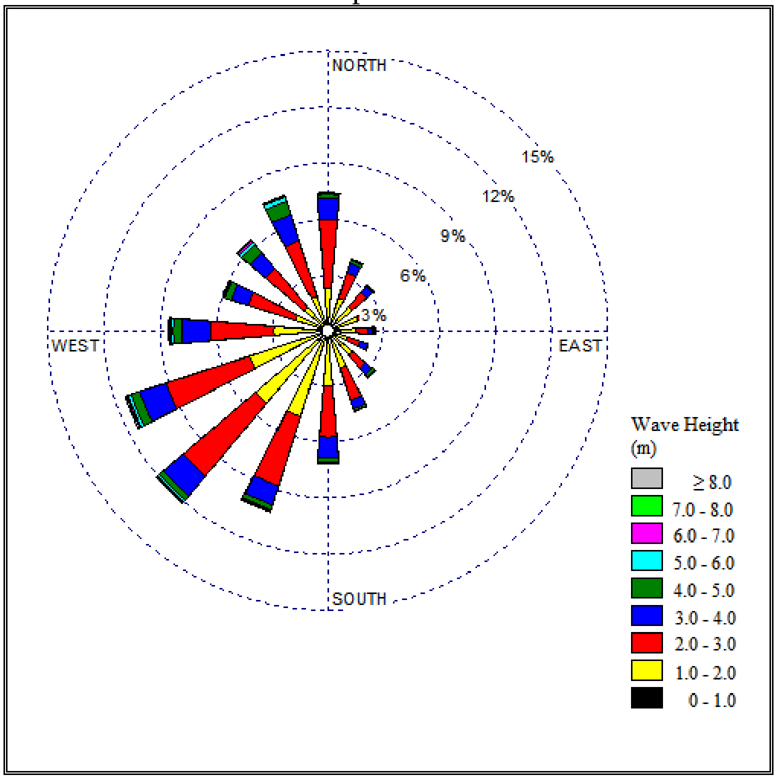
July


NORTH
SOUTH
EAST
WEST
6%
12%
18%
24%
30%
Wave Height (m)
≥ 8.0
7.0 - 8.0
6.0 - 7.0
5.0 - 6.0
4.0 - 5.0
3.0 - 4.0
2.0 - 3.0
1.0 - 2.0
0 - 1.0

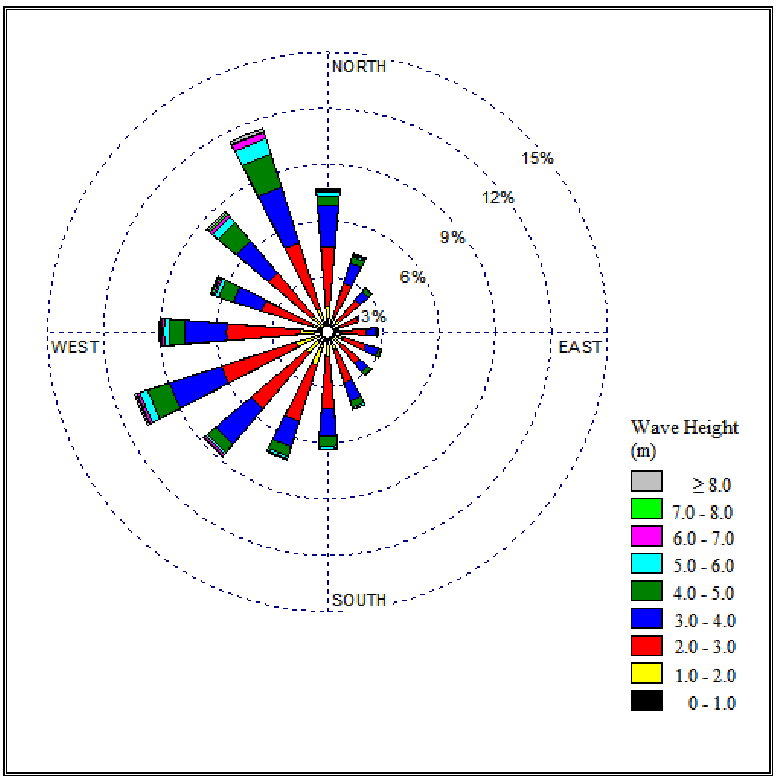
August


NORTH
SOUTH
EAST
WEST
5%
10%
15%
20%
25%
Wave Height (m)
≥ 8.0
7.0 - 8.0
6.0 - 7.0
5.0 - 6.0
4.0 - 5.0
3.0 - 4.0
2.0 - 3.0
1.0 - 2.0
0 - 1.0

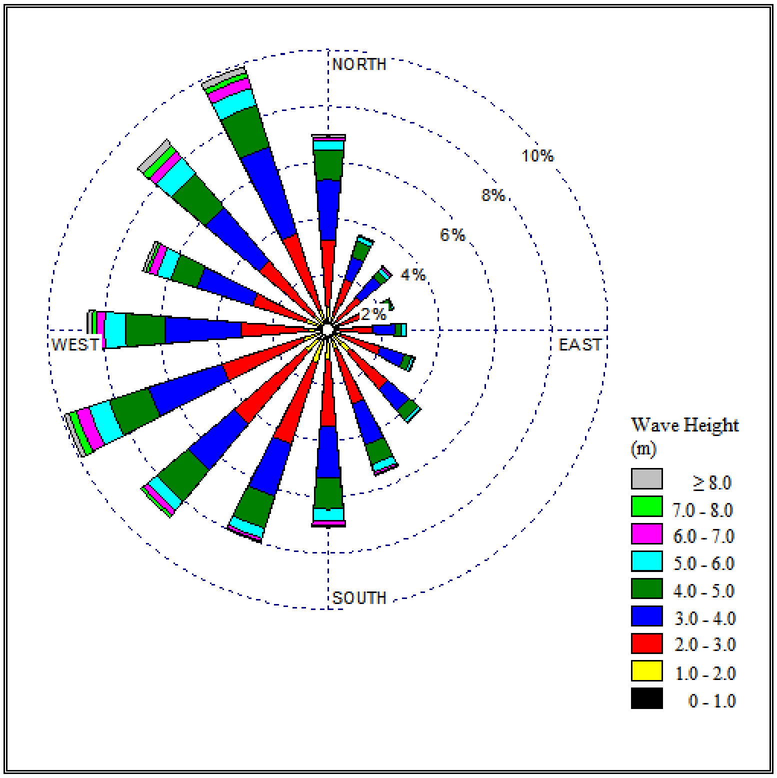
September



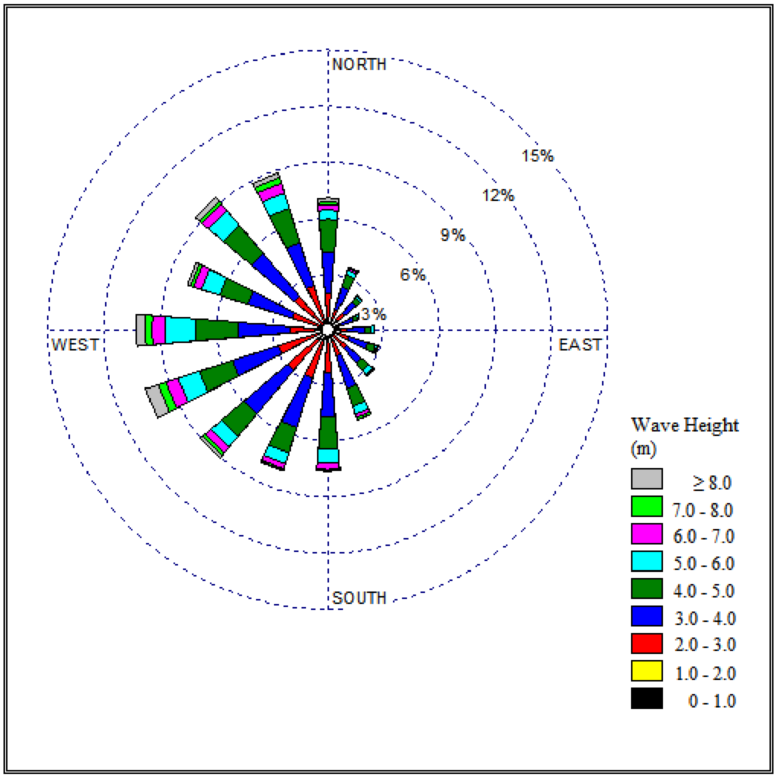
October



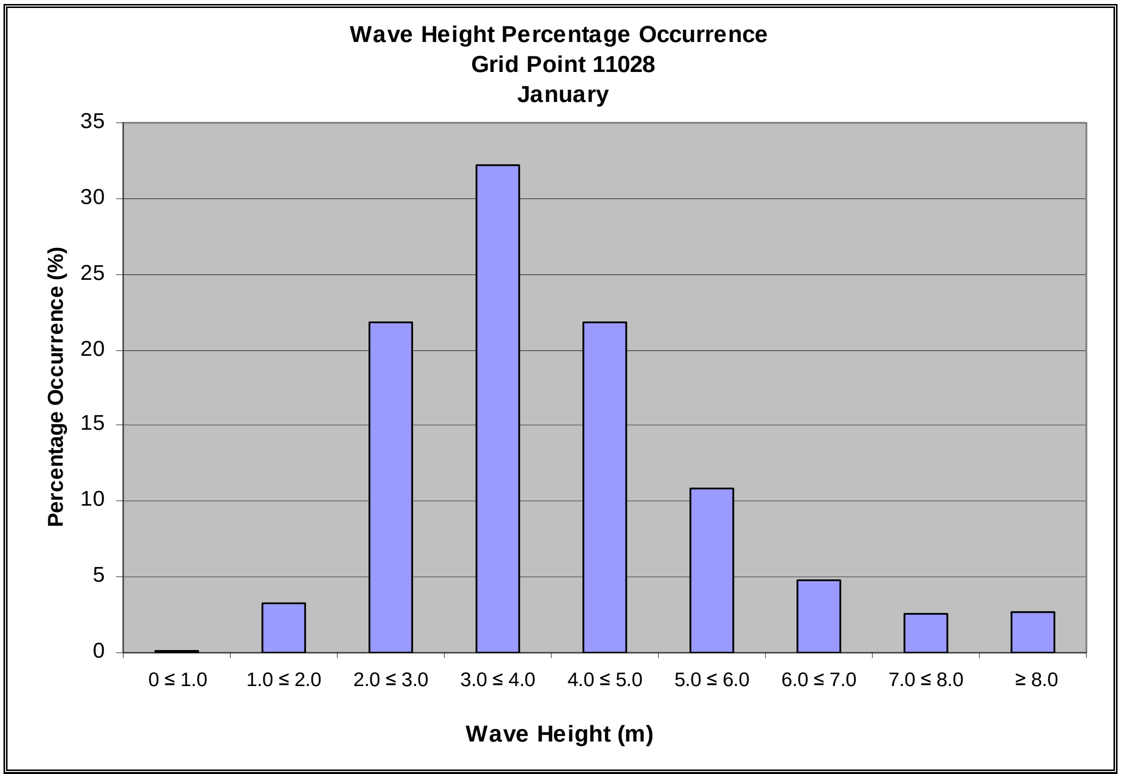
November

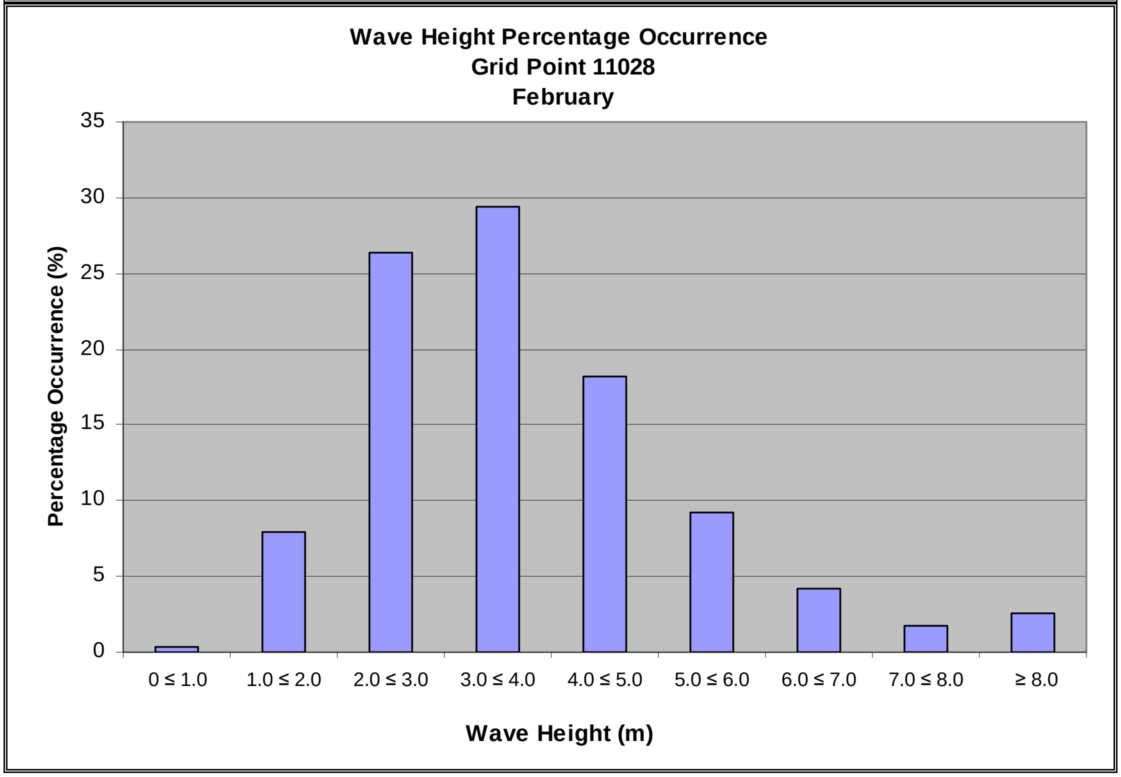


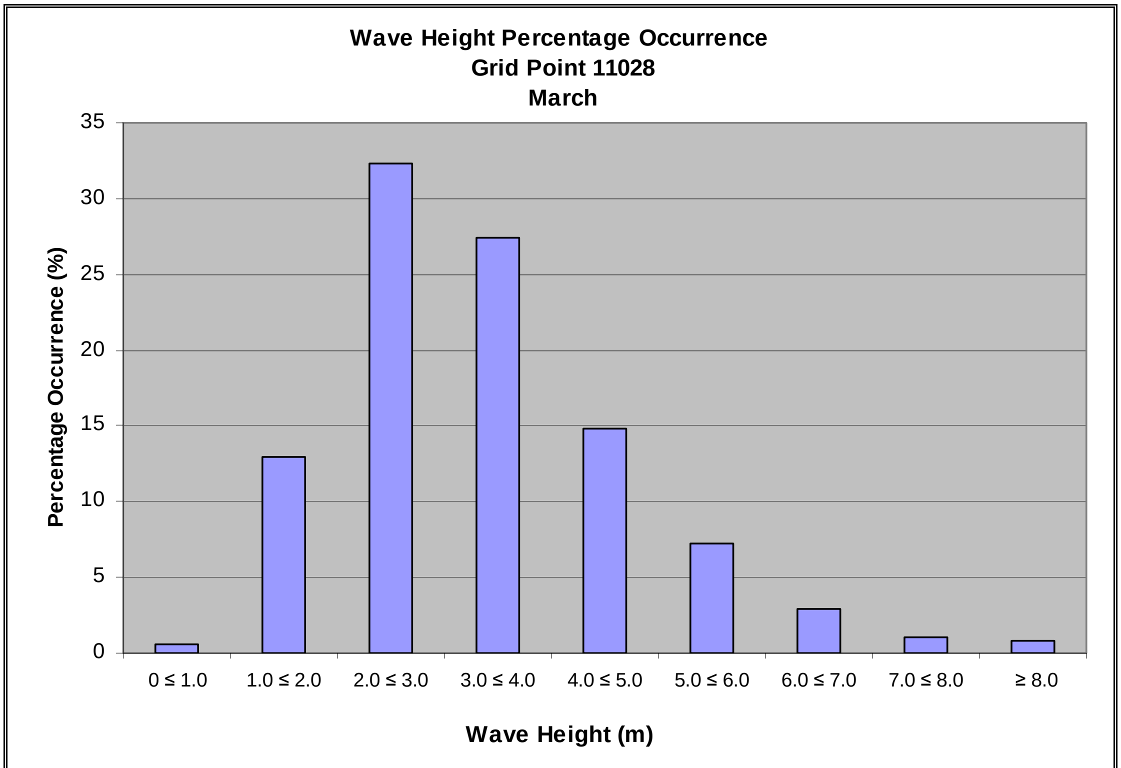
December

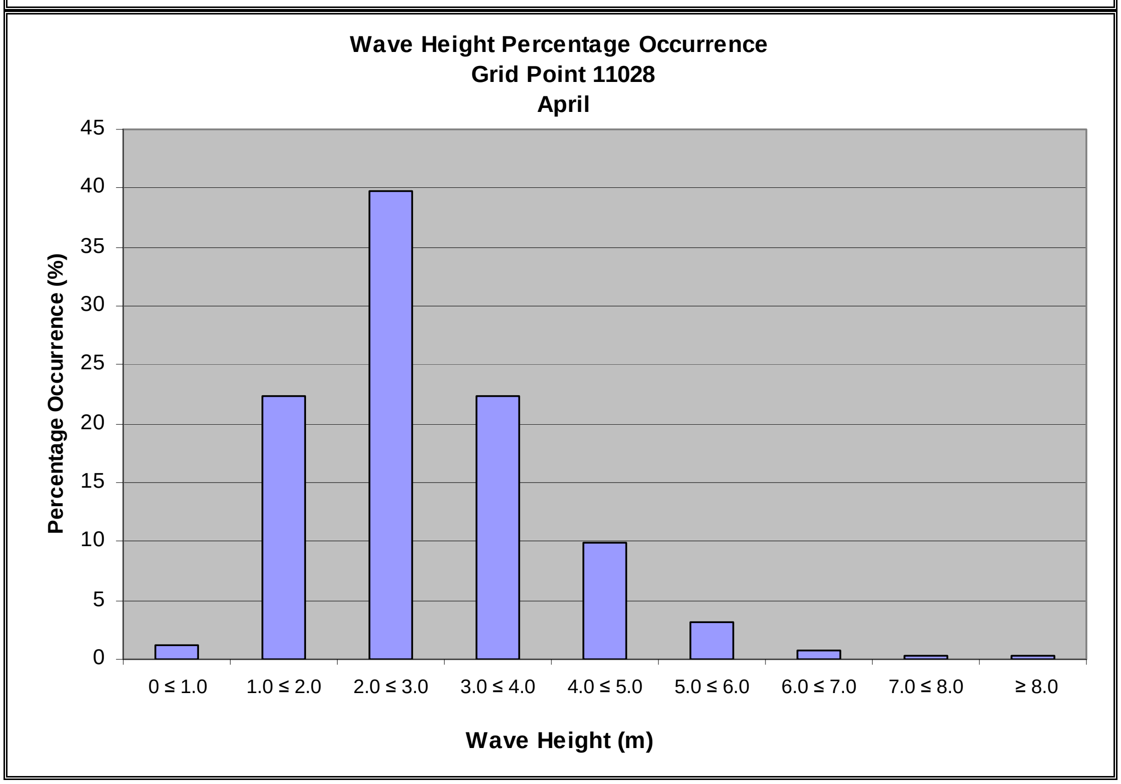


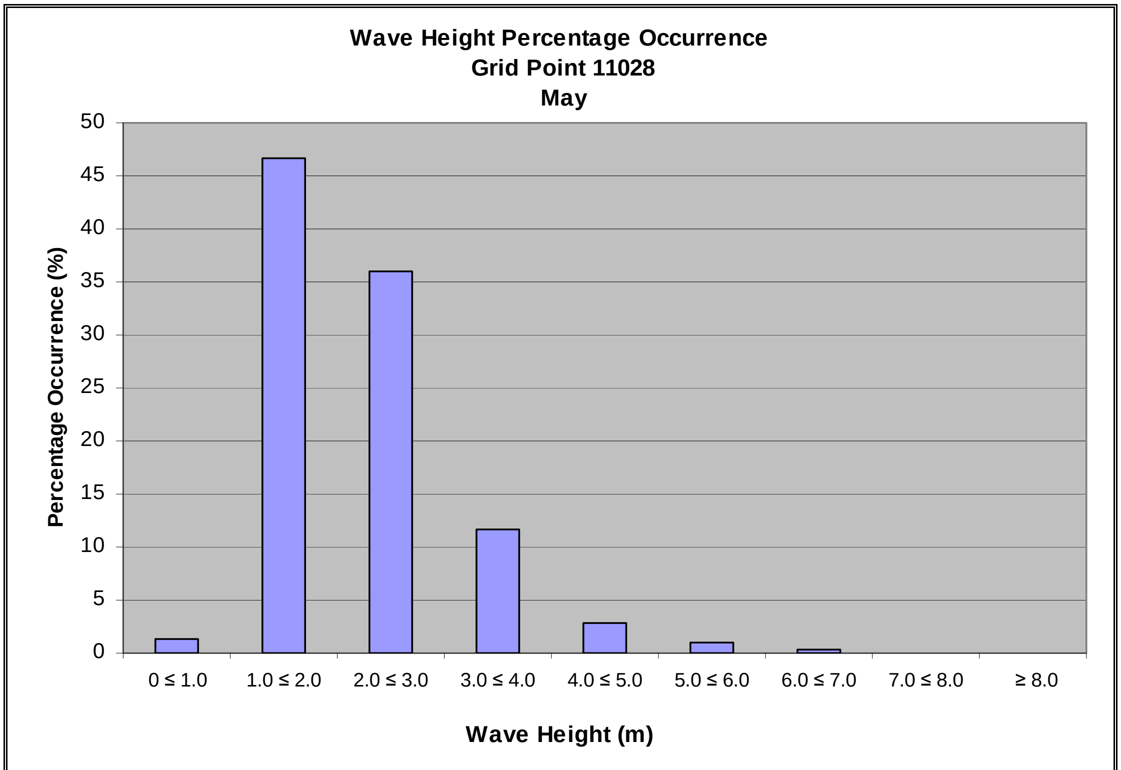
Appendix 4
Wave Height Frequency Distributions
for MSC50 GridPoint 11028


Wave Height Percentage Occurrence
Grid Point 11028
January
Percentage Occurrence (%)
35
30
25
20
15
10
5
0
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)

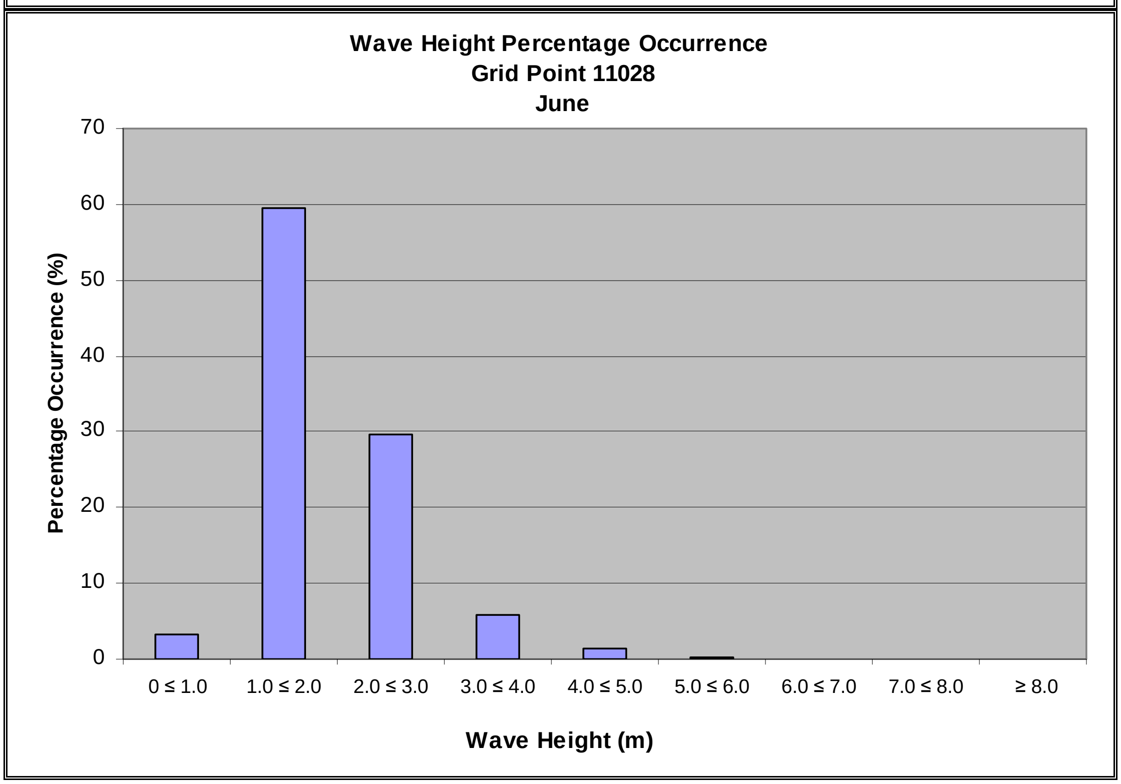

Wave Height Percentage Occurrence
Grid Point 11028
February
Percentage Occurrence (%)
35
30
25
20
15
10
5
0
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)


Wave Height Percentage Occurrence
Grid Point 11028
March
Percentage Occurrence (%)
0
5
10
15
20
25
30
35
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)

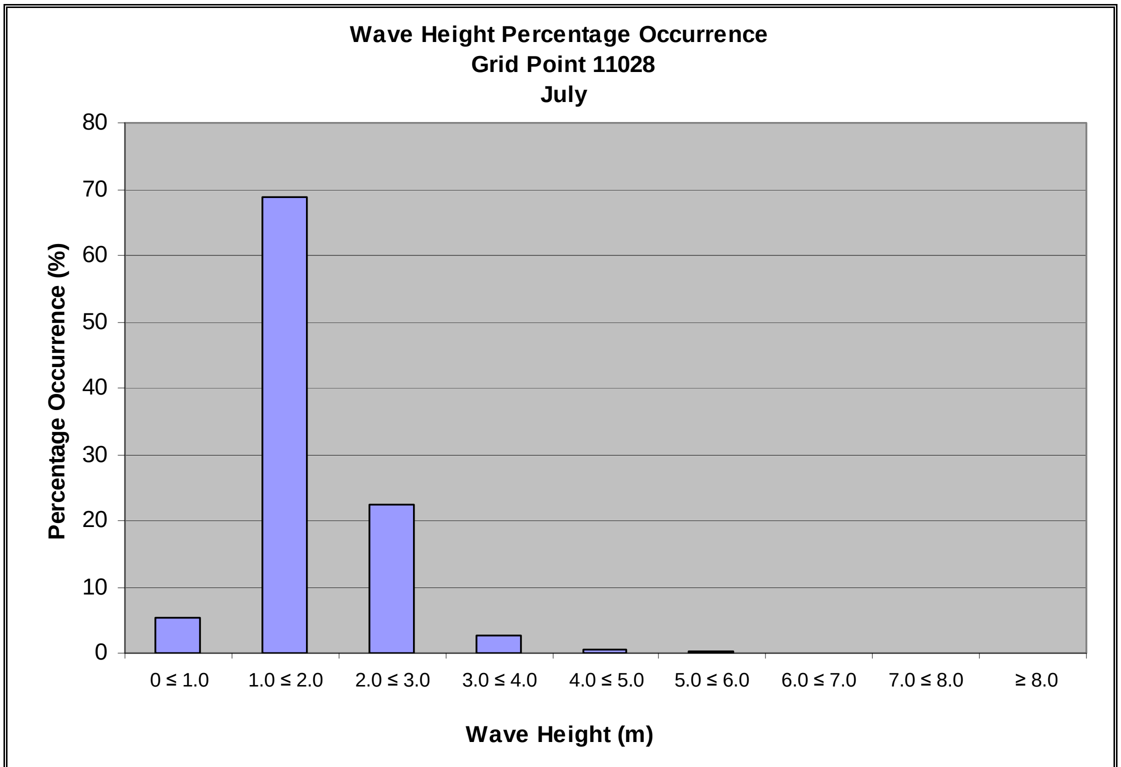

Wave Height Percentage Occurrence
Grid Point 11028
April
Percentage Occurrence (%)
0
5
10
15
20
25
30
35
40
45
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)

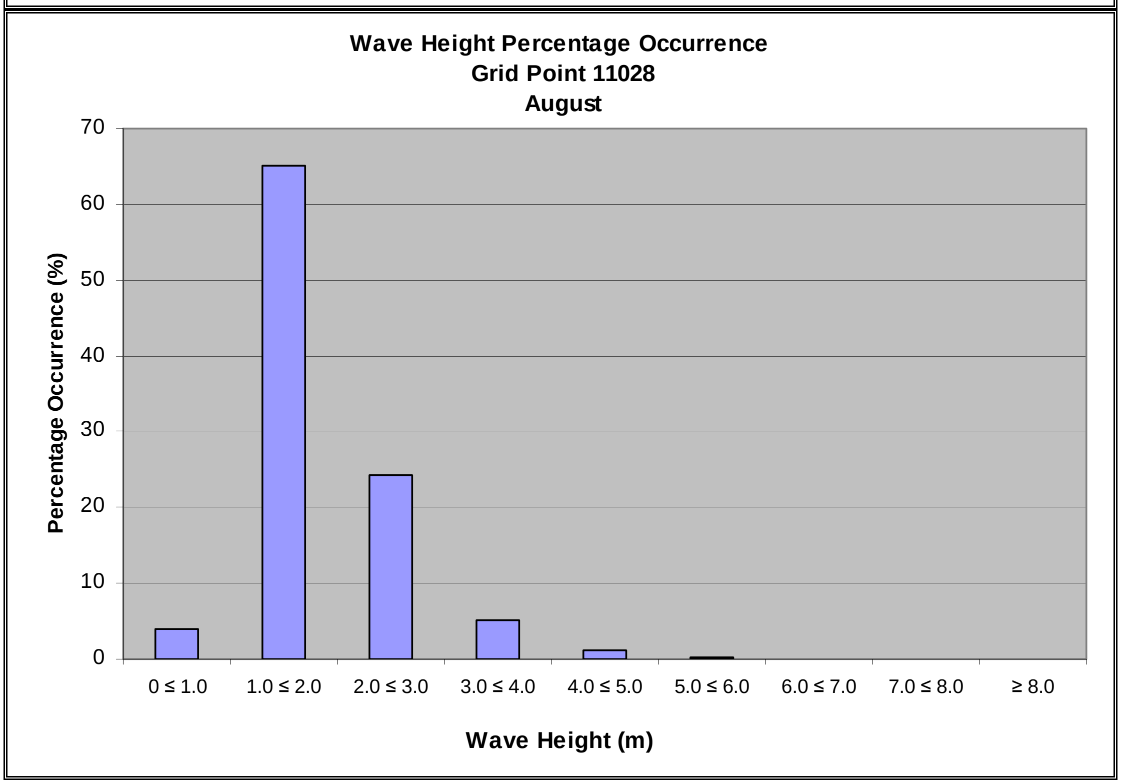


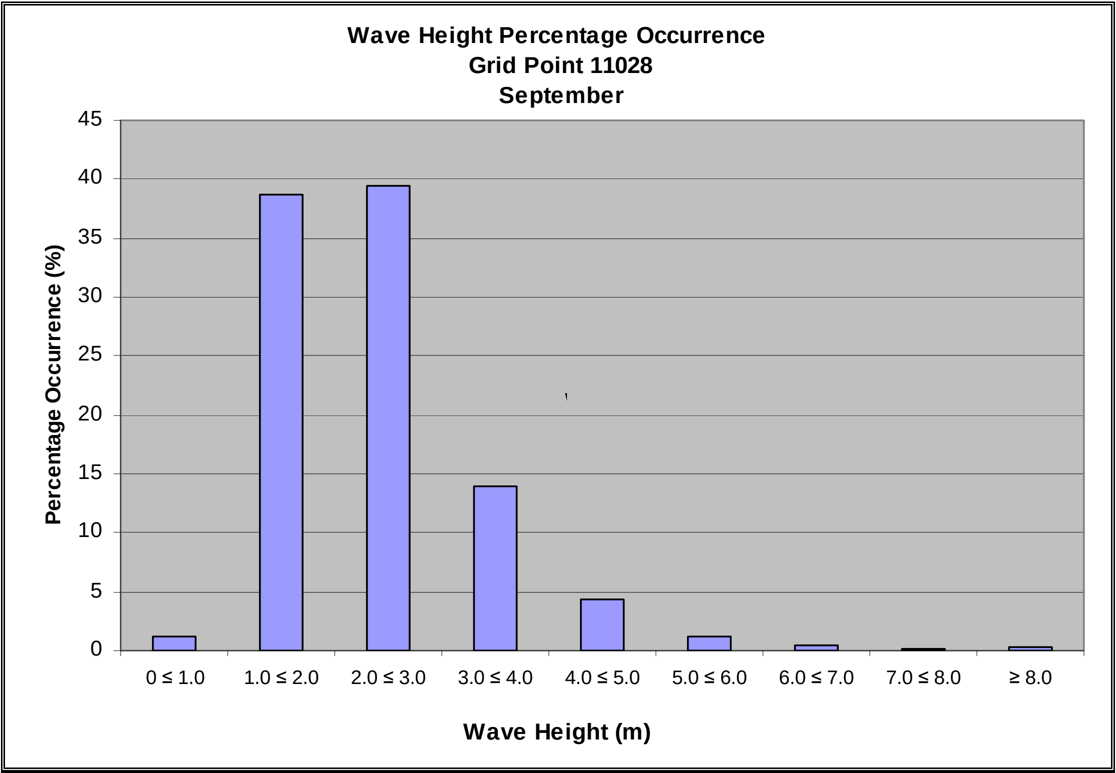
Wave Height Percentage Occurrence
Grid Point 11028
May
Percentage Occurrence (%)
50
45
40
35
30
25
20
15
10
5
0
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)

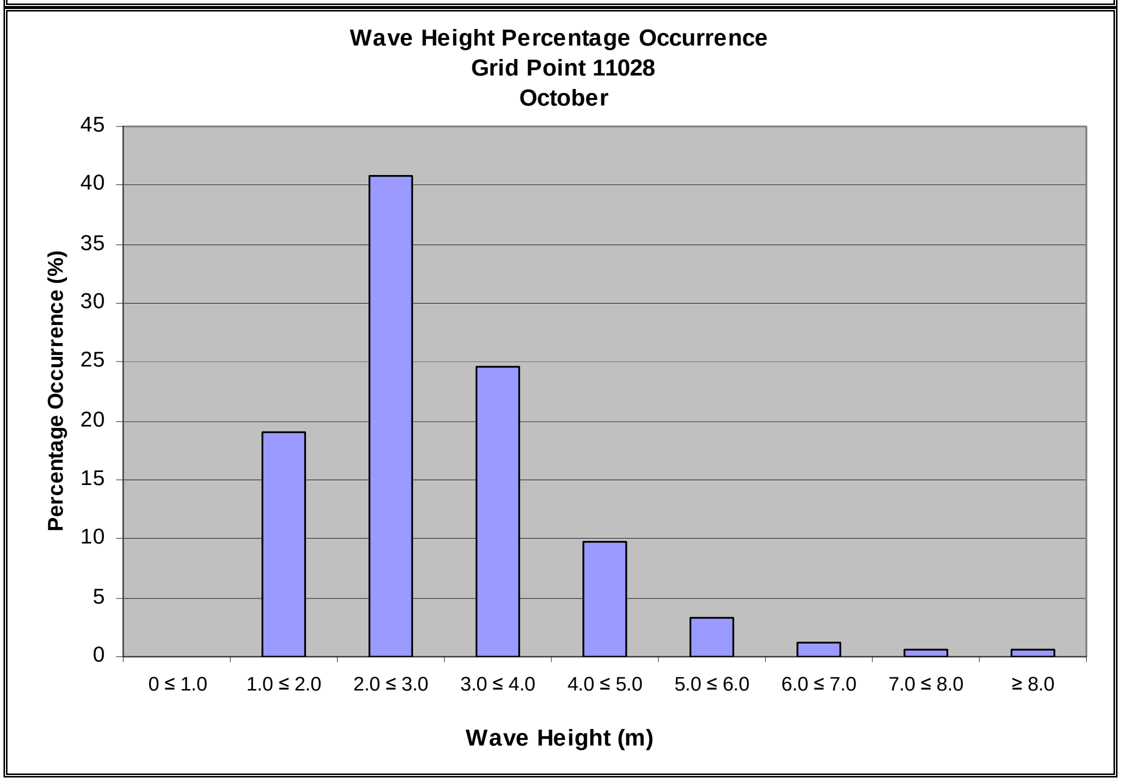


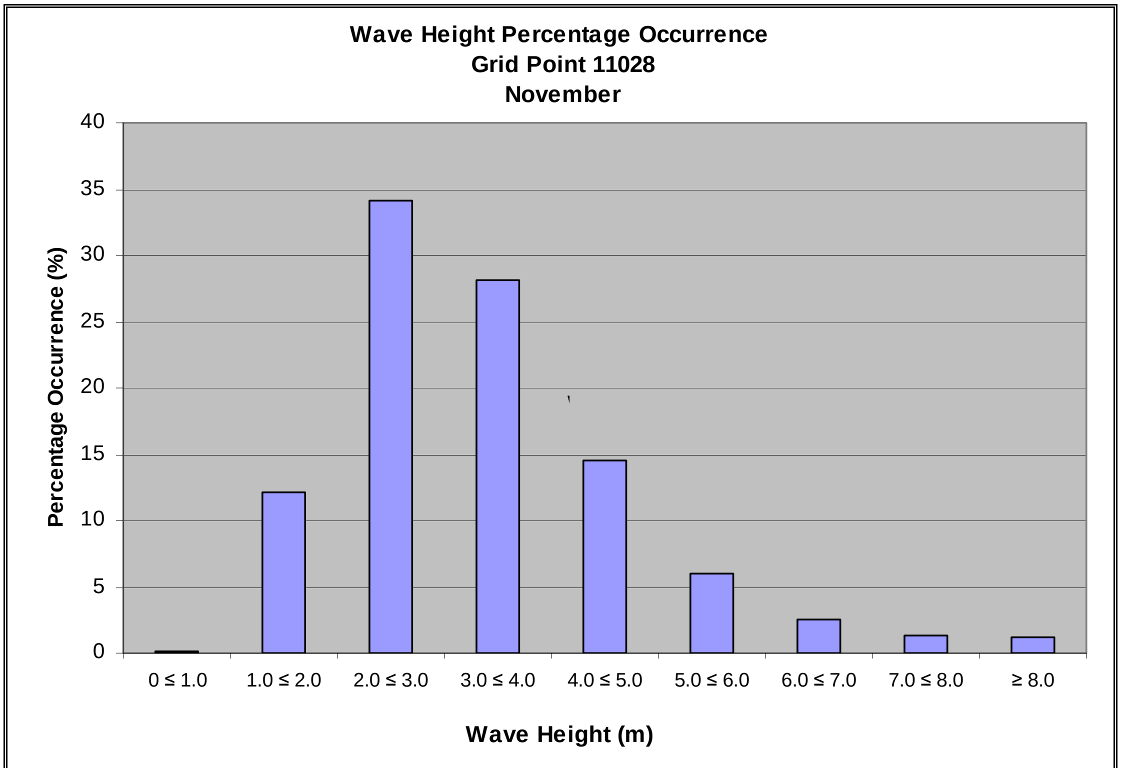
Wave Height Percentage Occurrence
Grid Point 11028
June
Percentage Occurrence (%)
70
60
50
40
30
20
10
0
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)

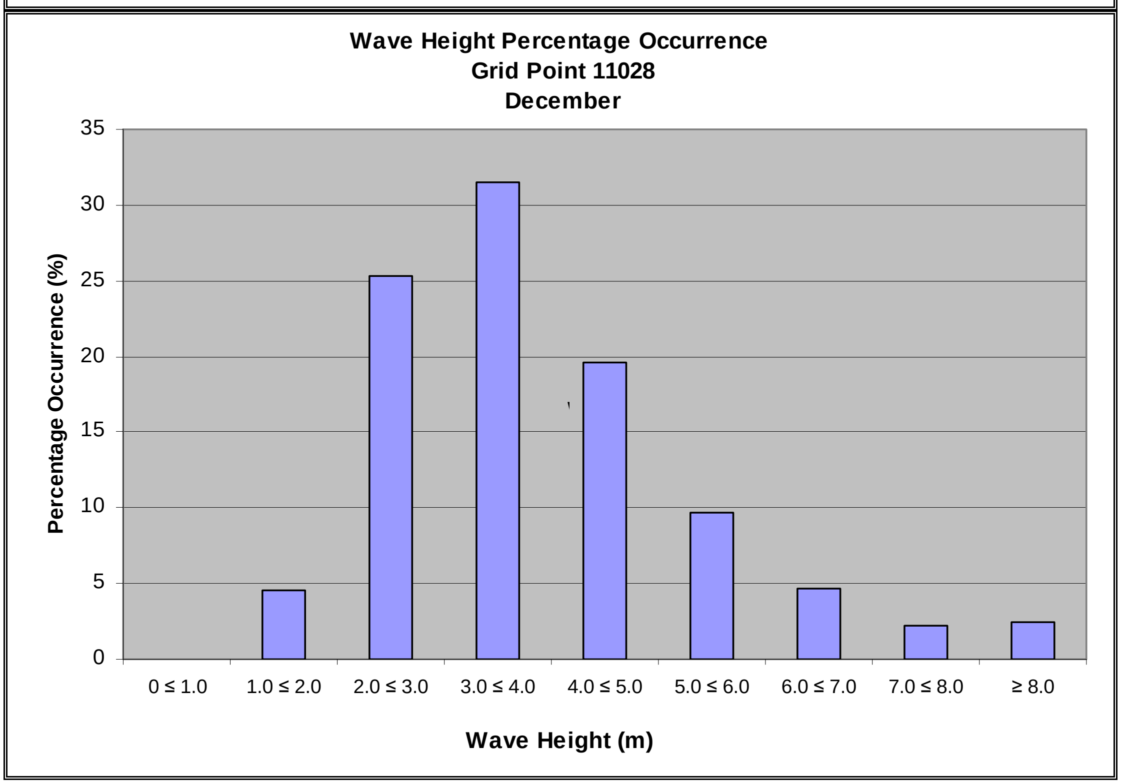

Wave Height Percentage Occurrence
Grid Point 11028
July
Percentage Occurrence (%)
80
70
60
50
40
30
20
10
0
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)


Wave Height Percentage Occurrence
Grid Point 11028
August
Percentage Occurrence (%)
70
60
50
40
30
20
10
0
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)


Wave Height Percentage Occurrence
Grid Point 11028
September
Percentage Occurrence (%)
45
40
35
30
25
20
15
10
5
0
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)


Wave Height Percentage Occurrence
Grid Point 11028
October
Percentage Occurrence (%)
45
40
35
30
25
20
15
10
5
0
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)


Wave Height Percentage Occurrence
Grid Point 11028
November
Percentage Occurrence (%)
0
5
10
15
20
25
30
35
40
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)


Wave Height Percentage Occurrence
Grid Point 11028
December
Percentage Occurrence (%)
0
5
10
15
20
25
30
35
0 ≤ 1.0
1.0 ≤ 2.0
2.0 ≤ 3.0
3.0 ≤ 4.0
4.0 ≤ 5.0
5.0 ≤ 6.0
6.0 ≤ 7.0
7.0 ≤ 8.0
≥ 8.0
Wave Height (m)