South East Regional Marine Plan

Impacts on the Natural System


Chapter 4 – Impacts of Petroleum

National Oceans Office

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1 Overview

This chapter outlines the potential environmental impacts associated with offshore petroleum activities and operations. Phases of petroleum activities addressed in this chapter include:

- Seismic Surveys
- Exploration Drilling
- Field Development
- Production Operations and
- Decommissioning

The level of impact from petroleum operations is highly dependent on timing, particularly with respect to the critical life cycle periods of marine species. As a general industry rule, development programs are coordinated to avoid highly sensitive periods (ie migration, calving and feeding). Potential consequences must be examined with reference to program timing and location.

Potential impacts vary greatly for each phase of the industry but broadly include:

- Changes in behavioural ecology (ie feeding, breeding and migratory regimes)
- Disturbances from noise related activities
- Direct impacts from hydrocarbon spills
- Direct impacts from seabed works and disposal of waste discharges

A summary of impacts is provided in Table 3. A list of South East regional species and communities likely to be impacted is provided in Appendix 1.

2 Seismic Survey

2.1 High Intensity Sound Discharges

High intensity noise discharges from seismic surveys are considered to be the most likely activity to impact marine systems. Research carried out in 1994 by the Independent Scientific Review Committee (ISRC), chaired by Professor John Swan, and commissioned by the Australian Petroleum Production Exploration Association (APPEA) and the Energy Research and Development Corporation, found that environmental issues relating to seismic surveys are largely concerned with:

- Pathological effects (lethal and sub-lethal injuries) – immediate and delayed mortality and physiological effects to nearby organisms
- Behavioural change to populations of marine organisms
- Disruptions to feeding, mating, breeding or nursery activities of marine organisms in such a way as to affect the vitality or abundance of populations
- Disruptions to the abundance and behaviour of prey species for marine mammals, seabirds and fish
- Changed behaviour or breeding patterns of commercially targeted marine species, either directly, or indirectly, in such a way that commercial or recreational fishing activities are compromised

McCauley (1994) found that the response of Australian marine fauna to marine seismic survey noise ranged from no effect to various behavioural changes. McCauley found no evidence that the majority of marine species suffer any lethal or pathological effects as a result of noise from seismic surveys. Immediate pathological effects are likely to be restricted to very short ranges and to be limited to animals that are unable to move from within the damage zone of 1 – 2 m from the energy source (McCauley, 1994; Gausland, 2000).

The effects of noise on whales and other marine fauna may potentially induce behavioural changes (ie feeding, breeding and migratory regimes). Behavioural changes may broadly include repulsion from the noise source, startle and alarm responses and even attraction to the source. Repetitious acoustic disturbance could cause abandonment of important habitats such as calving and nursery sites.

McCauley (1994) concluded that "…*given the relatively small scale of seismic activity, the often large scales over which biological events occur, the low probability of encounter between seismic surveys and 'at risk' populations at an appropriate time and place, then the wider implications of disruption by seismic surveys appear to be small for most species*".

Despite this, a discussion of the research and potential for effects on marine species as a result of seismic activity is provided for the reader.

Cetaceans

For most whale species there has been no documented evidence of any lethal effects resulting from exposure to noise from marine seismic surveys. Specific studies on the direct physical damage to the hearing organs of various marine mammal species resulting from seismic has not been undertaken. Physical damage to auditory systems is believed to occur at noise levels of about 230 – 240dB within 1 – 2 m of the energy source (Gausland, 2000). However, it is unrealistic to attribute one single value of sound level at which damage to the auditory system will begin for all marine mammals (National Research Council, 2000). Recent experiments on several smaller whale species to determine hearing damage as a result of exposure to intense signals indicate only temporary effects (Schlundt *et al.,* 2000) with no long term damage detected.

A summary of cetacean behavioural effects with respect to seismic activities has been summarised by McCauley and Duncan (2001):

- there is definitive evidence of behavioural responses of great whales to various noise sources, the type of response is variable, and ranges from none to active avoidance of a source
- there is evidence that at the species level whales respond differently to a given noise depending on their behavioural state or habits at that particular time
- there is evidence that the response of a species to artificial noise may change through time due to familiarisation or sensitisation of whales to the noise source

<u>Baleen and Toothed Whales</u>

Baleen whales are considered the most sensitive of the marine mammals to seismic arrays due to their use of low frequency signals (McCauley, 1994). The low frequency hearing capability is believed to overlap the energy output of seismic. Yet it is also believed that baleen whales, may be quite tolerant of low- and moderate- level noise pulses from distant seismic surveys (ie greater than 8km), (Richardson *et al.,* 1995). Lower received levels may have subtle effects[1] on surfacing, respiration and diving patterns (Richardson *et al*, 1995).

Toothed and baleen whales routinely expose themselves to signals of equal or greater intensity low frequency sounds to seismic noise (McCauley and Duncan, 2001) without any known effects. For these species therefore it is probable that exposure to the likely range of seismic signals will not be lethal (McCauley and Duncan, 2001).

The intensity and duration of sound required to cause permanent and temporary damage to whale auditory and other organs is not known. Baleen whales are thought to be at some risk of hearing damage from seismic noise (Richardson *et al*, 1995). Hearing sensitivity of toothed whales and pinnipeds is known to be poorer at lower frequencies (ie most sensitive at frequencies of at least several kilohertz), probably reducing the potential for auditory damage from prolonged exposure to low frequency artificial noise (in Richardson *et al*, 1995).

Within several kilometres, baleen whales may exhibit strong avoidance behaviour with disruptions of activities ranging from one hour or more (Richardson *et al.*, 1995). Short-term observations provide no information about the long-term effects (ie reproduction rates or distribution and habitat use) on baleen whales (Richardson *et al.*, 1995).

Toothed cetaceans[2] produce echo-location clicks that have the highest source levels of any recorded marine mammal sounds, ranging up to 220-230 dB re 1μPa-m. Most components of toothed whale social sounds are well above the low frequency range where marine seismic survey noise is concentrated (Richardson *et al*, 1995). Little published information is available about the reactions of smaller toothed cetaceans to seismic noise (McCauley, 1994). Smaller toothed cetaceans have poor hearing in the low frequency range of airgun array noise (10-300 Hz), so may be able to approach operating seismic vessels closely without adverse behavioural or pathological effects (McCauley, 1994).

The hearing capability of larger toothed whales (such as the sperm whale) is unknown, but it is possible that they can hear better in the lower frequencies than the smaller toothed cetaceans. If this is the case, in lieu of any other information, their reactions to seismic survey vessels may be akin to those of the baleen whales (McCauley, 1994).

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[1] Unlikely to have biologically significant impacts at either an individual or population level.

[2] Toothed cetaceans include species as the sperm whale, beaked whales, porpoises and dolphins

Humpback Whales

A recent study indicated migrating humpback whales are likely to be displaced (with no gross change in migratory paths) from an area of approximately 3km from the seismic activity (McCauley, 1998). Sedentary humpback whales appear more sensitive to intense noise, standing off at approximately 143 dB, or approximately 6-7km from a firing airgun array. Seismic surveys over humpback calving grounds may potentially seriously disturb populations within 20km (McCauley, 1999). If a survey is further than 20km from a humpback breeding/resting/calving area, adverse impacts are expected to be by way of irritation, rather than interruption.

Feeding humpback whales could be interrupted for an hour or two, or longer if feed species are also displaced from the area. However, it is assumed that whales would not be affected by a loss of a feeding area of a few cubic kilometres for a few days due to the large areas over which they feed.

Communication may be interrupted within the zone where seismic is above background ocean sound levels (i.e. approximately 50km). However, research indicates (Swan, 1994) that humpback whale population numbers in Western Australia, appear to have increased despite the large number of seismic surveys over the migration path in the last 20 years.

Blue and Fin Whales

As blue whales routinely produce intense low frequency signals over sustained periods it is probable that they can tolerate moderate levels of low frequency noise without any changes in hearing sensitivity (McCauley and Duncan, 2001). The effects of low frequency noise (from the US Navy's SURTASS low frequency active sonar) on the foraging ecology of blue and fin whales off the Californian coast concluded that there were no obvious responses (ie foraging behaviour, whale encounter rates and diving behaviour) to loud anthropogenic low frequency noise (Croll *et. al.*, in press). Although, the study does recognise that the cumulative effects of low frequency noise may be highly significant over both spatial and temporal scales. McDonald *et al.* (1993) also reported from observations within US waters that blue whales continue to call in the presence of noise pulses from airguns.

Beaked and Sperm Whales

There are some indications of behavioural reactions by sperm whales and beaked whales to low frequency sound pulses at long ranges (Bowles *et al.*, 1994; Davis *et al.*, 1995 in Richardson *et al*, 1995) but limited data is available to determine the significance of these reactions. There has been recent speculation that the Cuviers beaked whale (potential to occur in South East region) may be susceptible in the frequency range 100-500 Hz. Two instances of mass strandings and death of beaked whales have been correlated with US military trials of high powered low frequency sonar systems (in McCauley and Duncan, 2001).

Southern Right Whales

The observed pathological effects of seismic activities on southern right whales are poorly researched or understood. No direct data can verify whether the auditory system of the southern right whales can potentially be damaged by seismic, or if the research undertaken on other species occurring in South East regional waters is directly comparable to the southern right whale.

Expert opinion is that southern rights are likely to be less sensitive to noise disturbance than humpbacks (R. McCauley, CMST, Curtin University, pers. Comm – courtesy of Woodside Energy Ltd).

Dolphins

The effects of seismic operations on dolphin species within the South East region has not been accurately determined. Anecdotal evidence suggests that seismic surveys do not affect dolphins due to the species mobility and natural frequency range (Au *et al*, 1997 and Gausland, 2000). Sightings by seismic operators of dolphins near operating airguns generally confirm this assumption (Duncan, 1985 in McCauley, 1994). Although not directly comparable to Australia's common dolphin or bottlenose dolphin, studies undertaken by Au *et al.* (1997) observed the response to seismic noise for two members of the dolphin family (false killer whale and Risso's dolphin in the Pacific Ocean) and concluded that neither species would be negatively affected by seismic operations due to their high auditory thresholds.

Pinnipeds

Little data exists for low frequency thresholds and hearing sensitivities of Australian pinnipeds. Seals and sea lions, due to their tolerance levels and their poor hearing in the low frequencies, may potentially tolerate seismic shots of high intensity and may be able to approach operating seismic vessels to a close range, (McCauley, 1994). However, seismic may affect seal and sea lion breeding success by its influence on prey abundance or behaviour (McCauley, 1994). It is also recognised that seismic activity will only be a threat to pinnipeds if it take place close to critical habitats (Shaughnessy, 1999).

Turtles

Marine turtles displayed no long-term neurophysical damage, although a reduction in hearing capability was evident, the effect was temporary and returned to normal within a short period of time (McCauley *et al.*, 2000).

Marine turtles are expected to display behavioural changes at around 2km and avoidance around 1km of the seismic array (McCauley *et al*, 2000).

Fish

No lethal effects have been observed for adult fish, crustaceans and shell fish exposed directly to seismic arrays (McCauley, 1994).

A number of experimental studies on fish subjected to individual air-gun shots have indicated that no damage or significant physiological stress occurs (McCauley *et al*, 2000; McCauley, 1999; APPEA, 1998). However preliminary evidence from recent research indicates constrained fish (pink snapper, *Chrysophyrys auratus*) exposed to very short range air gun exposure, exhibit some damage to the hearing systems (ie ablated and damaged hair cells), implying that some fish may have reduced fitness after exposure (McCauley *et al.*, 2000). Although exposure regime required to produce such effects has not been established, it is believed such damage would require exposure to high-level air gun signals at short range from the source. The fish used in the trails were constrained and approached to short range with an operating air gun. This is unlike fish in the vicinity of an operating seismic vessel, where it could be expected that avoidance would occur before air gun signals reached levels sufficient to produce some form of hearing damage (McCauley *et al.*, 2000). It must also be noted that potential seismic effects of fish may not necessarily translate to scale effects or disruption to fisheries (McCauley *et al.*, 2000).

The nature and extent of behavioural change may vary depending on a range of parameters including the species involved, propagation and aspect of array. Available evidence also suggests that behavioural changes for some fish species may be no more than a nuisance factor (McCauley, 1994). Generally, it is considered that such consequences will be localised and transitory, with any displacement of pelagic or migratory fish insignificant at a population level.

A number of studies into the behavioural response of fish indicate that in broad terms (McCauley, 1994; McCauley *et al*, 2000):

- Demersal fish could be expected to begin to change their behaviour by increasing speed and swimming deeper in the water column
- Startle responses could be expected to be generated in fish within 300m and up to 2000m of the array
- As airgun level increases these fishes would be expected to form compact schools probably near the bottom in continental shelf depths (<200 m)

- Eventually levels may be reached at which involuntarily startle responses occur in the form of the classic C-turn
- In deeper water (>200 m) any effects would be expected to lessen with increasing depth, as the airgun signal level dropped accordingly
- Flight responses could be expected up to several kilometres

However, reactions and ranges of effects are only described for very few species (McCauley, 1994). Despite behavioural responses to seismic noise, some pelagic fish in the Gippsland Basin regularly damage hydrophone cables, implying at least some fish species may show no long-distance avoidance reaction (Colwell and Coffin, 1987 in McCauley, 1994).

Krill and Planktonic Larvae

The impact of seismic noise on krill is not known and so is assumed to be similar to that of fish and squid, where for a single air-gun signal, significant behavioural effects would be initiated at approximately 5 km or more and avoidance would occur at 3-5 km (McCauley and Duncan, 2001). The similarities of statocyst organs[3] between crustaceans and cephalopods suggests that krill, like cephalopods may be responsive to sound, but at this stage it is not possible to say this with any certainty, or what any responses, if any, may be (McCauley and Duncan 2001).

Plankton and larvae, which cannot readily remove themselves from the area, may be fatally affected in areas immediately adjacent to the noise source. However, the effect is likely to be limited and, due to population density, is not thought to have any long term effects on the species.

Studies have shown that larvae, fish eggs and other planktonic organisms are likely to be significantly affected (ie suffer pathological damage) within a few metres (five) of an airgun (McCauley, 1994). However, effects of seismic on larval fish and invertebrate populations are negligible when compared to total population sizes and natural mortality rate for eggs and larvae[4] (Gausland, 2000; McCauley, 1994).

2.2 Physical Presence of the Vessel

The physical presence of the vessel during seismic does not typically result in significant potential impacts.

Marine species, in particular marine mammals, are expected to easily avoid the vessel during seismic surveys due to exhibited avoidance behaviour to noise and the slow speed of the ship.

Seismic vessels do not typically anchor during survey programs, coupled with the offshore location of the vessels, the likelihood of disturbance to coastal and seabed environments (and associated benthic and epibenthic communities) due to anchoring or grounding is low.

2.3 Waste Discharges

Discharges of wastes to the sea during seismic programs are limited to biodegradable matter (ie macerated food scraps and sewage). This matter will result in localised increases in nutrient levels, which may stimulate microbial activity and therefore act as a food source for scavenging birds and/or marine animals.

[3] A sense organ that can provide orientation to the pull of gravity.

[4] Although high egg production of *N. australis* calculated in Tasmania waters range between 1.41 and 4.22mg m^{-3} per annum (Hosie, 1982), natural mortality rates for marine invertebrate eggs and larvae are normally greater than 99 percent (McCauley, 1994).

Low level contamination of organisms is also possible as a result of ingestion of this material: isolated population numbers of some organisms may be affected in the short term.

Atmospheric emissions associated with engine exhausts and other onboard sources are minor.

2.4 Ballast Water Discharges

Ballast water drawn from shallow seas or harbours and subsequently discharged into similar environments in different locations may cause a range of environmental consequences. Potential impacts and species that may be affected are further described in the National Oceans Office report (2001).

2.5 Hydrocarbon and / or Chemical Spills

Accidental discharge, although unlikely, may result from:

- Leakage or rupture from engines, equipment or streamer cables
- Spillage or leakage during diesel/fuel oil transfer operations
- Spill or leakage from bulk or packaged storage areas

In the event of a catastrophic collision, most spill fluids will consist of light hydrocarbons (diesel). Diesel is a light and highly evaporative petroleum product. Diesel disperses relatively rapidly after spillage to form a thin sheen. Under typical conditions, up to 95% of an initial spill volume can be lost by weathering during the first 5 days (GEMS, 2001)). Residual fractions would also be expected to continue to weather through processes of dissolution, biodegradation, photo-oxidisation and sedimentation.

Potential impacts will be short-lived and confined to the water column only. No long term detrimental adverse affects are anticipated by the industry on marine mammals and/or sensitive coastal environments. No seabed accumulation is anticipated to occur from a spill during seismic operations.

3 Exploration Drilling

3.1 Noise Emissions

Potential impacts to marine species from drilling activities are not well understood. There are a few key studies that describe potential impacts, and further research is anticipated from the industry in future years. Offshore exploratory drilling is not normally considered likely to have a significant impact on a matters of national environmental significance (Environment Australia, 2000).

Cetaceans

In response to noise generated from the rig and activities, cetaceans are likely to display behavioural changes rather than physiological effects.

Drilling noise is well below the source levels of the highest components of a humpback whale song (192 dB re 1μPa^2), and is not much greater than the ambient background noise level (McCauley, 1998). Rig tender vessels may generate higher levels of noise, especially if they are using engines to hold position alongside the platform for supply or transfer operations. Whales are not likely to be significantly impacted by noise disturbance, however, sound emitted from drilling operations may interfere with the cetaceans range and may induce stress. Avoidance behaviour and minor route alterations may occur within 3km of the wellhead. This behaviour is likely to be very localised and short-term, particularly for locations near high levels of shipping traffic (ie Bass Strait waters).

McCauley and Duncan (2001) estimated avoidance ranges for blue whales from petroleum drilling and ship noise in the Otway Basin (refer Table 1). However, there have been no further studies undertaken for other South East regional marine or cetaceans species.

Table 1: Predicted ranges for three artificial sources in Otway Basin [5]

Scenario	Drilling only (km)	Rig tender on station (km)	Ship steaming (km)
10% avoidance (gray)	1	8.75	4
50 % avoidance (gray)	0.5	6.75	3
90 % avoidance (gray	< 0.25	1.25	< 0.5
strong behavioural changes (bowhead)	< 0.25	2.25	< 1
typical avoidance (bowhead)	< 0.25	< 0.5	< 0.25

Results infer blue whales may potentially occur within less than one km of the drill rig during drilling activities and when rig tenders are idle. However, when the rig tenders are active (and at their noisiest state), it is unlikely blue whales will be found within a few km of a drilling rig.

[5] Each scenario based on sound levels given in Richardson et al (1995) and predicted propagation of (McCauley and Duncan, 2001).

Pinnipeds

Seal breeding colonies are known to be highly sensitive to noise and intruder disturbances. The level of disturbance is highly dependent on distance to colony, level of noise impact and project duration. No specific studies have been undertaken on the effects of drilling noise on pinnipeds. In general, pinnipeds haul out for pupping or moulting. Impacts associated with pinniped behaviour in response to aircraft noise include stampeding into the water (Richardson *et al*, 1995). However, seals show considerable tolerance of vessels, and it is unknown if they are truly affected or subject to stress.

Fish

Additional evidence from exploration conducted in the North West Shelf suggests that in response to drill noise, behavioural changes for some fish species are temporary and short ranged (ie. nuisance factor) (McCauley, 1998). Under ideal conditions (dead calm sea and no wind), drilling noise was recorded to be detectible up to 20 km away, though at levels below the expected hearing range of the fish studied (ie snapper, *Lutjanus apodus*).

Displacement of pelagic or migratory fish populations is unlikely.

Krill

Studies investigating the ability for krill to detect sound and the possible effects of noise (drilling or seismic) have not been undertaken. McCauley and Duncan (2001) have assessed the possible risks to krill associated with drilling noise, which are presented in Table 2.

Table 2: Potential Effects on Krill

Potential Effect	Potential Risk Level
Pathological effects	Unlikely risk
Behavioural effects	A small risk of short term avoidance from an initial startle response (less than 500 m)
Geographical scale of effects	Very small risk of effects confined to the immediate area around the drill site

3.2 Physical Presence of the Drill Rig

Marine species, in particular marine mammals, are expected to easily avoid the drill rig and support vessels during mobilisation and drilling activities due to exhibited avoidance behaviour to noise and the slow speed of the vessel.

It is unlikely that the drill rig or support vessels will run aground, due to the offshore water depths of the well locations.

Rig anchoring disturbance is dependent on the duration of the drilling program which typically varies from two weeks to two months. The area of seabed and associated benthic and epibenthic disturbance is typically in the order of $40m^2$. Benthic organisms are expected to recolonise quickly after drilling operations cease. Strong oceanic currents tend to moderate 'footprints' produced by equipment placement. The physical presence of the drill rig is likely to have a minor and short-term effect on the seabed. Physical disturbance from drill cutting and fluids are further discussed in Section 3.3.

3.2.1 Light Emissions

The continuous lighting of the drill rig may attract marine species (such as fish, seals and seabirds) and depending on the foraging range of some species, may result in a short-term abundance or concentration of species in the immediate vicinity. This impact is not considered to induce any long-term changes in feeding behaviours (eg. dependency) or population dynamics.

3.3 Drilling Waste Discharges

Offshore exploration drilling programs may discharge drilling fluids and drill cuttings to the oceanic seas.

3.3.1 Turbidity

Drilling activities and disposal of drill cuttings and fluids will produce suspended sediments in the water column, therefore increasing turbidity. Turbidity can reduce the amount of light and oxygen available at the seabed and lower levels of the water column, which may potentially impact light dependant biota.

Natural oceanic factors (ie water depth, tidal currents and the interplay of surface and oceanic currents) influence the dispersion and dilution rates of discharged wastes from the rig.

Depending on the location of the drill site, turbid waters are not expected to be transported to sensitive eastern mainland coastlines (ie coastal environments, kelp and seagrass beds, intertidal temperate reefs) and offshore islands (ie Hogan, Devils, Cutis , Judgement Rocks, Kent Group, the Furneaux Group).

Potential impacts to biota are generally restricted to within the disposal period and immediate discharge area (ie tens of metres within the plume and 50m around the well location).

3.3.2 Burial or Smothering Effect

Physical disturbance to the seabed during the disposal of drilling wastes will cause localised shifts in sediments, smothering benthic and epibenthic biota in concentrated areas close to the discharge point (ie 100-200m). Natural dispersion and dilution rates will moderate the smothering impacts of discharged cuttings. Sediment loads are rapidly reduced in the water column and any smothering impact is confined to the immediate point source.

The Bass Strait region has been described to be one of the most highly diverse areas on the temperate continental shelf (Parry *et al*, 1990), with benthic species recorded to display a high degree of endemism[6] (Wilson and Allen, 1987). The wide distribution of species and heterogeneity of benthic habitat recorded throughout the region (Phillips *et al*, 1984) broadly indicate that isolated drilling activities are unlikely to significantly disturb any unique faunal elements. However, infauna species are considered more susceptible to the effects of smothering. The community type is generally known to be resilient to physical smothering, provided that the overall characteristics of the sediments are unchanged. Adverse effects are exacerbated if cuttings contain contaminants or are of different grain size to the existing natural sediment structure.

In addition, environmental monitoring studies undertaken in the Bass Strait and Otway Basin showed localised effects were generally short lived, with most benthic organisms recovering within 4 months (BHP & Santos, 1993; Terrens *et al.*, 1998). Generally, the regional benthic community is not expected to be significantly impacted from cutting discharges due to the localised (100-200m) and short lived (<24 months)

[6] (ie 90-95% endemic to south eastern Australia)

nature of the impacts and activity (SKM 1996 & 1997; Kinhill Engineers 1997 & 1998; Hindwood *et al.*, 1994).

3.3.3 Toxicity

Drill fluids and cuttings may present a potential source of contamination for biotic organisms. In general, water-based drilling fluids are used containing 40-70% water as the main component of the system. Generally, the largest mineral component of drilling fluids is barite, and is considered one of the least toxic fluid available.

The Australian Petroleum Production and Exploration Associations (APPEA) (1998) findings on the toxicity effects of drill cutting and fluid disposal on the marine environment generally confer with Hinwood *et al.* (1994) in that:

- major contamination and community effects are limited to 250m from the wellsite;
- beyond 250m it is difficult to detect any community effects
- elevated concentration of heavy metals or hydrocarbons associated with drilling fluid is generally not detectable beyond 1000m

Nektonic and planktonic species will be directly effected, as these species are not able to move out of the plume due to their inherent mobility characteristics. Potential toxicological effects from drill waste disposal on regional values or areas of environmental sensitivity (beyond the immediate drilling rig; ie. coastal reefs and islands) are not considered significant.

3.3.4 Bio-accumulation

Toxic effects of drilling fluids on marine organisms are only likely to be found within short distances from the drill site (as described in Section 3.3.3). The potential for mineralisation of cuttings is expected to be low and any heavy metals present are unlikely to be bioavailable or in insoluble form (with the exception of very minor quantities of formation fluids that may be circulated).

3.4 Other Waste Discharges

Discharge of other wastes during drilling operations will have the equivalent impacts to seismic activities (refer Section 2.3).

3.5 Hydrocarbon and / or Chemical Spills

Accidental releases of hydrocarbons during drilling operations may be associated with accidental leakages of equipment, well blowout, or diesel fuel spill from the rig or supply vessel.

The risk of a major spill (associated with exploration drilling activities) occurring in Australian waters is low (estimated at 4.4 x10-3 per annum (WA EPA, 1997)), however, the potential environmental consequences are significant.

Almost 1,100 wells have been drilled and approximately 3,100 million barrels of oil have been produced in coastal and offshore Australia. Only about 600 barrels have been spilt in the marine environment from exploration and production operations. Most of these spills have involved less than 19 barrels of oil and in only a very few cases has the oil reached the shore. Major oil spills in Australian waters have been as a result of tanker related incidents, as opposed to oil/gas exploration/production. The reduction in spills is directly contributed to major improvements in technology, equipment and operating procedures.

Such events may result in contamination of seawater and the following impacts to the marine community:

- Oiling and contamination of nearby offshore islands, coastal reefs and intertidal ecosystems
- Oiling of seabirds
- Ingestion by seabirds, during feeding or preening, leading to poisoning
- Pathological effects to fish larvae

Plankton

Relatively low concentrations of hydrocarbons are toxic to both phytoplankton and zooplankton. However, plankton are widely distributed and dispersed throughout the upper layers of the water column and it is expected that current induced drift would rapidly replace any oil-affected population (Payne, 1992). Surface film could temporarily suppress primary productivity, which may have slight implications for consumers of phytoplankton.

Local breeding populations of many organisms including fish larvae may be impacted, particularly in confined inshore waters. In general, populations of phytoplankton, zooplankton, adult fish and marine mammals are not considered to be at serious risk (AMSA, 1998; Payne, 1992).

Macrophytes

Large amounts of oil stranded in intertidal or shallow subtidal waters would have a direct impact on seaweeds. Protected shoreline areas such as marshes and mangroves are the most susceptible environment for oil spill impacts. Within the region, salt marshes and mangroves can be found to the west, around Wilson's Promontory (Victoria), in Tasmania and on Bass Strait islands (including Flinders Island). Estuarine environments in a variety of locations might be at risk depending on the tidal flows at the time of any spill.

Such habitats are important since they are highly protective, form the basis of detrital food chains, provide breeding and nursery grounds for fish and wildlife and generally act as sediment and nutrient traps for surrounding inshore ecosystems. The extent of damage to such systems would, in general, be localised, but case histories indicate that ecological processes may be altered to varying degrees for several decades (ie reproductive capacity of some plants and algae) (Payne, 1992; Fukuyama *et al.*, 1998).

Although oil has severe effects on mangroves and mangrove communities, its effect on seagrasses is relatively small. Conversely, oil dispersants adversely affect seagrasses, yet use in offshore areas can reduce impacts to highly sensitive intertidal environments (NOAA, 2001).

Zoobenthos

Deep-water benthic invertebrates are usually protected from oiling by the buoyant nature of hydrocarbons, although the depth of oil penetration is dependent on turbulence in the water column. Hydrocarbons can also reach the benthos through the settlement of oiled particles such as faeces, dead plankton or inorganic sand particles (Jewett *et al.*, 1999).

Like protected shorelines, intertidal areas are very sensitive to heavy oiling and contaminated sediments. Some species of sediment dwelling organisms can be expected to suffer from adverse effects for several years (Payne, 1992). Exposure to oil can induce changes in burrowing depth into the substrate (which can lead to higher predation rates on some species) and can limit the growth, recruitment and reproductive capacity of some marine invertebrates (Fukuyama *et al.*, 1998).

Both oil and oil dispersants can be toxic to crustaceans, limpets, bivalves and seastars (Michel *et al.*, 1992; Fukuyama *et al.*, 1998; Jewett *et al.*, 1999). Commercial invertebrates, such as lobsters or scallops, may become tainted or suffer from sublethal effects. Polychaetes are less susceptible to the negative effects of oil and can show large fluctuations in abundances and species composition over time (Fukyama *et al.*, 1998; Jewett *et al.*, 1999).

Fish

Oil concentrations as low as 5ppm have been shown to cause fish mortality in laboratories. However, fish kills are rarely associated with hydrocarbon spills, where presumably, adult fish are able to avoid waters underneath oil spills (BHPP, 1995).

Even in sensitive locations (ie shallow waters with poor circulation) only small proportions of the total regional population are usually affected (Wells *et al.,* 1992).

Modification of habitat through the detrimental effects of hydrocarbon on other marine organisms (such as seagrasses) may adversely affect some fish species (Jewett *et al.,* 1999). Turbulent waters can disperse hydrocarbon throughout the water column, thereby exposing fish at depths to contamination or by reducing the amount of dissolved oxygen, which could potentially cause suffocation. Dispersal throughout the water column is highly likely in the South East region, due to high-energy oceanic conditions. The use of dispersants can be lethal to fish, and the combination of hydrocarbon and dispersants can increase the toxicity of the oil (Michel *et al.*, 1992).

Seabirds

Seabirds are considered the most vulnerable to hydrocarbon spills. Seabirds could become coated by hydrocarbons when foraging, or surfacing to breathe.

Contact with residue affects the waterproofing and insulating properties of the bird's plumage. This could result in hypothermia and an inability to remain afloat or fly (Walraven, 1992; Brown, 1992). Other external effects are irritation or ulceration of eyes, skin and mucous membranes such as nares, mouth and cloaca (Walraven, 1992). Ingested or inhaled oil following preening can also cause internal organ damage (ie liver, kidney and other tissue damage) or result in pneumonia.

Non-flying seabirds such as penguins are vulnerable to oil contamination when they return to land, as they move through oiled beaches. The main factor affecting the survival of oiled and then cleaned and rehabilitated Little Penguins was the extent of oiling. Survival rates of individuals halved for every extra quarter of body oiled (Goldsworthy and Geise, 1996). There are also indirect effects of oiling, with rehabilitated birds having a lower breeding success rate than birds that were unoiled (Goldsworthy and Geise, 1996). Spills can also have an indirect impact on seabirds by destroying food supply/sources, particularly for species restricted to a small area for foraging.

Cetaceans and Pinnipeds

The three possible effects of an oil spill on marine mammals include ingestion of oil droplets during grooming; loss of thermal insulation and/or waterproofing; and irritation to eyes and exposed mucous membranes. Secondary impacts may include the loss of prey items or bio-accumulation of hydrocarbon products through the food chain.

The effect of oil on cetacean skin was shown in one study to be minor and temporary (Geraci and St. Aubin, 1982). Direct contact with hydrocarbons appears to have little deleterious effect on whales, possibly due to the skin's effectiveness as a barrier to toxicity, although inhalation of any evaporated toxic components may pose a greater risk (Volkman *et al.*, 1994).

The potential impact of oil on baleen plates in filter feeding cetaceans is considered to be insignificant. Geraci and St. Aubin (1982) (in Volkman *et al.*, 1994) found that light to medium weight oils reduced the flow of water through baleen plates, however the flow returned to normal within 40 seconds. Heavy oils reduced the flow for up to 15 minutes. Clearance of the baleen fibres occurred within 15-20 hours.

Bottlenose dolphins *Tursiops truncatus* can detect and avoid oil on the surface of the water (Geraci and St. Aubin, 1982).

External oiling has little impact on seal thermoregulation, due to the presence of blubber layers (Michel *et al*., 1992). Corneal lesions from exposure to oil were observed on some pinnipeds after the Exxon Valdez oil spill. Internal effects of oil ingestion were observed to be not serious. Some pups lost weight, however, all recovered (Michel *et al*., 1992).

4 Field Development

All impacts described in the exploration drilling section are directly applicable for field development operations (Refer Section 3). The long-term implications of field development are typically the permanency of the site and the intense construction period of the development.

The only unique procedure associated with field development, as opposed to seismic or drilling activities is the construction of the facility and laying of the interconnecting infrastructure pipe.

4.1 Offshore Facility Construction

4.1.1 Noise

Noise impacts to the natural environment from construction of offshore facilities are directly comparable to drilling activities (Refer Section 3.1). However, it can be expected that noise emissions will be of marginally greater intensity and duration.

4.1.2 Location disturbance

Direct disturbances to seabed environments as a result of the production platform location will be of long-term duration and the effects are discussed in Section 5.1. The extent of disturbance is also dependent on the nature of the production facility (ie platform, monotower, FPSO, Sub-sea completion).

4.2 Pipelaying

Activities including the laying of the pipeline, ancillary drilling, positioning anchors and cables have the potential to disturb the seabed and may physically damage infauna and epibiota.

4.2.1 Long-Term Smothering and Barrier Effects

The effects of pipelaying disturbing unconsolidated sediments and benthic communities are localised and short-term compared to the region's extreme climatic events, rapid recolonisation behaviour of species, habitat type and depths present in Bass Strait (Duke Energy, 2001; Black *et al.,* 1994). Despite this, burrowing species and other habitats may suffer some mortality or direct disturbance from pipelaying. Typically, pipelines will self bury over time.

The presence of the pipeline in creating a significant barrier effect to the movement of some seabed species is considered extremely unlikely, as dispersal of larvae or eggs occurs in the water column and adults can move under the sand (and therefore potentially under the pipe) (OMV, 2000). It is also likely that the pipeline will provide a local artificial hard substratum for colonisation by marine species (invertebrates and seaweed). The extent to which the pipeline attracts biota will depend on the proportion of pipe which is not self-buried.

4.2.2 Pipeline Corrosion

A cathodic protection system commonly supplements the protective coating to prevent external corrosion of the pipeline. A small amount of zinc or aluminium will be oxidised and can be expected to be released into the marine environment. Zinc oxide and aluminium oxide are relatively insoluble and have very low toxicity. The impact of this form of corrosion protection is considered to be negligible (OMV, 2000).

5 Operation/Production

5.1 Physical Presence of the Platform

5.1.1 Physical Artificial Reef Habitat

It is well known that offshore platform facilities may contribute to the formation of physical artificial reef habitats. Platforms can be colonised by a diverse range of encrusting marine biota and higher trophic levels such as star fish, crustacean, fish and roosting birds. Information is largely anecdotal that platforms provide a localised (and not necessarily regional) benefit impact.

Seals in Bass Strait are routinely observed on and near offshore platforms, however, there are no studies to assess the impacts to the populations of seals or other species. Benefits are generally associated with provision of resting place and increase of available food source or range. Adverse impacts may include increased interaction with commercial fisheries and increased exposure risk to hydrocarbon contamination by being in close vicinity to waste discharges.

5.1.2 Light Emissions

There is little available information regarding the impacts of lighting of offshore structures and vessels on marine communities (Duke Energy, 2001). Based on evidence from lighthouses and fishing boats, it is possible that birds can become disorientated under certain lighting configurations and collide with structures.

5.2 Production Operations

Drilling impacts and consequences associated with operation and production are similar to exploration drilling, however, projects are required to be assessed on a permanent and site specific basis.

5.2.1 Noise Emissions

Noise generation is an unavoidable result of offshore production. There are few published data on underwater noise levels near production facilities and on the marine mammals near the facilities. However, underwater noise levels may often be low, steady and not very disturbing. Stronger reaction would be expected when sound levels are elevated by support vessels or other noise activities (Richardson *et al*, 1995)

Presumably, the habitation of pelagic fish near platforms suggests fish are unperturbed by platform or vessel-associated noise.

The information on effects on seabirds at sea is sparse. The Antarctic Division has developed guidelines (based on the only performance measure available – penguins) for approaching seabirds and provide a basis for determining appropriate distances for other fauna species such as pinnipeds:

- 100m by humans on foot
- 400m in vehicles (ie cars)

- 750 in helicopters
- 1 000m in twin engine helicopters

5.2.2 Produced Formation Water Disposal

Toxicological effects of produced formation water (PFW) undertaken by BHP Petroleum and Esso in Bass Strait, found that at dilution levels greater than 1:100, there were no detectable effects on reef building corals and planktonic species (Black *et al*, 1994). The area within which acute toxicological effects are likely to occur is the localised area within which the dilution is less than 1:1000 – which is likely to be less than a 150m radius (Black *et al*, 1994).

PFW may have a salt content greater or less than seawater causing localised transient salinity levels which are unlikely to affect nearby organisms. Bioaccumulation of metal and oils is typically expected to be confined to marine species that colonise the facility.

5.2.3 Other Waste Disposal

Discharge of other wastes during drilling operations will have the equivalent impacts to seismic activities and drilling (refer Section 2.3), however, on a permanent basis. Therefore, it can be expected that operation activities at producing platforms may induce some long-term foraging and feeding behavioural changes in local biota. Species particularly susceptible to such change include fish and potentially seal species.

5.2.4 Atmospheric Emissions

Exploration and production activities result in the release or emission of several greenhouse gases, notably carbon dioxide and methane. Small quantities of other gases such as the hydrocarbons propane and butane, and other products of fuel combustion are also released. Exploration and production activities contribute less than 3% of Australia's total greenhouse gas emissions (APPEA, 2001).

Reinjection of water or gas down wells is sometimes used to increase the amount of oil recovered. Reinjection of gas decreases the volume of gas that might be otherwise flared (reducing emissions of greenhouse gases) (APPEA, 1998). Reinjection of gas or water is costly but where possible, is often a more environmentally sound option than discharge to the environment.

The potential effects are generally considered significant on a global scale rather than at a regional level. Rather than direct impacts to species, impacts are considered to be of an accumulative effect from greenhouse gas induced climate changes.

5.2.5 Subsidence

Subsidence of the producing reservoir is a possible consequence of hydrocarbon extraction and is particularly evident in the North Sea. However, due to the dense sandstone composition of Australia's reservoirs (including the South East region), subsidence is not anticipated to be a significant environmental impact.

5.2.6 Hydrocarbon and / or Chemical Spills

Sections 2.5 and 3.5 describe the effects on the natural system in the event of an hydrocarbon spill.

6 Decommissioning

There have been two offshore facilities decommissioned and two facilities partially decommissioned in Australian waters up until the present date. As a result of such few decommissioning operations (and lack of precedence), it is difficult to assess the specific environmental impacts to the South East region.

Each offshore structure is different, as each is purpose built for a specific function in a specific location. The decision to allow an offshore installation, structure or parts thereof to remain on the seabed should therefore be based on a case by case evaluation. The Australian petroleum industry has determined that decommissioning should be planned to achieve the following objectives (APPEA, 1999):

- to isolate formation fluids from each other
- to isolate formation fluids from the surface
- to clear the seabed or reinstate land areas

Under International Maritime Organisation (IMO) (1989) guidelines platforms in waters less than 75m water depth and weighing less than 4,000 tonnes are to be entirely removed, which has potential implications for platforms in Bass Strait and the Otway Basin. In addition the IMO require that the following items be evaluated in relation to the natural system:

- Rate of deterioration of the material and its present and possible future effects on the marine environment
- The potential effects on the marine environment, including living resources
- The risk the material will shift from its position at some future time

In certain circumstances, the complete removal of an offshore facility may have a wider and larger environmental impact than leaving the structure in situ, due to significant disturbances.

6.1 Removal of Structures

Platforms

Removal of dismantled platform debris would remove contaminants from the sea, eliminate a source of debris and would derive some benefit from the recycled material. Environmental impacts from topside facility removal are generally considered negligible.

Floating Production, Storage and Offtake Facilities (FPSOs)

Floating Production, Storage and Offtake Facilities (FPSOs) are generally reused, or refurbished and reused.

Steel Jacket

The most likely source of significant environmental effect is the use of explosive cutting charges in dismantling the steel jacket. All fish are considered vulnerable in the immediate vicinity of an underwater blast, but at greater distances, fish with swim bladders are considerably more vulnerable than fish without (Side, 1992). Surveys undertaken one month after the South Marsh Island 146 Platform toppling indicated that fish populations had returned to normal (Quigel and Thornton, 1989, in Swan, 1994). However, significant uncertainty surrounds the effects and lethal range on planktonic, larvae and juvenile stages.

Birds are most at risk when either in or on the water. Marine mammals are also at risk; however, such impacts should not be viewed in isolation and impact assessments must consider timing of operations. Typically, such an event will be scheduled to avoid migratory, feeding, calving, breeding and other key life cycle periods, therefore minimal potential impacts can realistically be expected.

The benthic environment will be heavily disturbed from any explosive activities.

Pipeline

There are several options for the decommissioning of pipelines, backfill in-situ, leave in-situ or total removal, and all have low environmental impacts on the natural system. Based on ecological grounds, there is generally no need to undertake technically, demanding options (ie complete removal) in order to reduce or eliminate potentially significant impacts (AURIS, 1995).

Other Subsea Facilities (Bases, Wells, Trees, Flowlines and Umbilicals)

Parts of the structure may be embedded in the sea floor, so that total removal will create more disturbance to the environment than partial decommissioning in situ. Research into seabed debris stability and the effects of underwater structures on fish colonies suggest that remaining structures benefit the local ecology by providing an artificial habitat. Several independent studies have demonstrated that the environmental impact of sea disposal of clean steel (or concrete) is negligible (APPEA, 1996; Precious, 1997). Generally, leaving concrete gravity bases and other subsea structures in situ has the least environmental impact

Wellheads and trees are generally removed at or below the mudline and taken to shore for reuse and disposal during the process of plugging and abandoning the wells.

6.2 Waste Disposal

General Waste

The first stage of decommissioning includes the shutdown, purging and subsequent cleaning of production systems, process equipment and pipework. This may lead to a short-term increase in the discharge of chemical products and oily wastes. However, the environmental risk of accidental spillage of all or part of the oil, wax or sludge is difficult to assess. Such wastes are recovered and appropriately disposed onshore, in addition, the effectiveness of the pollution control equipment determines the size of the spill (AURIS Environmental, 1995).

The dismantling of topside facilities may also give rise to additional minor releases in chemical and metallic wastes. Such impacts to marine biota are comparable to drilling and seismic discharges, and are expected to be of short duration.

NORM Waste

Naturally Occurring Radioactive Material (NORM) is a common issue in oil and gas production worldwide. NORM sludges (or scale) are derived from radium dissolution in produced water, and typically accumulate in offshore equipment such as separators and flash tanks. NORM waste disposal to the marine environment is normally subject to a project specific environmental and safety assessment and the disposal method is highly dependent on the nature (radium/barite content) of the waste and regulatory requirements.

Potential NORM contaminated wastes generated offshore is typically recovered and disposed of onshore via a production specific NORM Disposal Plan. Controlled discharge of scale to the sea may slightly raise radiation doses to marine life, however, levels are expected to be only slightly elevated above the natural radiation background. Strong currents and water depth of disposal assist in the dispersion of discharged scale particles on the seabed. Generally, sealing the low-level radium material between concrete plugs (ie via injection into a plugged and abandoned well) will prevent the material contaminating the marine environment (BHP, 1996).

Sea Bed Residue

A number of residues may remain in the seabed including:

- Accidental losses during operations
- Associated permitted seabed structures
- Drill cuttings during drilling operations
- Any other chemical residue remaining after platform operations

The potential environmental effects, particularly toxicity and bioaccumulation are previously described in Section 3.3.

6.3 Beneficial Impacts and Recycling

Beneficial impacts associated with artificial reef effect of steel structures have been broadly described in 5.1.1.

The energy involved in marine operations during cutting, dismantling and transporting an installation to shore equals, and can exceed, the energy savings from recycling minus the energy used to manufacture new steel (Ecos, 1999). Scrapping and disposal technologies are limited. Reuse will only be practicable in a limited number of cases where the condition and specification of all or part of the installation meets current day requirements (or where an artificial reef program is an option) (Precious, 1997; Manago and Williamson, 1997).

Disposal may be the best option rather than recycling or re-use. Onshore disposal may have significant environmental implications if a recycling or reuse option can not be found.

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Table 3: Summary of Potential Impacts Associated with Petroleum Activities

Potential Hazards		Potential Impact	Ceteceans	Fish	Pinniped and Colonies	Coastal Environs & Intertidal Reefs	Offshore Islands	Benthic and Epibenthic	Sea Birds and Colonies	Zoobentos and other Planktonic Forms	Macrophytes
1	**Seismic Survey**										
1.1	High intensity sound discharges	▪ Lethal effects on significant marine animals									
		▪ Pathological damage to hearing systems or other organs									
		▪ Behavioural / lifecycle changes									
1.2	Physical presence of the vessel	▪ Collision with marine mammals causing injury or death									
		▪ Behavioural changes									
		▪ Disturbance to seabed through anchoring or grounding									
1.3	Waste discharges	▪ Changes to the quality of water of sensitive environments									
		▪ Modification of feeding habits in sensitive environments									
		▪ Low level contamination / toxicity of marine fauna in sensitive environments									
1.4	Ballast water discharges	▪ Introduction of foreign marine organisms									
		▪ Modified ecological processes (associated with competition, contamination, disease etc)									
1.5	Hydrocarbon and / or chemical spills	▪ Low level contamination and/or toxicity of marine fauna.									
2	**Drilling**										
2.1	Noise Emission	▪ Behavioural changes									
2.2	Physical presence of rig	▪ Collision causing injury or death during rig mobilisation									
		▪ Localised disturbance to seabed through anchoring or grounding									
		▪ Impacts resulting from light emissions during drilling activities									
2.3	Drilling cutting and fluid	▪ Increased turbidity									

	Potential Hazards	Potential Impact	Ceteceans	Fish	Pinniped and Colonies	Coastal Environs & Intertidal Reefs	Offshore Islands	Benthic and Epibenthic	Sea Birds and Colonies	Zoobentos and other Planktonic Forms	Macrophytes
	discharges	▪ Burial/Smothering of significant benthic communities									
		▪ Toxicity and bioaccumulation to marine organisms									
2.4	Other waste discharges	▪ Changes to water quality in sensitive environments									
		▪ Modification of feeding habits in sensitive environments									
2.5	Hydrocarbon and / or chemical spills	▪ Contamination and/or toxicity of marine fauna and nearby ecologically/environmentally sensitive environments									
3	**Field Development**										
3.1	Noise emission: construction and support vessels	▪ Behavioural changes									
3.2	Physical presence of platform	▪ Collision causing injury or death during platform mobilisation									
		▪ Localised disturbance to seabed through anchoring or grounding and other associated construction works									
		▪ Changes in ambient light emissions during construction.									
3.3	Pipelaying	▪ Increased turbidity									
		▪ Burial and/or Smothering									
3.4	Other waste discharges	▪ Changes to water quality									
		▪ Modification of feeding habits									
3.5	Hydrocarbon and / or chemical spills	▪ Contamination and/or toxicity of marine fauna and nearby ecologically/environmentally sensitive environments.									
4	**Operation/Production**										
4.1	Noise emissions generated from operation activities and support vessels	▪ Behavioural changes									
4.2	Physical presence of the platform	▪ Site selection and access disturbances									

Potential Hazards		Potential Impact	Ceteceans	Fish	Pinniped and Colonies	Coastal Environs & Intertidal Reefs	Offshore Islands	Benthic and Epibenthic	Sea Birds and Colonies	Zoobentos and other Planktonic Forms	Macrophytes
		▪ Changes in light emissions during operations (including flaring)									
		▪ Formation of artificial reef									
4.3	Produced Formation Water disposal	▪ Changes to water quality and temperature in sensitive environments									
		▪ Contamination and/or toxicity of marine fauna and nearby ecologically/environmentally sensitive environments									
4.4	Hydrocarbon and / or chemical spills	▪ Contamination and/or toxicity of marine fauna and nearby ecologically/environmentally sensitive environments									
4.5	Atmospheric emissions	▪ Changes in Greenhouse Gas Emissions									
5	**Decommissioning**										
5.1	Removal of structures	▪ Disturbances as a result of topside removal									
		▪ Disturbances to seabed from subsea removal									
		▪ Use of explosives									
5.2	Waste disposal	▪ General impacts									
		▪ Norm waste disposal impacts									
5.3	Beneficial impacts and recycling	▪ General impacts									