

Section 8

Impact assessment for exploratory and appraisal drilling activities

8 Impact assessment for exploratory and appraisal drilling activities

8.1 Introduction

This section considers the environmental impacts that may arise from the exploration and appraisal drilling activities that may occur following implementation of the licensing round. It addresses those impacts identified during the scoping and assessment process as having the potential to be significant (see Section 6). The assessment takes account of the range of possible scenarios and alternatives within these, and of the potential for cumulative and transboundary impacts.

8.2 Noise generation

8.2.1 Introduction

The issue of seismic survey noise generation is covered in Section 7. In addition, there is concern over the potential impact of sounds produced by drilling activities on cetaceans and other marine animals that may occur in the IOSEA1 area.

This section assesses the potential impacts of noise from drilling wells in the IOSEA1 area. As outlined in Section 4, it will be assumed that each well will be drilled using a semi-sub drilling rig, and that the drilling period will be 50 days. During drilling operations, the rig will be attended continuously by a safety boat. In addition, supply boats and helicopters will visit the rig three times each week for replenishment of equipment and materials.

8.2.2 Noise associated with the proposed operations

Noise generated during drilling operations

Due to the waters depths encountered over most of the IOSEA1 area, it is assumed that an anchored semi-submersible drilling rig will be used. During drilling operations, the rig will produce low-frequency noises. Due to increased surface area in contact with the water, and therefore the increased machinery noise and vibration entering the water column, semi-submersibles and drilling ships are inherently more noisy than fixed platforms (Simmonds *et al*, 2003). If the rig is anchored to the sea bed these sounds are likely to be in the range of 0.016 to 0.2 kHz, with received tonal levels between approximately 167 and 171 dB re 1 μ Pa-m (Richardson *et al*, 1995; Evans & Nice, 1996). Table 7.2 in Section 7.2.1 compares noises produced by drilling activities with those from other maritime activities.

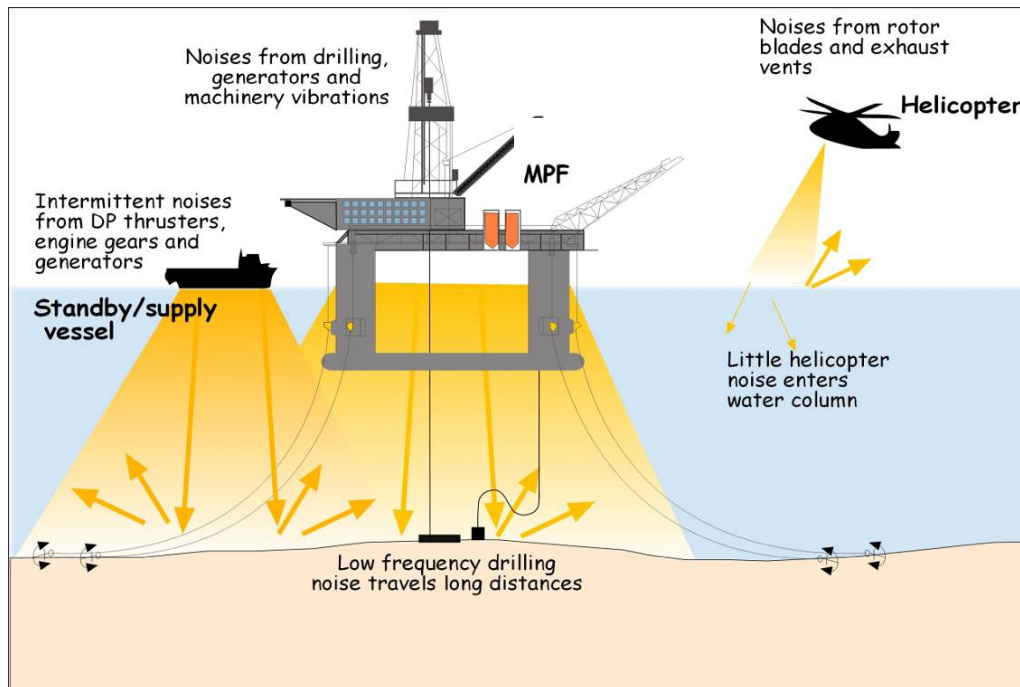
Individual drilling operations will only occur for a short time, usually around 50 days. During these drilling operations noise will be generated as the drill moves through the seabed strata, and from machinery vibrations and generator noise. On a semi-submersible rig the drilling machinery and generators are located on solid platforms above the water, where sound is lost as it transmits through the air and the rig flotation structure (Richardson *et al*, 1995).

8.2.3 Noise generated by other activities

Noise will also be produced by supply and standby vessels serving drilling rigs. Noise from these sources originates from ship engines and gears, propellers, and thruster noise if the vessel is operating on DP (Figure 8.1). Ships moving to site will generally produce more noise than stationary vessels because of propeller cavitation noise. However, if a supply vessel is required to refuel a drilling rig, the boat will have to maintain its position alongside the rig by DP.

In addition, rigs will be visited several times a week for personnel transfers. Low-flying helicopters may increase localised underwater noise levels. From the perspective of an underwater receiver, the noise created by rotor blades and exhaust pipes moves slightly in front of the helicopter in a narrow path and within an arc of 13° from the vertical. The majority of sound will be reflected off the sea surface (Figure 8.1). Only animals immediately below the aircraft will therefore be affected.

Figure 8.1 A representation of the noise generated by drilling activity



8.2.4 Impacts of noise from exploration/appraisal drilling

The impact of noise generated during the drilling of exploration and appraisal wells depends on ambient noise levels; the strength of the sound source; the sound transmission conditions of the receiving environment, and; the proximity of animals to the noise in relation to their ability to detect such sound frequencies.

Ambient noise

As mentioned in Section 7.2.1, sounds in the sea are produced by winds, waves and ocean currents, rain, ice breaking, echolocation and communication noises generated by cetaceans, and other natural sources such as tectonic activity. Table 7.1 displays some of the different types of natural sounds found in the marine environment. In addition, there are anthropogenic sounds generated by air traffic, shipping (including military, merchant and fishing) and oil and gas activity. Different combinations of these noises produce the highly variable ambient (background) noise levels in the northern North Sea.

Underwater noise generated by drilling rigs

Using the equation for spherical spreading described in Section 7.2.3, the received sound levels at various distances from various drilling facilities have been estimated in Table 7.2 in Section 7.2.1. The table shows that drill ships generally are more noisy than semi-submersibles, which in turn are generally more noisy than jack-up drilling rigs.

Effects of anthropogenic noise on marine mammals

The effect of anthropogenic noise on marine mammals is described in detail in Section 7. Available information on the effects of noise on marine mammals indicates that cetaceans and pinnipeds can react differently to the introduction of additional noise into the marine environment. Their reactions are attributable to sound source level, propagation conditions and ambient noise, in addition to animal type, age, sex, habitat, individual variation, and previous habituation to noise (Richardson *et al*, 1995).

Effects of drilling noise generation

The majority of sounds produced during drilling operations are continuous and of low frequency (Table 7.2, Section 7.2.1). The effects on most toothed whales and pinnipeds to such noises are considered to be minor as their sound sensitivity lies outside the main range of low frequency sounds (sounds below 200 Hz) produced by a semi-submersible drilling rig (Table 7.2). However, the susceptibility of baleen whale and seal auditory systems to damage from industrial noise may be high, particularly for baleen whales, as it is presumed their hearing sensitivity is good at low frequencies (Davis *et al*, 1990). Continuous sound produced by industrial activities such as drilling may elicit behavioural avoidance in baleen whales at received sound levels of 110 to 130 dB re 1 μ Pa-m (Evans & Nice, 1996). This indicates, using data in Tables 7.2 and the formula for spherical spreading, that baleen whale avoidance to noise from a jack-up drilling rig will be less than 7 m; a semi-submersible drilling rig between 675 to 1,040 m and a drill ship between 2,390 and 6,900 m. These values seem quite conservative compared to those found by Richardson *et al* (1995) reporting avoidance behaviour from gray whales (a baleen whale species) along the Californian coast (Table 8.1), and it can therefore be argued that these are likely to represent a precautionary estimation.

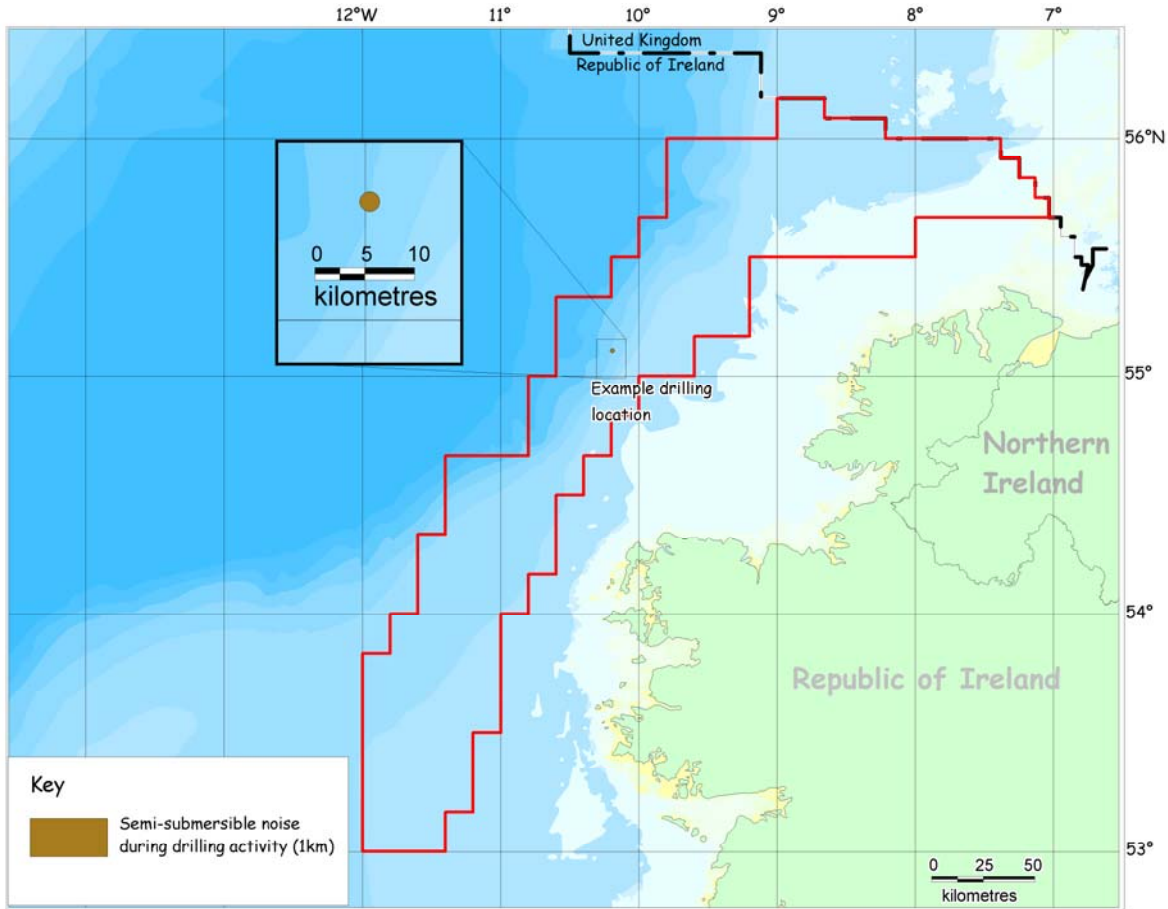
Table 8.1 Reaction of gray whales to industrial noise (Richardson *et al*, 1995)

Sound source	Levels of grey whale avoidance			Actual range (metres) for 50% avoidance
	10%	50%	90%	
Drill ship	110 db	117 db	122 db	1,100
Semi-submersible	115 db	120 db	>128 db	11
Drilling platform	114 db	117 db	>128 db	4
Production platform	120 db	123 db	>129 db	20

Most cetacean species recorded in the continental shelf waters of the IOSEA1 area are the toothed whales and dolphin species. Of the baleen whales, only minke whales have been commonly recorded in these relatively shallow water areas (Section 5). However, a number of the large baleen whales have been recorded in the deep water of the IOSEA1 area, along the continental shelf break and into deeper waters. Baleen whales may display avoidance reactions up to 1 km away from a well location during drilling activities from a semi-submersible rig. A radius of 1 km from any exploration or appraisal well (Figure 8.2) is therefore a conservative estimate of the zone of responsiveness during drilling operations, which could be estimated to last for approximately 50 days.

Close to the drilling site there is the possibility that low frequency drilling noises may mask marine animal calls if they are made within the same frequencies. In addition, Davis *et al* (1990) suggest that auditory damage would occur if a marine mammal were exposed to sounds greater than 120 dB for prolonged periods of time. To be exposed to such sound levels, the animal would have to be within 220 to 345 m of a semi-submersible drilling rig, or 840 to 2,900 m of a drill ship during drilling activities. It is considered unlikely that marine mammals would remain close to such a noise source for any length of time.

Figure 8.2 Estimated zone of responsiveness around a semi-submersible drilling rig



It is acknowledged that the significance of any effects on marine mammals at the population level cannot be fully assessed with present knowledge. However, given the nature and short duration of the noise source, the medium- to long-term risk of such effects currently appears to be comparatively low.

8.2.5 Data gaps

There is some uncertainty as to how sound travels and decays in strength under water, especially in complex bathymetric regions such as those found along the Irish Continental Shelf in the IOSEA1 area. Although it is evident that animals respond to underwater sounds generated by drilling rigs, knowledge is limited on the scale and implications of their reactions. However, the study of these effects is currently an active field of research.

Additionally, the temporal and spatial distribution of marine mammals in the IOSEA1 area is not well understood either, making the potential impact of anthropogenic sound difficult to assess. Further research into the distribution and movements of marine mammals along the Irish Shelf should help to establish a better understanding of 'where and when' certain marine mammal species are present in the IOSEA1 area, and whether they should be considered to be particularly vulnerable during these times or not. It should be noted that no data currently exist to identify foraging areas for seal species along the Irish Shelf, including the IOSEA1 area. Research into the distribution and abundance of cetaceans in the Atlantic has commenced in recent years (eg Aguilar de Soto *et al*, 2004; Ó Cadhla *et al*, 2004), and needs to be further developed.

8.2.6 Mitigation measures

Depending on the type of facility and their moorings, it is known that certain drilling facilities generate more underwater noise than others, with drill ships and semi-submersibles operating on DP being the noisiest. The selection of drilling facility can, therefore, be used to reduce the amount of sound entering the marine environment. However, it is understood that the choice of drilling rig is generally dictated by other factors.

8.2.7 Conclusions

Low frequency noises from drilling wells, and all associated vessels, will add to the ambient noise in IOSEA1 area of the Irish Atlantic Margin. A semi-submersible drilling rig produces sound levels at frequencies similar as those generated by a large merchant vessel (Table 7.2), and as such, their impact is considered to be comparable.

As most toothed whales have hearing ranges at medium to high frequencies, they are considered to be relatively unharmed by industrial noise, with the possible exception of beaked whales. Although seals are capable of hearing the low frequency sounds generated by a semi-submersible drilling rig over large distances, they are generally believed not to be adversely affected by drilling rig sounds as their hearing is more sensitive to higher frequency ranges.

Baleen whales are considered to be potentially at risk at close range, since the frequencies used in their communication noises and assumed levels of hearing overlap with the sound spectra of industrial noises. Large baleen whales have been recorded in the deep water areas of the IOSEA1 area, and also in continental shelf waters; however, minke whales would be the more commonly recorded baleen whale species in shelf waters.

The impact of the noise generated is difficult to assess due to uncertainties in how noise affects specific marine mammals, and how far the noise will be transmitted in the sea. However, it is estimated that the underwater noise produced could elicit response from some individual marine mammals if they pass within 1 km of a drilling rig. It is not likely that such effects would have any significant impacts at the population level.

The assessment of available information, taking into account the limited number of wells forecast as a result of the Draft Plan, together with the short duration of each drilling scenario (50 days), does not indicate any significant impacts from underwater noise generated during drilling operations. However it is felt that the effect of drilling noise on marine animals is still poorly understood and warrants further investigation in the context of this and other noise-producing exploratory activities. As further information is gathered on this factor, and the distribution of marine mammals in the IOSEA1 area, the potential interactions should be considered in the context of reviews and new applications for drilling activity.

8.3 Discharge of drill cuttings and disturbance to sea bed

8.3.1 Introduction

During drilling of exploration and appraisal wells, drill cuttings and spent drilling muds require disposal. An introduction to the use and types of drilling muds is provided in Section 4.

Cuttings and particulate material from spud mud (usually seawater with high viscosity bentonite sweeps) used to drill the top hole section(s) is always deposited at the sea bed close to the wellhead. A small quantity of the cement used to secure the first set of casings in the borehole is also deposited here.

Cuttings generated from subsequent sections of a well are contaminated with residual drilling muds and associated chemicals following cleaning on the drilling rig. As discussed in Section 4, cuttings containing more than 1% oil based fluid, are not allowed to be discharged to sea and are shipped to shore for disposal. However, it is usual for WBM cuttings to be disposed of at sea, by discharge from the drilling rig or ship through a caisson just below the sea-surface. Drilling muds recovered from the cleaning process are re-used, but used WBM may be discharged overboard upon completion of each well section.

Most of the discharged material will end up as deposits on the sea bed, where the main potential for environmental impact occurs. In addition, discharges from caissons create plumes of suspended fine sediment, which may cause localised chemical changes as sediment settles through the water column. The impacts of drilling discharges on both the sea bed and its associated fauna, and on marine organisms in the water column, therefore need to be considered. Chemicals are added to drilling muds and to cement used to secure well casings, and drilling rigs and ships also carry contingency chemicals which might be used in the event of an abnormal occurrence. The potential for such chemicals to be toxic to marine organisms when discharged therefore needs to be assessed.

The likely options for drilling units for use in the IOSEA1 area are discussed in Section 4. Semi-submersible rigs and jack-up rigs involve use of anchors for positioning, and jack-up rigs also have legs that are driven into the sea bed. A degree of localised direct disturbance to the sea bed is

therefore expected to occur from the use of subsea equipment and by scouring action from anchors and anchor chains. There are sometimes concerns about damage to seabed habitats or species, especially if these are sensitive or of particular ecological or conservation importance.

8.3.2 Impacts

Procedures for chemical risk assessment and approval

In Ireland, the environmental risks of using chemicals in drilling muds or for contingency purposes must be assessed and approved with reference to the OSPARCOM (Oslo Paris Commission) draft PLONOR list (list of substances/preparations used and discharged offshore which are considered to pose little or no risk to the environment) and the HOCNF (harmonised offshore chemical notification format) classification schemes (see Sections 3.3.4 to 3.3.6).

Under the HOCNF scheme, individual components of drilling mud formulations are classified into Groups A to E. Group A substances pose the highest potential environmental risk and Group E substances (or PLONOR list substances) are considered the most environmentally benign, and therefore pose the lowest risk to the environment. For each category of chemical used, tonnage limits can be set that trigger the requirement for an operator to provide prior notification of use of chemicals, to undertake an environmental risk assessment and to provide justification for their selection where alternatives are available. Details of how chemicals are tested and classified under the HOCNF scheme are provided in Appendix 3.

Disposal of WBM cuttings and cement at sea

The amount of cuttings generated, and volumes of drilling muds discharged, depends on the stratigraphy, the target depth and aspects of the well design, including the bore widths of the different sections. A well can be structured with a 'normal' well bore or as a 'slim-hole', which has a smaller diameter well bore than usual. Assuming a normal well bore, Table 8.2 provides indicative amounts of cuttings and muds that may be discharged, based on various exploratory wells west of Scotland and in the Celtic Sea. The amount of drilling muds discharged from the top sections of the well depends on whether a full WBM formulation is used, or simply seawater.

Table 8.2 Typical discharges of cuttings and associated WBM from exploratory and appraisal wells

Combined sections	Discharge point	(Dry) cuttings discharged (tonnes)	Muds discharged (tonnes)
Top	Near the sea bed	450	0 to 450
Remainder	Near the sea surface	250	30
Total	-	700	30 to 450

Impacts on water column

Discharge of cuttings and WBM at the sea bed will cause local increases in suspended solids in the near-seabed water layer. Changes in the amount and type of suspended sediment in the benthic boundary layer may cause direct irritation to marine organisms, abrading protective mucous coatings and increasing their susceptibility to parasites and infections, as well as affecting growth, reproduction and feeding. This is discussed below under impacts on benthic organisms.

Cuttings and residual WBM discharged at the sea surface will be suspended in sea water. A discharge 'plume', which may initially be a visible area of turbid water near the discharge caisson, will be subject to rapid dilution and dispersion. The temporary increases in suspended sediment levels within the water column could potentially affect primary production locally through reduction of light levels. Chemical additives in WBM are generally water-soluble and dissolve and degrade naturally in the water column.

Experimental evidence suggests that, where dilution is rapid, discharges of muds containing additives will not significantly alter primary production in the vicinity of drilling platforms (Alldredge *et al*, 1986). The same authors found that, following exposure of marine phytoplankton assemblages to various drilling muds and mud additives for periods of 1 to 120 hours, phytoplankton composition was not altered. It is expected that actively swimming organisms such as fish will simply avoid any plume. Overall, with the low toxicity of water based mud, and rapid dispersion due to the tidal streams, the environmental impact of drilling discharges on the water column is likely to be minimal.

Deposition on the sea bed

The cuttings and drilling fluids discharged from the riser-less top sections of the wells are expected initially to form small cuttings piles in the immediate vicinity of each wellhead, together with relatively small amounts of excess cement from setting the top hole sections. They will then spread out gradually in the vicinity of the well heads under the influences of gravity and the relatively strong seabed currents.

As the cuttings and drilling fluids from the remaining well sections are discharged from near the sea surface, they are likely to disperse over a wider area. The deposition pattern tends to reflect the particle size distribution, with larger and heavier (cuttings) particles landing on the sea bed relatively close to the discharge point, and small (mud) particles travelling much further before they reach the sea bed. The area and depth of deposition is highly dependent on water depth and currents; in continental shelf areas a recognisable footprint may be detectable, whereas in deep water there may be no detectable deposition. Drill cuttings modelling is sometimes used to predict the likely deposition pattern, but must be interpreted carefully with due regard to the limitations of the input data.

Alteration of sediment structure

The discharge of cuttings, muds and cement will initially alter the seabed topography and sediment structure of a small area close to the wellheads. The material deposited will be a mixture mostly of cuttings (rock fragments and sediment removed from the well) of various sizes and drilling mud including particles of barite (barium sulphate: BaSO₄) and bentonite, a mineral clay. The natural sediments in the IOSEA1 area are also generally mixed and consist mostly of sands and gravels with some finer muddy area on the lower slope (see Section 5 and Annex Section 2).

Indications of the persistence of WBM cuttings piles are available from experience in the North Sea. In the southern North Sea, near-bed current velocities and sediment mobility are generally sufficient to prevent detectable local accumulation of cuttings. It has been predicted that any surface-hole cuttings piles in the southern and central North Sea area will be dispersed typically over a timescale of one to five years, mainly through re-suspension and bedload transport due to tidal and wave-induced currents (DTI, 2002), while those in the more quiescent northern North Sea will typically be dispersed over a time scale of one to ten years (DTI, 2001).

Sediment movement on the continental shelf is predominantly to the north/northeast, though there are also cascading currents over the shelf edge. Long-term sediment movement is cyclonic in the bottom of the Rockall Trough, with deposition in contourite bodies such as the Feni Drift.

Contamination of sediments

From post-drilling environmental surveys on cuttings piles contaminated purely by WBM in the North Sea, impacts to the seabed sediments in the immediate vicinity of the well can be summarised as follows:

- elevated levels of barium;
- elevated levels of some trace metals associated with the barium;
- mild organic enrichment of the sediment at some locations.

Barium inputs arise from the use of barium sulphate (or barite) as a weighting agent in drilling mud. Barium sulphate is an insoluble, chemically inert mineral powder that normally also contains measurable concentrations of several trace metals. In this form, the barium is 'biologically unavailable' and will have no measurable effect, in chemical terms, on the benthic fauna (Jenkins *et al*, 1989; Hartley, 1996). The environmental impact of other trace metals will depend on their concentration in the WBM-contaminated cuttings, which depends to some extent on the geological source of the barite. However, studies have shown consistently that metals associated with WBM are virtually unavailable to marine organisms that might come into contact with discharged drilling fluids (Neff *et al*, 1989; McKelvie, 1996).

WBMs contain very small amounts of organic material. Slightly elevated concentrations of hydrocarbons have been recorded at some sites in the North Sea drilled with WBMs. Although the origins of such inputs have not always been clear, diesel has often been implicated in the past. Its presence could arise from the now outdated practice of using diesel to free stuck drill strings or when formation problems were encountered. Payzone cuttings could also have been the cause in some cases.

Impacts on benthic organisms

Considerable data have been gathered from the North Sea and other production areas, indicating that physical disturbance is the dominant mechanism of ecological disturbance where WBMs and cuttings

are discharged (DTI, 2001). Biological effects on seabed faunal communities from the discharge of WBM and associated cuttings are usually subtle or undetectable, although the presence of drilling material at the sea bed is often chemically detectable (see above). Monitoring studies around well sites drilled with WBMs have rarely shown any effects to benthic infauna (at a community level) detectable beyond 50 m. Subtle impacts to the benthos were identified at up to 750 m from a production site developed using WBMs, but these were associated with hydrocarbon contamination (Hartley & Bishop, 1986).

The sedentary fauna in the immediate vicinity of the well heads may well be buried by the accumulation on the sea bed of cuttings and WBM particles from the tophole sections. In addition, enhancement and altered particle size distribution of suspended particles in the water near the sea bed may impair respiratory and feeding processes, inducing metabolic stress and reducing growth and survival rates in individuals of some species outwith this area. Laboratory studies have shown that elevated concentrations of bentonite and barite, the two major constituents of WBMs, can affect the growth of suspension feeding organisms (Cranford & Gordon, 1992; Cranford *et al*, 1999; Barlow & Kingston, 2001), and some species are more sensitive than others. It is also feasible that changes in sediment particle size characteristics could affect the suitability of the sea bed for re-colonisation by species normally characteristic of the area, although in a dynamic area it is probable that the sediments will rapidly return to their original composition under the influence of seabed currents and natural sedimentation.

The net result can be expected to be a short-term reduction in productivity just after drilling, and medium-term change in the composition of the benthic community over a small area centred on the wellheads. Long-term effects can be expected to be minimal due to both the overall low toxicity of the WBM, and the currents close to the sea bed that will enable (most of) the cuttings to disperse over a wide area so that any impacts are indistinguishable from natural background variation. No detectable effects on the benthic community are expected outside of the area affected by materials discharged at the well heads.

Of the benthic fauna known to occur in the IOSEA1 area, cold water corals such as *Lophelia pertusa* and *Madrepora oculata* are particularly important because they provide suitable substrata for other animals, thereby greatly enhancing local diversity, and they are of conservation importance under the EU Habitats Directive. Various studies have shown that exposure of warm water corals to drilling fluids may result in reduced viability, morphological changes, altered feeding behaviour or disruption to the pattern of polyp expansion, and that the effects may vary between species. There is some evidence that *L. pertusa* may tolerate some exposure to drilling discharges, but further information is needed on the effects of exposure to drilling muds on growth and reproduction of *L. pertusa* and other habitat-forming cold-water corals (Freiwald *et al*, 2004). This is an ongoing area of research at SAMS and elsewhere. In California, an adverse impact on *Caryophyllia* species (a solitary coral, two species of which occur in Irish waters) on the outer continental shelf and slope depended on the doses of cuttings received and the time of exposure, and was attributed to the physical effects of increase sediment loading rather than to toxic effects (Hyland *et al*, 1994 cited in Freiwald *et al*, 2004).

Direct seabed disturbance

Introduction

Localised areas of sea bed will be disturbed during installation and subsequent removal of the drilling rig, principally by manoeuvring and dragging of anchors and their chains, and by the legs (spud cans) if a jack-up rig is used. As discussed in Section 4.4.2, eight to twelve anchor lines may radiate several kilometres from the rig. For each anchor, several hundred metres of anchor chain will rest on the sea bed. In water depths of 200 m, for example, it has been estimated that 600 m of each anchor chain may lie along the sea bed.

Impacts on benthic organisms and habitats

Direct effects to the benthos include localised disturbance and damage. Resettlement of disturbed sediment could lead to some minor smothering effects as described above for drilling discharges, but on a much smaller scale. Such impacts need to be assessed in the context of the nature of species and communities affected and the scale of the activities. As outlined above, the overall nature of the benthic environment in the IOSEA1 area is dynamic, and impacts associated with the scraping and dragging of anchors and chains in most areas are likely to be minor with good potential for rapid recovery. However, considerable evidence of impacts on deep coral communities from fishing activities shows that such coral communities are susceptible to physical damage and slow to recover (Freiwald *et al*, 2004), although the scale of impact from anchor scouring is expected to be far less than that from trawling.

Archaeological impacts

The only archaeological features that could possibly be damaged by subsea equipment (or drilling discharges) are historic shipwrecks, if these lie in the immediate vicinity of a well or anchor location. Wrecks have been recorded throughout the IOSEA1 area, especially in the northern part, although known historic wrecks are predominantly found in coastal waters (see Section 5.4.4). Direct disturbance by subsea facilities or anchors and chains would be the main threat to any wrecks, and the presence of wrecks is also a hazard to drilling activities.

Overall assessment of potential impacts

Implementation of the Draft Plan may result in up to 19 wells in total (not including pre-existing activity, which is dealt with under cumulative impacts in Section 9) being drilled over the period 2008 to 2011 (Sections 4.2 and 4.4.2). The impacts of activities such as anchoring, and the discharge of drilling wastes, will be primarily to the sea bed rather than to the sea surface or water column. Impacts on the benthic communities from discharges of WBM and cement may occur in the immediate vicinity of each well, with likely recovery within months or a few years. Assuming an area of impact of 50 m radius (see above) around each of 19 wells, a total area of less than 150,000 m², or 0.15 km², would be affected to some extent by burial or smothering impacts.

In the event that drilling is conducted via an anchored drilling rig or ship, direct disturbance and damage to benthic animals will arise mostly from the anchors and anchor chains. Relatively little movement of anchor chains is expected due to the deep water and the number of anchors employed. Assuming eight chains per rig each impacting an area of sea bed 600 m long and 2 m wide, 9,600 m² of sea bed may be subject to varying degrees of disturbance over the estimated drilling period of 50 days for each well. For the maximum of 19 wells drilled, a total of 182,400 m², or 0.18 km², of sea bed could be temporarily affected. As a very rough estimate, therefore, the direct sea bed disturbance involved from anchoring and discharge of solid wastes at up to 19 well sites could total 0.33 km².

The spatial extent of these impacts is clearly only a very small proportion of the total sea bed area of 25,000 km² lying within the IOSEA1 boundary. In addition, the temporary nature of anchoring impacts, and the very localised extent and low toxicity of discharged drilling wastes on the sea bed, lead to good recovery potential in the dynamic benthic environment of the IOSEA1 area. However, the significance of any impact depends on the presence of particularly sensitive or important habitats or species, sea bed features or notable archaeological interest (wrecks most likely) within the affected areas. As discussed above, cold-water corals, which are of particular ecological and conservation importance, may be more susceptible to direct physical damage and slower to recover than other macrofaunal species likely to be encountered in the IOSEA1 area.

8.3.3 Data gaps

In order to assess the actual impacts of drilling activities to sea bed features, habitats, species and archaeology, knowledge of these aspects of the receiving environment is required for specific exploration sites. At present, the location of the exploratory drilling activity likely to arise from the Draft Plan is unknown. In addition, whilst much general information about the sea bed (including depth, topography and sea bed type) in the IOSEA1 area has been gathered in recent years (Section 5 and Annex), much analysis is still underway and in any case would not necessarily contain all the detailed site-specific information required for appropriate environmental assessment. For any proposed drilling site, once the location is known, adequate information may already exist from survey work carried out to date, or if not then such information should be obtained through site-specific survey.

8.3.4 Mitigation measures

Impacts from drilling discharges are unlikely to be significant, but various mitigation measures are either required or can be taken by operators to further reduce impacts, as summarised below. The significance of impacts resulting from direct physical disturbance of the sea bed depends on the occurrence of key features of ecological or archaeological conservation importance in the immediate vicinity of operations.

Existing measures

- All chemicals used are regulated under the OSPAR HOCNF scheme and approved by use of a PUDAC (see Sections 3.3.4 and 3.3.5). Selection of all chemicals that may be used in drilling the proposed wells should be based upon both their technical specifications and their environmental performance, and the use of all chemicals minimised where practicable.
- Actual mud and chemical usage must be monitored during drilling operations, and subsequently reported to the PAD (see Sections 3.3.6 and 3.3.8).

- It is prohibited to discharge to sea cuttings contaminated with OBM or SBM.
- Best practice should be followed to minimise the amount of excess cement deposited on the sea bed.
- Mud recovery systems should be used, thus minimising the amount of drill fluids to be discharged.
- Site surveys are undertaken with regard to geohazards such as shallow gas, gas hydrates and slope instability.

Potential additional measures

- Consideration should be given to drilling slimhole wells (ie thinner than usual well bore) where possible. These generate fewer cuttings, require less drilling fluid and chemicals, and are generally faster than a conventional drilling programme.
- Consideration should be given to requesting that modelling of the dispersion of discharged drill cuttings be undertaken. This would also necessitate collection of tidal stream information at different depths through the water column, depending on the overall water depth, and validation of the predictions once drilling was complete.
- Certain sea bed features, including pockmarks and carbonate mounds, may qualify as Annex 1 habitat features under the Habitats Directive (Figure 5.5 and Section 5.3.1). There is evidence for a field of pockmarks within Blocks 13/4, 13/5 and 14/1 in the Donegal Basin, in addition to which some small pockmark-like features have been identified in the Corrib Field. In addition, two isolated carbonate mounds occur on the slope in the Erris Basin (Figure 5.5). Until more is known about these particular features and the marine communities they support through more detailed study, it would be prudent to prevent any damaging activities such as anchoring or the discharge of drilling wastes taking place in their immediate vicinity.
- As insufficient information is available on the precise occurrence and distribution of key habitats, megafaunal species and historic wreck sites, site-specific survey data will be required in order to assess the impacts resulting from direct disturbance during the installation and removal of drilling structures. This could be carried out as part of the site survey normally undertaken prior to all drilling activities. The PAD may require an environmental survey as part of the EAA approval process (see Section 3.3.7). Careful consideration needs to be given to the design of such surveys, making use of non-destructive survey methods where appropriate.
- For areas known to be close to or within likely herring spawning grounds, particularly around the breeding period of August to September, a herring spawning ground assessment survey should take place prior to drilling to ensure that impacts to valued herring spawning habitat are avoided.
- Best practice should be followed in order to limit dragging of anchors and chains.
- The proposed works should be subject to a detailed underwater archaeological impact assessment in advance, and this should follow the format detailed in guidelines being developed on *Acquisition and interpretation of geophysical data for archaeological assessment during oil industry geophysical route and site surveys in water depths exceeding 50 m* (Quinn, 2005). Any shipwrecks or objects of potential archaeological interest should be reported to the Director of the National Museum of Ireland within 4 days. If wreckage found is more than 100 years old, the Underwater Archaeology Unit and the Garda Síochána must also be notified within 4 days.

8.3.5 Conclusions

Using the significance criteria defined in Section 6, the discharges of cuttings and muds near the sea surface are expected to have a minor impact on both the water column and the sea bed. The substantial water depths (>50 m) and the oceanographic conditions in the area enable good dispersion and dilution.

The discharges of drill cuttings, muds and cement from the top sections of the wells, which are deposited close to the sea bed at the wellheads, are expected to have a moderate impact at each well site. However, the area affected will be very small, and any adverse effects on the benthic communities are expected to be limited to the immediate vicinity of the wellheads (generally within 50 m). The cuttings piles are expected to be dispersed completely over a time scale of one to ten years, and the overall impact is not likely to be significant.

The greatest potential for significant impact at the sea bed arises from direct damage by placement and scouring of anchors and chains. If wells and anchors are well sited using adequate site specific data on megafaunal communities, these impacts can be minimised.

8.4 Atmospheric emissions

8.4.1 Introduction

As outlined for seismic survey vessel emissions in Section 7, current concern over global warming and air quality mean that the potentially larger atmospheric emissions from the exploratory and appraisal drilling activity proposed were judged to be of concern. Exhaust emissions from drilling will include those from the drilling rig and other vessels involved in the activity but, in the event that drilling is successful and hydrocarbons are discovered, may additionally include those arising from the combustion of produced hydrocarbons during well testing.

This section outlines the scale of emissions that may result from the proposed plan, and assesses the significance of impacts to which these emissions contribute.

8.4.2 Estimation of atmospheric emissions arising from exploration and appraisal drilling scenarios

The results of emissions calculations for the drilling activity scenario, as outlined in Section 4, are shown in Table 8.3. These show that CO₂ production will amount to an indicative level of 5,754 tonnes per well, or roughly 109,326 tonnes from the maximum expected total of 19 wells. The atmospheric emissions from each well will have a global warming potential (GWP) of approximately 10,280 tonnes CO₂ equivalent, whilst the total from, say three wells per year could result in a GWP of ~30,840 tonnes CO₂ equivalent.

Atmospheric emissions from fuel combustion also generally have the potential to cause acidification of rain. The main contributors to this are the SO₂ and NO_x content of the fuels in use. The total acidification potential of the estimated annual emissions from drilling activity is approximately 82 tonnes of SO₂ equivalent (Table 8.3), whilst that for three wells per year would be 246 tonnes.

Table 8.3 Indicative exhaust emissions from drilling rig and support vessels per well

	Large tugs (14 days)	Anchor handling vessel (x 2, for 2 days at each end)	Semi-sub drilling rig (50 days)	Supply vessel (21 return visits)	Standby vessel (50 days)	Helicopter flights (21 return flights)	Total per well
Fuel consumption (tonnes)	350.00	100.00	1,000.00	168.00	150.00	30.01	-
Emissions (tonnes)							
CO ₂	1,120.00	320.00	3,200.00	537.60	480.00	96.03	5,753.63
CO	5.50	1.57	15.70	2.64	2.36	0.47	28.24
NO _x	20.79	5.94	59.40	9.98	8.91	1.78	106.80
N ₂ O	0.08	0.02	0.22	0.04	0.03	0.01	0.40
SO ₂	1.40	0.40	4.00	0.67	0.60	0.12	7.19
CH ₄	0.06	0.02	0.18	0.03	0.03	0.01	0.33
VOC	0.70	0.20	2.00	0.34	0.30	0.06	3.60
Global Warming Potential (tonnes CO₂ equivalent)	2,000.98	571.71	5,717.08	960.47	857.56	171.57	10,279.37
Acidification Potential (tonnes SO₂ equivalent)	15.95	4.56	45.58	7.66	6.84	1.37	81.96

Calculations according to UKOOA (1999).

In addition to the emissions to the atmosphere from the drilling rig and associated vessels and aircraft support, any well testing needed will also consume fuel and produce exhaust emissions. As outlined in Section 4, a requirement for one well test per year may result from the proposed exploratory drilling, and the predicted indicative emissions from these are given in Table 8.4.

The results of emissions calculations for each well test are shown in Table 8.4. These show that CO₂ production will amount to an indicated 5,064 tonnes per well. The atmospheric emissions from each test will have a GWP of just over 7,000 tonnes CO₂ equivalent. The acidification potential of the estimated emissions from one well test is approximately 1.5 tonnes of SO₂ equivalent (Table 8.4).

Table 8.4 Indicative exhaust emissions from well testing

	Well test (2 million m³ gas)
Fuel consumption (tonnes)	1,778.76
Emissions (tonnes)	
CO ₂	5,063.58
CO	11.92
NO _x	2.13
N ₂ O	0.14
SO ₂	0.02
CH ₄	80.04
VOC	8.89
Global Warming Potential (tonnes CO₂ equivalent)	7,008.13
Acidification Potential (tonnes SO₂ equivalent)	1.52

Calculations according to UKOOA (1999), and in the absence of generalised information relevant to hydrocarbons from the IOSEA1 area, assume a default molecular weight of 21 and a default sulphur concentration of 6.4 ppm.

8.4.3 Environmental impacts resulting from atmospheric emissions

Assessing the impacts of these potential emissions at a local level is difficult due to the nature of the offshore environment. As related earlier in Section 7, impacts are generally mitigated circumstantially by the open and dispersive environment offshore. Drilling rigs and support vessels are in general built and operated to standards that preclude significant impacts to the health of their crews, whilst other environmental receptors (eg flora and fauna) tend to be sparsely distributed and/or transient in the local area. Impacts at this level are therefore both difficult to measure and to distinguish from background variation. On this basis, it is more profitable to consider emissions impacts at a regional or wider scale.

To put these emissions in a national context, total emissions in Ireland resulting from energy use rose between 1990 and 2001 from approximately 30 million tonnes CO₂ equivalent to just over 45 million tonnes, and have since declined slightly to approximately 42 million tonnes (EPA, 2003). The 10,280 tonnes CO₂ equivalent to be emitted by drilling one well represents just 0.02% of the total emissions in Ireland resulting from energy use, whilst including the well test in the total raises the proportion to 0.04%.

National emissions of SO₂ and NO_x, together the main emission components responsible for acidification, were 76,370 tonnes and 119,750 tonnes respectively in 2003 (EPA, 2003). Against this, the total SO₂ and NO_x emissions from drilling each well (Table 8.3) are insignificant, as are the amounts contributed in addition from well testing (Table 8.4). Emissions of SO₂ nationally have declined by 60% since 1990, whilst those of NO_x have shown no significant change overall. However, the contribution to NO_x emissions from the power generation industry has declined by 28% since 1990. Both this, and the notable decrease seen in SO₂ emissions, were seen as due to the increasing share of natural gas as a fuel in power generation (EPA, 2003).

8.4.4 Data gaps

No data gaps have been identified with regard to atmospheric emissions.

8.4.5 Mitigation measures

The main sources of atmospheric emissions from drilling activity will be from fuel use and potentially from well testing or flaring of produced hydrocarbons.

In terms of fuel use, measures can be taken from an early stage to include fuel efficiency in the selection process for drilling rigs, support ships and helicopters, and to use low sulphur fuel for example. Such steps could be required through the national legislative and policy framework, as driven by, for example, the European Union strategy to reduce the contribution of shipping to acidification, ground-level ozone, eutrophication, health, climate change and ozone depletion (European Commission, 2006).

With regard to well testing, emissions may also be influenced by careful selection of drilling rig and contractors and by the use of maximum efficiency 'green' burners (in the case of oil or condensate wells). The amount of fuel flared can also be minimised by appropriate design of the test programme. If appropriate, well testing systems that do without the need for flaring at all (closed chamber well tests) can be built into the test programme.

8.4.6 Conclusions

Atmospheric emissions will arise from exploratory and appraisal drilling activity following the current licensing round. The level of activity proposed from the new licensing round will be similar to or slightly higher than that seen on average since 1978. The resultant emissions will not have any significant localised impacts to health or the environment due to the dispersive nature of the offshore environment. They will contribute to issues such as global warming, acid rain and air pollution, but given their relative scale in relation to past and current exploration activity levels nationally, and to emissions nationally and at a UK and European level, impacts are unlikely to be significant.

While the emission levels likely to arise from implementing the Draft Plan are relatively small, their acceptability overall needs to be considered in the context of the national energy policy, and national policy for the management of greenhouse gases and commitments to the EU and the Kyoto Protocol.

8.5 Physical presence

8.5.1 Introduction

In order for exploration drilling to take place, a drilling rig is towed into position over the well site by towing vessels and anchored into position by the same vessels performing an anchor handling role. During the drilling operation itself supply vessels will serve the drilling rig with bunkering and other supplies and helicopters will carry out personnel changes. Dependent on where the licenses for exploration well drilling will be awarded, it is unlikely that drilling will take place close to the nearest coast and therefore is unlikely to be visible from the Irish coastline. The environmental issues identification process together with the scoping responses identified interference with other sea users (especially the fishing industry) due to physical presence of the rig, vessels, and subsea equipment, including any exclusion zones as having the potential to have a moderate impact and should be considered further.

8.5.2 Drilling rig

The drilling scenario assumptions, as stated in Sections 4.2 and 4.4.2, suggest that a maximum of 19 wells will be drilled in the period 2008 to 2011. These wells are likely to be drilled by a semi-submersible drilling rig, over a period of around 50 days per well. For safety reasons a 500 m exclusion zone will surround the drilling rig whilst on site patrolled by a safety standby vessel, leading to the temporary loss of fishing access, and will require all other forms of vessels from shipping to military to avoid the area. If four to five wells per year are drilled then there will be four to five areas closed by exclusion zones (each 0.79 km², totalling less than 4 km²) and made inaccessible for fishing or other activities for periods of up to 50 days in each case.

8.5.3 Supply and support vessels

Due to the requirement for a support vessel to be on standby during drilling operations, a vessel will be present for the duration of drilling operations. Supply vessels and helicopters will ferry goods and personnel to and from the drilling rig, leading to a slight increase in vessel activity in the region. This would only take place over the 50 day drilling period. Supply vessels will use ports at Killybegs and Ayr in Scotland to bunker and ship essential supplies. These ports are currently in use to supply the existing oil and gas activities west of Ireland. Relatively low shipping intensity in the IOSEA1 indicates that impacts upon other shipping operations in the region will be low.

8.5.4 Suspended well

If the well is plugged and abandoned at the end of the drilling programme, the riser will be completely removed to below the sea bed and will therefore pose no threat to ship anchors or over-trawling by

fishing vessels. However if the well is suspended, the 500 m exclusion zone will remain in force. The exclusion area is not likely to have any significant commercial impact on fisheries.

8.5.5 Data gaps

No data gaps have been identified.

8.5.6 Mitigation measures

At the time of submitting a well plan for approval, operators are obliged to inform fishermen by means of the established Irish Offshore Operators Association (IOOA) procedures. In addition, in the case of a well planned in an area of intensive fishing, discussions with the Sea Fisheries Control Division of the Department of Communications, Marine and Natural Resources must be initiated as early as possible, and in any case at least 90 days before planned commencement of drilling. Procedures are in place between IOOA members and the fishing industry to resolve possible disputes over damaged equipment.

In the event of a well being suspended, over-trawlable protection should be put in place in areas most used for demersal fishing activities.

8.5.7 Conclusion

The total area potentially excluded to other sea users, predominantly commercial fishing, will be up to 4 km² for 50 days per year. Redirection of fishing effort from one area to another nearby is unlikely to significantly affect fishing revenues in general. Profitability of fishing operations is influenced more by factors such as fish prices, stock levels, quotas and fuel costs. Any effects to the fisheries are considered to be minor. The number of wells that may be drilled as a result of this Frontier licensing round are few, the duration of drilling is short and therefore the impact of the physical presence of the drilling rig and possible suspended wells is not considered to be significant.

8.6 Accidental events

8.6.1 Introduction

The risk of accidental hydrocarbon and/or chemical spillage to the sea is one of the main environmental concerns associated with oil industry developments. Spilled oil and chemicals at sea can have a number of environmental and economic impacts, the most conspicuous of which are on seabirds and marine mammals. The actual impacts depend on many factors, including the volume and type of oil spilled, and sea and weather conditions. During exploration and appraisal drilling, there is a risk of spillage of oil (fuel/crude), and spillage or leakage of chemicals. It is worth noting that gas is the main anticipated hydrocarbon in the IOSEA1 and not crude oil. Although crude oil shows were identified at one well drilled in the Erris Basin, these were in non-commercial quantities.

Specific wildlife related issues to the IOSEA1 include the vulnerability of seabirds, seals and cetaceans offshore, the presence of the cold-water coral *Lophelia pertusa*, and in the coastal areas a large number of habitats and species of international and national conservation importance. Potential economic issues include impacts on coastal fisheries, mariculture and tourism.

8.6.2 Likelihood of hydrocarbon spill occurrence

Zero discharges or spillages of oil were reported from Irish oil and gas activities offshore in 2003 (OSPAR, 2005). Data obtained from the UK oil and gas sector has been used to demonstrate the likelihood of hydrocarbon spill occurrence during exploration and appraisal drilling in the IOSEA1 area. Historical data indicate that the probability of a large hydrocarbon spill occurring during exploration and appraisal drilling is very low. The most likely spills are small leaks (<1 tonne) arising from loading and bunkering oils between the drill rig or ship and supply vessels. Oil based muds have been the largest source of hydrocarbon spills during drilling operations in the UK sector of the Atlantic Margin, accounting for 55% of all hydrocarbons spilled (Table 8.5). The discharge of oil based muds is not permitted in Irish waters.

Table 8.5 Atlantic Margin oil spill summary for drilling operations between 1990 to 2002 (ERT, 2003)

Hydrocarbon	Total spilled (tonnes)	Number of spills	% by volume	% by number of spills
Condensate	0.0940	2	1.41	9.52
Crude oil	1.904	7	28.46	33.33
Drilling base muds	3.6769	4	54.97	19.05
Diesel	0.43	2	6.43	9.52
Lube/hydraulic oil	0.0244	3	0.36	14.29
Other/unknown	0.56	3	8.37	14.29
Total	6.6893	21	100.00	100

Potential accidental causes of hydrocarbon spills include collision events with other vessels and well control incidents or 'blowouts'. Between 1980 and 2003 the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (SINTEF) database recorded a total of 34 blowout events on the UK and Norwegian continental shelves during drilling operations (SINTEF, 2004). During this period over 10,000 wells have been drilled which gives a risk of a blowout occurring once in every 314 wells. This compares with a figure of one shallow gas blowout per 200 for exploration wells and one per 500 for development wells from worldwide statistics (UNEP, 1997). The SINTEF database defines a blowout as an incident where formation fluid flows out of the well or between formation layers after all the predefined technical well barriers or the activation of the same have failed. The figures include a range of well control incidents from the loss of a few litres of hydrocarbon to major events. The chances of a major hydrocarbon blowout involving spillage of crude in any significant quantity are therefore very low, particularly so in the IOSEA1 area where the hydrocarbon finds in commercially viable quantities have invariably been gas. Although crude oil shows were identified at one well drilled in the Erris Basin, these were in non-commercial quantities. The amount of hydrocarbon released from a blowout varies widely and depends on the characteristics of the reservoir and also the reason for the loss of containment. In deeper water, flow rates for crude oil blowouts are limited by the hydrostatic pressure of overlying water.

The probability of a ship collision with a drilling ship or rig is very low. Frequencies calculated for the Faroese offshore deepwater areas indicate the probability of only one incident per 3,000 drilling operations (GEM/FOIG, 2000). Between 1975 and 2001 for the UK continental shelf the mean incident frequency for all ship collision incidents with semi-submersible drilling rigs with attendant vessel types was 0.2379 incidents/year (one every 4.2 years) with incidents resulting in moderate or severe damage at 0.0487 incidents/year (one every 20.5 years). There were no incidents over this period with passing vessels and semi-submersible drilling rigs (HSE, 2003). The frequency with which a collision will cause an oil spill will be even less.

Gas

Expectations are that gas will be the main hydrocarbon found in the IOSEA1 area. The risk associated with shallow gas is discussed in Section 8.6.7.

Crude

Most crude oil spills to the marine environment have been from hydrocarbon drop-out during flaring as a result of incomplete combustion of hydrocarbons during well testing. High efficiency burners are now used to maximise the combustion of hydrocarbons which, in turn, minimises the probability of hydrocarbon drop-out to the sea surface.

For a total of 4,580 wells drilled on the UK continental shelf between 1990 and 2002 only one spill was larger than 50 tonnes, 112 tonnes in 1990, which represents a probability of just 0.0002 of a crude oil spill greater than 50 tonnes occurring during drilling operations. Zero discharges or spillages of oil from Irish offshore oil and gas activities were reported in 2003 compared to 8,998 tonnes across the whole OSPAR maritime area (OSPAR, 2005). For comparison the amount of crude spilt in the 1993 *Braer* coastal tanker accident was 85,035 tonnes and 72,000 tonnes from the *Sea Empress* in 1996.

Statistical analysis of the DTI data set (1990 to 2002) shows that there have been seven crude oil spills in 207 wells drilled in the Atlantic Margin during this period (ERT, 2003). This equals to a historical probability of 0.034 (ie once in every 29.6 wells drilled). All of the recorded spills were less than 5 tonnes, with the majority (5) of them less than 0.1 tonnes.

Diesel

Diesel oil spills account for 6.4% of oil spilled in the UK sector of the Atlantic Margin and generally occur during bunkering operations. Diesel will be the main fuel for power generation onboard the drilling rig/ship, and will therefore be the largest amount of hydrocarbons stored on any drilling unit whilst on station. Assessment of the DTI dataset 1990 to 2002 show that there have only been two diesel spills recorded within this period, bringing the probability of any diesel spill occurring in the Atlantic Margin down to 0.0097 (ie once in every 103.5 wells drilled). Data for the whole of the UK continental shelf show the probability of a diesel spill occurring is 0.0191 (one spill in every 55.85 wells drilled; ERT, 2003). As most diesel spills tend to occur during bunkering operations the volumes spilled tend to be relatively small (<5 tonnes). The worst case scenario, complete loss of the diesel inventory, will only occur in the event of a catastrophic event, such as a collision with another ship.

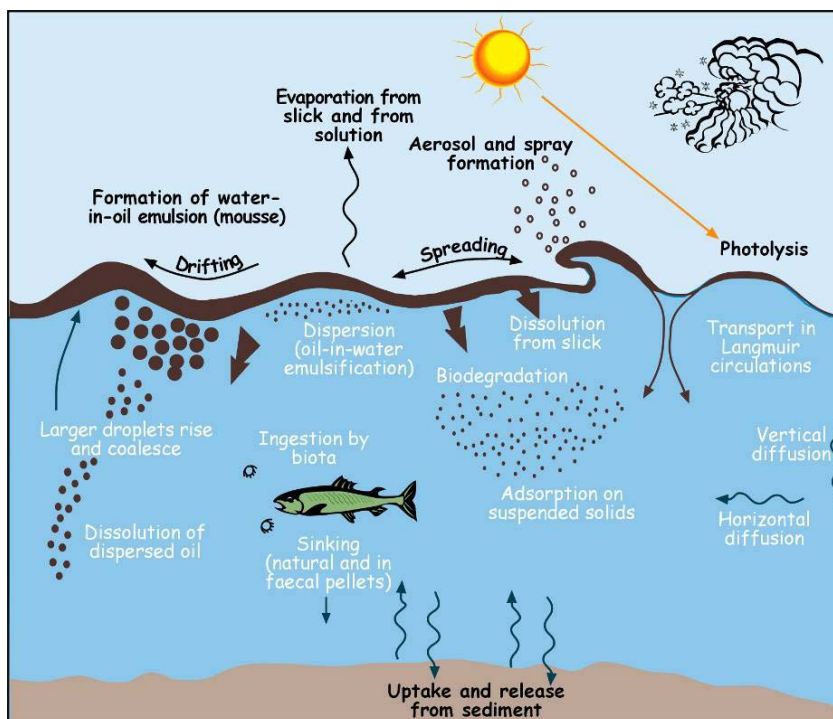
8.6.3 The behaviour of hydrocarbons at sea

When oil is released into the marine environment it undergoes a number of physico-chemical changes, some of which assist in the degradation of the spill, while others may cause it to persist. These changes are dependent upon the type and volume of oil spilled, and the prevailing weather and sea conditions. An overview of the main processes influencing the fate and behaviour of spilled oil at sea is given in Figure 8.3.

Evaporation and dispersion are the two main mechanisms that act to remove oil from the sea surface. Following a hydrocarbon spill, evaporation is the initial predominant mechanism of reducing the mass of oil, as the light fractions (including aromatic compounds such as benzene and toluene) evaporate quickly. If the spilled oil contains a high percentage of light hydrocarbon fractions, such as diesel, a large part of the spilled oil will evaporate relatively quickly in comparison to heavier (crude) oil. The evaporation process will be enhanced by warm air temperatures and moderate winds and can produce considerable changes in the density, viscosity and volume of the spill.

After the light fractions have evaporated from the slick the degradation process slows down and natural dispersion becomes the dominant mechanism in reducing slick volume. This process is dependent upon sea surface turbulence which in turn is affected by wind speed. Water soluble components of the oil mass will dissolve in the seawater, while the immiscible components will either emulsify and disperse as small droplets in the water column (an oil-in-water emulsion) or, under certain sea conditions, aggregate into tight water-in-oil emulsions, often referred to as 'chocolate mousse'. In practice, usually only one of the two processes will take place (dominate), as they will hardly ever will take place at the same time.

Figure 8.3 Fate and behaviour of spilled oil at sea



The rate of this emulsification is dependent upon the oil type, sea state and the thickness of the oil slick. Thick (large) oil slicks tend to form water-in-oil emulsions, where thin (smaller) slicks tend to form oil-in-water emulsions that usually disappear by natural dispersion.

When a water-in-oil emulsion (chocolate mousse) is formed, the overall volume of such a water-in-oil emulsion increases significantly, as it may contain up to 70 or 80% water. This chocolate mousse will form a thick layer on the sea surface reducing slick spreading and inhibiting natural dispersion. By diminishing the surface area available for weathering and degradation, these chocolate mousses will be difficult to break up using dispersants. In their emulsified form, with drastically increased volume, they can cause difficulties for mechanical recovery devices as well.

Wind and surface current speed and direction are the main parameters involved in affecting where a slick travels. The slick will roughly travel at the same speed and direction as the surface water current. Additionally, the prevailing wind drives a slick downwind at 3 to 4% of the wind speed.

Spill modelling in the oil and gas industry is undertaken as a matter of course as there is usually a requirement, prior to drilling, that an Oil Spill Contingency Plan (OSCP) is prepared (OSCP is a requirement in Ireland, and subject to approval by the Irish Coast Guard). A range of oil spill scenarios are modelled including both crude/condensate and diesel. Deterministic 'worst case scenario' modelling is used to determine the shortest beaching time using predetermined weather conditions. Single trajectory modelling for an instantaneous release of around 1,200 m³ of diesel (a common standard inventory of a drilling rig) shows that, under a constant 30 knot wind, the released diesel would normally evaporate and disperse rapidly into the water column within eight hours. These calculations assume that there is no intervention of the slick although, in practice, oil spill response resources would be mobilised immediately and do not take into account weather conditions that may enhance the dispersion process.

For crude oil spills, modelling has to be based on the expected characteristics of the crude ie heavy/light, which are determined by the reservoir the crude originated from. Therefore site-specific modelling should be undertaken where drilling is expected to take place in an oil bearing formation.

The OSCP produced for all drilling operations will specify the level of spill response equipment and facilities present both offshore and onshore.

8.6.4 Potential impacts of a hydrocarbon spill

Factors important in determining oil spill impacts and recovery rates include the type of oil, the thickness of shore deposits, climate and season, the biological and physical characteristics of the area, the relative sensitivity of species and communities and the type of clean-up response. The impacts arising from oil spills are well documented, and a summary of these impacts and their effects is given in Table 8.8.

Table 8.6 Summary of the potential impacts of hydrocarbon spills

Group	Comments
Plankton	Short-term effects have been recorded. However, serious impacts on planktonic organisms have not been observed in the open sea. The main impact is considered to be through initial acute toxicity and long-term effects have been reduced possibly because of high reproductive rates and immigration from outside of the effected area.
Benthos	Effects on the benthos include acute toxicity and possible organic enrichment. Offshore impacts are likely to be minimal, and influenced by water depth and local hydrography. Shallow inshore areas and the shoreline are susceptible to heavy mortalities if coated with fresh crude oil. Recovery times are variable, dependant on many environmental factors, and may be in the region of 1 to 10+ years. The cold-water corals <i>Lophelia pertusa</i> and <i>Madrepora oculata</i> may occur in the IOSEA1 area, although no clusters have been identified to date. There is no research available yet on the effects of hydrocarbon contamination, however evidence from other coral species suggests that chronic contamination may result in sub-lethal effects and interfere with reproduction and hence recruitment in cold-water corals.

Table 8.7 Summary of the potential impacts of hydrocarbon spills

Group	Comments
Fish and cephalopods	<p>Adult fish tend to avoid impacted areas however populations moving back into an effected area may take some time to recover. Eggs and larvae in shallow areas may suffer heavy mortalities under fresh slicks, particularly if dispersants are used. There is no evidence that offshore fish populations have been significantly effected. Peak spawning periods for fish species within the IOSEA1 and adjacent coastal area are between January and June.</p> <p>Spills that affect spawning migration of fish into rivers can affect populations in subsequent years.</p>
Mammals and reptiles	<p>It has been rare for cetaceans to be affected following a spill; they may be able to avoid affected areas and are not believed to be susceptible to the physical impacts of oil and oil emulsion lowering their resistance to the cold. Respiratory problems may be caused by volatile hydrocarbon fractions.</p> <p>Seals are susceptible to oiling and the contamination of food sources, particularly in the coastal areas around their colonies, where their density is highest. While they come ashore throughout the year, the majority of grey seals remain close to shore during the breeding and moulting seasons, September to April. Harbour seals undergo a similar cycle between June and September, although they continue to forage at sea throughout their breeding season. New born pups are considered most at risk from oil coming ashore.</p> <p>There is little evidence of impact on European otters by oil spills, although food sources may be contaminated. However, thermoregulatory abilities of otters and seals can be impaired when their fur comes into contact with oil.</p> <p>Impacts on marine turtles in the study area are considered to be similar to those for cetaceans. There are no nesting beaches in Ireland.</p>
Birds	<p>Potential fatalities of some sensitive offshore species particularly auks and divers, may arise, although this tends to be dependent on species present at the time of the spill. Birds are sensitive to physical fouling of feathers and toxicity by ingestion.</p> <p>The impact on breeding colonies and bird populations depends upon the existence of a reservoir of young non-breeding adults from which they can be replenished and the reproductive rate of the impacted species. There is no evidence that oil spills have permanently damaged any seabird populations, but any small indigenous populations could potentially be at risk.</p> <p>Vulnerability of individual species against time of year are detailed in Section 5.2.5.</p>
Archaeology	<p>Wrecks within the IOSEA1 area are unlikely to be effected by hydrocarbon spills, and many recent wrecks are themselves sources of hydrocarbon contamination. The depth of water over the majority of the IOEA1 area will separate wrecks from hydrocarbon spills. Historic wrecks and archaeological sites in sheltered shallow water on the coast may be at risk from large hydrocarbon spills. The OSCP should take the location of National Monuments into account when deciding upon response strategies. Impacts on coastal archaeology are associated with smothering and damage from clean up operations.</p>
Fisheries and mariculture	<p>Fish exposed to oil may become tainted by oil-derived substances. It is of particular concern in caged fish and shellfish culture. Major spills can result in loss of fishing days and exclusion zones and bans on certain species may be enforced and may last several years. Media coverage together with public perception can also damage fisheries.</p>
Tourism	<p>Coastal tourism is vulnerable to the effects of major oil spills. The impact would be influenced by a number of factors including media coverage and public perception.</p>

8.6.5 Data gaps

No data gaps have been identified.

8.6.6 Mitigation measures

The following measures are already in place, either integral with good practice, or with regulatory systems, or both.

The crew of the drilling rig/ship should undergo environmental awareness and safety training. All equipment used on the rig/ship should have safety measures built in to minimise the risks of any oil spillage.

A two-barrier well control policy should be implemented at all times as a minimum. Primary well control (ie mud hydrostatic) and secondary well control (blow-out preventers or BOPs) should be maintained throughout the drilling of a well. A full risk assessment should be performed as part of the planning phase of the well.

The drilling rig or ship should have built-in safety measures to minimise the risk of an oil spillage, notably blow-out preventers, and fuel-transfer hoses.

As the highest risk of diesel spillage occurs during re-fuelling (bunkering) operations at sea, all bunkering should take place during suitable weather conditions, preferably in daylight hours, and a continuous watch should be posted during the operations. The bunkering hoses should be segmented and have pressure valves that, in the event of a drop in pressure within the line as a result of loss of diesel, will close, preventing the further release of diesel.

An OSCP is required under the Sea Pollution (Amendment) Act 1999, and this requirement is re-stated in the PAD Rules and Procedures Manual (PAD, 2005a). The OSCP is designed to assist the decision-making process during an oil spill, indicate what resources are required to combat the spill, minimise any further discharges and mitigate its effects. The OSCP must be submitted to the Irish Coastguard for approval.

Any oil spill must be reported immediately, however small. The level and manner of the required oil spill response will be overseen by the Irish Coast Guard, and determined by the volume and type of oil spilled, and the weather and sea conditions at the time.

Any oil spill likely to have impacts in UK waters will be reported by the Irish Coast Guard to the relevant UK authorities. The Irish Coast Guard has a close working relationship with the UK Maritime and Coast Guard Agency (MCA) and is currently finalising a Service Level Agreement for co-operation on search and rescue and oil spill response. Recently the Irish Coast Guard and the UK MCA concluded a joint search and rescue and oil spill response exercise off the Donegal coast.

8.6.7 Chemical spills

Chemical spills to the marine environment can have a number of environmental and economic impacts. The chemical inventory on drill rig/ship and supply vessels will include drilling mud formulation and cementing chemicals. Whilst little data are held on the frequency of chemical spills offshore, it is assumed that spills of such chemicals, if any, will be mostly small (<1 tonne) and will rarely exceed 10 tonnes.

Impacts of chemical spillage

The environmental implication of a chemical spill is largely dependent on the type of chemical involved, the size and location of the spill and the weather conditions at the time. The actual hazard presented by a spill will depend on the exposure concentration, which is determined by the quantity and rate of spillage and the dilution and dispersion rates. These factors will differ according to whether the spill takes place at the sea surface or sea bed.

The dilution and dispersion of a sea surface spill will depend on the sea state at the time: larger waves will be more effective at dispersing the spill than calm sea states. It will be diluted as it sinks and will be moved by tidal currents and wave activity. Diluted chemicals would be carried with the body of ambient seawater and gradually disperse and degrade. Although it may be detectable within a circle of a tidal motion, it will only be toxic within a very limited area and for a short period of time.

The fate of a spill at seabed level will depend on the properties of the chemical. If the chemical is denser than seawater it may spread over the sea bed and become mixed within the substrate causing potential harm to the benthic community. A lighter chemical will leach into the water column and be dispersed with the currents.

8.6.8 Gas blowout

A gas blowout may be caused when a drilling pipe encounters a shallow or a deep pressurised gas zone or an over-pressured rock layer in the subsurface without being prepared to counter the pressure. This allows the gas or the fluid from the rock layer to enter the drilling pipe and up towards the surface. Any gas zone penetrated before a blowout preventer (BOP) has been installed is called a shallow gas blowout.

Shallow gas blowouts occur in approximately one in every 200 wells drilled (UNEP, 1997). While potentially dangerous there are few studies available on gas interactions with the marine environment. Naturally occurring gas blowouts have been linked to gas hydrates and form a potential natural geohazard in the marine environment (Section 5).

Impacts of gas blowout

In addition to planned operations such as power generation, atmospheric emissions may also occur as a result of a blowout in an emergency situation. Emissions would be reservoir specific and likely to contain a large proportion of methane (CH₄) with smaller amounts of volatile organic compounds. In the unlikely event of an explosion and hydrocarbons burn then combustion products including carbon dioxide (CO₂) and carbon monoxide (CO) will be emitted. Exact emissions would be well specific but could be considered to be large in a worst case scenario.

8.6.9 Data gaps

No data gaps have been identified.

Mitigation

The following measures are already in place, either integral with good practice, or with regulatory systems, or both.

- The potential for shallow gas should be identified and minimised by site survey prior to drilling.
- The BOP is installed to prevent gas blowout once drilling has progressed beyond the riserless stage.
- Gas detection systems are installed on mud shakers to give early indication of any potential for gas blowout
- Training in safety awareness and response procedures for drilling crews will ensure that the risk of a blowout will be minimised, and be able to make the appropriate response should one occur.

8.6.10 Conclusions

Outputs from ENVID exercise in Section 6 rate the significance of environmental impact from worst case accidental spillages of hydrocarbons as High with potential Major or Severe effects. A review of the vulnerability of the ecology and economic interests outlined in Section 5 against the possible impacts of a major hydrocarbon spill suggests overall Moderate or Major effects on the coast and Minor effects in the offshore area.

The risk of a major crude oil spill or gas blowout during exploration, appraisal and development drilling is considered to be very low. Historical data suggest that small diesel spills from rigs and vessels of less than one tonne represent the most likely oil spill scenario. Impacts from diesel spills of this magnitude and frequency (once every 50 to 100 wells drilled) would be Negligible.