7.5 Environmental Effects Analysis and Mitigation

Potential environmental effects on marine fish and fish habitat during all phases of the Project are discussed by Project phase and summarized at the end of this chapter.

7.5.1 Construction and Installation

7.5.1.1 Change in Habitat Quantity

Nearshore

Construction of the bund wall, drydock, Back Cove ferry terminal, dredged areas and any in-water dredge spoil disposal areas may be declared a HADD of fish habitat by DFO and likely require a Section 35(2) *Fisheries Act* Authorization, requiring any loss of fish habitat to be compensated with the objective to achieve no net loss of productive capacity of fish habitat. The footprint of the bund wall, the area of drydock, upgrades to the Back Cove ferry terminal (including temporary replacement of the pier), the area to be dredged and the footprint of any at-sea disposal will be quantified and detailed within the Habitat Compensation Strategy report for the Hebron Project. The development and implementation of the Strategy and subsequent Habitat Compensation Plan will prevent significant adverse residual environmental effects to habitat quantity.

The bund wall footprint, Back Cove ferry terminal (pier) footprint and the area to be drained for the drydock in Great Mosquito Cove may temporarily affect to a small degree, the quantity of available habitat for fish and shellfish for an estimated 24 months. During this time, the submerged surface area of the bund wall will provide new habitat for some species. Species associated with boulder habitats like periwinkles, barnacles and blue mussels may increase in abundance where boulders replace fine grained substrates. The addition of boulders to a relatively flat sand/gravel habitat may attract fish and shellfish. Adult lobster will be attracted from marginal habitats in the immediate area by newly created habitat that the armour stone crevices may provide. Areas vacated by these individuals may become available for new recruit lobsters. Other fish species that may colonize the bund wall area are rock gunnel (*Pholis gunnellus*), eelpout, radiated shanny (*Ulvaria subbifurcata*) and longhorn sculpin (*Myoxocephalus octodecemspinosus*). The bund wall may not only provide shelter for these species, but also create a feeding ground for several additional fish and shellfish species. Invertebrate species may inhabit the rocky subtidal portions of the bund wall, include rock crab, mussels, polychaetes, starfish, brittlestars, periwinkles, barnacles, urchins and fan worms.

The drydock area will be drained and unavailable for use by fish or shellfish for an estimated 24 months, until the bund wall is removed for the tow-out of the GBS to the deepwater site in Bull Arm.

If dredging is required prior to GBS tow-out, there will be an alteration of habitat within the dredged area(s). Macrobenthic species diversity may decrease briefly, but overall abundance and biomass of the benthic community in most habitats will likely not decrease as opportunistic invertebrate and fish species move into and thrive in the dredged area. Depending on the depth of the overburden in the area to be dredged, a very similar habitat to the existing substrate may be exposed and the dredged area will be re-colonized from neighbouring communities within one (*e.g.*, polychaetes and amphipods) to several (*e.g.*, scallop) years. This habitat disturbance within the dredged area is therefore temporary and highly reversible. Existing benthic habitat within the disposal area will be altered by the placement of dredged material. The magnitude of the alteration will depend on the similarity of the dredged material to the existing substrate within the disposal area. For example, if the dredged material is a mix of cobble and boulder and the material is placed over existing rocky substrate, less alteration of the habitat is expected compared to disposal of fine grained sediments in an area of rocky substrate.

With respect to the Nearshore Project Area, a HADD compensation plan will be required, since installation of a bund wall and de-watering of the proposed drydock area to allow for construction of the GBS and some potential dredging (and blasting) of native sediments in selected locations within Great Mosquito Cove will likely be considered a HADD by DFO. As its preferred option for HADD compensation, EMCP is proposing to enhance fish habitat in GMC by re-locating bund wall material[2] to featureless sedimentary areas of the sea floor, which currently have low commercial fish productivity. The re-located rock material will be deposited in closely-spaced piles (to maximize 'edge' effects) with the intention of creating 'artificial reefs'. In addition, local fishers have recommended that the rock 'reefs' be placed in shallow, sub-tidal areas of Great Mosquito Cove (<20 m water depth), which are adjacent to areas with bedrock, boulder and medium to coarse gravel substrates, which will provide access corridors to allow for development of juvenile lobsters into later life stages and ultimately into mature, commercial-size adult lobsters and facilitate the growth of kelp species that provide food and/or cover for a variety of fish and invertebrate species.

Offshore

Activities affecting habitat quantity during offshore construction include Hebron Platform and OLS installation / protection and flowline installation.

There is currently no plan to trench the OLS, but to protect the line with rock cover and or concrete mattresses. The footprint of the OLS on the seafloor will restrict access by fish and shellfish to some habitat. ~~However, t~~The presence of unburied material over the OLS (*i.e.*, concrete mattresses and rock cover) is expected to create habitat by increasing the amount of available hard substrate habitat that could be colonized by local flora and fauna, creating a reef effect for fish populations in otherwise barren sandy or soft bottom areas. Where flowlines and equipment are buried, the overlying sediments will provide habitat upon which benthic communities will recover. Nevertheless, the OLS installation may be declared a HADD of fish habitat by DFO and likely require a Section 35(2) *Fisheries Act* Authorization, requiring any loss of fish habitat to be compensated with the objective to achieve no net loss of productive capacity of fish habitat.

Installation of the GBS will have a similar effect in that access to habitat under the GBS will be lost to fish and shellfish, but colonization by invertebrates on the concrete GBS is

2 According to DFO guidelines, the re-located rock material should be clean and free of sediment and a combination of equal portions of boulder (250 to 750 mm), rock (130 to 225 mm) and cobble (65 to 130 mm). In addition to the bund wall material, there is also the possibility that some dredged native sediments would be available for incorporation into the proposed rock reefs if not taken to an onshore site for disposal / reuse.

expected. Nevertheless, the installation of the GBS may be declared a HADD of fish habitat by DFO and likely require a Section 35(2) *Fisheries Act* Authorization, requiring any loss of fish habitat to be compensated with the objective to achieve no net loss of productive capacity of fish habitat.

The Hebron Platform and the rock mattress and/or concrete mattress cover over the flowline and OLS will provide new hard substrate habitat to be colonized and perform as an artificial reef. The presence of these structures over an unstable sand and gravel substrate enhances the habitat complexity of the surrounding area and increases localized productivity. The new surfaces will become colonized by sponges, anemones, brittlestars and seastars, which themselves provide habitat for smaller epifaunal and epifloral species. Studies in the North Sea indicate most of the fouling biomass in the upper 50 m is composed of seaweeds, hydroids, soft corals, anemones and mussels. Hydroids, soft corals, anemones and tubeworms are the most common animals below 50 m (Welaptega 1993, in Husky Oil 2000). An artificial reef effect is created shortly after the installation and the structures become a source of food and shelter for several species of fish and shellfish, especially juveniles.

With respect to the Offshore Project area, it is predicted that the increased hard surface area afforded by structures (not including the Hebron Platform itself) and associated rock cover in the Hebron offshore production field will likely offset any footprint losses (including the base area of the Hebron Platform). Therefore, EMCP submits that HADD compensation will not be required for the offshore Project Area based on preliminary design of these elements[3]. EMCP will provide DFO with a habitat quantification report for the offshore Project Area once final design details of these structures are available in order to make a final determination of whether HADD compensation may be required.

~~Future Activities~~Potential Expansion Opportunities: Construction

If excavated drill centres and flowlines are installed as part of the Hebron Project in the future, associated dredging 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 drill centre excavation, which will confine sediment dispersion and the disposal pile footprint to near the excavation site. The suction hopper dredge vessel would cut the substrate and vacuum the material up to the vessel for disposal at a pre-approved disposal site.

The areas to be dredged will result in a temporary loss of productivity within the footprint of the excavated drill centre or flowline. Several 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 two to four years following cessation (Kenny *et al.* 1998; Sardá *et al.* 2000; Van Dalfsen *et al.* 2000). It has been suggested that recolonization of a dredged area by polychaetes occurred within 5 to 10 months after the cessation of dredging in a site located within the North Sea, with

[3] While the rock cover over the flowlines and the armouring around the Platform has the potential to constitute fish compensation, it would be contingent upon the size of the rock material and its likely benefits to species within the area.

restoration of biomass to pre-dredge levels anticipated within two to four years (Van Dalfsen *et al.* 2000).

Productivity within the footprint of the dredge spoils disposal area is decreased due to smothering under several centimetres of sand and gravel dredged from the excavated drill centre. However, on the surface of the disposal pile, the emergence of infauna from the excavation will create a newly available food source for snow crab, skate and any flatfish or benthic feeder in the area.

On the periphery of the disposal pile, 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.

The installation of pipelines / flowline to the Hebron Platform will require protection to be in place, such as concrete mattresses, rock cover or other flowline insulation. These structures have the potential to provide new hard substrate habitat to be colonized and function as an artificial reef and would likely be colonized by sponges, anemones, brittlestars and seastars.

As with the nearshore, any offshore activities including excavated drill centre(s) and spoils disposal, the OLS or installations of pipeline(s) / flowline(s) (including related infrastructure such as concrete mattresses, rock cover or other flowline insulation) and testing from excavated drill centre(s) to the Hebron Platform may be declared ~~to cause~~ a HADD by DFO and~~will~~ require a Section 35(2) *Fisheries Act* Authorization and any loss of fish habitat will be fully compensated with the objective to achieve no net loss of productive capacity of fish habitat. Offshore Project design has not progressed to the stage of being able to accurately quantify the footprint of possible excavated drill centre(s), the OLS or installation of pipeline(s) / flowline ~~installations~~ (including related infrastructure such as concrete mattresses, rock cover or other flowline insulation) and testing from excavated drill centre(s) to the Hebron Platform, nor the area of the dredge spoil disposal footprint. However, potentially affected areas can be estimated from previous similar projects on the Grand Banks. The nominal areal extent of the activities with the potential to affect habitat quantity is provided in Table 7-10.

Table 7-10 Nominal Seafloor Disturbance Area for Offshore Project Components

Project Component	Quantity	Typical Dimensions on the Seafloor	Typical Seafloor Area
Hebron Platform	1	133 m	13,892 m^2
OLS	2	0.6 x 2,400 m	1,440 m^2
~~Future Activities~~Potential Expansion Opportunities			
Excavated Drill Centre (70 m x 70 m)	Up to 4	130 x 130 m	16,900 m^2
Excavated Drill Centre dredge spoils disposal	Up to 4	1 km x 1 km	1 km^2
Flowline bundle	Up to 4	0.5 x 4,000 m	2,000 m^2

In accordance with the DFO policy of no net loss of fish habitat, a habitat compensation program will be developed in conjunction with DFO as a mitigation measure for the net loss of fish habitat resulting from nearshore and offshore Hebron Project activities.

7.5.1.2 Change in Habitat Quality

Project activities may affect water and sediment quality and the sound environment, as described in this section. To mitigate these environmental effects, measures have been included within the Project design so that significant residual adverse ~~residual significant~~ environmental effects will likely not occur.

Nearshore

Bund wall construction and removal, drydock dewatering, concrete washwater discharge, dredging, blasting and sheet pile driving are the primary nearshore construction activities that could affect the quality of fish habitat in the Nearshore Project Area. The potential environmental effects of these activities are discussed separately below, but considered together in the effects analysis and significance determination of the Hebron Project on fish and fish habitat.

Suspended Sediment

Fine-grained sediment can be suspended in the water column during the following nearshore Project activities:

- Bund wall construction
- Dredging of bund wall and possibly sections of tow-out route
- Disposal of dredged material at sea
- Drydock dewatering
- Mooring replacement / upgrades
- Blasting in areas of fine-grained sediment

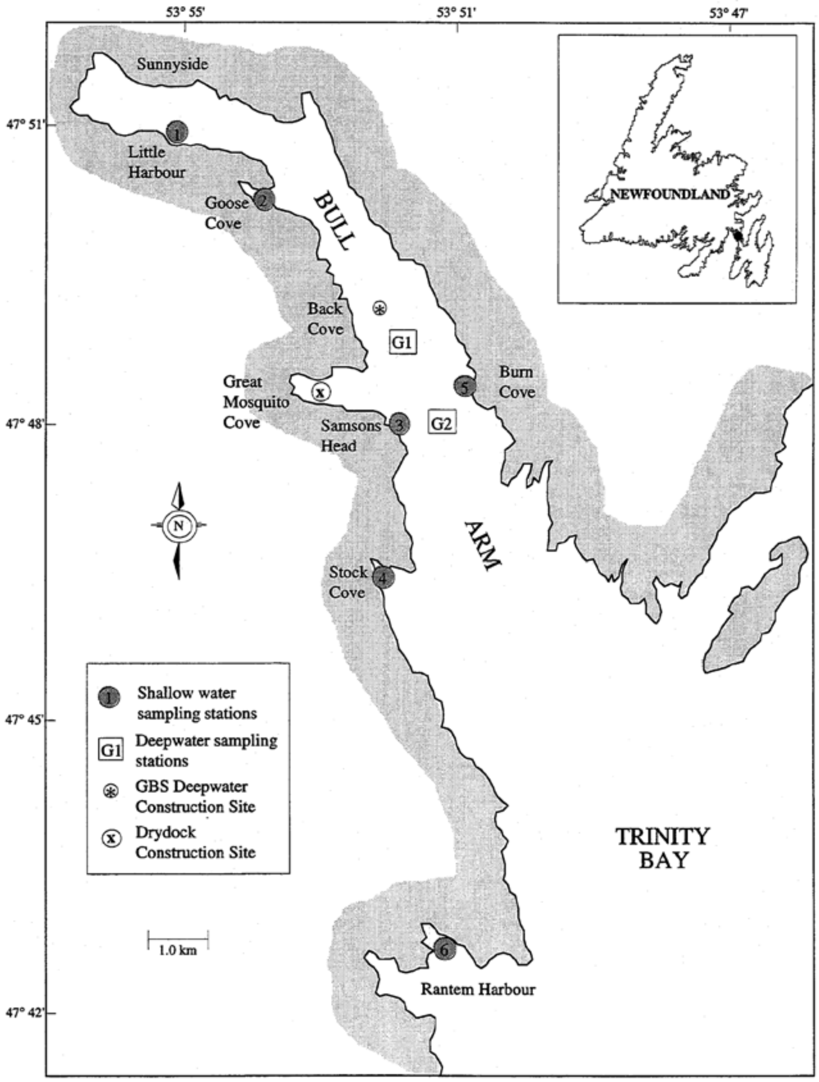
One effect of increased levels of suspended sediment is a reduction in the amount of light that is able to transmit through the water column. If elevated levels of suspended solids are sustained before or during a plankton bloom, a decrease in primary productivity may result. In turn, the food supply for young fish and shellfish may be diminished during that period. Zooplankton may be affected as well. Copepods show negative effects and reduced numbers when there is moderate loading of suspended solids (Robinson and Cuthbert 1996, and references therein). This may have localized effect on prey selection for some fish species.

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 (see Section 7.5.1.3).

Shellfish are generally more susceptible to the effects of increased sediment load than finfish because they are filter feeders (Peddicord 1980). If the levels of suspended solids are sufficient, non-organic 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 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 Great Mosquito Cove area are comprised predominantly of sands, often with gravels. The frequent outcrops of consolidated sediments suggest a very thin layer of unconsolidated sediments on top of the bedrock (Lee 2005). 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.

An EEM program was conducted within Bull Arm from 1991 to 1997 (Christian and Buchanan 1998) during the Hibernia GBS construction phase. In an effort to monitor the potential environmental effects on the quality of fish and fish habitat, six shallow water (<20 m) sampling stations were established throughout Bull Arm from the innermost site at Little Harbour near Sunnyside to the outermost one at Rantem Harbour. In addition, deepwater (>120 m) grab samples for surficial sediments were collected at two stations; one just north of, and one immediately south of the entrance to Great Mosquito Cove (Figure 7-15~~2~~). A total of 43 field trips were conducted at Bull Arm during the Hibernia EEM Program.



Source : Christian and Buchanan (1998)

Figure 7-157-12 **Environmental Effects Monitoring Study Area, Hibernia Project, Bull Arm**

Nearshore sedimentation was measured as total deposited solids (TDS) and volatile deposited solids (VDS) during the Hibernia EEM program (Christian and Buchanan 1998). Generally, the highest values of TDS and VDS occurred in the fall, followed by a decrease in the winter and a slight increase in the spring. Those areas with the most freshwater influence (*i.e.*, Stock Cove and Goose Cove) displayed the highest absolute levels compared to the other stations. The most marked inter-annual difference occurred at Station 3, the station nearest the construction site, during the time of breaching the drydock bund wall (Figure 7-12). At this time, the TDS increased and the VDS / TDS decreased markedly. TDS amounts also increased at adjacent stations but to a lesser degree.

The following is a list of mitigation measures designed to reduce sediment loading during construction. These will be implemented, where applicable, to reduce potential effects. Additional mitigation measures will be investigated during Front-end Engineering Design (FEED) and detail design and engineering:

- Investigate the use of washed rock or in-water sediment control measures for fill material in the construction of the bund wall (different measures will be investigated, and a proven method will be implemented)
- Chemistry of rock and till material will be tested prior to placement
- Efficient installation with minimal seabed disturbance
- Investigate technologies to reduce sedimentation during dredging operations (different measures will be investigated, and a proven method will be implemented)
- Minimal movement of barge anchors to reduce resuspension of sediments
- Releasing water for hydrostatic testing only when it meets criteria set out in the *Fisheries Act* or *Canadian Environmental Protection Act* ~~(CEPA)~~ (or the Newfoundland and Labrador *Environmental Control Water and Sewer Regulations*, 2003, of discharged from a land-based settling pond), prior to discharge
- Where applicable, adherence to Canadian Council of Ministers of the Environment (CCME) *Environmental Quality Guidelines* for the protection of aquatic life when considered in conjunction with existing ambient water quality and site-specific factors
- Use of settlement basins and/or containment areas for concrete washwater
- Use of best practices, continuous improvement programs and best available technology

Contamination

If the dredge spoils or material used for bund wall construction have levels of metals, hydrocarbons or other compounds above background level, there is increased risk of introducing or spreading contaminated soils. Concrete washwater or uncured concrete can be very alkaline and affect the quality of fish habitat if exposed to the marine environment.

The EEM results within Bull Arm during the Hibernia GBS construction phase (Christian and Buchanan 1998) tested for the effects of contamination and indicated no detectable effect on fish heath as measured by Mixed Function Oxygenase ~~(MFO)~~ activity, histopathology, bile metabolites or gill parasitism. During the EEM program, iron and manganese were the only elements recorded above the Maximum Allowable Effects Levels, the concentration level in sediments above which the frequency of associated biological effects are unacceptable. At Station 3, 10 of the 21 trace metal analytes were distinctly more concentrated in the "breach" composite sample (Figure 7-12). Most PAHs and total petrogenic hydrocarbons in sediments collected throughout the EEM were below their respective Maximum Allowable Effects Levels.

Blue mussels were also monitored during the Hibernia EEM program to test for indications of contamination. There were no obvious differences in condition index of blue mussels sampled outside of the bund wall breach time and those sampled during and immediately following breach time. Concentrations of 13 trace metal analytes in mussels were essentially unchanged throughout the EEM program regardless of location, exposure time duration, sampling season and period of exposure relative to bund wall breaching. Concentrations of the remaining eight trace metal analytes appeared most affected by sampling season. Arsenic, copper, nickel, selenium and tin consistently appeared most concentrated in mussel soft tissue sampled in May. Barium, chromium and vanadium appeared most concentrated in mussels sampled in the fall. Almost all polycyclic aromatic hydrocarbon (PAH) concentrations in muscle tissue were below the analytical detection limit. Those that did exceed limits of quantitation were considered to be minimal (Christian and Buchanan 1998).

The potential environmental effeimpact from concrete production is the effects of washwater released to the environment. Liquid wastes may contain hazardous materials such as cement, concrete additives and oil.

Cement is very alkaline and washwater from spoiled concrete or from the cleaning of the batch plant mixers and mixer trucks, conveyors and pipe delivery systems can be expected to have very high pH, which may exceed regulatory limits. Similarly, spoiled concrete or washwater would contain concrete additives and agents, some of which are toxic to aquatic species. Aggregates, particularly the finer sand fractions can be expected to be washed from spoiled concrete or discharged in washwater. Uncontrolled release of such washwater will be prevented.

Mitigation measures to reduce the risk of contamination during nearshore construction may include:

- Concrete washwater containment and testing to meet applicable regulations *(e.g., Canadian Environmental Protection Act*~~CEPA~~, *Fisheries Act* and provincial *Water Resources Act*) prior to discharge
- Investigate use of washed-rock for bund wall construction
- EPP to address discharge of all chemicals to the marine environment
- Treatment of washwater from batch plants prior to discharge / disposal

Noise and Blasting

Nearshore fish habitat quality may also be affected by noise. Underwater noise created by blasting, sheet piling and vessel traffic (including vessel traffic associated with the tow-out of the GBS to the deepwater site, completion of GBS construction and Topsides mating at the deepwater site, hook up and commissioning of Topsides and Hebron Platform tow-out from the deepwater site) can affect the physiology of fish and invertebrates. Background noise in the ocean can originate from a range of natural and anthropogenic sources, including oceanic turbulence, thermal noise, surface wave action, animal communications and vessel traffic. Large tankers, at full steam, may have a source noise level of 170 dB re 1 µPa at 1 m and average fishing vessels emit noise between 127 and 146 dB at 100 m. Typical peak levels of ambient noise range from 110 to 120 dB re 1 µPa in shallow water (Richardson *et al.* 1995), depending on oceanographic conditions, shipping and other human activity. Therefore, typical peak background values of 110 dB re 1 µPa are a reasonable assumption for shallow nearshore waters. However, noise level is very much dependent upon frequency, in that levels at higher frequencies are typically lower.

Fish with swim bladders and specialized auditory couplings to the inner ear (*e.g.*, herring) are considered to be most 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). The swimbladder is the most likely site of damage in finfish, but the kidney, liver and spleen may also be ruptured. In comparison to finfish, benthic invertebrates and shellfish are likely less affected by sudden pressure changes underwater because they do not have contained airspaces.

Acoustic modelling of pile driving activity into bedrock at Great Mosquito Cove was conducted. The model estimated a source level of 216 dB re 1 µPa @ 1 m and that a sound pressure of >190 dB re 1 µPa (rms) will extend to approximately 300 to 400 m from the bottom of Great Mosquito Cove, depending on distance of the bund wall from the shoreline (JASCO 20109). If pile driving is required at the deepwater site in Bull Arm, the model estimates that a sound pressure of >190 dB re 1 µPa (rms) will occur less than 100 m from the source. At sound pressures of 192 dB re 1 µPa, fish may be stunned temporarily and internal injuries may result at levels of 200 dB re 1 µPa (Turnpenny and Nedwell 1994). There is limited risk of these interactions occurring given that fish are expected to avoid the area near in-water construction activity. The mitigation measures outlined below will further reduce the risk of damage to fish.

Underwater noise levels from a tug vessel were estimated at 185 dB re µPa at 1 m during transit and as 193 dB re µPa @ 1 m when the vessel is doing an anchor pull. These are conservative assumptions used for modelling (JASCO 20109). The sound pressure level emitted by the tug is not expected to cause any physical injury to fish since the 193 dB is the maximum sound pressure expected within 1 m of the tug's propeller (see JASCO 20109).

Blasting may be required at Great Mosquito Cove to provide adequate draft or channel width for the GBS tow-out to the deepwater site. Because the details of the potential blasting have not yet been determined, a sample scenario was developed using the simple case of a single explosive charge with size and burial depth as prescribed by current DFO guidelines (Wright and Hopky 1998). If blasting were required in Great Mosquito Cove, results of acoustic modelling for the largest single charge that is permissible under the DFO 100 kPa overpressure guideline (Wright and Hopky 1998) indicate that greater than 200 dB re 1 uPa (rms) sound exposure levels would occur for approximately 50 m from the blast source and that sound pressures of between 190 and 199 dB re 1 uPa (rms) sound levels would occur from the mouth of Great Mosquito Cove to the eastern side of Bull Arm (JASCO 20109). Sound exposure levels in excess of 214 dB re 1 uPa (rms) are not expected from this blasting scenario and therefore injury to egg and larval stages is not expected (Turnpenny and Nedwell 1994).

In-water blasting will be limited in duration and frequency and will be governed by a series of mitigation measures designed to reduce potential effects on fish. Any blasting that may be required near the shoreline will adhere to DFO's *Guidelines for Use of Explosives in Canadian Fisheries Waters* (Wright and Hopky 1998). The following are a selection of mitigations rather than the exhaustive list of mitigations contained withinthese guidelines. The following mitigations plus others noted in Wright and Hopky (1998) will be implemented to reduce environmental effects associated blastingmitigations listed in these guidelines include:

- Backfilling a loaded charge hole
- No detonation of explosive in or near fish habitat that produces, or is likely to produce, an instantaneous pressure change (*i.e.*, overpressure) greater than 100 kPa (14.5 psi) in the swimbladder of a fish
- No detonation of explosive that produces, or is likely to produce, a peak particle velocity greater that 13 mm/s in a spawning bed during the period of egg production
- Mitigation to help further reduce the potential for physiological effects of noise on fish and fish habitat during construction may include:
- Use of acoustic harassment devices or a ramp-up of detonation pressures to encourage fish to move away from the blasting area
- Use of bubble curtains and other acoustic absorbents, where feasible; to contain shock waves
- Consultation with DFO on blasting plans prior to use
- Compliance with section 32 of the *Fisheries Act* as detailed in Section 35(2) *Fisheries Act Authorization*

Light Attraction

Light attraction's primary environmental effects is related to habitat use (Section 7.5.1.3) but it can also affect habitat quality in that the light / dark cycle may be interrupted and fish and invertebrates in the area may not react in their normal manner. This has the potential to result in physiological stress, as light resulting in 24-hour light regime affects their normal circadian rhythm. The response of fish to changes in their circadian rhythm varies among species. Examples of the effects of a 24-hour light regime on fish species are provided to demonstrate the potential for physiological stresses.

Nighttime rest deprivation in zebra fish was found to result in a significant decline in daytime locomotor activity and in a heightened arousal threshold, compared to basal recordings (Zhdanova and Reebs 2006). Leonardi and Klempau (2003) demonstrated that the application of 24-hour light period for 60 days induced an increase of cortisol in trout that lasted up to two months after return to normal light regimes. The changes observed in fish towards the end of the two-month illumination period (increased haematocrit values and erythrocyte numbers) can be explained as a consequence of acute stress or, alternatively, as a stimulation of erythropoiesis by increased light exposure. Hemre *et al.* (2002) found that a 24-hour light regime for Atlantic cod resulted in a delay in gonadal maturation and evident anaemia.

Offshore

There are several construction and installation activities in the Offshore Project Area that could affect the quality of fish habitat. Installation of the OLS, flowlines, concrete mattress pads (rock dumping over OLS offloading lines), installation of temporary moorings, underbase grouting, possible offshore solid ballasting, placement of rock scour protection on seafloor around final Hebron Platform location,~~and~~ Hebron Platform and surveys (geophysical, seismic, geohazard and/or geotechnical surveys) and potential future excavated drill centre construction, are the primary offshore construction activities which could affect the quality of fish habitat.

Suspended Sediment

The above discussion regarding sedimentation and potential effects on fish and shellfish in the nearshore also applies to the assessment of potential offshore effects. The primary difference between the nearshore and offshore sites is the role that the contrasting physical environment will have on the dispersion of suspended sediments.

Dispersion of sediment during dredging and dredge spoils disposal, installing concrete pad / rock dumping over OLS offloading lines, installation of temporary mooring, placement of rock scour protection on seabed floor around final Hebron platform location, and placement of Hebron platform is dependent upon the excavated or disturbed sediment grain size, water depth and currents in the area in which they are disposed or disturbed. Surficial sediments in the offshore are much coarser than those in Great Mosquito Cove and are therefore expected to settle more quickly. Observed sediments within the Hebron Project Area are comprised predominantly of sands and gravels with limited fine material (see Section 3.1.6).

Contamination

As summarized in Section 7.3.3.2, there are indications of previous drilling activities in the surficial sediments of the Offshore Project Area. Several metals were found to have concentrations above the median for the Offshore Project Area (Chevron 2003). The areal and temporal extent of discharged drill wastes (as measured by barium and total petroleum hydrocarbon (TPH) concentrations in sediments) tend to be related to differences in the number of wells and associated volume of discharges, mud types, current speed and direction, water depth and/or sediment mobility at the drilling location (Hurley and Ellis 2004). Hurley and Ellis (2004) also concluded that changes in the diversity and abundance of benthic organisms were detected within 1,000 m of drill sites, most commonly within the 50 to 500 m range of drill sites. The results were consistent for both literature (international) review case studies and for east coast offshore petroleum project EEM data. 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."

The Terra Nova EEM program has conducted a baseline characterization in 1997 and has conducted six operational EEM programs to date. A review of the first five operational EEM programs for Terra Nova conducted in 2000, 2001, 2002, 2004 and 2006 found that total petroleum hydrocarbons were detected at 35 (2000) to 52 (2002) of the 53 stations (Petro-Canada 2001, 2002, 2003, 2005, 2007). Elevated hydrocarbon levels were detected above 4 mg/kg within 2 km (2000, 2002) to 3.5 km (2002) from the various Terra Nova drill centres. The maximum $>C_{10}$-C_{21} levels were 13.3 mg/kg at station 750 m from Northwest (NW) drill centre (2000); 28.6 near Northeast (NE) drill centre (2001); 925 mg/kg at 150 m from Far East (FE) drill centre (2002); 6.550 mg/kg at 150 m from FE drill centre (2004); and 980 mg/kg at 150 m from FE drill centre (2006).

Barium levels at Terra Nova were slightly elevated compared to baseline conditions in 2000, with a maximum barium level of 230 mg/kg at 250 m from Southwest (SW) drill centre and the median barium level of 130 mg/kg (Petro-Canada 2001). Barium levels in 2001 (Petro-Canada 2002) were comparable to baseline conditions (1997 levels). Elevated barium levels were observed within 1 to 2 km of drill centres for 2002, 2004 and 2006 (Petro-Canada 2003, 2005, 2007). During these years the maximum barium concentrations were observed at 150 km from far east drill centre and were 2,200, 2,100 and 16,000 mg/kg respectively (Petro-Canada 2003, 2005, 2007).

The Petro-Canada baseline amphipod survival had 1 of 54 samples that was considered to be toxic (Petro-Canada 1997). There were no toxic amphipod results for 2000, 2001 and 2002. In 2004 and 2006 (Petro-Canada 2005; 2007) amphipod survival had a toxic response within 150 m from the FE drill centre (station 30FE). In 2006 (Petro-Canada 2007), in addition to the toxic response within 150 m from the FE drill centre, there were two other toxic amphipod survival responses located at 1.08 and 1.28 kms from a drill centre (W14). The hydrocarbon levels ($>C_{10}$-C_{21}) for the within 150 m from the FE drill centre (station 30FE) were 6,550 mg/kg in 2004 and 925 mg/kg in 2006.

The benthic community structure in 1997 at Terra Nova was dominated by polychaetes, with good abundances of amphipods, bivalves, gastropods, echinoderms and anthrozoa and a similar relationship was observed in 2000 (Petro-Canada 1998, 2001). Potential enrichment of polychaetes (primarily of spionidae family) was observed from 2001 through 2006 (Petro-Canada 2002, 2003, 2005, 2007). An inhibitory response on abundance and richness was observed within 150 m from FE drill centre (30 FE station) in 2002, 2004 with an inhibitory response in richness observed in 2006 for the 30FE station (Petro-Canada 2003, 2005, 2007). Inhibitory responses on amphipods were observed within 150 m from FE drill centre (30 FE station) in 2004 and 2006 (Petro-Canada 2005, 2007).

The highest levels of barium, lead, manganese and strontium within the Offshore Project Area were found less than 750 m southeast of an abandoned oil well. These metals in other samples from the Offshore Project Area were well within the range from baseline and Year One of EEM programs at Terra Nova (Chevron 2003). The metal concentration for sediment samples collected at the Hebron site (Chevron 2003) were not above the ISQGs and Probable Effects Levels as listed in the ~~Canadian Ccouncil of Ministers of the Environment (~~CCME~~)~~ interim marine sediment quality guidelines provided in CCME (1999).

~~Given that the metals concentrations reported are total concentrations, there is little risk that the metals will become highly bioavailable to filter feeding organisms should the sediments become suspended during offshore construction activities.~~

Low-level fuel and lube range hydrocarbons were detected in 16 and 11 of 20 samples, respectively, during the sediment quality survey at Hebron (Chevron 2003). The median concentration of fuel range hydrocarbons was 0.81 mg/kg, while the median for lube range hydrocarbons was 0.75 mg/kg. Hydrocarbon concentrations were below 2 mg/kg in all samples. PAHs were not detected above an estimated quantification limits (EQL) of 0.05 mg/kg in any sediment samples from Hebron.

These are not concentrations that are expected to cause hydrocarbon contamination should they become suspended in the water column during offshore construction activities.

Hebron plans to re-inject SBMs for drilling completed from the GBS and only release SBMs associated with satellite wells drilling from MODU in potential future well developments. The EEM programs from Hibernia have demonstrated that reinjection of SBMs reduces the contaminant footprint associated with the release of SBMs. Hibernia commenced cuttings reinjection in March 2001, with greater than 95 percent cuttings reinjection achieved by second quarter 2002. Since the installation of the cuttings reinjection systems, hydrocarbon and barium concentrations around the Hibernia platform have returned to near baseline conditions for most contaminants beyond 250 m from the Platform.All discharges during the construction and installation phase of the Project will adhere to the *Offshore Chemical Selection Guidelines* (NEB *et al.* 2009).

Underbase grouting has the potential to cause localized contamination immediately to the bottom of the Hebron Platform. The footprint of this contamination would be contained within the footprint associated with the release of WBMs.

Noise

There are several potential sources of noise during offshore construction activities. Surveys geophysical, seismic and/or geohazard surveys), and possible pile driving for OLS installation are the primary potential sources. Other sources of noise from construction include geotechnical surveys vessels, and in water construction activities such as dredging of excavated drill centres, and installation of the OLS, flowlines and Hebron Platform structures included related activities such as placement of concrete mattress pads (rock dumping over OLS offloading lines), installation of temporary moorings, possible offshore solid ballasting and placement of rock scour protection on seafloor around the final Hebron Platform location. It is not certain whether these activities will be required during the construction phase of the Project or whether they may be spread out over the entire life of the Project.

The focus of this analysis is on the effects of seismic sound sources on fish habitat quality, given that seismic surveys potentially produce the highest levels of sound pressure of all the geophysical surveys proposed for this Project. Seismic airguns release most of the acoustic energy focused in a vertically downward direction. The noise associated with airguns can range between approximately 215 and 235 dB re 1 µPa-m for a single airgun and approximately 235 to 260 dB re 1 µPa-m for arrays (Richardson *et al.* 1995). Source levels off to the sides of the array in the horizontal are generally lower. In general, the frequency output of an airgun depends on its volume: larger airguns generate lower-frequency impulses. However, due to the pulsive nature of the source, airguns inevitably generate sound energy at higher frequencies, above 200 Hz, although the energy output at these frequencies is substantially less than at low frequencies.

Sub-lethal injury has only been observed as a result of repeated exposure to very high received levels of sound, at a higher cumulative level than would be expected in the field under normal seismic operating conditions (LGL 2008a). Depending on source noise level, water depth and distance of the fish relative to the source, injuries (such as eyes and internal organs) would only occur within a few tens of metres with lesser symptoms such as hearing damage possible out to several hundred metres (Turnpenny and Nedwell 1994).

Snow crab eggs have shown delayed embryonic development after exposure to seismic energy (Payne 2004). Christian *et al.* (2004) exposed snow crab eggs to 221 dB at 2 m and demonstrated possible signs of retarded development. However, eggs in nature are unlikely to be exposed to noise levels of range or intensity as they are carried by the female on the seafloor (the same is true for shrimp). Results from a DFO (2004a) study on the effects of seismic activity on adult snow crab indicated no changes to embryo mobility of hatched larvae affected.

Sub-lethal physiological effects on lobsters exposed to seismic energy were observed by Payne *et al.* (2007) during preliminary exploratory studies. The observed serum biochemical effects included reduced levels of serum protein, specific serum enzymes, and serum calcium. In some cases, the reduced levels persisted for a period of weeks.

In conclusion, invertebrates without gas-filled organs appear less vulnerable to the effects of airguns than fish with gas-filled organs. Benthic invertebrates in water deeper than about 20 m (*i.e.*, at the Hebron Offshore Project Area) are likely far enough away from the seismic source near the surface so that particle velocity effects become negligible.

Seismic activities associated with the Project will adhere to the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 201108).

Potential Expansion Opportunities: Construction and Installation

The hook-up, production testing and commissioning of excavated drill centres has the potential to cause contamination related to possible releases of limited amounts of chemicals that maybe involved with these activities. These activities are of limited duration and the amount of potential chemical releases would be small. The implementation of the chemical selection management system and adherence to regulatory limits with respect to discharges to marine waters are mitigation measures that would be implemented to limit the potential for environmental effects associated the hook-up, production testing and commissioning of evacuated drill centres.

7.5.1.3 Change in Habitat Use

There are Project activities that have the potential to affect the behaviour of fish and shellfish. In-water activities in the Nearshore and Offshore Project Areas may affect habitat use by fish and shellfish by causing avoidance or attraction behaviours. To mitigate these environmental effects, measures have been included within the Project design so that significant residual adverse residual significant environmental effects will likely not occur. These measures include noise control measures, and application of standard seismic mitigation measures. These are described in more detail in this section.

Nearshore

Increased noise levels associated with dredging, bund wall construction and removal, vessel traffic (including vessel traffic associated with the tow-out of the GBS to the deepwater site, GBS ballasting and de-ballasting, completion of GBS construction and topside mating at deepwater site, hook up and commissioning of topsides and platform two-out from deepwater site), blasting and surveys (*e.g.*, geophysical, geohazard, geotechnical, environmental) may affect habitat use by causing an avoidance of fish and invertebrates. Lights and related structures with light sources (including the floating batch plant for concrete production) may affect habitat use by providing an attraction of fish and invertebrates. Drydock dewatering and the re-estabhlishment of moorings at the Bull Arm deepwater site may affect habitat use as there will be a loss of habitat quantity in these areas. The habitat use environmental effects associated with noise and lights are discussed below. The environmental effects of drydock dewatering and the re-estabhlishment of moorings at the Bull Arm deepwater site on habitat use is directly related to the temporary loss of habitat which triggers a HADD and are been discussed in Section 7.5.1.2. Increased noise and activity levels due to dredging, bund wall construction, vessel traffic, blasting, lights and surveys (*e.g.*, geophysical, geohazard, geotechnical, environmental) during nearshore construction and installation activities may affect habitat use by causing avoidance or attraction of fish and invertebrates.

A comparison of moderately-sensitive species, such as cod, haddock, pollock and redfish, determined a measurable behavioural response in the range of 160 to 188 dB re 1 µPa (Turnpenny and Nedwell 1994; Richardson *et al.* 1995). If blasting were required in Great Mosquito Cove, results of acoustic modelling for the largest single charge that is permissible under the DFO 100 kPa overpressure guideline (Wright and Hopky 1998), indicate that 180 and 190 dB re 1 uPa (rms) sound levels occur at 2.7 km and 0.99 km, respectively, from the blast site (JASCO 2010). The noise from nearshore blasting is therefore expected to cause a startle response and temporary avoidance of the area by some species. Behavioural effects of noise on benthic invertebrates, such as lobster and crab, are not well documented. Few invertebrates have gas-filled spaces, and therefore, are less likely to be behaviourally affected by underwater noise, as are fish.

Most available literature indicates that the environmental 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.

The mitigation measures presented above for noise and blasting (Section 7.5.1.1), in addition to procedures in place specifying speed for vessels within the traffic lane in Bull Arm and limiting survey equipment and vessels to using only the power required to attain data (thereby minimizing noise), may also reduce the potential effects from noise on habitat use. Operational lights used in or near the marine environment may affect pelagic migratory fish species. Studies from the Pacific coast report changes in juvenile herring and sand lance distribution at night, in artificially lighted areas (Nightingale and Simenstad 2002). Predators may also have been attracted by the increase in juvenile herring and sandlance under the lights (Nightingale and Simenstad 2002). Lights are also known to attract squid, if they are present in the area. 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 have active swimming ability.

Offshore

Installation of the OLS, flowlines and Hebron Platform, The footprint of the OLS on the seafloor, concrete mattress pads / rocking dumping over OLS offloading lines, installation of temporary moorings, Platform tow-out/offshore installation, placement of rcok scour protection on seabed around the final Hebron Platform location,the operation of vesselssupply, support, standby and tow vessels, barges, diving), geophysical, seismic, and/or geohazard and/or geotechnical surveys and potential future excavated drill centre construction are the primary offshore construction activities that could affect the behaviour of fish and invertebrates, and therefore, habitat use. These activities could affect the behaviour of fish and invertebrates by causing avoidance or attraction. In addition to avoidance or attraction behaviours, some of these construction activities could also have an effect on habitat use directly related to the temporary loss of habitat, which would trigger a HADD; these have been discussed in Section 7.5.1.2.

The focus is on the environmental effects of seismic sound sources on fish habitat use, given that seismic surveys potentially produce the highest levels of sound pressure of all the geophysical surveys proposed for this Project.

Source levels during seismic surveys are usually in excess of the noise levels that elicit a response in fish, so the area in which fish react to the noise may extend several kilometres in the open ocean. There are several well documented observations of fish and invertebrates exhibiting behaviours that appeared to be in response to exposure to seismic activity like a startle response, a change in swimming direction and speed, or a change in vertical distribution (Blaxter *et al.* 1981; Schwarz and Greer 1984; Pearson *et al.* 1992; McCauley *et al.* 2000; Wardle *et al.* 2001; Hassel *et al.* 2003), although the importance of these behaviours is unclear. Some studies indicate that such behavioural changes are temporary (*i.e.*, within minutes (Pearson *et al.* 1992, in Skalski *et al.* 1992)), while others imply that marine animals might not resume pre-seismic behaviours and/or distributions for a number of days (Løkkeborg 1991; Engås *et al.* 1996). Conversely, pollock on a shallow coastal reef were observed during a signal of 230 dB re1 µPa (Wardle *et al.* 2001). Direct visual observations determined that only minor changes in fish behaviour patterns were detectable around the reef. When smaller pollock passed within a few metres of the array and were exposed to approximately 229 dB, they showed a typical "C-start" response and moved away only a few metres.

The expected distance for fish to react to a typical peak source level of 250 to 255 dB re 1 µPa is from 3 to 10 km (Engås *et al.* 1996). A reaction may simply mean a change in swimming speed or direction (Løkkeborg *et al.* 2010). The spatial range of response in fish will vary greatly with changes in the physical environment in which the sounds are emitted. In one environment, fish distribution has been shown to change in an area of 74 km x 74 km (40 x 40 nautical miles (nm)) and 250 to 280 m deep for more than five days after shooting ended, with fish larger than 60 cm being affected to a greater extent than smaller fish (Engås *et al.* 1996). The potential effect of a spatial response in fish during sensitive times is unknown, in part due to data constraints associated with life histories of many species and overall lack of knowledge of seismic effects during sensitive periods for most, if not all species. Behavioural effects on lobsters exposed to seismic energy were observed by Payne *et al.* (2007) during preliminary exploratory studies. Four of the five exposure trials resulted in observed increases in food consumption, and these feeding differences were often apparent several weeks post-exposure. Behavioural effects of exposure of caged cephalopods (50 squid and two cuttlefish) to sound from a single 20-inch airgun have been reported (McCauley *et al.* 2000). The behavioural responses included squid firing their ink sacs and moving away from the airgun, startle responses and increased swimming speeds.

Christian *et al.* (2004) conducted a behavioural investigation during which caged snow crabs were positioned 50 m below a seven-gun array. No obvious startle behaviours were observed. Results from a DFO (2004a) study on the effects of seismic activity on adult snow crab, indicated no changes in feeding activity.

Seismic activities associated with the Project will adhere to the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* ~~Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment~~ (C-NLOPB 2011~~08~~). Potential environmental effects of lighting on fish are addressed in the nearshore discussion above.

Potential Expansion Opportunities: Construction and Installation

Evacuated drill centre dredging and spoil disposal, installation of pipelines / flowlines, testing from evacuated drill centres to the Hebron Platform, concrete mattresses, rock cover and other flowline installation, as well as hook-up, production testing and commissioning of excavated drill centres may affect habitat use by fish and shellfish by causing avoidance or attraction behaviours. The primary avoidance of habitat would be related to noise disturbances, which has been discussed in detail under the offshore portion of Section 7.5.1.2.

7.5.1.4 Potential Mortality

Project activities may result in lethal effects to fish and shellfish, as described in this section. To mitigate these environmental effects, measures have been included within the Project design so that significant adverse residual environmental effects likely will not occur. These measures include standard blasting control measures,~~–~~ and the application of standard seismic mitigation measures. These are described in more detail in this section.

Nearshore

Mortality of fish and shellfish during nearshore construction could result from dewatering the dry-dock area, dredging, spoils disposal, GBS ballasting and deballasting, bund wall construction and blasting.

Dredging and dredge spoils disposal increase the levels of suspended sediment. 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 mortality of 10 percent after 5 and 11 days (Peddicord 1980). However, the highest suspended sediment levels reported during concurrent activities of till placement, dredging, drilling and underwater blasting for the Hibernia project at the mouth of Great Mosquito Cove were less than 40 mg/L (LeDrew, Fudge & Associates 1991). Dredging may cause mortality of some sessile invertebrates, like mussels and scallops, by crushing if a clam dredge is used. Sessile epifaunal species may be smothered during dredge spoils disposal. GBS ballasting and deballasting could potentially cause mortalilty of some fish species (including larval and eggs) if they are sucked into the ballast system during ballasting and deballasting procedures.

The blasting program in the nearshore will be designed to minimize the risk of mortality to fish. Nearshore and in-water blasting will adhere to DFO's *Guidelines for Use of Explosives in Canadian Fisheries Waters* (Wright and Hopky 1998), which is designed to mitigate fish mortality. In-water sound exposure levels in excess of 214 dB re 1 uPa (rms) are not expected from this blasting scenario and therefore, fish mortality is not expected (Turnpenny and Nedwell 1994). Nevertheless, mortality of sessile invertebrates in the immediate area of blasting is likely due to compression waves and flying debris.

During the dewatering of the drydock, a fish recovery and relocation program (to will be included as part of the Environment Protection Plan (in progress)) will be initiated. The goal of the program is to remove fish that would be stranded as a result of the drydock dewatering and relocate them to the nearby marine environment. It is acknowledged that while every reasonable effort will be made to recover and relocate the stranded fish, a certain degree of fish mortality may occur. Note: during the construction of the Hibernia GBS, fish were not present within the drydock when it was dewatered.

Mitigation measures to reduce the risk of mortality to fish during nearshore construction activities are provided in Section 7.5.1.2. In addition to the mitigations noted in Section 7.5.1.2, the mitigation measure of installing the water intake at a depth of 10 m, below most productive zones, will be implemented.

Offshore

It is very early in the design to determine if temporary mooring will be required for the installation of the Hebron Platform at its offshore location. If temporary moorings are required, up to four lines (two in one direction, (*e.g.*, south), and one to each side (*e.g.*, east and west) will be installed prior to the arrival of the Hebron Platform. During the final Hebron Platform installation phase, these lines would be connected to the bow of towing tugs and when system is tightened up, the final positioning will be achieved by use of the tugs winches.

The mooring lines may consist of a conventional drag embedded anchor (10 to 15 tonnes), short piece of chain and approximately 400 m of 64 mm steel wire rope buoyed at the surface. The anchors will be set approximately 1,000 m away from the final Hebron Platform location.

It is assumed that the lines will be installed a couple of weeks prior to the final Hebron Platform installation and removed immediately after completion of Hebron Platform installation. Both installation and retrieval may be done by one or two towing tugs using conventional anchor handling methods.

~~Potential for future dredging of excavated drill centre, spoils disposal and flowlines installation have the potential to cause mortality of shellfish and potentially to eggs and larvae of fish.~~

Platform tow-out and offshore installation, placement of rock scour, i~~I~~nstallation of the OLS and placement of concrete mattress pads~~GBS~~ has the potential to cause mortality of benthic invertebrate species. However, the relative number of individuals potentially within the footprints of these sub-sea structures is negligible when compared to the population numbers in adjacent habitat.

Potential for future dredging of excavated drill centre, spoils disposal and flowlines installation have the potential to cause mortality of shellfish and potentially to eggs and larvae of fish.

Dredging and spoils disposal will be required for excavated drill centre construction, but also may be required for OLS and flowline installation. Regardless of the dredging method chosen, some mortality of sessile invertebrates (*e.g.*, clams and scallops) may be expected from crushing and smothering. Smothering of sessile invertebrates is also expected from installation of the Hebron Platform, ~~and~~ concrete and/or rock mattress placement over the flowlines and OLS and placement of rock scour protection on the seafloor around the Hebron Platform location. Anchoring of construction and support vessels or drill rigs will have similar, highly localized effects. These effects are considered highly reversible on a population level, as disturbed areas will soon recolonize, including colonization of the subsea structures themselves.

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; Sardá *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 two to four years following cessation (Kenny *et al.* 1998; Sardá *et al.* 2000; Van Dalfsen *et al.* 2000). It is recognized that long-lived species such as corals, while unlikely to be present in the dredged area, may take longer to recover.

The risk of direct mortality to fish and shellfish from seismic surveys is limited to pelagic eggs and larvae. Acute mortality of eggs and larvae has been demonstrated in experimental exposures, but only when the eggs and larvae were exposed very close to the seismic sound sources and the received pressure levels were very high (see Dalen *et al.* 2007 for a review).

Recent collaborative research was conducted by the Fish Food and Allied Workers (FFAW) Union and ~~Fisheries and Oceans Canada (~~DFO~~)~~ on the potential effects of sound on developing monkfish eggs (Payne *et al.* 2009). This study found that there were no significant differences observed between control and exposed larvae examined 48 to 72 hours post-esposure. T~~h~~his study recognizes the potential difficulty in collection of monkfish veils, so it was decided that research should also be conducted on capelin eggs. Although artificial fertilization was poor, no significant differences in mortality were observed between control and capelin eggs exposed to seismic energy and examined three days post-exposure to 20 airgun discharges (Payne *et al.* 2009). Payne *et al.* (2009) concluded it is unlikely that seismic surveys pose any real risk to either monkfish eggs or near-hatch larvae that may float in veils on the sea surface during monkfish spawning.

There have been no reports of mass fish kills from seismic surveys (Payne 2004). Since fish are likely to be driven away by approaching seismic shots, fish mortality is not expected (Turnpenny and Nedwell 1994).

Mortality in shrimp was not observed after exposure to an airgun array with a peak pressure of 196 dB (re 1µPa at 1 m) (Andriguetto-Filho *et al.* 2005). Caged shrimp were also exposed to the airguns at very close range; there were no reported mortalities (Andriguetto-Filho *et al.* 2005). Webb and Kempf (1998) subjected shrimp to a 15-gun array (volume 480 cubic inches with source levels of 190 dB re 1µPa at 1 m depth) and reported no evidence of mortality or reduced catch rates for the shrimp.

Data on the effects of seismic surveys on macroinvertebrates (*e.g.*, crab and scallops) are limited, but the available data suggest that mortality through physical harm is unlikely below sound levels of 220 dB re 1 µPa @ 1 m (Royal Society of Canada 2004). There are no indications of acute or mid-term mortality in 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 2004a). 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.

Seismic activities associated with the Project will adhere to the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* ~~Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment~~ (C-NLOPB 2011~~08~~). The risk of mortality to sessile invertebrates from dredging will be reduced by having dredging contained to the smallest area possible and restricting dredge spoils disposal to a designated disposal area. EMCP will consult with relevant federal departments regarding the location of the disposal area.

The environmental effects of the Project during the construction and installation phase and the mitigations to be implemented are summarized in Table 7-11.

Table 7-11 Environmental Effects Assessment: Construction and Installation

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
Nearshore Project Activities							
Presence of Safety Zone	• Potential Decrease in Fish Mortality	• None required	1	2	3~~2~~/6	R	2
Bund Wall Construction (*e.g.*, sheet / pile driving, infilling~~, *etc.*~~)	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Bubble curtains, if feasible • HADD authorization and compensation • Chemistry of rock and till material will be tested prior to placement • Investigate use of washed-rock or in-water sediment control measures in bund wall construction~~.~~	1	1	3/1	R	2

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
In-water Blasting	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Adherence with Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters • Bubble curtains, if required • Compliance with terms of Section 32 *Fisheries Act* Authorization	1	2	2/1	R	2
Dewater Drydock / Prep of Drydock Area	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Fish Recovery and Relocation Program • Compliance with terms of Section 35(2) *Fisheries Act* Authorization • Fish habitat compensation	1	1	32/ 1	R	2
Upgrades to Ferry Terminal in Back Cove	• Change in Habitat Quantity • Change in Habitat Use	• Bubble curtains, if feasible • HADD authorization and compensation	1	1	2/1	R	2
Concrete Production (floating batch plant)	• Change in Habitat Quality • Change in Habitat Use	• Washwater from the cleaning of mixers, mixer trucks and concrete delivery systems will be treated prior to discharge or directed to a settling basin • Concrete wash water containment and testing to meet applicable regulations	1	1	3/3	R	2
Vessel Traffic (*e.g.*, supply, tug support, tow, diving support, barge, passenger ferry to / from deepwater site, *etc.*)	• Change in Habitat Quality • Change in Habitat Use	• Procedures will be in place specifying speed for vessels within the traffic lane and in Bull Arm	1	1	3/6	R	2
Lighting	• Change in Habitat Quality • Change in Habitat Use		1	1	3/6	R	2
Re-establish Moorings at Bull Arm deepwater site	• Change in Habitat Quality • Change in Habitat Use	• Restrict disturbance to mooring sites	1	1	2/1	R	2

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
Dredging of Bund Wall and Possibly Sections of Tow-out Route (may require at-sea disposal)	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Investigate use in-water sediment control measures • Fish habitat compensation • Proper disposal site selection • Compliance with terms of Section 35(2) *Fisheries Act* Authorization	1	1	2/1	R	2
Removal of Bund Wall and Disposal (dredging / ocean disposal)	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Bubble curtains, if required • Investigate use in-water sediment control measures • Compliance with terms of Section 35(2) *Fisheries Act* Authorization (if required) • Proper disposal site selection • Removal of construction debris	1	2	2/1	R	2
Tow-out of GBS to Bull Arm deepwater site	• ~~Change in Habitat Quality~~ • Change in Habitat Use		1	1	1/1	R	2
GBS Ballasting and De-ballasting (seawater only)	• ~~Change in Habitat Quality~~ • Change in Habitat Use • Potential Mortality	• Intake of water at depth (10 m, below most productive zone) ~~and adhering to the *Freshwater Intake End-of-Pipe Fish Screen Guidelines*~~	1	1	1/1	R	2
Complete GBS Construction and Mate Topsides at Bull Arm deepwater site	• ~~Change in Habitat Quality~~ • Change in Habitat Use	• Use of best practices, continuous improvement programs and best available technology	1	1	2/2	R	2
Hook-up and Commissioning of Topsides	• ~~Change in Habitat Quality~~ • Change in Habitat Use	• Comply with appropriate regulatory limits with respect to discharges into marine waters	1	1	2/2	R	2
Surveys (*e.g.*, geophysical, geological, geotechnical, environmental~~, *etc.*~~)	• ~~Change in Habitat Quality~~ • Change in Habitat Use	• Survey equipment and vessels will only use the power required to attain the data , therby minimizing noise.	1	1	2/1	R	2

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
Dredging for Tow-out from the Deepwater Site to the Offshore Location	• Change in Habitat Quantity • Change in Habitat Use	• Investigate use in-water sediment control measures • Fish habitat compensation • Proper disposal site selection	1	1	2/1	R	2
Platform Tow-out from deepwater site	• ~~Change in Habitat Quality~~ • Change in Habitat Use		1	1	3/6	R	2
Offshore Construction / Installation							
Presence of Safety Zone	• Potential decrease in Mortality	• None required	1	2	3/6	R	2
OLS Installation and Testing	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Efficient installation with minimal seabed disturbance • Fish habitat compensation • Chemical selection management system • Adherence to regulations • Compliance with terms of Section 35(2) *Fisheries Act* Authorization	1	2	5~~2~~/1	R	2
Concrete Mattress Pads / Rock Dumping over OLS Offloading Lines	• Change in Habitat Quantity • Change in Habitat ~~Use~~Quality • Change in Habitat Use • Potential Mortality	• Efficient installation with minimal seabed disturbance • Fish habitat compensation • Compliance with terms of Section 35(2) *Fisheries Act* Authorization	1	2	5~~2~~/1	R	2
Installation of Temporary Moorings	• Change in Habitat Quality • Change in Habitat Use	• Use of best practices, continuous improvement programs and best available technology	1	1	2/1	R	2
Platform Tow-out / Offshore Installation	• ~~Change in Habitat Quantity~~ • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Fish habitat compensation • Compliance with terms of Section 35(2) *Fisheries Act* Authorization	1	4	~~2~~5/6	R	2
Underbase Grouting	• Change in Habitat Quality	• Use of best practices, continuous improvement programs and best available technology	1	1	2/1	R	2
Possible Offshore Solid Ballasting	• Change in Habitat Quality	• None required	1	1	2/1	R	2

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
Placement of Rock Scour Protection on Seafloor around Final Hebron Platform Location	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Use of best practices, continuous improvement programs and best available technology • Compliance with terms of Section 35(2) *Fisheries Act* Authorization • Fish habitat compensation	1	1	5~~2~~/ 1	R	2
~~Hook-up and Commissioning of Hebron Platform~~	• ~~Change in Habitat Quality~~	• ~~Implement chemical selection management system; adherence to regulatory limits with respect to discharges in to marine waters~~	~~1~~	~~1~~	~~2/1~~	~~R~~	~~2~~
Operation of Vessels (supply, support, standby and tow vessels / barges / diving / ROVs)	~~• Change in Habitat Quality~~ • Change in Habitat Use		1	2	3/6	R	2
Lighting	~~• Change in Habitat Quality~~ • Change in Habitat Use		1	1	3/6	R	2
Potential ~~Future Construction Activities~~Expansion Opportunities							
Presence of Safety Zone	• Potential Decrease in Mortality	• None required	1	2	3/6	R	2
Excavated Drill Centre Dredging and Spoils Disposal	• Change in Habitat Quantity ~~• Change in Habitat Quality~~ • Change in Habitat Use • Potential Mortality	• Fish habitat compensation	1	2	2/1	R	2
Installation of Pipeline(s) / Flowline(s) and Testing from Excavated Drill Centre(s) to Platform, plus Concrete Mattresses, Rock Cover, or Other Flowline Insulation	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Efficient installation with minimal seabed disturbance • Fish habitat compensation • Compliance with terms of Section 35(2) *Fisheries Act* Authorization	1	2	5~~2~~/ 1	R	2
Hook-up, Production Testing and Commissioning of Excavated Drill Centres	• Change in Habitat Quality • Change in Habitat Use	• Implement chemical selection management system; adherence to regulatory limits with respect to discharges in to marine waters	1	2	2/2	R	2

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
Surveys (*e.g.*, geophysical, geological, geotechnical, environmental, ROV, diving~~, *etc.*~~)	~~• Change in Habitat Quality~~ • Change in Habitat Use	• Survey equipment and vessels will only use the power required to attain the data, thereby minimizing noise	1	3	2/1	R	2

KEY

Magnitude:
1 = Low: <10 percent of the population or habitat in the Study Area will be affected
2 = Medium: 11 to 25 percent of the population or habitat in the Study Area will be affected
3 = High: >25 percent of the population or habitat in the Study Area will be affected

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

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

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

Reversibility:
R = Reversible
I = Irreversible

Ecological / Socio-economic Context:
1 = Area is relatively pristine or not adversely affected by human activity
2 = Evidence of adverse environmental effects

[A] Where there is more than one potential environmental effect, the evaluation criteria rating is assigned to the environmental effect with the greatest potential for harm

Significant adverse environmental effects on fish and fish habitat from construction and installation activities nearshore and offshore are not likely to occur. Environmental effects are generally low in magnitude, of limited geographic extent and reversible.

7.5.2 Operations and Maintenance

7.5.2.1 Change in Habitat Quantity

~~All~~ The majority of Project environmental effects on habitat quantity occur in the construction phase. As presented in Section 7.5.1.1, a Project-specific Habitat Compensation Strategy and Plan will be developed and implemented to mitigate adverse environmental effects and prevent significant adverse residual environmental effects on marine fish habitat. As part of potential future activities, drilling operations from a MODU at future evacuated drill centres have the potential to have environmental effects on habitat quantity, primarily as a result of the evacuated drill centres and related seafloor infrastructures. Any offshore activities, including future evacuated drill centres and seafloor infrastuctures contained within, may be declared to cause a HADD by DFO and will require a Section 35(2) *Fisheries Act* Authorization; any loss of fish habitat will be fully compensated with the objective to achieve no net loss of productive capacity of fish habitat.

~~During the operations and maintenance phase, the potential environmental effects of the Project on fish habitat quantity will result from the presence of new subsea structures. Primarily, the Hebron Platform and the rock mattress and/or concrete mattress cover over the flowline and OLS will provide new hard substrate habitat to be colonized and perform as an artificial reef. The presence of these structures over an unstable sand and gravel substrate enhances the habitat complexity of the surrounding area and increases localized productivity. The new surfaces will become colonized by sponges, anemones, brittlestars and seastars, which themselves provide habitat for smaller epifaunal and epifloral species. Studies in the North Sea indicate most of the fouling biomass in the upper 50 m is composed of seaweeds, hydroids, soft corals, anemones and mussels. Hydroids, soft corals, anemones and tubeworms are the most common animals below 50 m (Welaptega 1993, in Husky Oil 2000). An artificial reef effect is created shortly after the installation and the structures become a source of food and shelter for several species of fish and shellfish, especially juveniles.~~

7.5.2.2 Change in Habitat Quality

Operational discharges (WBM and cuttings, seawater discharges, storage displacement water, produced water, grey and black water, drains~~, *etc.*~~) could affect fish habitat quality. Potential ~~future developments~~expansion opportunities could include drilling from a MODU at excavated drill centres. The effects of excavated drill centre construction have been discussed in Section 7.5.1.2, but the effects of MODU drilling on fish habitat quality are addressed here.

To mitigate potential environmental effects on water and sediment quality, measures have been included within the Project design so that significant adverse residual environmental effects will likely not occur. Use of best practices, continuous improvement programs and best available technology will be applied if technically and economically feasible and reliable. Results from the EEM programs at Hibernia, White Rose and Terra Nova have confirmed their respective assessment predictions of no significant environmental effect on the marine environment as a result of discharges. These are described in more detail in this section.

Drilling Discharges

Discharge of WBMs and associated cuttings is regulated by the C-NLOPB. WBMs and cuttings do not require treatment prior to discharge (in accordance with the *Offshore Waste Treatment Guidelines* (OWTG) (National Energy Board (NEB) *et al.* 201~~0~~2)). The discharge of WBMs may increase metals such as barium, arsenic, cadmium, copper, lead and zinc in sediments, but these metals are not bioavailable, and thus unlikely to accumulate in benthic species. Elevated levels of metals have been found to 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). Signals of drill muds (*i.e.*, barite) have been detected 5,000 m from Terra Nova (18 production wells) and 8,000 m from Hibernia (32 production wells) (Hurley and Ellis 2004), but not at levels likely to have any biological effect.

From modelling of WBM cutting discharge from 52 wells at the Hebron Platform, thicknesses of 1 to 2 m is estimated within 10 m distance and 10 to 20 cm within 25 m distance. These estimates are based on preliminary analyses which will be updated during FEED and detailed engineering phases. Thicknesses of at least 1 cm are generally confined to within about 50 to 60 m of the GBS. These cuttings near the GBS are almost exclusively the fast-settling pebbles and sand (a very small percentage of the fines will drift for a time and ultimately settle near the GBS) whereas at distances greater than about 50 to 200 m, the deposits will be exclusively fines (see AMEC 2010a).

WBMs are expected to remain in suspension in a thin layer area above the seafloor. 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 (Canadian Association of Petroleum Producers (CAPP 2001a). Although changes in benthic density and diversity from drilling muds have been detected within 1,000 m of drill sites, most of these effects are found within the 50 to 500 m range and are of short duration (Hurley and Ellis 2004). Additives to WBMs are selected for use in accordance with the *Offshore Chemical Selection Guidelines* (National Energy Board NEB *et al.* 2009), 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 (Canadian Association of Petroleum ProducersCAPP 2001a; Hurley and Ellis 2004). There will be no discharge of SBMs from the Hebron Platform during normal operations.

SBM cutting reinjection will be undertaken for Platform drilling as a means of waste reduction. SBM cutting reinjection is not technically feasible for MODU drilling and SBM cuttings will be discharged overboard after treatment in accordance with the OWTG. These estimates are based on preliminary analyses which will be updated during FEED and detailed engineering phases. Thicknesses of at least 1 cm are generally confined to within about 50 to 60 m of the GBS. These cuttings near the GBS are almost exclusively the fast-settling pebbles and sand (a very small percentage of the fines will drift for a time and ultimately settle near the GBS) whereas at distances greater than about 50 to 200 m, the deposits will be exclusively fines (see AMEC 2010).There is potential for SBM and WBM discharge from MODU operations at excavated drill centres during the life of the Project. The effects of SBM drill mud and cuttings release on the Grand Banks has been assessed in the Hibernia environmental assessment (Mobil Oil 1985), White Rose Comprehensive Study and addendum (Husky Oil 2000; 2001), the Terra Nova environmental assessment (Petro Canada 1997), Significant Discovery License (SDL) 1040 Delineation Drilling Screening (Husky and Norsk Hydro 2006) and the Husky exploratory drilling environmental assessments and updates (LGL 2003, 2005a, 2006a, 2007a). Primary literature and industry reports on the effects of drill mud and cuttings have been reviewed in US Minerals Management Service (MMS) (2000), CAPP (2001a, 2001b), 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 environmental 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 environmental 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.

Liquid Discharges

Produced water will be discharged with cooling water, below the summer thermocline depth. Produced water (see Section 2.6.4.3) discharges may induce flocculation that could concentrate and transport metal and organic compounds contained in formation water to the benthos. The temperature of the produced water discharge will be approximately 70°C and below the summer thermocline, which occurs between 20 and 30 m from the surface (see Chapter 3). Storage displacement water will also be discharged below the thermocline, at a temperature of approximately 30°C. Temperature of the liquid discharge will reach ambient within meters of the discharge point.

Based on preliminary analyses to be updated during FEED and detailed engineering phases, at a modelled produced water discharge elevation of 35 m, the plume reaches the bottom. A dilution factor of 300 is achieved within a horizontal distance of 139 m (in August) to 171 m (in February) (AMEC 2010a). At a discharge rate of 56,000 m^3/day, a dilution factor of 300 is reached within a horizontal distance of 379 m in February under average current conditions, and within a distance of 676 m under low ambient current conditions. In August, the dilution factor of 300 is reached at distances of 74 m under average current speeds and out to 352 m under low current speeds (AMEC 2010).

For storage displacement water, the modelling shows that under all ambient conditions that can typically be expected in the Project Area, an oil concentration criteria of 0.1 ppm can be achieved within a distance of 200 m, but will be unlikely to rise near the ocean surface (AMEC 2010a).

Sensitivity analyses indicate that increasing the discharge elevation has little effect on dilution, and reducing the discharge temperature has only limited effect on dilution.

Effects resulting from the discharge of produced water are expected to be undetectable further than 500 m from the Hebron Platform. Within 500 m, Querbach *et al.* (2005) quantified these potential effects of chronic and acute exposure to produced water from an offshore oil production facility on some commonly found marine organisms. They concluded that survival, growth and fertilization success of the species in question (haddock, lobster and sea scallop) were all reduced. The assessed levels of exposure were also shown to have negative effects on the physical condition of a species of diatom, *Thalassiosira pseudonana*. The early planktonic life stages of fish, as well as phytoplankton and zooplankton, are particularly sensitive to contaminants due to the inability of these organisms to move from areas of contamination. However, the proportion of the total population that is exposed to these routine discharges is very small and indistinguishable from the high rate of natural mortality.

Operational discharges will be dispersed rapidly and planktonic organisms will be exposed to continuously diminishing concentrations of produced water as they drift away from the source. Experiments on the toxicity of produced water on snow crab larvae indicate that produced water has a very low toxicity potential (J. Payne, pers. comm., in Jacques Whitford 2005). Somerville *et al.* (1987) found that cod and herring larvae and phytoplankton appear to be unaffected by produced water. Both PAHs and phenols have been detected at very low concentrations in marine bivalves attached to legs of offshore Gulf of Mexico platforms; all concentrations were well below the marine acute criteria and there appears to be little net bioaccumulation in fish species that may prey on biofouling organisms (Neff 2002).

The two primary components of produced water that are of environmental concern are the aromatic hydrocarbons (or the benzene, toluene, ethylbenzene and xylene (BTEX) fraction of total petroleum hydrocarbons (TPH) analyses) and PAHs. BTEX is soluble in seawater and highly toxic to marine organisms. However, there is minimal exposure risk to marine organisms given the rapid loss due to evaporation, adsorption and sedimentation, biodegradation and photolysis (Johnsen *et al.* 2004). PAHs are less soluble but more persistent in the environment (Holdway and Heggie 2000) and the associated toxicity to marine organisms are primarily related to benzene and naphthalene fractions (Brand *et al.* 1989, in Holdway and Heggie 2000).

Naphthalene fractions are rapidly degraded in the water column (Johnsen *et al.* 2004). Low-molecular weight PAHs are the dominant fraction of produced water; these fractions degrade more readily than the high-molecular PAH fractions, which generally have a more specific toxicological nature, potentially interacting with cellular protein and DNA (Neff 2002; Johnsen *et al.* 2004). However, their concentrations in a produced water plume are very low due to the rapid dilution following discharge, and are rarely at levels high enough to cause toxic effects in marine plants and animals (Neff 2002; Johnsen *et al.* 2004).

Concentrations of phenols (and alkylated phenols) in produced water declines rapidly due to dilution, evaporation and bio- and photo-degradation with distance from a discharge point (Neff 2002). The solubility of phenols is very low in sea water, with concentrations often below detection limits; however, concern remains about their potential to disrupt reproduction when the degree of alkylation is increased (Johnsen *et al.* 2004). Laboratory-based studies on uptake of alkylated phenols in fish species have indicated that there is uptake in fish within 100 to 1,000 m of a discharge point, located primarily in the gastro-intestinal tract; and that the fish excreted the alkylated phenols (and all other associated compounds) via bile to background levels within 24 to 48 hours (Sundt and Baussant 2003).

The expected amount of toxic and/or carcinogenic forms of PAHs and alkylated phenols in a produced water plume are generally below detection limits or at very low concentrations (Neff 2002). Produced water discharge will be treated to meet the oil in water limits stipulated in the OWTG (National Energy BoardNEB *et al.* 201002). The feasibility of produced water re-injection is being investigated during FEED studies.

Grey and black water (see Table 2-10) produced on the Hebron Platform will be treated as per the OWTG (NEB *et al.* 2010). Black water or sewage will be macerated to 6 mm particle size or less prior to discharge. Organic matter associated with discharges will disperse quickly in an open ocean environment and degraded by bacteria. Any biocides used will be screened in accordance with an approved and established chemical management system.

All liquid wastes discharges from the Hebron Project drilling and production operations will be discharged in accordance with the OWTG.All liquid discharges will adhere to the OWTG discharge limits and are subject to an Offshore Chemical Management System screening. Discharges limits are based on best available technologies and are the focus of continuous improvement programs. Where practicable, use of technology to reduce discharge limits below those in the OWTG will be implemented.

7.5.2.3 Change in Habitat Use

During the Hebron Project operations and maintenance phase, there is potential for noise generated by geophysical surveys, dredging, vessel traffic, and drilling and maintenance activities (diving , ROV), all of which could affect fish habitat use. The environmental effect of noise from geophysical surveys and vessel traffic was discussed in Section 7.5.1.2 as a construction phase activity. To mitigate these environmental effects, measures have been included within the Project design so that significant residualadverse residual significant environmental effects will likely not occur. These mitigation measures include noise control and application of standard seismic mitigation measures, more specifically those mitigation measures referenced within the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* (C-NLOPB 2011).

A semi-submersible drill rig produces a broad band noise level at approximately 154 dB re 1 μPa (Richardson *et al.* 1995), which would be reflective of the MODU drilling for potential development of excavated drill centres in the future. Drilling noise from the Hebron Platform is expected to be less, given that the drill rig is inside the Hebron Platform. For comparison, noise from a drillship is emitted at a range between 174 and 185 dB re 1 μPa, a dredge vessel at 187 dB re 1 μPa and a large tanker can emit noise at approximately 186 dB re 1 μPa (Richardson *et al.* 1995).

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 environmental effects on individuals and populations. Behavioural effects of noise on benthic invertebrates, such as crab, are not well documented. Few invertebrates have gas-filled spaces, and therefore, are less likely to be affected by underwater noise, as are fish.

There is some evidence that lights on the water may attract some fish species. Operational lights used in or near the marine environment may affect pelagic migratory fish species. Studies from the Pacific Coast report changes in juvenile herring and sand lance distribution at night, in artificially lighted areas (Nightingale and Simenstad 2002). Predators of these species may also have been attracted by the increase in juveniles under the lights (Nightingale and Simenstad 2002). Lights are also known to attract squid, if they are present in the area. 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 have active swimming ability.

The artificial reef effect created by subsea structures may attract nearby fish and shellfish to feed or for shelter. The rock mattress used to cover the OLS is not expected to pose an obstacle to the movement of snow crab.

7.5.2.4 Potential Mortality

Operational discharges of WBMs may result in mortality of shellfish, whereas the presence of a Safety Zone may actually decrease the mortality rate. To mitigate adverse environmental effects, measures have been included within the Project design so that significant adverse residual significant environmental effects will likely not occur. These measures include standard blasting control measures and the application of standard seismic mitigation measures. These are described in more detail in Section 7.5.1.2 and in this section.

Shellfish such as scallops will be smothered within a 50 m radius of the WBM discharge, whereas infauna such as clams are burrowing species and can be expected to resurface from a covering of several centimetres (Husky and Norsk Hydro 2006; Fredette and French 2004; Maurer *et al.* 1980). Based upon the published literature (reviewed in Husky 2000, 2001; LGL 2005a, 2006b; US 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).

In the case of potential MODU drilling, WBMs and treated SBMs will be released. Due to a larger average size and discharge rate, SBM cuttings stay closer to the well site and do not disperse as widely as WBMs and cuttings (CAPP 2001). SBM cuttings do not tend to disperse like WBM cuttings do unless the fluid retention values are below 5 percent (Getliff *et al.* 1997; CAPP 2001a). Due to the fact that SBM related particles are not water miscible, they tend to aggregate, resulting in rapid fall velocities (CAPP 2001a). Due to the rapid fall velocity, SBMs tend to fall through the water column faster, be deposited in smaller areas, and to accumulate in higher concentrations near the discharge point than would WBM cuttings (CAPP 2001a; Sayle *et al.* 2002; CAS International 2004; Jacques Whitford Stantec Limited 2009). Fine suspended solids associated with WBMs are not trapped in agglomerations like fines associated with SBMs (CAPP 2001a). This allows these WBMs fines to disperse in the marine environment and travel farther than fines in SBMs before contacting the seabed (CAPP 2001a; Sayle *et al.* 2002; JWSL 2009). For MODU-based drilling, the discharge of SBM cuttings will be in accordance with the OWTG (NEB *et al.* 2010). No additional 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.

Implementation of a Safety Zone around the Hebron Platform, OLS and flowlines could have a minor positive effect by creating an artificial reef and provide food and shelter to benthic species. The Safety Zone may act as refuge for some species and decrease mortality rates.

The effects of geophysical, seismic, geohazard and geotechnical have been assessed as a construction activity.

The environmental effect of the Project during the operations and maintenance phase and the mitigation to be implemented are summarized in Table 7-12.

Table 7-12 Environmental Effects Assessment: Operations and Maintenance

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
Presence of Safety Zone	• Potential Decrease in Mortality	• None required	1	2	5/6	R	2
Presence of Structures	• ~~Change in Habitat Quanity~~ • Change in Habitat Quality • Change in Habitat Use	• Minor positive reef effect, no mitigation required	1	1	5/6	R	2
Lighting	• Change in Habitat Use		1	1	5/6	R	2
Maintenance Activities (*e.g.*, diving, ROV~~, *etc.*~~)	• Change in Habitat Use	• Use of best practices, continous improvement programs	1	1	5/3	R	2
Wastewater (produced water, cooling water, storage displacement water~~, *etc.*~~)	• Change in Habitat Quality • ~~Change in Habitat Use~~	• Use of best practices, continuous improvement programs • Adherence to discharge limits as per OWTG	1	2	5/6	R	2
Chemical Use / Management / Storage (*e.g.*, corrosion inhibitors, well treatment fluids~~, *etc.*~~)	• Change in Habitat Quality • ~~Change in Habitat Use~~	• Use of best practices, continuous improvement programs • chemical management system for screening of chemicals	1	2	5/6	R	2
Well Activities (well completions, work overs~~, *etc.*~~)	• Change in Habitat Quality • ~~Change in Habitat Use~~	• Use of best practices, continuous improvement programs and best available technology	1	1	5/2	R	2
WBM Cuttings	• ~~Change in Habitat Quantity~~ • Change in Habitat Quality • ~~Change in Habitat Use~~ • Potential Mortality	• Re-use of drill mud	1	2	5/2	R	2
Operation of Vessels (supply, support, standby and tow vessels/shuttle tankers / barges / ROVs)	• Change in Habitat Use		1	1	5/6	R	2
Surveys (*e.g.*, geophysical, 2D / 3D / 4D seismic, VSP, geohazard, geological, geotechnical, environmental, ROV, diving~~, *etc.*~~)	• Change in Habitat Quality • Change in Habitat Use • ~~Potential Mortality~~	• Adhere to the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines*~~Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment~~ (C-NLOPB 201~~08~~1)	1	3	3/2	R	2
Potential ~~Future Operational Activities~~Expansion Opportunities							
Presence of Safety Zone	• Potential decrease in Mortality	• None required	1	2	5/6	R	2

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
Presence of Structures	• ~~Change in Habitat Quanity~~ • Change in Habitat Quality • Change in Habitat Use	• Minor positive reef effect, no mitigation required	1	1	5/6	R	2
Drilling Operations from MODU at Future Excavated Drill Centres	• Change in Habitat Quanity • Change in Habitat Quality • Change in Habitat Use		1	1	3/6	R	2
WBM and SBM Cuttings	• ~~Change in Habitat Quanity~~ • Change in Habitat Quality • ~~Change in Habitat Use~~ • Potential Mortality	• Use of best practices, continuous improvement programs • Adherence to OWTG	1	2	5/6	R	2
Chemical Use and Management (BOP fluids, well treatment fluids, corrision inhibitors~~, etc.~~)	• Change in Habitat Quality • ~~Change in Habitat Use~~	• Use of best practices, continuous improvement programs • Chemical management system for screening of chemicals	1	1	5/6	R	2
Geophysical / Seismic Surveys	• Change in Habitat Quality • Change in Habitat Use • ~~Potential Mortality~~	• Adhere to the *Geophysical, Geological, Environmental and Geotechnical Program Guidelines* ~~Statement of Canadian Practice on Mitigation of Seismic Noise in the Marine Environment~~ (C-NLOPB 2011~~08~~)	1	3	3/2	R	2

KEY

Magnitude:

1 = Low: <10 percent of the population or habitat in the Study Area will be affected

2 = Medium: 11 to 25 percent of the population or habitat in the Study Area will be affected

3 = High: >25 percent of the population or habitat in the Study Area will be affected

Geographic Extent:

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

Duration:
1 = < 1 month
2 = 1-12 months.
3 = 13-36 months
4 = 37-72 months
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Frequency:

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

Reversibility:
R = Reversible
I = Irreversible

Ecological / Socio-economic Context:
1 = Area is relatively pristine or not adversely affected by human activity
2 = Evidence of adverse environmental effects

[A] Where there is more than one potential environmental effect, the evaluation criteria rating is assigned to the environmental effect with the greatest potential for harm

Operations and maintenance activities are not likely to result in any significant adverse environmental effects on Fish and Fish Habitat. Environmental effects are generally low in magnitude, limited in geographic extent and reversible. The presence of ~~structures and~~ Safety Zones will create ~~reef and~~ refuge effects~~, respectively~~. Results from the EEM programs at Hibernia, White Rose and Terra Nova have confirmed the respective assessment predictions of no significant environmental effect on the marine environment for those production projects.

7.5.3 Offshore Decommissioning and Abandonment

The Operator will decommission and abandon the Hebron production facility according to regulatory requirements in place at the time of end of Project life. The GBS infrastructure will be decommissioned and the wells will be plugged and abandoned. The GBS structure will be designed for removal at the end of its useful life, although the decision as to whether this will be required will be made at that time. The decision to remove or abandon in place the pipeline and other subsea equipment will be made after a thorough analysis and in compliance with all applicable regulations. The use of best practices and continuous improvement programs will be inplementated at that time as mitigation measures for removal of Hebron Platform and OLS loading points, plugging and abandoning wells, and abandoning the OLS pipeline.

7.5.3.1 Change in Habitat Quantity

The possible removal of offshore subsea infrastructure during Project decommissioning and abandonment may affect the quantity of fish habitat in the Offshore Project Area; however, the effects of habitat quantity will be of less magnitude and geographic extent than during Project construction (see Section 7.5.1.1). The possible removal of the Hebron Platform, rock and/or concrete mattress cover over the OLS and or flowlines, will remove the reef and refuge effect that these structures had created.

7.5.3.2 Change in Habitat Quality

Project decommissioning and abandonment activities may affect fish habitat quality during the possible removal of subsea structures through vessel noise (associated with the operations of vessels including supply, support, tow vessels, barges) and suspended sediments. In addition, noise maybe associated with surveys (geophysical, VSP, geohazard, geological, environmental, ROV, diving) that may be required or undertaken as apart of the decommissioning and abandonmernt activities. The environmental effects of these activities are expected to be similar in nature to those of construction, but of less magnitude and geographic extent. Potential effects of noise and suspended sediments on fish habitat quality are discussed in Section 7.5.1.2.

7.5.3.3 Change in Habitat Use

Project decommissioning and abandonment activities could affect the behaviour of fish and invertebrates and therefore habitat use. The noise and underwater activity required during possible removal of subsea structures (*e.g.*, OLS, flowlines and wellhead) will be similar in nature to those of construction, but of less magnitude and geographic extent. Potential effects of noise and underwater activity on fish habitat use are discussed in Section 7.5.1.3.

7.5.3.4 Potential Mortality

Project decommissioning and abandonment activities have the potential to cause mortality of fish and shellfish during the possible removal of subsea structures (including the Hebron Platform abnd OLS loading points, if they are removed). Activities will be similar in nature to those of construction, but of less magnitude and geographic extent. Potential for underwater construction activity to cause mortality of fish and shellfish is discussed in Section 7.5.1.4.

A minor negative environmental effect could result from the removal of a Safety Zone around the Hebron Platform, OLS and flowlines. The refuge effect created by the Safety Zone for some species will be removed upon Project decommissioning and abandonment.

The environmental effect of the Project during the decommissioning and abandonment Phase and the mitigation to be implemented are summarized in Table 7-13. Where there is more than one potential environmental effect, the evaluation criteria rating is assigned to the environmental effect with the greatest potential for harm.

Table 7-13 Environmental Effects Assessment: Decommissioning and Abandonment

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
Presence of Safety Zone	• Potential Mortality		1	2	3/6	R	2
Removal of the Hebron Platform and OLS Loading Points	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Use of best practices, continous improvement programs	1	2	2/1	R	2
Lighting	• Change in Habitat Use		1	1	3/5	R	2
Plugging and Abandoning Wells	• Change in Habitat Quality • Change in Habitat Use	• Use of best practices, continous improvement programs	1	1	3/2	R	2
Abandoning the OLS Pipeline	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use	• Use of best practices, continous improvement programs	1	2	3/1	R	2
Operation of Vessels (supply, support, standby and tow vessels / barges / ROVs)	• Change in Habitat Quantity • Change in Habitat Use		1	3	3/6	R	2
Surveys (Geophysical, Geological, Geotechnical, Environmental, ROV, Diving~~, etc.~~	• Change in Habitat Quality • Change in Habitat Use • ~~Potential Mortality~~		1	2	3/2	R	2

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context

KEY

Magnitude:

1 = Low: <10 percent of the population or habitat in the Study Area will be affected

2 = Medium: 11 to 25 percent of the population or habitat in the Study Area will be affected

3 = High: >25 percent of the population or habitat in the Study Area will be affected

Geographic Extent:

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

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

Frequency:

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

Reversibility:
R = Reversible
I = Irreversible

Ecological / Socio-economic Context:
1 = Area is relatively pristine or not adversely affected by human activity
2 = Evidence of adverse environmental effects

[A] Where there is more than one potential environmental effect, the evaluation criteria rating is assigned to the environmental effect with the greatest potential for harm

Decommissioning and abandonment activities are not likely to result in any significant adverse environmental effects on fish and fish habitat. Environmental effects are generally low in magnitude, limited in geographic extent and reversible.

7.5.4 Accidents Malfunctions and Unplanned Events

The potential environmental effects from ~~spill~~ accidental events on fish and fish habitat in the Nearshore and Offshore Study Areas are assessed together under each environmental effect category.

The type and probability of various types of accidental events involving hydrocarbons~~spill~~ in the offshore is discussed in Chapter 14, as well as modelling results for oil spill trajectory in the nearshore and offshore. The complete modelling reports are provided as ~~AMEC~~ ASA 2011a, 2011~~0~~b.

Spill prevention will be incorporated into the design and operations of the Hebron Project. All offshore systems and structures, procedures and programs will be designed with consideration of preventing the loss of any hydrocarbons or chemicals. Examples of measures to reduce the likelihood of an accidental event involving a hydrocarbon release ~~oil spills~~ include equipment and facility design, routine maintenance and testing for all aspects of the production program, the use of good communications and sound marine practices, regular inspections and audits of the offshore structures, and employee awareness training. ~~ExxonMobil Canada Properties (~~EMCP~~)~~ will also undertake all of the necessary planning, training, and exercising to ensure that the appropriate spill response capability is in place for all phases of the Project, in the unlikely event of an accidental event resulting in a hydrocarbon release. Oil Spill Response is included as part of the contingency planning undertaken for the Project.

Additional mitigation measures to reduce the potential occurrence of an accidental event include:

- o Ship operations will adhere to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78);
- o Ice management plan; and
- o Adherence with all standard navigation procedures, Canadian Coast Guard requirements and navigation systems.

7.5.4.1 Change in Habitat Quantity

The quantity of fish habitat would not be expected to be affected due to an accidental event (nearshore spill, failure or spill from the OLS, subsea blowout, crude oil surface spill, marine vessel incident, or collision) resulting in hydrocarbon releasesrelease of hydrocarbons in the nearshore or the offshore. In the nearshore, an accidental event resulting in the release of diesel resulting from a collision or grounding of a construction vessel or barge is the most credible scenario. An accidental event resulting in diesel spill releases on the surface of the water would not likely affect the quantity of habitat, given its properties of evaporation and dispersion (see AMEC ASA 20110ab). In the offshore, a spill of crude oil (failure or spill from OLS, subsea blowout, or crude oil surface spill) would dissipate through a variety of different process including evaporation as well would have the potential to form tar balls (Iliffe and Knap 1979; Ramamurthy 1991; NRC 2003). Tar balls may be transported long distances from source and concentrating in convergence zones or shorelines (NRC 2003). The actual fate of the tar balls will be dependent upon their specific gravities, which are influenced by the amount of sediment and other extraneous materials incorporated into the tar balls. Tar balls and the PAHs associated with them have low bioavailability (Gustafsson *et al.* 1997; Baumard *et al.* 1999). The quantity of fish habitat that may be affected by an accidental event would be examined as part of an environmental effects monitoring program in the event of an accidental event.In the offshore, a spill of crude oil would dissipate through evaporation as well, but would have potential to form tar balls and sink to the sea floor. In any case, the quantity of fish habitat affected by an accidental event resulting in a hydrocarbon releasespill would be negligible.

An accidental event (other spills) resulting in the release of cuttings and muds (WBMs and/or SBMs) would form a small component and would be contained within of the cuttings footprint discussed in Section 7.5.1.2above.

7.5.4.2 Change in Habitat Quality

The quality of fish habitat could potentially be affected by an accidental event resulting in the release of hydrocarbons (nearshore spill, failure or spill from OLS, subsea blowout, crude oil surface spill, marine vessel incident, or collisions),or chemicals (other spills) or a bund wall rupture in the Nearshore or Offshore Study Areas.

Environmental effects of an accidental event involving the release of hydrocarbons (from nearshore spill, failure or spill from OLS, subsea blowout, crude oil surface spill, marine vessel incident, or collisions)oil spills on plankton would be short-lived, although 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) found that zooplankton densities declined near an accidental event that resulted in a release of hydrocarbonsspill but rebounded within five days. Data from the *Prestige* oil spill did 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). The capability of both phytoplankton and zooplankton to metabolize hydrocarbons would reduce the environmental effects on the pelagic ecosystem. Fish would accumulate hydrocarbons if they eat contaminated zooplankton, but they are also able to metabolize hydrocarbons, so there is no potential for biomagnification.

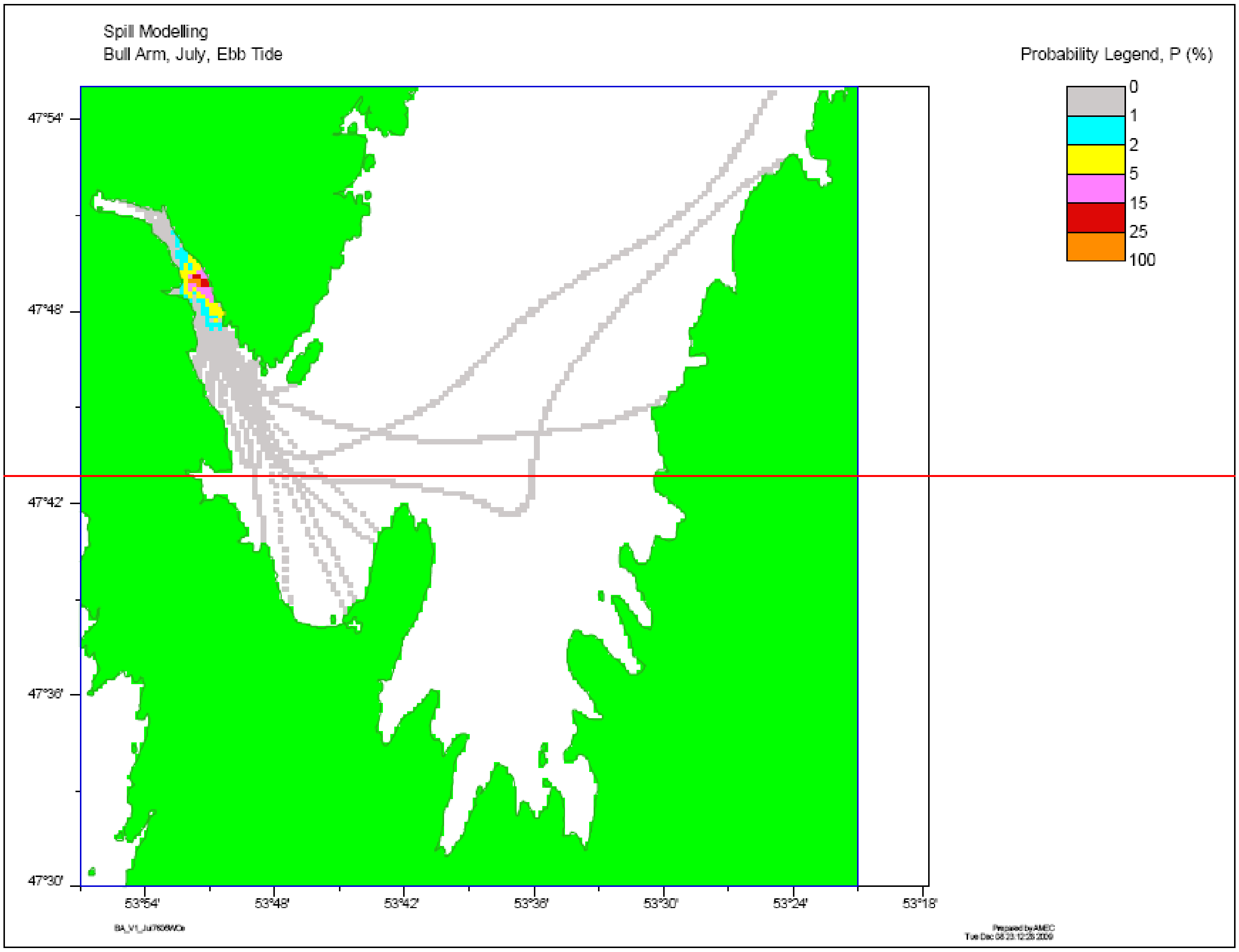
The environmental effects of an accidental event resulting in the release of hydrocarbons spill on invertebrates and invertebrate habitat (from nearshore spill, failure or spill from OLS, subsea blowout, crude oil surface spill, marine vessel incident, or collisions) are determined by factors such as 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. When small spills of diesel are stranded on shorelines, the diesel will penetrate porous sediments, but are quickly washed by wave action and tidal flushing.

The benthic community would be at most risk from an accidental event involving the release of hydrocarbons as a result of a blowout (subsea or crude oil surface spill). Oil from a blowout 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 accidental events resulting from a release of hydrocarbons 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).

When compared to an accidental event involving the relase of crude (failure or spill from OLS, subsea blowout, or crude oil surface spill), the nature of diesel fuel (marine vessel incident or collision) is such that it evaporates from the surface relatively quickly and does not persist in the environment for any length of time (National Oceanic and Atmospheric Administration 2006). Diesel has a low viscosity and is readily dispersed within the water column when winds reach approximately 9 to 13 km/h (5 to 7 knots) or with breaking waves. It is possible for diesel to be dispersed by wave action and may form droplets that are kept in suspension and move with currents. Diesel may also be restricted from dispersion and evaporation by sea ice and therefore maintain its toxic potential. An accidental event resulting in a hydrocarbon releasespill in Bull Arm (marine vessel incident) during the ice season would have a localized effect on productivity. Microalgae grow on the undersurface of sea ice and can account for up to 30 percent of the annual productivity in the water column (Clark and Finley 1982).

Egg and larval stages would be more subject to physiological effects from an accidental event involving a release of hydrocarbons (nearshore spill, failure or spill from OLS, subsea blowout, crude oil surface spill, marine vessel incident, or collisions), crude or diesel 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 (see Section 7.5.4.4).

~~Given the potential spill scenarios within the Nearshore and Offshore Study Areas (see Sections 14.2 and 14.3, respectively), there is more potential for diesel to interact with the benthic community than crude oil.~~ In the unlikely event of an accidental event resulting in a release of diesel ~~spill~~ from a vessel or barge accident in the nearshore, diesel could reach the shoreline of the Nearshore Study Area (Figure 7-16~~3~~). Diesel has been found to have an immediate toxic effect on many intertidal organisms, including periwinkles, limpets, gastropods, amphipods and other potential prey of fish and shellfish (Pople *et al.* 1990; Stirling 1977; Wormald 1976; Cripps and Shears 1997; Kennicutt *et al.* 1991).



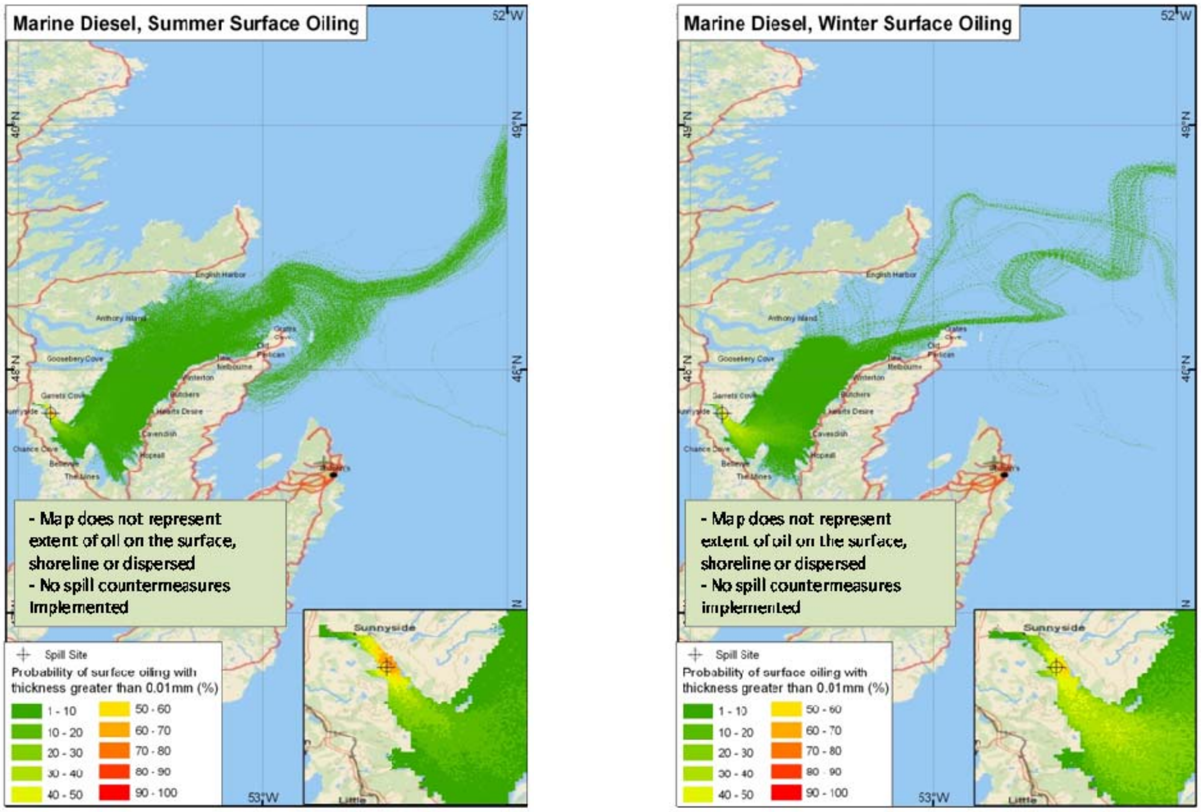


Figure 7-16~~-13~~ ~~Diesel Spill~~ Probability ~~Plot~~ of Surface Contact from a Release of 100 m^3 of Marine Diesel in the Nearshore Study Area in Summaer (left) and Winter (right)

Another potential accidental event~~spill~~ scenario is the failure of the SBM handling system during potential future MODU drilling resulting in the release of SBMs (other spills). There are few studies that focus on the fate and effects of an accidental event resulting in the release~~release~~ of drilling muds and fluids (US Minerals Management Service 2004b; Canada-Nova Scotia Offshore Petroleum Board 2005). Drilling fluids and muds are known for their degradation under certain environmental conditions. The rate of biodegradation is dictated by temperature, hydrostatic pressure and oxygen levels. Smothering of potential food sources for fish and shellfish may occur due to the weight of the barite where the SBM collects in a layer of 1 cm or more (Bakke *et al.* 1989), in particular in areas where sediment unevenness may permit pooling of the SBM. The SBM would likely be confined to the sediment-water interface and would not likely be incorporated into the sediment as would be the case with cuttings. Marine fauna that depend on this interface for food or that are non-tolerant to the SBM would be most affected. Another potential environmental effect would be reduced recruitment caused by habitat selection in settling invertebrate larvae.

Biological effects are usually not detectable outside 500 m (Hurley and Ellis 2004), but may occur to a distance of 1,000 m (Olsgård and Gray 1995). At concentrations of 1.5 mg/L, ParaDrill IA appears to have caused weight loss in sea scallop somatic and reproductive tissues; however, the effects were reversed after exposure ceased (Armsworthy *et al.* 2005). Bioaccumulation of PAHs from ParaDrill IA particulate can occur in scallop, depending on the concentration, suspended particulate matter and feeding rate of the scallop. The sea scallop is one of the most sensitive species to drilling waste in that low PAH levels of 0.05 to 2.0 mg/L have been shown to affect growth and reproduction (Cranford *et al.* 2005). These effects likely result from physical effects, since SBMs are non-toxic. These effects are caused by the physical properties of the SBMs and WBMs, as fine particles of bentonite and barite interfere with digestion and feeding of scallops (Armsworthy *et al.* 2005) and possibly other bivalve species (Barlow and Kingston 2001).

A bund wall rupture that has the potential to result in change in habitat quality as a result of increased suspended sediment and contamination. A varietry of construction activities will be ongoing behind the bund wall such that a bund wall rupture could result in a immediate release of suspended solids, chemicals and hydrocarbons carried into Bull Arm as the water breaches the bund wall. The environmental effects of suspended solids and contamination have been discussed in Section 7.5.1.2 and would also apply to this accidental event scenario.

7.5.4.3 Change in Habitat Use

An accidental event (including bund wall rupture, nearshore spill, failure or spill from OLS, subsea blowout, crude oil spill, other spills, marine vessel incident or collisions) in the Nearshore or Offshore Study areas could cause a change in fish behaviour and thus affect use of a particular habitat. Juvenile and adult finfish have been known to avoid areas of oiled sediment (Irwin *et al.* 1998). Less mobile invertebrates could not so easily avoid the oil. The ability of fish to avoid an oiled area must be considered within the context of their habitat requirements. Presumably, if fish were avoiding an area, they would seek the next clean area of similar habitat. The habitat seeking behaviour may have consequences on the mortality rates of juvenile fish and shellfish through predation and on the success of foraging of all life stages, if alternate habitats are not readily available. However, alternate habitats are available for both the Nearshore and Offshore Study areas and changes in behaviour not likely to have further consequences.

An accidental release of drill muds (most likely accidental event scenario) and other related production chemicals from the MODU or Hebron Platform could result in a change in habitat use primarily as a result of potential reduced recruitment caused by habitat selection in settling invertebrate larvae or other physical-related effects, as SBMs are non-toxic. The footprint of such an accidental event would be limited to near the Hebron Platform (where the accidental event would occur) and would be contained within the footprint of the WBMs and most likely limited to 500 m. Additional information on the environmental effects of SBMs are discussed in Sections 7.5.2.2, 7.5.2.4 and 7.5.4.2.

7.5.4.4 Potential Mortality

In the unlikely event of a rupture in the bund wall, mortality of fish and shellfish in the immediate area could result. Depending on the rate of collapse of the bund wall, some fish and shellfish near the rupture point could be entrained in the surge of water into the drydock area. Fish and mobile shellfish outside the immediate entrainment area would likely avoid the risk.

In the unlikely event of an accidental event involving a release of hydrocarbons or chemicals ~~spill~~, lethal effects on eggs and larvae are more likely to occur during an accidental event resulting in a release of hydrocarbons or chemicals~~oil spill~~ than adult fish mortality. Eggs and larvae tend to congregate in the upper water column where they could be directly exposed if they occur at the same time and in the same space as an the accidental event resulting in a release of hydrocarbons or chemicals (other spills)~~oil spill~~. Also, fish eggs and larvae are more vulnerable to hydrocarbons since they have not yet developed any detoxification mechanisms, and cannot actively avoid the area of the accidental event~~spill~~. Fish eggs generally appear to be highly sensitive to ~~oil~~ hydrocarbon 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 hydrocarbon~~oil~~ exhibiting morphological malformations, genetic damage and reduced growth. Embryo damage may not be apparent until the larvae hatch (Kühnhold 1974).

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 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).

The accidental release of SBMs or WBMs (other spills) would result in smothering of benthic organisms due to the weight of the barite where the SBM / WBM collects in a layer of 1 cm or more (Bakke *et al.* 1989), in particular, in areas where sediment unevenness may permit pooling of the SBM / WBM.

The spatial extent of an accidental event resulting in the release of hydrocarbons or chemicals (other spills) in the nearshore and offshore is highly variable depending on the nature of the ~~spill~~ accidental event and the weather conditions immediately after the ~~spill~~accidental event. A summary of those scenarios is presented in Sections 14.2 and 14.3, and ~~a~~ complete spill modelling reports are~~is~~ provided in ~~AMEC 2010b~~ASA (2011a, 2011b).

The environmental effect of the potential accidental events and the mitigation to further reduce the likelihood of occurrence and potential effects is summarized in Table 7-14.

Table 7-14 Environmental Effects Assessment: Accidental Events

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
Bund Wall Rupture	• Change in Habitat Quality • Change in Habitat Use • Potential Fish Mortality	• Prevention through design standards and maintenance	1	1	1/1	R	2
Nearshore Spill	• Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Emergency Response Contingency Plan • Spill Response Plan	~~1~~3	~~3~~4	2/1	R	2

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context
Failure or Spill from OLS	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Prevention through design standards and maintenance • Emergency Response Contingency Plan • Spill Response Plan	1	5	2/1	R	2
Subsea Blowout	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Prevention through design standards and maintenance • Emergency Response Contingency Plan • Spill Response Plan	2	5	3/1	R	2
Crude Oil Surface Spill	• Change in Habitat Quantity • Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Emergency Response Contingency Plan • Spill Response Plan • Prevention through design standards and maintenance	1	5	2/1	R	2
Other Spills (fuel, chemicals, drilling muds or waste materials on the drilling unit, GBS, Hebron Platform)	• Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Emergency Response Contingency Plan • Spill Response Plan	1	1	2/1	R	2
Marine Vessel Incident (*i.e.*, fuel spills)	• Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Emergency Response Contingency Plan • Spill Response Plan • Ship operations will adhere to Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)	1	5	2/1	R	2
Collisions (involving Hebron Platform, vessel, and/or iceberg)	• Change in Habitat Quality • Change in Habitat Use • Potential Mortality	• Prevention through design standards and maintenance • Ice Management Plan • Adherence with all standard navigation procedures,Coast Guard requirements and navigation systems	1	3	2/1	R	2

Project Activity	Potential Environmental Effect	Mitigation	Evaluation Criteria for Assessing Residual Adverse Environmental Effects[A]				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Ecological / Socio-economic Context

KEY

Magnitude:
1 = Low: <10 percent of the population or habitat in the Study Area will be affected

2 = Medium: 11 to 25 percent of the population or habitat in the Study Area will be affected

3 = High: >25 percent of the population or habitat in the Study Area will be affected

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

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

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

Reversibility:
R = Reversible
I = Irreversible

Ecological / Socio-economic Context:
1 = Area is relatively pristine or not adversely affected by human activity
2 = Evidence of adverse environmental effects

[A] Where there is more than one potential environmental effect, the evaluation criteria rating is assigned to the environmental effect with the greatest potential for harm

Due to the reversibility and limited duration of an accidental event, potential environmental effects of a accidental event resulting in the release of~~spill (~~hydrocarbons or chemicals~~)~~, blowout or bund wall rupture on marine fish and fish habitat is considered adverse but not significant and not likely to occur. Natural recruitment is expected to re-establish the population to its original level and avoidance of the area is expected to be temporary should an accidental event occur.

7.5.5 Cumulative Environmental Effects

7.5.5.1 Nearshore

Cumulative environmental effects on marine Fish and Fish Habitat in the Nearshore Study Area could occur as a result of the proposed Project in combination with commercial fisheries, which can contribute to physical disturbance during trawling and noise effects, and marine transportation, which can contribute to contamination and noise effects.

It is unlikely that nearshore routine activities associated with marine transportation would have much adverse direct environmental effects on marine Fish and Fish Habitat within the Nearshore Study Area. There is some recreational marine transportation, but other than commercial fisheries-related transportation, there is little commercial vessel traffic within the Nearshore Study Area. While commercial fisheries have an environmental effect on marine invertebrates and fish through resource exploitation, the current level of commercial fishing activity within the Project Area is limited. The commercial fishery is managed by DFO to maintain fish populations at sustainable levels.

7.5.5.2 Offshore

In the Hebron Offshore Study Area, cumulative environmental effects on marine fish and fish habitat could occur as a result of the proposed Project in combination with the following activities:

- Hibernia Oil Development and Hibernia Southern Extension (drilling and production)
- Terra Nova Development (drilling and production)
- White Rose Oilfield Development and Expansions (drilling and production)
- Offshore exploration drilling activity
- Offshore seismic activity
- Marine Transportation and
- Commercial fisheries

Cumulative environmental effects on marine Fish and Fish Habitat in the Hebron Offshore Study Area could occur as a result of the proposed Project in combination with past, present and future oil and gas activities, which can contribute to physical disturbance, contamination, smothering of benthic organisms and noise effects. Commercial fisheries contribute to physical disturbance during trawling and noise effects, while chronic oil spills by marine transportation contributes to contamination as well as noise effects within the Hebron Offshore Study Area. These industries can interact cumulatively with the Hebron Project to have adverse environmental effects on Fish and Fish Habitat.

As of February 2010, there have been a total of 308 exploration, delineation and development / production wells drilled on the Grand Banks, including 104 exploration wells, 45 delineation wells and 159 development / production wells (C-NLOPB 2010a). As of April 2010, there were 46 SDLs, 24 Exploration Licenses (ELs) and eight Production Licenses active on the Grand Banks (C-NLOPB 2010b). According to the C-NLOPB website, there are two proposed exploratory drilling programs on the Grand Banks. The currently proposed drilling activities are summarized in Table 7-15.

Table 7-15 Proposed Drilling Activity on the Grand Banks

Proponent	Exploration Activity (*e.g.*, wells, seismic surveys)	Location	Timing	Comments
Statoil Canada	Maximum of 27 wells	Jeanne d'Arc Basin Flemish Pass	2008 to 2016	Single and/or dual side-track exploration and appraisal / delineation wells
Suncor	Maximum of 18 wells	Jeanne d'Arc Basin	2009 to 2017	Single and/or dual side-track exploration wells
Husky	Wells	Jeanne d'Arc Basin	2008 to 2017	Eighteen oil and gas targets; combination of vertical and deviated (twin) wells

EEM programs for production facilities in the Newfoundland offshore have demonstrated that the mitigation measures being implemented with respect to marine fish and 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 data from current Canadian EEM programs suggest that benthic community change can be detected within 1,000 m of the drill site, with some habitat types and more sensitive species affected over greater distances, particularly along the axis of predominant current (Hurley and Ellis 2004).

The effects of drill mud and cuttings deposition in the area immediately adjacent to a well lessen considerably one to two 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 re-injection of SBM drill cuttings commenced in March 2000; full re-injection capacity began in September 2002. In the 2002 EEM field study, a substantial reduction in hydrocarbon concentrations in sediment was already observed. The concentration of hydrocarbons was comparable to levels found in 1998 after one year of drilling and concentrations of barium were comparable to 1999 levels, after two years of drilling. The biological effects of drilling are considered reversible.

For the assessment of StatoilHydro Canada Ltd.'s proposed drilling program, LGL (2008b) calculated that for the drilling of up to 45 wells between 2008 and 2017, the total area of seabed potentially covered by at least 1 cm of drill cuttings would be approximately 45 x 0.8 km^2 or 36 km^2 (approximately 0.034 percent of the StatoilHydro Canada project area). The Husky White Rose New Excavated Drill Centre Construction and Operations Program, is proposing up to 54 wells; the total area potentially affected by drill cuttings deposition (without consideration of the potential for overlap) would be 54 x 0.8 km^2 or 43.2 km^2. These two areas combined represent approximately 0.07 percent of their cumulative project areas (LGL 2008b). The Hibernia South Project proposed a maximum of six excavated drill centres each supporting up to 11 wells, resulting in the worst case scenario (*i.e.*, no overlap of cuttings) of 8.8 km^2 of seabed covered by a minimum of 1 cm of drill mud and cuttings (Jacques Whitford 2009). Such is most likely not to be the case and as the cumulative affected area of 8.8 km^2 is an over-estimation. This cumulative area represents less than 1 percent of the Hibernia South project area.

The proposed Hebron Project could have up to 52 wells drilled from the Hebron Platform, with an additional 15 wells that may be drilled from MODUs within the Project Area. As a worst case, if it is assumed that all wells outside the Hebron Platform are separated such that drill cuttings are not re-injected and deposits around each well do not overlap, the result would be 12 km^2 of cuttings deposition around the MODU wells (0.8 km^2 x 15), plus 0.8 km^2 around the Hebron Platform. A total of 12.8 km^2 equals less than 0.5 percent of the Offshore Project Area of approximately 2,560 km^2.

There is a potential cumulative environmental effect from the WBM discharge when considered together with other drilling projects. While it is acknowledged that each production or exploration well is contributing to a cumulative environmental effect on marine fish habitat, each of these projects is affecting a localized area and the environmental effects are reversible. Each of these projects is also required to adhere to the OWTG (~~National Energy Board~~NEB *et al.* 201~~0~~2) and related monitoring requirements.

It is unlikely that routine activities associated with marine transportation have much adverse direct environmental effect on marine Fish and Fish Habitat. However, although commercial fisheries can have an environmental effect on marine Fish and Fish Habitat, the current level of commercial exploitation within the Project Area is very limited and DFO manages the fishery to keep populations at sustainable levels.

All discharges from the Hebron Project will be in accordance with the OWTG (National Energy BoardNEB *et al.* 20102). As general marine vessel discharges are also regulated, it is not predicted that any significant cumulative environmental effects on marine fish habitat would result. Produced water potentially affects the chemistry of the receiving environment within 50 to 500 m from each operating facility (HMDC 2005; Querbach *et al.* 2005), so there will be no additive environmental effect between projects. Pelagic organisms are not likely to be exposed to more than one plume. If fish do move between operation platforms, the ability of fish to metabolize low level hydrocarbons will reduce the potential for chronic effects.

The timing of seismic surveys within and between projects within the Hebron Offshore Study Area are unlikely to overlap. The only known project to coincide with the timing of the Hebron surveys is the Statoil Canada seismic survey of the Jeanne d'Arc Basin (in and near Exploration License (EL) 1100 and EL 1101), and within the Terra Nova Field), which may continue up to 2016. Both the Suncor seismic survey in the Jeanne d'Arc Basin and the EMCP geohazard survey are scheduled for 2010.

The Hibernia South Project anticipated up to six drill centres may be required, and possibly two, 1-km^2 dredge spoil disposal areas, although more may be required. The Hebron Project may require up to four excavated drill centres as part of future developmentpotential expansion opportunity plans. As a conservative assumption, the excavation of each excavated drill centre may require its own dredge spoil area, each approximately 1 km^2. However, it is possible that a dredge spoils disposal area may be used more than once. The total area of the potential HADD has yet to be determined, but EMCP will adhere to the DFO policy of no net loss of the productive capacity of fish habitat from this Project. The spatial and temporal scales of potential environmental effects from dredging, compared to the amount of existing similar habitat on the Grand Banks, the high potential for reversibility and the commitment for habitat compensation, will reduce the cumulative environmental effects from dredging and disposal.

Given that the predicted environmental effect of the proposed Project is not significant, and that other oil and gas activities in the Offshore Project Area are likely to have similar environmental effects on Fish and Fish Habitat, and given the limited nature of commercial fishing in the area, and the temporal and spatial overlap with other projects is limited, the cumulative environmental effects of the Project on Fish and Fish Habitat are predicted to be not significant.

7.5.6 Determination of Significance

The determination of significance is based on the definition provided in Section 7.2. It considers the magnitude, geographic extent, duration, frequency, reversibility, and ecological context of each environmental effect within the Study Area, and their interactions, as presented in the preceding analysis. Significance is determined at the population level within the Study Area.

The significance of potential residual environmental effects, including cumulative environmental effects, resulting from the interaction between Project-related activities and Fish and Fish Habitat, after taking into account any proposed mitigation, is summarized in Table 7-16.

The potential environmental effects of the Project on Fish and Fish Habitat are not considered of sufficient geographic extent, magnitude, duration, frequency and/or reversibility to result in a decline in abundance or change in distribution of a population(s) over more than one generation within the Nearshore and/or Offshore Study Areas. Any potential environmental effects of the Project on marine fish habitat will be mitigated. The potential environmental effects of the Hebron Project on Fish and Fish Habitat are therefore predicted to be not significant.

Table 7-16 Residual Environmental Effects Summary: Fish and Fish Habitat

Phase	Residual Adverse Environmental Effect Rating[A]	Level of Confidence	Probability of Occurrence (Likelihood)
Construction / Installation[B]	NS	3	N/A[D]
Operation and Maintenance	NS	3	N/A
Decommissioning and Abandonment[C]	NS	3	N/A
Accidents, Malfunctions and Unplanned Events	NS	2	N/A
Cumulative Environmental Effects	NS	2	N/A

KEY

Residual Environmental Effects Rating:	Level of Confidence in the Effect Rating:	Probability of Occurrence of Significant Environmental Effect:
S = Significant Adverse Environmental Effect	1 = Low level of Confidence	1 = Low Probability of Occurrence
NS = Not Significant Adverse Environmental Effect	2 = Medium Level of Confidence	2 = Medium Probability of Occurrence
	3 = High level of Confidence	3 = High Probability of Occurrence

[A] As determined in consideration of established residual environmental effects rating criteria.
[B] Includes all Bull Arm activities, engineering, construction, removal of the bund wall, tow-out and installation of the Hebron Platform at the offshore site.
[C] Includes decommissioning and abandonment of the GBS and offshore site.
[D] Effect is not predicted to be significant, therefore the probability of occurrence rating is not required under CEAA

As required by the *Canadian Environmental Assessment Act* (CEAA), an analysis of potential environmental effects to the sustainable use of renewable resources associated with this VEC has been considered. No significant adverse residual environmental effects on Fish and Fish Habitat are predicted that could affect renewable resource use.

7.5.7 Follow-up and Monitoring

The CEAA definition of "follow-up program" is "a program for (a) verifying the accuracy of the environmental assessment of a project, and (b) determining the effectiveness of any measures taken to mitigate the adverse environmental effects of the project". Follow-up programs serve as the primary means to determine and quantify change from routine operations on the receiving environment. Compliance monitoring on its own, does not satisfy the requirements for a follow-up program. Compliance monitoring is conducted to ensure that a project and its activities are meeting the relevant environmental standards, guidelines and regulations. Compliance monitoring will be conducted for the Project in accordance with regulatory requirements.

An environmental protection program may require effects monitoring at Bull Arm during construction. Similarly, if ocean disposal permits are required, EMCP will implement a monitoring program in accordance with the provisions of the Ocean Disposal Permit.

The offshore and nearshore EEM programs that will be designed and implemented for this Project are both considered as follow-up monitoring as defined by CEAA.

EMCP will implement an offshore EEM program that will be designed to determine if activities associated with the Hebron Project, as predicted in this environmental assessment, are affecting the receiving environment. The parameters of the EEM program may include those being monitored by other offshore oil and gas operations (*i.e.*, sediment chemistry, sediment toxicity, water chemistry, fish taint, fish health and body burden). However, the details of the EEM design program will be determined in consultation with regulatory, scientific authorities and other interested stakeholders. An overview of the process that will be followed in the design of the EEM program is provided in Section 15.2.

A fish habitat compensation monitoring program will also be implemented as a follow-up monitoring program once the habitat compensation measures implemented. Details of the compensation monitoring program will be outlined in the Hebron Habitat Compensation Strategy report.