This section of the Devil Creek Development Project Draft PER presents the existing social environment for the Pilbara Region and in the vicinity of the DCDP.

6.1 STUDIES AND SURVEYS

The information on the existing social environment has been derived from a variety of published and unpublished data. The key study commissioned by Apache to provide project-specific information in respect of Aboriginal heritage values included Aboriginal heritage site surveys particular to the DCDP areas conducted in 2006 and 2007. These surveys were undertaken in consultation with two Aboriginal groups that claim to hold Native Title over the project area and that had provided heritage advice to the proponent since 1997 when land areas, currently considered for the DCDP, were utilised in support of the Stag oil field development.

6.2 SOCIAL PROFILE

The location of the DCDP is within the Shire of Roebourne. The Shire of Roebourne extends over an area of approximately 15,197 km^2 within the Pilbara Region and contains six town sites. These are the industry-based towns of Dampier, Karratha and Wickham, the historic towns of Roebourne and Cossack, and the coastal retreat of Point Samson. In addition, the indigenous community of Cheeditha is located near Roebourne. All of these town sites are located within a 50-km radius of each other (PDC, 2006a).

A number of indigenous groups form a part of the Shire of Roebourne community, including the Ngarluma and the Yindjibarndi people, the Yaburara and Coastal Mardudhunera people and also the Wong-Goo-Tt-Oo people.

6.3 DEMOGRAPHICS

In 2001, the Shire of Roebourne had a population of over 15,000 people, representing 39% of the Pilbara region (PDC, 2006a) of these 11.75% being indigenous. In 2005, the population of the Shire of Roebourne increased in response to the resource boom and consequent expansion of resource industries in the Pilbara.

The population of the Shire of Roebourne reflects the impact of the current resource boom and subsequent employment opportunities. It is characterised by:

- Higher proportion of males to females.
- Large portion of the population (28.5%) aged from 25 to 39.
- Aged population low at 7.5% compared to that across state of 15%.

6.4 ECONOMIC PROFILE AND WORKFORCE

The Western Australian economy is growing in response to the increasing demand for natural resources and subsequent business investment in construction work for major resource projects. Employment growth is strong, with skills shortages being experienced in many sectors across the state.

A large proportion of business development has been occurring in the North West, particularly the Pilbara Region; and further development is expected over the next decade in response to the growing demand for liquefied natural gas and iron-ore production. As a result, the Pilbara Region is experiencing and is expected to continue to experience a high rate of economic growth. The report Indicators for Regional Development in Western Australia (DLGRD, 2003) states that the gross regional product per capita, as an indicator of the level of economic activity, is $114,625 and therefore higher than any other region of the state, including the Goldfields-Esperance Region.

Considerable employment opportunities have arisen within the Pilbara in response to the resource boom. The rate of unemployment in the Pilbara Region was 4.3% in 2003 compared with 6.6% in Perth (DLGRD, 2003). Indigenous unemployment was, however, higher at 18.3% in 2001 according to the Australian Bureau of Statistics, with a non-indigenous unemployment rate of 4.8% at the same time.

6.5 HOUSING AND ACCOMMODATION

The median house price for the Pilbara Region is much higher compared with the rest of regional Western Australia. The demand for accommodation and housing in the Shire of Roebourne is directly linked with new development and operation of resource industries in the region. Median house prices have risen from $162,900 in July 2002 to $628,980 at the close of June 2007, indicating a 286% increase in the median house price over a five-year period (PDC, 2006b).

Rental prices in the town of Karratha fluctuate greatly with the level of resource development and expansion projects in the region. The price of residential rental has increased significantly in the region, while at the same time the number of rental units available has reduced significantly. These trends have subsequently put pressure on other options for rental accommodation and also on temporary accommodation, including caravan and holiday parks.

To accommodate transient work forces, a number of workforce accommodation camps have been established throughout the region. Many of these are currently at capacity, and further camps and expansion are being proposed to provide workforce accommodation for new developments.

6.6 REGIONAL INFRASTRUCTURE AND SOCIAL SERVICES

The Shire of Roebourne is well serviced with infrastructure and social services considering its isolation; however, there is considerable pressure on these (as there is across the Pilbara Region) in response to the current population of the region, housing and accommodation shortages and higher than average costs of living.

The key available services in the Karratha/Dampier area are detailed in **Table 6.1**.

Element	Description
Services	
Health	The regional hospital is located in Port Hedland. The towns of Karratha, Roebourne, Wickham, Tom Price, Paraburdoo, Onslow, and Newman are serviced by district hospitals. Community nursing posts or company-operated clinics service smaller communities.
Education	Both government and non-government schools are present in major towns, and the Pilbara TAFE college delivers accredited vocational education and training across campuses in the Pilbara.
Sporting and recreation	Residents have access to a wide range of sporting and recreational activities that are supported by local, regional and state associations and agencies, with more than 500 sporting, recreation and community organisations represented throughout the Pilbara.
Tourism	Tourism is a small but valuable contributor to the Pilbara's regional economy. Contributions of $225 million to the Pilbara economy for the 2004/2005 year are estimated (DLGRD, 2003).
Accommodation	Numerous hotels, motels, caravan parks and camp grounds are located in the Shire of Roebourne.
Infrastructure	
Roads	The North West Coastal Highway is the main sealed road in the vicinity of the project area. This road runs from Perth to Dampier and is managed by Main Roads WA. A new sealed road is currently being constructed from Karratha to Tom Price.
Airports	There are four major airports in the region, the closest to the DCDP is the Karratha airport approx 45 km from the DCDP. There are other unsealed strips in the area servicing mining operations.
Communications	Major towns in the Pilbara Region have Internet connections and access to ISDN, STD, facsimile, telex and data link services. Parts of the region also have access to broadband ADSL services. Residents and businesses in smaller communities and remote areas have Internet and data transfer access through Telstra's two-way satellite service.
Ports	The Port of Dampier, managed by the Dampier Port Authority, is the closest port to the project area. The Port of Dampier is one of Australia's largest ports by tonnage, and it facilitates the export of iron ore, salt, liquefied natural gas, liquefied petroleum gas and condensate.
Energy	The North West Interconnected System (NWIS) is the electricity grid that links the coastal regions of the Pilbara and extends inland. It is formed from an interconnection of systems owned and operated by Western Power, Pilbara Iron, Alinta and BHP Billiton. The NWIS has current generation capacity of 450 megawatts and is fuelled predominantly by natural gas sourced from the North West Shelf. Towns not connected to the NWIS are serviced by isolated electricity generators.
Water	Water supply for the Karratha area is sourced from the Millstream natural aquifer and the Harding Dam. Desalination is now in operation to support industrial water use in the Dampier region.
Waste disposal	An existing refuse disposal facility is located approximately 10 km from Karratha via the Karratha to Dampier Road. A number of transfer stations exist in smaller centres throughout the region.
Other	The State Emergency Services and Sea Search and Rescue are also established in the region.

Table 6.1 Key services and infrastructure in the region.

6.7 LAND USE AND TENURE

The land tenure for the onshore elements of the DCDP includes areas of gazetted road reserve, special reserves, crown reserves and pastoral leasehold land. The DCDP land tenure and ownership details are outlined in **Table 3.2**.

Current land use of the DCDP area includes:

- State Waters – proposed Regnard Marine Management Area (extending seaward from low-water mark).
- Uncommitted Crown land (low-water mark to high-water mark) – used for camping and boat access.
- Crown Reserve 46588 – used for camping and boat access.
- Special Reserve 46694 – shore-based marine facility.
- Public road reserve.
- Rural use as pastoral lease land (including the Mullewa–De Grey stock route).
- Dampier to Bunbury natural gas pipeline easement.

Some of these areas are shown on the aerial photograph in **Figure 6.1**.

6.8 NATIVE TITLE

The DCDP area lies within two overlapping Native Title claims:

- Yaburara and Coastal Mardudhunera people, identified in the Federal Court as WAD 127 of 1997 (WC 96/89).
- Wong-Goo-Tt-Oo people, identified in the Federal Court as WAD 625 of 1998 (WC 98/40).

The claim by the Yaburara and Coastal Mardudhunera people covers approximately 13,941 km^2 of land and sea in the Pilbara Region, and the claim by the Wong-Goo-Tt-Oo people covers 20,240 km^2, all lying within the Shires of Ashburton and Roebourne. Both claims have been in part dismissed, that is, as separate claims for the area that overlaps with the Ngarluma Yindjibarndi determination area. The remainder of the claims, however, remains on foot (Office of Native Title, 2008).

The state has notified its intention to take interests, including Native Title rights and interests, over land areas required for the DCDP so that the state may confer rights to the proponent in the form of leases, easements and other interests as may be required for the DCDP.

Figure 6.1 Nearshore Development Area Showing Existing Land Uses.

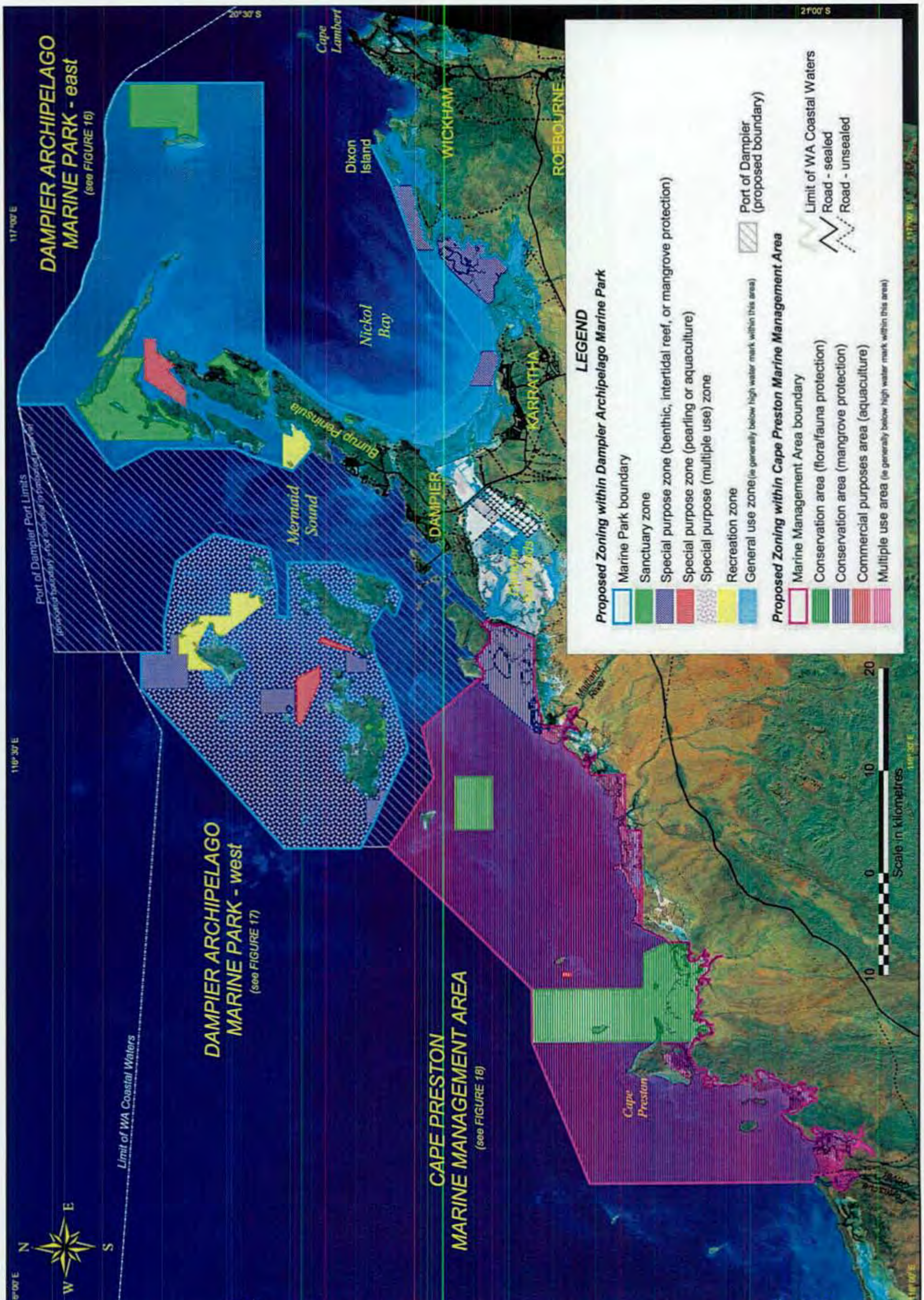

Figure 6.2 Proposed Boundaries and Zoning for Dampier Archipelago Marine Park and Regnard Marine Management Area.

The state and the proponent have entered into agreements with the Yaburara and Coastal Mardudhunera people and with the Wong-Goo-Tt-Oo people such that the required leases, easement and interests may be granted to the proponent in the future.

6.9 PROTECTED AREAS

The DCDP is located in the vicinity of a number of areas that are relatively pristine and of ecological significance, several of which are formally protected under legislation and include marine parks and management areas, nature reserves, national parks and conservation areas. There are no World Heritage areas or Wetlands of International Significance in or within in the vicinity of the DCDP Area.

6.9.1 Marine Parks and Management Areas

Marine parks and reserves are protected under the *Conservation and Land Management Act 1984* (WA), are vested in the Marine Parks and Reserves Authority and are managed on its behalf by the DEC. Marine parks are established to protect the natural features of an area while allowing recreation and commercial uses that do not compromise the conservation values. Marine management areas provide an integrated management framework over multiple use areas with high conservation value.

The Dampier Archipelago has been proposed as a marine park, and the area between Cape Preston and the Dampier Archipelago has been proposed as a marine management area. These proposals have received Ministerial approval and are awaiting final Cabinet approval.

The proposed Dampier Archipelago Marine Park comprises a number of management zones, including sanctuary zones, special-purpose zones for benthic and mangrove protection, and recreational use zones. All other areas within the park are designated for general use (approximately 50% of the marine park). This proposed marine park encompasses many of the islands of the Dampier Archipelago. The southwest boundary lies approximately 30 km northwest of the DCDP area.

The proposed Regnard Marine Management Area, previously known as the proposed Cape Preston Marine Management Area, straddles the mainland coast west of Dampier and covers an area of approx 62,000 ha. It extends from Eaglehawk and West Intercourse islands eastwards to South West Regnard Island and seaward to approximately 20 km from the coast. The proposed Regnard Marine Management Area comprises conservation areas for flora and fauna protection and commercial areas for aquaculture. The remaining 82% of the marine management area is unzoned.

Three conservation areas have been proposed for the Regnard Marine Management Area to protect important flora and fauna. The proposed conservation zones of South West Regnard Island and South Eaglehawk Island provide intertidal mud flats, reefs, subtidal soft-bottom habitats, intertidal mud flats and mangroves and therefore have been proposed as conservation zones for flora and fauna protection, while the proposed Maitland conservation zone protects the diverse mangrove communities of the region.

The DCDP's proposed land area is within the unzoned area of the proposed Regnard Marine Management Area, 25 km southwest of the Maitland conservation zone and approximately 5 km northeast of the suggested South West Regnard Island conservation zone. **Figure 6.2** shows the proposed areas for the Dampier Archipelago Marine Park and the Regnard Marine Management Area and its proposed conservation zones in relation to the DCDP area.

6.9.2 Nature Reserves and National Parks

The Dampier Archipelago Nature Reserve is approximately 40 km northeast of the DCDP area and includes a number of archipelago islands incorporated into four nature reserves. Nature reserves are protected under the *Conservation and Land Management Act 1984*, vested in the National Parks and Nature Conservation Authority, and managed by the DEC.

In the vicinity of the DCDP, the Regnard Islands and Eaglehawk Island are currently managed by the DEC and are gazetted nature reserves (Reserve 33831 and Reserve 36913).

There are no national parks in the immediate vicinity of the DCDP, the closest being the Millstream-Chichester National Park located approximately 100 km southeast.

6.10 FISHERIES

6.10.1 Commercial Fisheries

The Pilbara region contains a significant proportion of Western Australia's commercial fisheries. The principal fisheries of the Pilbara Region target tropical finfish, tuna and other large pelagic species, crustaceans (including prawns and scampi) and pearl oysters (Fisheries, 2006).

The management of commercial fisheries is divided between the Western Australian Department of Fisheries (DFWA) and the Commonwealth Australian Fisheries Management Authority (AFMA). The DFWA is responsible for managing fisheries in coastal waters that extend to 3 nautical miles from the territorial baseline, while the AFMA manages fisheries beyond 3 nautical miles to the extent of the Australian Fishing Zone (i.e., 200 nautical miles from the mainland and territorial coasts) (WEL, 2006a). Within the commercial fisheries, however, there are arrangements in place between the Commonwealth and Western Australia whereby the coastal waters of the state are deemed a part of the Australian Fishing Zone.

Commonwealth Fisheries

The AFMA manages a number of fisheries that occur in the vicinity of the DCDP. These include:

- Western skipjack.
- Western tuna and billfish.
- Southern blue fin tuna.

None of these fisheries are likely to operate within the shallow nearshore waters of the DCDP area.

Western Australian State Managed Fisheries

The DFWA manages a number of fisheries in the vicinity of the DCDP. These include the Onslow Prawn Fishery, which targets western king prawns (*Penaeus latisulcatus*) brown tiger prawns (*Penaeus esculentus*) endeavour prawns (*Metapenaeus spp.*) and banana prawns (*Penaeus merguiensis*). Although the DCDP area is within the defined fishing area for the Onslow Prawn Fishery, it is not likely that the shallow intertidal region will be subject to trawling by the licensed operators.

A significant commercial fishery operating in the region is the Pilbara Demersal Finfish Fishery, which comprises:

- The Pilbara Fish Trawl Managed Fishery.
- The Pilbara Trap Managed Fishery.

The majority of the demersal finfish caught in the Pilbara Region are taken by the Pilbara Fish Trawl Managed Fishery. The ten main species targeted are the blue-spot emperor (*Lethrinus hutchinsi*), threadfin bream (*Nemipteridae spp.*), flagfish (*Lutjanus vitta*), red snapper (*Lutjanus malabaricus*), red emperor (*Lutjanus sebae*), scarlet perch (*Lutjanus malabaricus*), goldband snapper (*Pristipomoides multidens*), spangled emperor (*Lethrinus nebulosus*), frypan snapper (*Argyrops spinifer*) and Rankin cod (*Epinephelus multinotatus*) (Fisheries, 2006).

The key areas of operation of the Pilbara Fish Trawl Managed Fishery are well offshore and generally occur between the 50-m and 200-m isobath (WEL, 2006a).

The Pilbara Trap Managed Fishery targets six of the species targeted by the Trawl Managed Fishery (blue-spot emperor, spangled emperor, red emperor, Rankin cod, red snapper and goldband snapper). Fishing activity occurs offshore between the 30-m and 200-m isobaths by a number of licensed operators.

6.10.2 Recreational Fisheries

The popularity of recreational fishing has grown substantially over recent years in the Pilbara Region, with a clear seasonal peak in the winter months in response to higher numbers of visitors to the region. The most common species caught by recreational fishers in the Pilbara Region are spangled emperor (*Lethrinus nebulosus*), narrow-barred Spanish mackerel (*Scomberomous commerson*), golden trevally (*Gnathanodon speciosus*), blue-lined emperor (*Lethrinus laticaudis*) and blue swimmer crabs (*Portunus pelagicus*) (Fisheries, 2006).

Given the high tidal range, much of the recreational fishing is boat-based; and the Pilbara has the highest boat ownership per capita in Australia (CALM, 2000).

In the portion of the DCDP area that occurs within the Regnard Marine Management Area, recreational fishing is a highly popular pastime. Line fishing, netting and spear fishing are used by fishers to target a variety of fish species, including mangrove jack (*Lutjanus argentimaculatus*), barramundi (*Lates calcarifer*), mackerel (*Scomberomorus spp.*), coral trout (*Plectropomus leopardus*) and spangled emperor (*Lethrinus nebulosus*), as well as crustaceans and other invertebrates.

Forty Mile Beach has vehicle access to the beach, camp sites and an intertidal boat access facility and is utilised as a recreational fishing area by locals and tourists, particularly during the winter months (see **Figure 6.1**).

6.10.3 Aquaculture

Aquaculture in northwest Western Australia is dominated by the production of pearls from the species *Pinctada maxima*, particularly in the Kimberley Region.

There is a lesser extent of pearling aquaculture along the Pilbara coast; however, the warm water temperatures, high nutrient levels, protection from wave damage and relatively shallow waters provide good conditions for the production of pearls.

Currently, there are a number of pearling leases in region. The closest leases are northeast of Regnard Island (approximately 8.5 km northwest of Gnoorea Point) and west of Cape Preston (approximately 20 km west of Gnoorea Point), although neither of these are currently being utilised.

6.10.4 Marine Aquarium Fisheries

In Western Australia, marine aquarium fishers target more than 250 species of fish, as well as species of corals and invertebrates in the Marine Aquarium Managed Fishery. This fishery is primarily a dive-based fishery that uses hand-held nets to capture the desired target species. The fishery has a low catch rate and supports a relatively small industry with just 13 licenses throughout Western Australia. Some of these licenses are in operation in the Dampier Archipelago area and have been reported to operate in the vicinity of Forty Mile Beach.

6.11 TOURISM

Tourism is a small but valuable contributor to the Pilbara's economy. The industry is growing as more travellers, both domestic and international, become aware of the natural attractions of the Pilbara.

Tourism statistics are calculated for Tourism Western Australia based on biennial averages. On average, an estimated 339,000 domestic and international visitors stayed overnight in the Pilbara Region during 2004 and 2005, a 11.6% increase compared to the previous period. Visitors to the region stayed a total of 2.4 million nights, accounting for 5.1% of the total tourist market in Western Australia. During this period, the total expenditure was $225.9 million, 31% higher than the previous period. Peak tourist periods are in the winter and autumn months (DLGRD, 2006).

Site ID	Site Name	Description / Location
8417	Gnoorea Point	Artefacts scatter; lying outside and to the west of Project Area 2.
10526	Gas Pipeline 29	Artefacts scatter; lying within the southeast margin of Project Area 4 and predominantly to the east of Project Area 4.
11816	Devil Creek, Mardie Station	Engraving, grinding patches/grooves; location uncertain but apparently lying outside and to the north of Project Area 7.
15018	Karratha Station	Artefacts scatter, engraving, grinding patches/grooves; lying within Project Area 3(a).
18091	Devil Creek Camp	Artefacts scatter, historical; lying within the eastern margin of Project Area 4 and predominantly to the east of Project Area 4.

Source: DIA heritage site database.

Table 6.2 Previously recorded Aboriginal heritage sites

Major tourist attractions in the west Pilbara Region include the region's coastline and the islands of the Dampier Archipelago. These areas are popular with both locals and tourists for various aquatic activities, including boating, fishing, swimming, and diving.

Forty Mile Beach is popular with locals and tourists, especially during the winter months. Visitors use the access road to the beach, camping areas and boat access ramp, as well as the protected shallow waters of Regnard Bay for various recreational activities.

6.12 ABORIGINAL HERITAGE

6.12.1 History

The history of Aboriginal habitation in the Dampier Archipelago/Cape Preston region dates back 20,000 years. The Dampier Archipelago and Burrup Peninsula in particular contain a rich collection of Aboriginal rock art and engravings, some of which are the earliest examples of Aboriginal art in Australia. Other such features found in the region include mythological and ceremonial sites, graves, rock shelters, standing stones, artefact quarries, burial sites and middens. In recognition of the Aboriginal heritage values, the Dampier Archipelago (including the Burrup Peninsula) was included in the National Heritage List in July 2007, and this place is now the subject of a Draft Management Arrangement as published for comment in February 2008.

Although the majority of indigenous people live in towns (such as Karratha, Wickham and Roebourne), they still retain strong ties to traditional lands, including sites of ethnographic significance. There is also some use of the coast for camping and fishing and also limited hunting of turtles and dugongs.

The DCDP area lies within two overlapping Native Title claims as registered by the Yaburara and Coastal Mardudhunera people and by the Wong-Goo-Tt-Oo people, groups that retain ties with the project area.

6.12.2 Significant Sites

A search of the DIA heritage site database showed a total of five previously recorded and registered Aboriginal heritage sites were within or in close proximity to the proposed DCDP area as defined in **Figure 3.2**. These are listed in **Table 6.2** and shown on **Figures 6.3a, 6.3b, 6.3c,** and **6.3d**.

Field survey work conducted in 2006 and 2007 in consultation with representatives from the Aboriginal groups served to verify the location of these sites, as well as to identify a further number of previously unrecorded Aboriginal heritage sites within the project area.

A summary of the newly recorded heritage sites located within the DCDP area is provided in **Table 6.3** and shown on **Figure 6.3a-6.3d.** These sites are described further in **Table 6.4**. No Aboriginal heritage sites were found within the shore-based marine facility, which has been subjected to previous ground disturbance.

Project Area	Area (ha) Surveyed	Proposed Use	Newly Recorded Sites
2	5	Construction support of the pipeline shore crossing. Part of the onshore section of the supply gas pipeline easement.	Nil
3(a)	18.7	Part of the onshore section of the supply gas pipeline easement.	9
3(b)	9.6	Part of the onshore section of the supply gas pipeline easement.	1
4	50.8	Part of the onshore section of the supply gas pipeline easement. Devil Creek gas plant.	16
5	9	Devil Creek gas plant area. Evaporation ponds.	4
6	1.2	Devil Creek gas plant area. Water storage.	1
8	8.1	DCDP Accommodation Facility Area.	2
		Total sites	**33**

Table 6.3 Summary of newly recorded Aboriginal heritage sites within the DCDP area (Project Area defined in **Figure 3.2**)

Figure 6.3a Aboriginal Heritage Sites in the Vicinity of the DCDP (1 of 4).

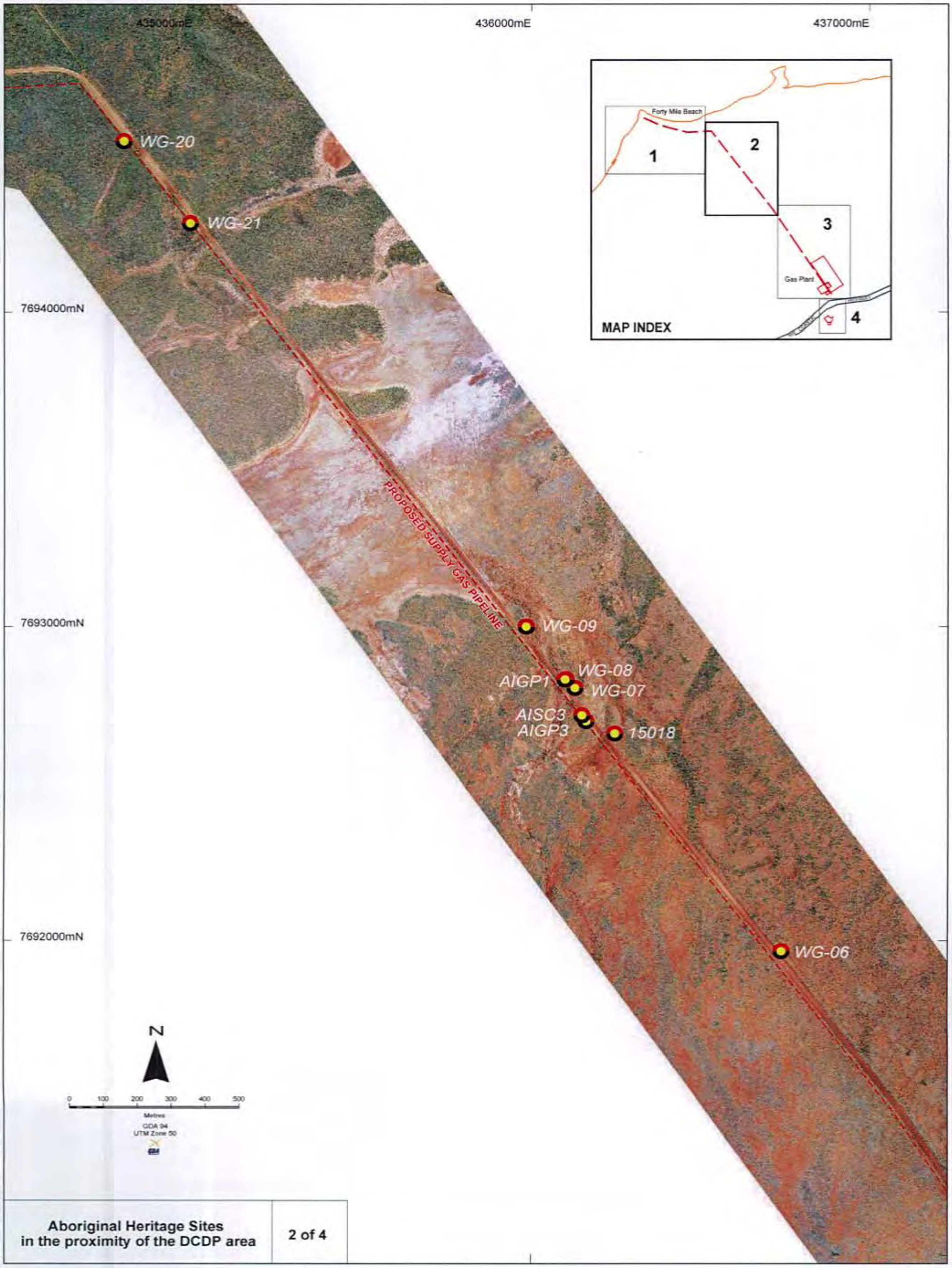

Figure 6.3b Aboriginal Heritage Sites in the Vicinity of the DCDP (2 of 4).

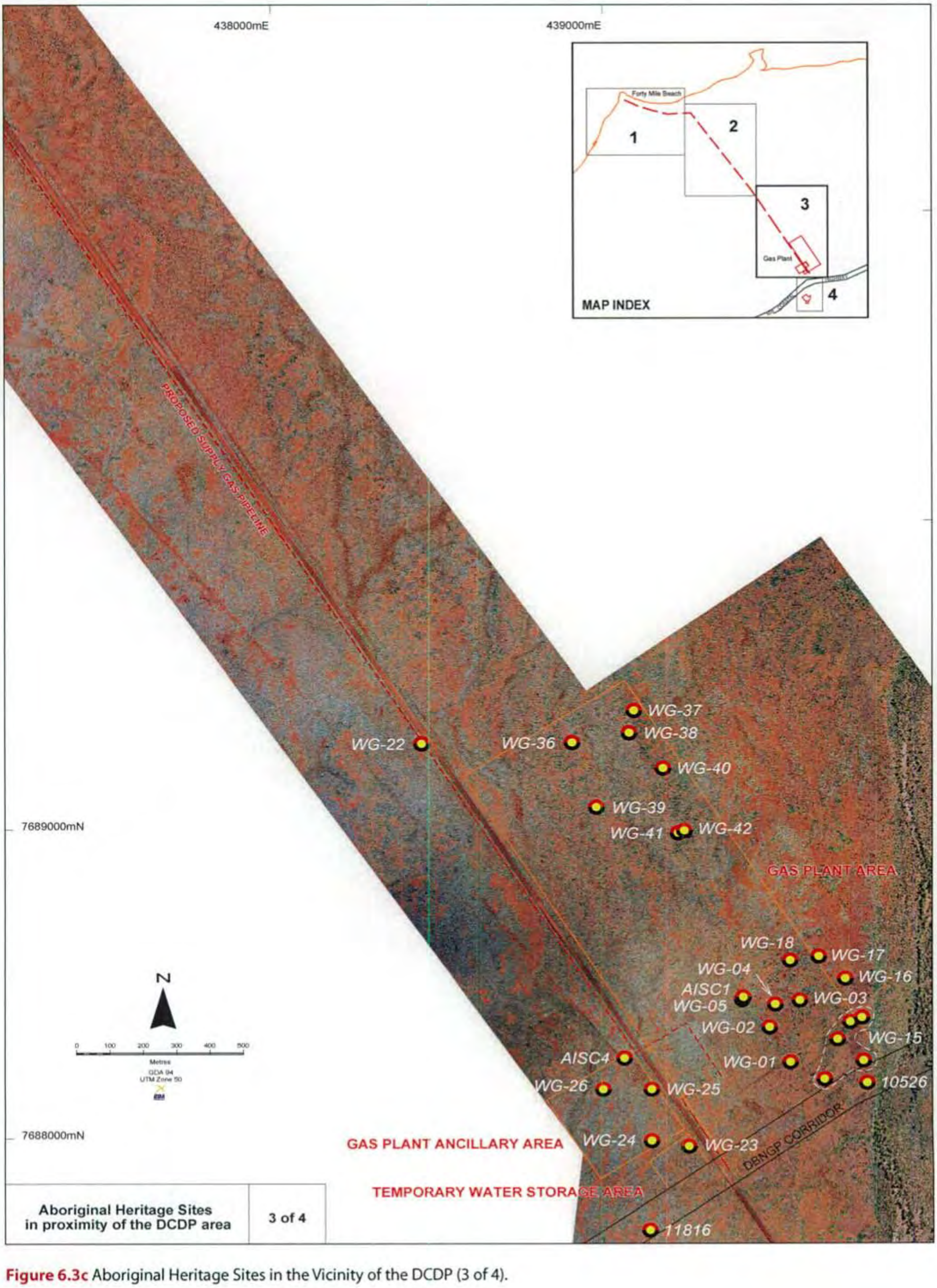

Figure 6.3c Aboriginal Heritage Sites in the Vicinity of the DCDP (3 of 4).

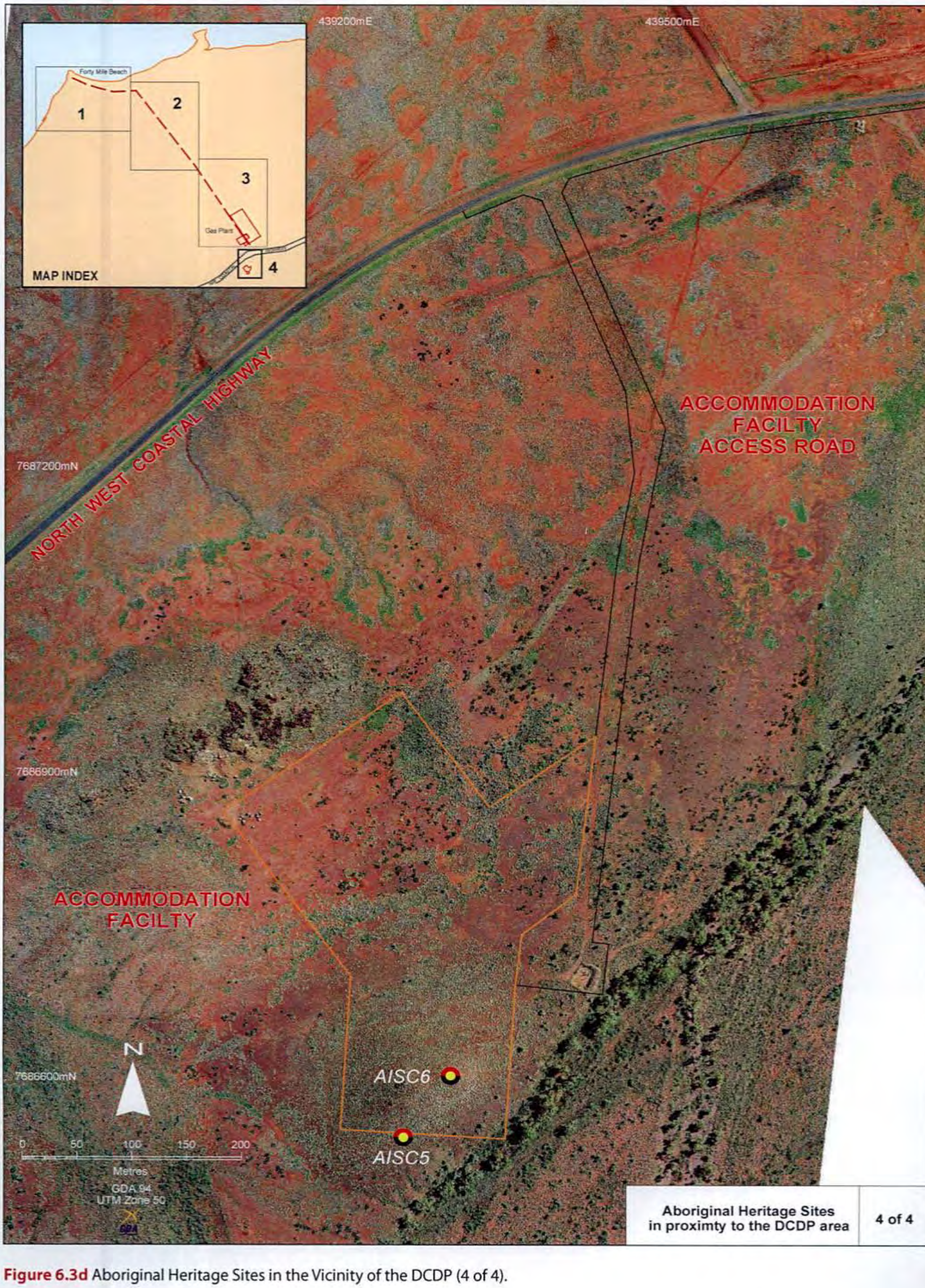

Figure 6.3d Aboriginal Heritage Sites in the Vicinity of the DCDP (4 of 4).

Site ID	Description
Survey Area: Onshore Pipeline Route 3a (18.7 ha)	
WG-06	Two possible grinding stones (40 x 25 x 8 cm and 25 x 20 x 10 cm), sparse scatter of 20 cores and blades, 1 jasper blade and some baler shell fragments. Note: Site is common with AIGP1 (see below).
WG-07	Jasper flake, 2 quartz blades and baler shell fragments in a 3 x 2 m area.
WG-08	Basal grindstone slab (27 x 30 x 8 cm) and 1 flake.
WG-09	1 large chopper and baler shell fragments within roadside bank.
WG-20	Grindstone base (30 x 25 x 8 cm) and 1 dolerite blade. At 11 m southeast, 1 dolerite flake, then 9 m further east 1 dolerite blade, then 9 m south 1 dolerite blade, then 9 m further south 4 dolerite flakes. All except the grindstone base are in an area disturbed by road works.
WG-21	A quartz core has been flaked (14 pieces) within a 3 x 2 m area.
WG-22	Artefact scatter within a 20 x 10 m area and comprising 50 to 100 pieces including dolerite core with associated flakes, quartz and jasperite cores with associated flakes.
AIGP1	Grinding platform (45 x 30/20 x 8 cm). Note: Site is common with WG-06 (see above).
AIGP3	Grinding patch.
AISC3	Artefact scatter.
Survey Area: Onshore Pipeline Route 3b (9.6 ha)	
WG-19	3 quartz flakes, 1 dolerite blade, scatter of baler shell fragments and 2 unworked quartz pebbles.
Survey Area: Plant Site Area 4 (81.9 ha)	
WG-01	5 cores, 1 chopper and 2 blades in a 10 x 10 m area within a snakewood thicket.
WG-02	3 large choppers, 6 small cores and 4 blades in a 10 x 8 m area within a low snakewood thicket.
WG-03	5 large cores, 3 blades and 20 flakes in a 10 x 15 m area within a low snakewood thicket.
WG-04	1 grindstone, 1 chopper and 2 flakes in an 8 x 6m area within a low snakewood thicket.
WG-05	Sparse scatter of choppers, cores and blades (100 pieces approx.) in an area 100 m east-west x 20 m north-south within a snakewood thicket. Note: Site is common with AISC1 (see below).
WG-15	More or less a continuous scatter of cultural material within the area defined by the 5 sets of coordinates.
WG-16	2 cores and 2 blades in an 8 x 8 m area.
WG-17	1 large core and 2 flakes in a 5 x 5 m area
WG-18	1 chopper, 1 hammer stone and 2 cores in a 30 x 20m area.
WG-36	Artefact scatter (about 100 pieces) comprising cores, blades, flakes (90%) and some quartz and jasperite (10%) in a 32 x 40 m area.
WG-37	Very sparse dolerite artefact scatter (about 200+ pieces) in a 50 x 50 m area.
WG-38	Artefact scatter (25 pieces) comprising 4 river pebble cores, dolerite and river pebble flakes and blades in a 10 x 10 m area.
WG-39	4 river pebble cores and 7 river pebble flakes in a 4 x 4 m area.
WG-40	Very sparse dolerite and river pebble artefact scatter (about 40 to 50 pieces), including 8 large cores, some flakes and blades in a 20 x 20 m area.
WG-41	5 river pebble cores and 6 flakes struck from the cores in a 4 x 4 m area.
WG-42	3 small river pebble cores, 1 blade and 6 flakes in a 5 x 4 m area.
AISC1	Medium density scatter constituting tools and blanks with density varying from 5 to 10 artefacts per m^2. Area confined to 10 m radius from the central point. Site is common with WG-05 (see above).
Gas Plant Ancillary Area (9 ha)	
WG-24	Small artefact scatter (6 pieces).
WG-25	Small artefact scatter (4 pieces).
WG-26	Small artefact scatter (4 pieces).
AISC4	Small artefact scatter.
Water Storage Area (1.2 ha)	
WG-23	Small artefact scatter (4 pieces).
Accommodation Facility Area (8.1 ha)	
AISC5	Artefact scatter.
AISC6	Artefact scatter.

Table 6.4 Aboriginal heritage sites recorded during 2006 and 2007 surveys.

The heritage survey ethnographic reports prepared in consultation with the Aboriginal groups detailed that the newly discovered heritage sites are of low to moderate significance to both groups and are known to be replicated in great numbers elsewhere throughout the group's traditional lands. The significance of the sites arises from the fact that they are associated with the groups' ancestors and therefore have historical and cultural significance for that reason. Neither the previously recorded sites nor the newly discovered heritage sites lying within the DCDP land areas have ritual or ceremonial significance to the groups.

6.13 EUROPEAN HERITAGE

The Pilbara Region was first settled in the 1800s at Cossack near the mouth of the Harding River in support of the pearling and whaling industries. The pastoral industry grew during the late 1800s, and this led to the establishment of the towns of Onslow, Point Samson and Port Hedland. It was not until after the 1960s that local discoveries of iron ore, natural gas and offshore petroleum led to the establishment of the Port of Dampier and Karratha township.

Buildings and places of European heritage value include historic homesteads and buildings, old pastoral stockyards, grave sites, remains of early industrial operations, shipwrecks, campsites, beaches, waterways, islands, vegetation, hills and valleys, and the wildlife they support.

The Heritage Council of WA, established under the *Heritage of Western Australia Act 1990* is the state's advisory body on heritage matters. The council manages the State Register of Heritage Places, a list of places that should be preserved for future generations and considered when assessing impacts of development. Neither places listed on the State Register of Heritage Places (HCWA, 2008) nor the Register of National Estate as compiled by the Australian Heritage Commission (AHC, 2008) occur in the vicinity of the DCDP. Places of indigenous heritage are discussed in **Section 6.12**.

6.14 MARITIME HERITAGE

The Dampier Archipelago/Cape Preston region has a rich maritime heritage. The islands were first chartered in 1628 by Dutch explorers; however, the earliest recorded landfall by Europeans is attributed to William Dampier in 1699.

There are numerous ship wrecks in the region, including many pearling luggers from the 19th century; the 30-tonne yacht *Sedjatr* from World War II, which was wrecked off the northwest tip of Enderby Island; and a Catalina flying boat belonging to the 10th Air Wing of the US Navy, which was wrecked on Enderby Island during the same period. Closer to the DCDP area, within the proposed Regnard Marine Management Area, is the wreck of the dredging barge *McCormack*, which broke its moorings off West Lewis Island in 1989 during Cyclone Orson and was wrecked on Eaglehawk Island.

7.1 OVERVIEW

Environmental impact assessment refers to a process where hazards are quantitatively and/or qualitatively assessed for their impact on the environment (physical, biological, and socio-economic) of a defined location.

This chapter provides an environmental impact assessment of the known and potential environmental impacts of the DCDP as it is described in Chapter 3. Environmental risk avoidance, mitigation and management measures are also discussed in this chapter.

The reports from environmental impact assessment studies are provided on a CD, accompanying this PER.

7.1.1 Defining Environmental Significance

Throughout the environmental impact assessment presented in this section, the terms "significant" or "significant impact" are often used. These terms are used in accordance with the definition in the EPBC Act Policy Statement 1.1 (DEH, 2006c):

'A "significant impact" is an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts'.

For a significant impact to be "likely":

'it is not necessary for a significant impact to have a greater than 50% chance of happening; it is sufficient if a significant impact on the environment is a real or not remote chance or possibility'.

While the assessment in this chapter is as objectively based as possible, Apache's working knowledge of the North West Shelf gained over many years of oil and gas exploration and development means that the overall assigning of significance to a particular issue or impact also takes into consideration this subjective knowledge in conjunction with the hazard identification process undertaken for the DCDP (see **Section 7.2.2**).

7.2 ENVIRONMENTAL IMPACT ASSESSMENT METHOD

7.2.1 Background

As with any major activity or development that Apache undertakes, the hazard identification process is an integral part of analysing the known and potential environmental, engineering, safety and social hazards involved with the DCDP. By analysing the risks of these hazards during the early design stage of the development, any hazard that is deemed an unacceptable risk can and must be designed out or mitigated for before engineering can continue.

Risk assessment is defined as the process of determining the frequency of occurrence of an event and the probable magnitude of adverse effects – economic, human safety and health, or ecological – over a specified period of time (Kolluru, 1994).

The process of identifying the risks and likelihood of given events and the magnitude of their effects consists of several interrelated steps, including:

- *Risk identification* – recognising that risks exist and identifying their characteristics.
- *Risk determination* – determining the characteristics of risks either qualitatively or quantitatively. These may include frequency, magnitude, spatial scale, duration and intensity of adverse consequences.
- *Risk control* – setting up a management system with standards, procedures, guidelines and so forth to decrease or eliminate risk and to review performance.

The identification of environmental hazards is the first step of the environmental impact assessment process. Hazard identification is undertaken to identify all the environmental hazards associated with a project likely to occur from routine and accidental activities and to assign a potential risk to each hazard. It is undertaken in line with the Australian risk management standard AS/NZS 4360:1999.

7.2.2 Hazard Identification Method

A pre-hazard identification meeting is a method of improving the effectiveness of hazard identification workshops. The main purpose is to ensure that key issues and project-specific matters are appropriately prioritised. The objectives of the meeting are to:

- Review project details and ensure key information is presented at the hazard identification workshop.
- Agree on the scope and objectives for the workshop.
- Identify any preparations required for the workshop.

A pre-hazard identification meeting for the DCDP was held in late November 2007.

The objectives of the hazard identification workshop were to:

- Identify potential environmental hazards associated with:
  - HDD operations.
  - Onshore pipeline installation and commissioning.
  - Gas plant, ancillary area installation and commissioning.
  - Gas plant operations.
- Identify potential risks associated with the identified hazards.
- Rank each hazard in terms of its likelihood and severity.
- Where possible, quantify releases and probability of occurrence.
- Determine whether each hazard has the potential to impact the environment.
- Where necessary, propose actions or recommendations to improve the design and safeguards to prevent the identified hazards or mitigate them to as low as reasonably possible (ALARP).

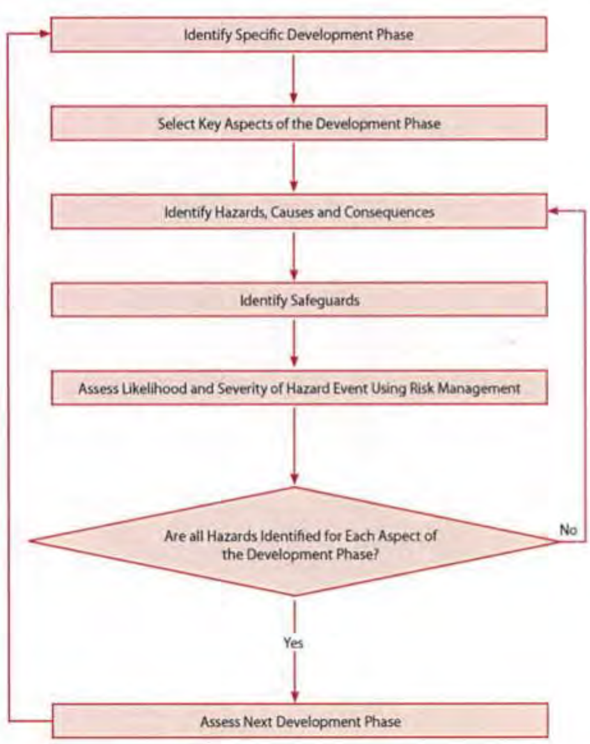

Figure 7.1 Hazard identification workshop approach.

The major environmental hazard identification workshop for the DCDP took place over three days in early December 2007. It was attended by a multi-disciplinary team of up to 14 people, including representatives from Apache, specialist environmental and engineering consultants, and the DoIR and was facilitated by the independent engineering and environmental consultancy IRC Global Risk Management (IRC). Some attendees at the workshop had detailed gas plant design and process knowledge from experience in designing and operating gas facilities, while others had extensive knowledge of marine and terrestrial ecology and/or the environmental approvals process through experience in managing offshore oil and gas facilities. The approach followed during a hazard identification workshop is illustrated in **Figure 7.1**. Results from the environmental hazard identification workshop form the basis for this chapter.

The environmental risks associated with the operation of the onshore section of the supply gas pipeline were addressed in a safety and environmental risk assessment workshop, facilitated by IRC, in mid-November 2007. Some attendees at the workshop had detailed gas pipeline design, construction and operational knowledge, while others had knowledge of terrestrial ecology and/or the environmental approvals process through experience in managing oil and gas facilities. The results from this workshop have been integrated into this chapter.

7.2.3 Determining Environmental Hazards

At the pre-hazard identification meeting, the DCDP was broken down into various phases of work (i.e. HDD, onshore pipeline installation, gas plant installation and commissioning, and production). The workshop participants used industry knowledge and experience to determine the hazards associated with each aspect of the proposed project.

The workshop participants then ranked all the identified hazards using the risk-ranking matrix in **Table 7.1**. The risk ranking is determined by assessing the likelihood and severity (consequences) of the hazard. To categorise the relative likelihood and consequence of each environmental hazard, the qualitative measures defined in **Tables 7.2** and **7.3** were applied. These risk assessment tables are Apache-specific, based on the Australian risk management standard AS/NZS 4360:1999.

Likelihood

The workshop team made a decision by consensus as to the likelihood of a hazard occurring, based on relevant databases and professional judgement. The decision took into consideration the controls that will be in place to prevent the hazard, the nature of

		Consequences				
		Serious	**Significant**	**Moderate**	**Minor**	**Negligible**
Likelihood	Expected to Occur	Unacceptable	Unacceptable	Unacceptable	B	Negligible
	Probably will Occur	Unacceptable	Unacceptable	A	B	Negligible
	Moderate	Unacceptable	A	B	B	Negligible
	Unlikely to occur	A	A	B	Negligible	Negligible
	Rare	A	B	Negligible	Negligible	Negligible

Category	Description and Response
Unacceptable	Immediate changes to design or procedures are required (e.g., hazardous discharge, large volumes of contaminant).
A	Risk reduction measures are required.
B	Acceptable risk; risk reduction measures should be considered depending on proximity to sensitive resources.
Negligible	Risks are sufficiently low to be acceptable.

Table 7.1 Environmental risk-ranking matrix.

Likelihood of Hazard Occurring	
Expected to Occur	Is expected to occur in most circumstances during the life cycle of an individual item or system.
Probably will Occur	Will probably occur in most circumstances during the life cycle of an individual item or system.
Moderate	Likely to occur at sometime during the life cycle of an individual item or system.
Unlikely to occur	Unlikely, but possible, to occur at sometime in the life of an individual item or system.
Rare	May occur but only in exceptional circumstances.

Table 7.2 Guidance for determining the likelihood of a hazard occurring.

Consequence	Description
Serious	Large-scale detrimental effect that is likely to cause a highly significant effect on local ecosystem factors, such as water quality, nutrient flow, community structure and food webs, biodiversity, habitat availability and population structure (e.g., abundance, fecundity, age structure). Long-term recovery period measured in decades.
Significant	Detrimental effect that will cause a significant effect on local ecosystem factors. Recovery period measured in years to decades.
Moderate	Impact that will cause a detectable effect in local ecosystem factors. Recovery period measured in months to years.
Minor	Incidental changes to abundance or biomass of biota in the affected area, insignificant changes to overall ecological function. Recovery measured in months.
Negligible	Short-term, localised and insignificant impacts to habitat or populations. Rapid recovery measured in days to months.

Table 7.3 Guidance for determining environmental consequence.

the materials or substances that contribute to the hazard, and the frequency with which the activity that may lead to the hazard may occur. A likelihood rating is allocated to the hazard according to the categories given in **Table 7.2**.

Consequences

The consequences of the identified hazards were rated according to the matrix given in **Table 7.3**. The consequences are dependent on the potential impact of the event in the first instance. Quantities and concentration released, time scale of release, and regulatory requirements were considered.

Risk Ranking

The environmental risk ranking (see **Table 7.1**) was determined by a combination of the likelihood of the hazard occurring (see **Table 7.2**) and the consequence of its occurrence (see **Table 7.3**). Risk ranking helps to prioritise the risks, that is, to determine whether the risk of an activity or incident is acceptably low or whether management actions are required to reduce the risk to ALARP.

Table 7.4 summarises the risks assessed during the hazard identification workshop, and **Appendix 6** presents the detailed environmental risk assessment.

7.3 TERRESTRIAL PHYSICAL IMPACT

The construction, operation and physical presence of the DCDP may potentially result in environmental impacts to:

- Landforms and soil.
- Hydrogeology.
- Hydrology.
- Air quality.

7.3.1 Landforms and Soils

Key hazards that have the potential to impact landforms and soils in the DCDP area include:

- *Vegetation clearing and earthworks:* The removal of vegetative cover and earthworks (including excavation) has the potential to adversely change natural drainage patterns.
- *Soil compaction:* Movement of construction vehicles and equipment and stockpiling and storage of materials have the potential to result in soil compaction.
- *Disturbance of acid sulphate soils:* When dewatered or disturbed (for instance by excavation), acid sulphate soils can produce sulphuric acid, resulting in the release of toxic quantities of iron, aluminium and other heavy metals adversely affecting surface and groundwater quality with subsequent negative impacts on flora and fauna populations.

Other stressors that can potentially cause impacts to landforms and soils, such as spillages of chemicals, hydrocarbons and waste materials, are discussed in **Sections 7.4** to **7.6**.

7.3.1.1 Impacts

The potential impacts of the hazards to landforms and soils include:

- Changes to natural drainage patterns potentially resulting in erosion and sedimentation.
- Deterioration of soil quality.
- Deterioration of water quality.

Area	Environmental risk			
	Negligible	B	A	Unacceptable
HDD				
Laydown area establishment	17	10	0	0
Water supply	9	0	0	0
Drilling operations	23	10	0	0
Pipe stringing	12	5	0	0
Pipe installation (offshore activities)	5	3	0	0
Demobilisation	6	6	0	0
Onshore Pipeline Installation and Commissioning				
Pipeline installation	26	2	0	0
Demobilisation	3	0	0	0
Gas Plant and Ancillary Area Installation and Commissioning				
Site preparation	23	4	0	0
Construction activities	28	2	0	0
Demobilisation	2	0	0	0
Onshore Pipeline Operations				
Construction defects / corrosion	8	0	0	0
External impacts	7	0	0	0
Flooding / erosion	5	0	0	0
Operations and maintenance	5	0	0	0
Gas Plant Operations				
General	17	3	0	0
Pig receiver	1	0	0	0
Slug catcher	0	0	0	0
Gas dehydration	2	0	0	0
Mercury removal	2	0	0	0
Hydrocarbon dewpoint control	1	0	0	0
Sales gas compression	3	0	0	0
Condensate stabilisation	0	0	0	0
Condensate storage	3	0	0	0
Condensate road tanker load-out	2	0	0	0
Inert gas	0	0	0	0
Hot oil system	1	0	0	0
Produced water rundown and treatment	1		0	0
Unplanned operation – produced water disposal – single liner	7	3	0	0
Unplanned operation – produced water disposal – triple liner	9	1	0	0
Instrument and plant air	1	0	0	0
Power generation	2	0	0	0
Power distribution	1	0	0	0
Potable water	0	0	0	0
Flare	4	2	0	0
TOTAL	**211**	**51**	**0**	**0**

A = Risk reduction measures are required.
B = Acceptable risk; risk reduction measures should be considered depending on proximity to sensitive resources.

Table 7.4 Summary of risks assessed during the hazard identification workshop.

Changes to Natural Drainage Patterns

Disturbance to soils and landforms as a result of vegetation clearing and earthworks will be unavoidable during construction. The removal of vegetative cover and earthworks have the potential to adversely change natural drainage patterns and can result in the formation of erosion features (such as rills and gullies) and deposition of eroded material on adjacent land surfaces or in creeks (sedimentation).

Factors influencing the risk of erosion and run-off risks include the nature of soils, the steepness and length of slopes and the likelihood and severity of rainfall. The site topography is relatively flat; therefore, it is not expected that any significant concentration or channelling of water flow would be likely to occur. Stormwater is likely to pond in depressions and infiltrate into the ground or flow overland, if significant quantities of rainfall occur. Impacts to surface watercourses, such as the ephemeral Devil Creek, from increased sediment loads are expected to be minimal as these types of watercourses are expected to have naturally high levels of sediment when they do run following heavy rainfall.

Stormwater drainage patterns will be altered by the presence of impermeable and low permeability surfaces at the DCDP gas plant. These impacts are discussed further in **Section 7.3.3.1**.

Deterioration of Soil Quality

Deterioration in soil quality from compaction is expected to occur where vehicles and heavy items of machinery are used during construction. Soil compaction within the project area is expected to be limited to the areas where these operate.

Impacts of soil compaction include a decrease in water infiltration capacity with flow-on effects of reduced soil moisture and increased surface ponding and run-off of stormwater. Vegetation also can be negatively impacted by soil compaction with unfavourable conditions for root growth and establishment of new vegetation.

Deterioration of Water Quality

Disturbance of acid sulphate soils (ASS) or potential acid sulphate soils (PASS) can result in the oxidation of iron pyrites with the subsequent release of sulphuric acid, iron precipitates, and dissolved quantities of heavy metals, such as aluminium, iron and arsenic (WAPC, 2003). These chemicals can have adverse impacts on surface and groundwater quality and on flora and fauna populations dependent on these resources. The severity of impacts will be dependent on the amount of ASS or PASS materials disturbed and the length of their exposure to air. The release of acid may also increase the corrosion risk for infrastructure, such as the onshore section of the supply gas pipeline.

As described in **Section 4.2.4**, an initial desktop investigation to assess the presence or absence of indicators for ASS and/or PASS in the project area has been undertaken (Coffey Environments, 2007). Based on the results of the desktop ASS investigation, the project area showed an inferred level of ASS risk ranging from "no to low" to "moderate to high" (see **Table 4.4** and **Figure 4.3**).

In line with the Draft Identification and Investigation of Acid Sulfate Soils – Acid Sulfate Soils Guideline Series (DEC, 2006), further intrusive sampling was undertaken across the subareas identified in the desktop assessment as having low to moderate risk or moderate to high risk of ASS/PASS. Results from field tests (soil pH_F and pH_{FOX}) undertaken during this sampling programme indicated that there are no ASS/PASS materials within the project area. The laboratory results (Coffey Environments, 2008) supported the field findings with most soil samples below the Department of Environment's most conservative action criterion (Net Acidity) of 18 mol H+/tonne (DoE, 2006). Although there is acidity present slightly exceeding the criteria at four locations along the pipeline easement, there is an excess acid neutralising capacity such that the soil is capable of neutralising the existing and potential acidity of the soils in these locations. This determination of acid neutralising capacity took into account the factors of soil particle size, armouring, reaction kinetics and laboratory methods as discussed in the Draft Identification and Investigation of Acid Sulfate Soils – Acid Sulfate Soils Guideline Series (DEC, 2006). In addition, the soils exhibiting some acidity are above the natural seasonal groundwater table (i.e. naturally dry). Based upon the low probability of acid generation and low consequence of impact an ASS management plan is not considered warranted. This conclusion has been supported through discussions with the DEC's Contaminated Sites Branch. It should also be noted that unnecessary lime treatment (used to neutralise acidity from disturbed ASS/PASS) of the soils may have a detrimental effect on soil chemistry (Coffey Environments, 2008).

Additionally, groundwater was encountered at two locations (where the pipeline easement traverses the saline scald) during the investigation at approximately 1.5 metres below ground level (mbgl) and 1.8 mbgl. In consideration of a nominal excavation depth of 1.15 mbgl for the pipeline installation, it is expected that dewatering of excavations will not be required during the construction phase. As a result of this shallow depth of excavation and the excess acid neutralising capacity in these locations, a dewatering management plan is not considered necessary (Coffey Environments, 2008).

Stormwater drainage quality may also be impacted by contaminants on impermeable and low permeability surfaces at the DCDP gas plant. These impacts are discussed further in **Section 7.3.3.1**.

7.3.1.2 Management

The construction environmental management plan (CEMP) includes a number of measures to manage the impacts to landforms and soils from the hazards described. These measures are summarised in **Table 7.5**.

7.3.1.3 Residual Risks

Taking into account the existing topography of the project area and the implementation of avoidance, mitigation and management measures to control clearing and earthworks, the residual risks of clearing and earthworks and of soil compaction are considered to be "negligible".

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Landforms and soils	Clearing and earthworks	*Site preparation, access tracks.*	Changes in natural drainage patterns potentially resulting in erosion and sedimentation.	• Limit the area to be cleared to the minimum required for the project. • Stabilise cleared areas of soil promptly following clearing. • Install erosion and sediment control structures where deemed necessary. • Routine inspection of any erosion and sediment control structures, especially following rainfall events, to ensure they remain effective. • Limit the movement of vehicles and equipment to designated access tracks and working areas. • Develop erosion and sedimentation control measures to take into account potential for cyclonic rainfall.
	Soil compaction	*Site preparation, access tracks.* *Vehicle movements.*	Deterioration of soil quality. Reduction in water infiltration capacity. Reduced soil moisture content. Unfavourable conditions for vegetation growth.	• Limit the area to be cleared to the minimum required for the project. • Limit the movement of vehicles and equipment to designated access tracks and working areas. • Provide designated areas for the laydown and storage of materials and equipment. • Include ripping of compacted ground prior to the replacement of topsoil as part of the rehabilitation of temporary areas following construction.
	Disturbance of acid sulphate soils	*Excavation or dewatering.*	Deterioration of water quality Increase in concentration of acidity and metals in surface and ground water.	• Intrusive investigation and laboratory analysis concluded that although acidity is present in four locations along the pipeline route, excess acid neutralising capacity is available such that net acidity generated through soil disturbance will be negligible.

Table 7.5 Summary of management measures for landforms and soils.

Taking into account the results of the intrusive site investigation and laboratory analysis for ASS and PASS, the residual risk of impacts from the disturbance of acid sulphate soils has been ranked as "negligible", which infers an acceptable level of risk.

7.3.2 Hydrogeology

Hazards that can affect the hydrogeology of the project area include:

- *Groundwater extraction:* Groundwater will be the single source of water for the DCDP throughout all phases of the project. Water will be obtained from up to four bores located within the project footprint (see **Section 3.5.8.3**). Abstraction of groundwater has the potential to drawdown aquifer levels, potentially affecting other groundwater users in the area and impacting groundwater-dependent habitat.

- *Groundwater contamination:* Both the construction and operational phases of the DCDP have the potential to cause groundwater contamination from leaks or spills of fuels, chemicals or waste material. Groundwater hazards associated with the disturbance of ASS/PASS have been discussed in **Section 7.3.1** above.

7.3.2.1 Impacts

The potential impacts of the hazards to hydrogeology include:

- Drawdown of aquifer levels.
- Reduction in groundwater quality.

Drawdown of Aquifer Levels

Ongoing groundwater extraction can have adverse environmental impacts, including declines in stream flow or impacts on groundwater-dependent vegetation or groundwater-fed wetlands. Any adverse impact on riparian vegetation is also likely to have a negative impact upon the fauna that relies upon the habitat formed by these plant communities.

The riparian vegetation associated with Devil Creek, taking into account its ephemeral nature, is likely to be dependent on the unconfined aquifer associated with this drainage feature.

Additionally, aquifer drawdowns can have a negative impact upon groundwater-dependent stygofauna (see **Section 7.4.4**) that exist within the saturated interstitial spaces within an aquifer. The groundwater drawdown around an operational well, in the zone of influence (**Figure 7.2**), effectively reduces the amount of habitat available to these communities.

Seagrass environments may also be reliant on the nutrients and other constituents transported by groundwater, as well as the lower salinity discharge generated from that source. Significant reductions in groundwater flow to the nearshore environment may have an adverse impact on these habitats.

Other users of the groundwater resource could potentially be affected by the drawdown of aquifer levels, should the drawdown be significant enough to interrupt the supply of water to these bores.

The proponent commissioned a hydrogeological investigation of the aquifer characteristics at the DCDP site to determine aquifer response to proposed groundwater extraction during the construction and operational phases of the project (Coffey Geotechnics, 2007). The investigation included pump testing of an evaluation well on the gas plant site (PB1) and of Devil Creek Well adjacent to the accommodation facility. The results of the pump testing indicated that:

- Yield from PB1 was not sufficient to meet the project's water demands, with sustainable yield unlikely to exceed 15 kL/day.
- Devil Creek Well is able to provide a sustainable yield greater than 1,000 kL/day. A maximum pumping rate of 10 L/s was recommended (unless pump testing is carried out at a greater rate and can demonstrate that a higher sustainable yield is achievable). At a pumping rate of 10 L/s, drawdown in the well is predicted to be 2.4 m according to the non-equilibrium Jacob-Cooper (1946) equations. This drawdown estimate is based on a 90-day period of continuous pumping (Coffey Geotechnics, 2007).

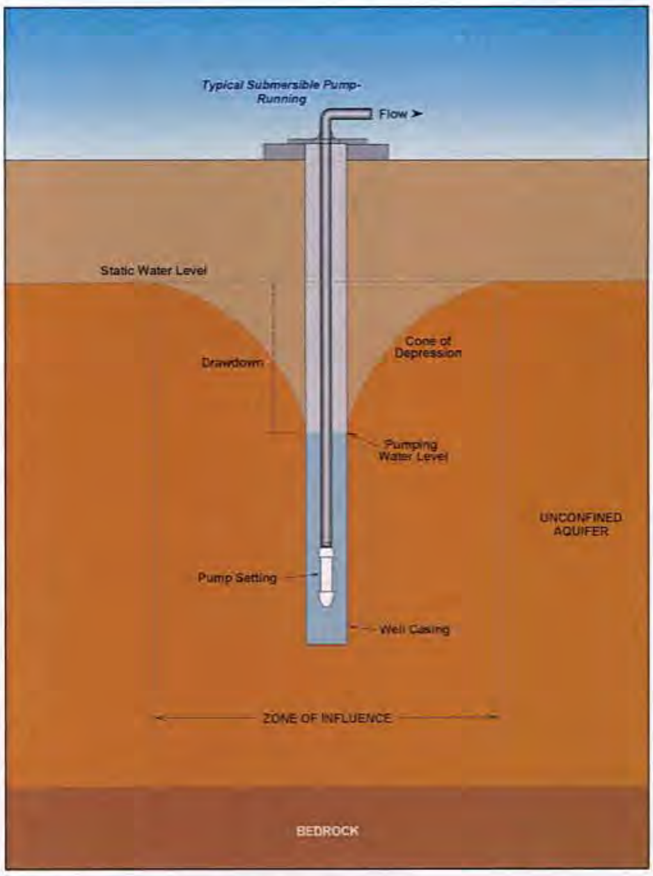

Figure 7.2 Schematic illustrating groundwater drawdown around a well.

To support the potential impact assessment on groundwater-dependent habitat, aquifer drawdowns in the vicinity of Devil Creek Well were estimated. The basis for the estimate was continuous pumping at peak water demand, predicted at the time to be approximately 19,820 kL/day for a 4-month period at a pumping rate of 7.5 L/s. Drawdowns were estimated to be in the order of 4 to 5 m in the bore; 1.85 m at 20 m radius; 1.2 m at 100 m radius; and 0.5 m at 500 m radius according to the non-equilibrium Jacob-Cooper (1946) equations (Coffey Geotechnics, 2007). This estimate uses groundwater calculations that assume a homogeneous aquifer; however, it is known that the aquifer in this area is not homogeneous and comprises fractured bedrock of the Cleaverville Formation (Coffey Geotechnics, 2007). It is therefore expected that drawdowns in the fractured system will be larger at greater distances, but drawdowns in encompassing bedrock will be smaller.

A re-estimate of construction phase water requirements (see **Section 3.5.8.3**) saw an increase in water demand from a total of approximately 208 ML over 20 months (with a peak of approximately 20,000 kL/month for a 4-month period) to 287 ML over the same period (with an average demand of approximately 20,000 kL/month for the first 12 months and a peak of approximately 28,000 kL for 3 months within this period). Additionally, since the aquifer drawdown estimates described above were produced, the water supply philosophy for the DCDP construction phase has changed from one of using Devil Creek Well as the principal source of water to one of obtaining water from up to four new groundwater wells (and leaving Devil Creek Well for use by the Mardie Station pastoralist). The spread of water abstraction over the four wells is likely to result in smaller aquifer drawdowns surrounding the wells than the above prediction, which is based on abstraction from a single well; however, this drawdown will be observable in up to four locations. Further hydrogeological investigation work will be undertaken following the installation of these wells to quantify their impacts.

Groundwater requirements during the operational phase of the DCDP are relatively small, in the order of 600 kL/month. It is expected that water abstraction during this phase, from up to two wells, will not have a significant impact on any groundwater-dependent habitat.

Water will be managed to promote its efficient use. The requirement to use best available techniques to use water efficiently has been included within the Onshore EPC Works contract for the DCDP. During construction, water use for dust suppression will represent a significant proportion of the daily water demand. Visual dust monitoring will be undertaken and the frequency of monitoring adjusted as required to ensure adequate suppression is attained without excess water use. Water from the washdown of concrete plant will be used for dust suppression in the vicinity of the concrete batching plant. The accommodation facility will be installed with water saving technology, such as dual flush toilets and water efficient shower heads, to minimise domestic water demand. Treated domestic wastewater will be used to irrigate a landscaped area, approximately 1.1ha, within the accommodation facility.

Reduction in Groundwater Quality

Both the construction and operational phases of the DCDP have the potential to cause groundwater contamination from leaks or spills of fuels, chemicals or waste materials. Potential sources of groundwater contamination identified in the hazard identification workshops included:

- HDD drilling mud and cuttings leakage due to storage bund failure or overtopping from cyclonic rainfall.
- Fuel and oil leaks from machinery (in-use) or during refuelling operations.
- Washdown of plant and equipment.
- Discharge from site ablutions facilities.
- Liquid and solid waste spillage.
- Spillage of hydrotest chemicals.
- Leakage of well fluids from the onshore section of the supply gas pipeline due to damage, corrosion or over-pressurisation leading to loss of containment.
- Spillage of oil from hot oil system during commissioning first fill, refilling or seal failure.
- Spillage of production and maintenance chemicals, such as methanol, biocide, engine oil, hydraulic fluids, paints and thinners.
- Run-off from hardstandings and process areas.
- Condensate storage tank failure.
- Condensate spillage during road tanker load-out.
- Leak of oil-contaminated produced water from treatment equipment or transfer pipework.
- Overflow of produced water from the evaporation ponds due to increased produced-water cut or cyclonic rain input.
- Leakage of produced water from the evaporation ponds due to liner damage (for instance, if they are accessed by vehicular equipment to remove accumulated solids).

The hazard identification workshop did not identify discharge of HDD cutting or mud from the storage bunds to the marine environment as a credible scenario given the topography of the site and surrounding area. **Figure 7.3** illustrates the preliminary layout of the HDD Construction Site with the natural relief of the site indicated by contour lines. It can be seen that the fall of the site is generally from north to south. In the unlikely event of an overflow from either the cuttings storage bund, mud recycling bund or water storage area, for example due to the result of cyclonic rain or associated storm surge, it is expected that the liquids would drain to the low point to the south of the site, away from the marine environment, in line with the natural fall of the land.

7.3.2.2 Management

The CEMP and operational environmental management plan (OEMP) includes a number of measures to be implemented to reduce the impacts to groundwater. These measures are summarised in **Table 7.6**.

7.3.2.3 Residual Risks

Existing groundwater use within the project area and surrounding environs is limited to small-volume extraction for stock watering purposes. It is expected that the project's water extraction will not have a negative impact on these existing groundwater users. Based upon the results of the hydrogeological investigations undertaken to date at the DCDP site, it is expected that the extraction of groundwater will not have an adverse impact on any groundwater-dependent ecosystems. Based upon this preliminary work, the residual risk of groundwater use was ranked as "negligible". However, as discussed above, the water supply philosophy for the project has evolved since this work was undertaken. Apache will undertake additional hydrogeological studies to investigate the significance of the impacts to groundwater from the altered strategy prior to the commencement of construction.

Taking into account the proposed controls for managing the risks to groundwater quality, the residual risks of this potential impact have been ranked ranging from "B" to "negligible".

7.3.3 Hydrology

Hazards associated with hydrology include:

- *Vegetation clearing and earthworks:* The removal of vegetative cover and earthworks have the potential to adversely change natural drainage patterns.
- *Soil compaction:* The movement of construction vehicles and equipment and the stockpiling and storage of materials have the potential to result in soil compaction and increased run-off.
- *Spills, leaks and unplanned discharges:* These have the potential to result in stormwater run-off contamination.
- *Flooding:* Flooding and storm surge inundation with the DCDP area may have the potential to result in adverse environmental impacts.

7.3.3.1 Impacts

The potential impacts of the hazards identified above include:

- Changes in natural drainage patterns potentially resulting in erosion and sedimentation.
- Deterioration of water quality.
- Flooding and storm surge inundation.

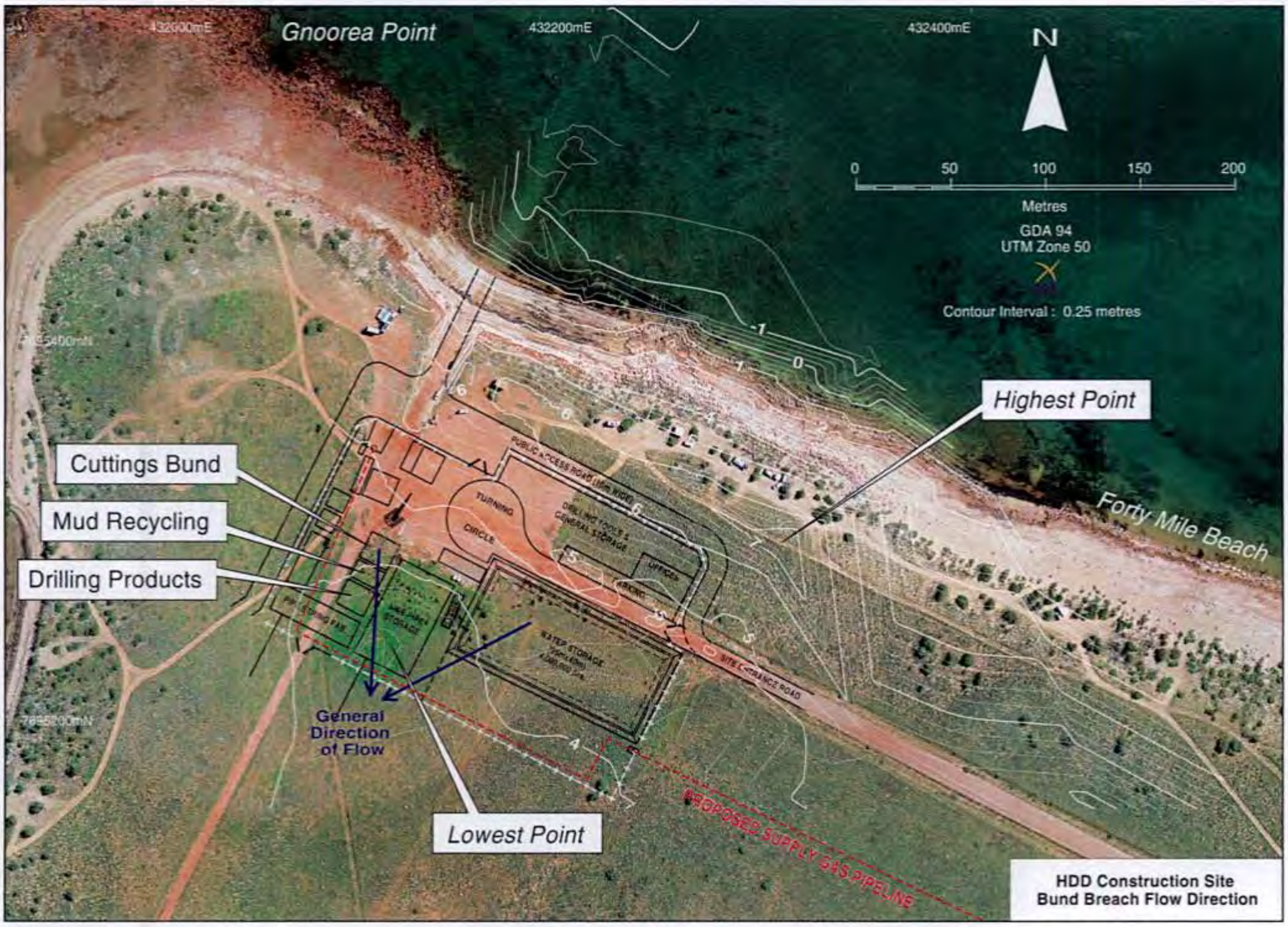

Figure 7.3 HDD construction site bund breach flow direction.

Changes to Natural Drainage Patterns

Changes to natural drainage patterns can result in the formation of erosion features (such as rills and gullies) and deposition of eroded material on adjacent land surfaces or in creeks (sedimentation). Installation of impermeable or low permeability surfaces can also increase the volume of run-off generated from an area and reduce the infiltration to the underlying soil and groundwater.

Deterioration of Water Quality

The potential impacts to water quality posed by increased sediment run-off from the project area during construction and from the disturbance of ASS or PASS materials, together with the proposed management measures to minimise and mitigate these impacts, are described in **Section 7.3.1**.

Both the construction and operational phases of the DCDP have the potential to cause stormwater run-off contamination from leaks or spills of fuels, chemicals or waste materials. The sources of surface-water contamination include many of the risks to groundwater quality identified in the hazard identification workshops and listed in **Section 7.3.2**.

Flooding and Storm Surge Inundation

The predicted 100-year ARI flood levels from Devil Creek range from 19.5 m to 17.7 m AHD south to north across the plant site, indicating a shallow depth of flow (typically 0.5 m) over the plant site (JDA, 2007). Design standards for the 100-year ARI have therefore been selected by Apache for the gas plant. It is proposed that the surface of the gas plant site will be built up to approximately 0.6 m above natural grade for flood protection.

The risk of flood waters from Devil Creek flooding the evaporation ponds is minimal. The natural ground level of the gas plant ancillary area, on the western side of the Forty Mile Beach Road, where the ponds are to be constructed is approximately 20 m AHD. The Forty Mile Beach Road, built up above natural ground level and the pond embankments (constructed 0.8 m above natural ground level) will both provide additional protection against surface water ingress (Golder, 2007).

The evaporation ponds have also been designed and will be operated to accommodate both inflow of produced water and inflow from a 24-hour, 100-year ARI rainfall event, including an additional freeboard. Water will be cycled between the two evaporation ponds to maximise the surface area available for evaporation. The ponds will become inactive (and water diverted to the second pond) when they reach 80% of storage capacity, allowing for a 24-hour, 100-year ARI rainfall event to be safely contained while retaining a 0.5 m freeboard (Golder, 2007).

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Hydrogeology	Groundwater extraction	*Construction and operations water – HDD, bulk earthworks, civil works, dust suppression, hydrotesting, potable and domestic use.*	Drawdown of aquifer levels.	• Undertake further hydrogeological investigation to establish sustainable rates of groundwater extraction following the installation of new water supply wells. • Agree on groundwater abstraction rates with the Department of Water (DoW) prior to the commencement of construction. • Undertake groundwater abstraction in accordance with agreed DoW licence conditions (quantity and rate). • Water will be managed to promote it's efficient use during construction and operations. • Groundwater monitoring undertaken in compliance with DoW and DEC licence conditions. • Aquifer drawdown levels will be monitored. • Subject groundwater monitoring records to verification audit and annual environmental performance reporting.
	Groundwater contamination	*Produced water, sewage and greywater, spillage of fuels, chemicals and wastes and wash-down.*	Reduction in water quality.	• The CEMP and OEMP contain measures to reduce the likelihood of spillages, including: – Minimum requirements for fuel, oil, and chemical storage, including provision of secondary containment and access control. – Storage of waste within enclosed containers, and provision of secondary containment for liquid waste. – Provision of designated washdown areas with effluent management controls – Procedures for refuelling operations. – A site evacuation procedure, covering the requirement to secure storage areas, in the event of an approaching cyclone. – Design of temporary containment bunds to ensure sufficient capacity. – Spillage response procedure. Spill response materials will be required to be readily available on-site, with construction personnel aware of their location and use. • Include in the DCDP design measures reducing the risk from the operations phase spills and leaks. • Implement a number of design and operational controls to reduce the likelihood of potential leakage from the onshore pipeline. These include external and internal corrosion protection, access and accidental interference prevention, and operational controls and monitoring to prevent pipeline over-pressurisation. • Include in the preliminary design for the evaporation pond system (Section 3.5.5) sufficient capacity and freeboard to contain the anticipated inflow of the produced water plus fluvial inflow arising from extreme storm events. A robust lining system, comprising a high-density polyethylene liner installed over a compacted clay horizon, will be provided to preserve pond liner integrity and prevent seepage of the water into the surrounding environment. • Locate groundwater monitoring (levels and quality) wells upstream and downstream of potential sources of contamination, such as storage tanks or the evaporation ponds. • Reduce the likelihood of spills and leaks at the gas plant during operations through design controls, equipment and plant inspection and maintenance, operator training and the use of standard operating procedures. • Design the stormwater collection and treatment system (see Section 3.5.8.5) to minimise the risk of contamination through the collection and treatment of potentially contaminated run-off.

Table 7.6 Summary of management measures for hydrogeology.

The lowest surface elevation within the DCDP footprint (2 m AHD) occurs around kilometre point 4.1 (KP4.1) of the proposed route for the onshore section of the supply gas pipeline, where the Forty Mile Beach Road crosses over a saline scald that is subject to seasonal flooding. The road is built up in this area with culverts to allow the passage of water. Storm surges associated with cyclones (**Sections 4.2.1.4** and **4.2.8**) are likely to cause flooding of this area, as well as saturated groundwater conditions. The infrastructure associated with the onshore section of the supply gas pipeline will be buried and is not deemed to be at risk to storm surge flooding. The portion of the supply gas pipeline that will pass through this section of the route has also been specified to be concrete weight coated for stability under these conditions.

The onshore isolation valve will be located in a subterranean chamber, with surface access, in the vicinity of Gnoorea Point. The surface elevation of the pit is approximately 4 m AHD and would be subject to flooding in the event of a 1-in-50-year storm surge (5.9 m AHD). Inundation of the valve pit, however, is not considered to pose an environmental risk. The isolation valve will have corrosion protection, and the pit will be self-draining.

As the lowest point of the gas plant site has an elevation of approximately 15.5 m AHD, there is no risk of inundation from a cyclone-related storm surge (1-in-1,000-year event predicted to be 8.2 m AHD).

At the request of the EPA, an assessment of the risk of the coastal location of the DCDP to future sea level changes has been undertaken. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) includes model-based projections of global sea level rise for the last decade of the 21st century (2090 to 2099). The worst-case scenario for sea level change predicts a rise ranging from 0.26 m to 0.59 m compared to the 1980 to 1999 baseline. The most likely impact will be observed as an increase in the frequency of flooding of the saline scald between KP3.8 and KP4.7, which is currently subject to flooding during spring tides. As mean high water is currently defined as 1.65 m AHD, an increase of 0.59 m in sea level would raise it to approximately 2.24 m AHD.

However, as the onshore section of the supply gas pipeline is buried and provided with corrosion protection and weight coating for stability under saturated groundwater conditions, it is expected that increased flooding in this area will not have any adverse impacts. Taking into account the elevation of the remainder of the infrastructure discussed above, it is considered that future predicted sea level rises do not pose a credible environmental risk to the DCDP.

7.3.3.2 Management

The gas plant design, CEMP and OEMP include a number of measures to be implemented to reduce the impacts to surface water. These include a series of requirements to manage fuels, chemicals and waste materials in order to reduce the likelihood of spillages. These measures are summarised in **Table 7.7**.

7.3.3.3 Residual Risks

Taking into account the proposed controls for managing the risks to and posed by hydrology, the residual risks have been ranked ranging from "B" to "negligible".

7.3.4 Air Quality

Key hazards that have the potential to affect air quality in the DCDP area and beyond include:

- *Emission of combustion products and atmospheric pollutants:* Combustion products will be produced during all phases of the proposed project as a result of equipment operation. These include emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), particulate matter (PM) and sulphur oxides (SO_x). Fugitive emissions of the product gas and vapours include volatile organic compounds are also expected to occur in very small amounts. Secondary air pollutants, such as ground level ozone, can also be generated from the emissions from the project.
- *Dust:* Dust emissions from the DCDP are expected to be mostly generated during the construction phase of the project from such activities as vegetation clearing and earthworks, traffic movements on unsealed roads and wind action over cleared areas and material stockpiles.

7.3.4.1 Impacts

The potential impacts of the hazards identified above include:

- Deterioration of local and regional air quality with associated health and vegetation impact.
- Contribution to climate change.
- Dust impacts on safety, amenity, health and vegetation.

Deterioration of Local and Regional Air Quality

A number of substances emitted to atmosphere from the DCDP can impact on human health and the environment. A discussion of the impacts associated with these emissions and the secondary pollutants that they can generate is provided in **Box 1**.

Emissions from Construction

Atmospheric emissions from the construction phase of the project will result from the combustion of fuel during the use of construction machinery and equipment, including generators, and the use of vehicles for construction materials and workforce transport. These emissions will be transient in nature and are considered to be minor compared to those that will be generated during the operational phase.

Emissions from Operations: Routine Operating Conditions

Atmospheric emissions from the operational phase of the project will be emitted from the following sources under routine operating conditions:

- Two Solar Taurus 60 gas turbine generators of nominal 5,000-kW capacity providing electrical power requirements.
- Two sales gas compressors each powered by a Solar Taurus 60 gas turbine.
- An elevated flare.
- A ground flare.

Predictions of emissions for DCDP operations, based on both gas trains operating for a total throughput of 200 MMSCFD of sales gas, are summarised in **Table 7.8**. These emission predictions were used as the basis of air quality impact modelling for routine conditions. The 200 MMSCFD operating case was modelled to assess the impacts posed by the maximum generation of air emissions from the DCDP during routine operations.

Fugitive emissions due to leakages of the product gas from the various plant processes may be expected. These emissions gases which will include volatile organic compounds (such as methane, ethane, and propane), are only expected to occur in very small amounts. Other potential sources of fugitive emissions of volatile organic compounds include emissions from condensate storage tanks, load-out facilities and other vents; however, these emissions will be diverted to the waste gas low-pressure flare tip within the elevated flare for incineration. For these reasons, the potential emission of BTEX is considered to be minimal and has not been modelled.

Particulate matter (PM_{10}) emissions from gas-fired equipment and routine flaring are considered to be negligible.

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Hydrology	Vegetation clearing and earthworks	*Site preparation, access tracks.*	Changes to natural drainage patterns. Deterioration of water quality.	• Limit the area to be cleared to the minimum required for the development. • Stabilise cleared areas of soil promptly following clearing. • Install erosion and sediment control structure where deemed necessary. • Routinely inspect any erosion and sediment control devices, especially following rainfall events, to ensure they remain effective. • Limit movement of vehicles and equipment to designated access tracks and working areas. • Design erosion and sedimentation control measures to take into account potential for cyclonic rainfall.
	Soil compaction	*Site preparation, access tracks.* *Vehicle movements*	Changes to natural drainage patterns.	As above.
	Spills, leaks and unplanned discharges	*Hydrocarbons and chemical use and storage, hydrotest water spillage of wastes, wash-down, sewage and greywater.*	Deterioration of water quality.	• The CEMP contains measures to reduce the likelihood of spillages, including: – Minimum requirements for fuel, oil, and chemical storage, including provision of secondary containment and access control. – Storage of waste within enclosed containers, and provision of secondary containment for liquid waste. – Provision of designated washdown areas with effluent management controls. – Procedures for refuelling operations. – A site evacuation procedure, covering the requirement to secure storage areas, in the event of an approaching cyclone. – Design of temporary containment bunds to ensure sufficient capacity. – Spillage response procedure. Spill response materials will be required to be readily available on-site, with construction personnel aware of their location and use. – Apache incident reporting procedure (AE-91-IF-002). • Design measures to reduce the risk from the operational phase spills and leaks. • Gas plant stormwater collection and treatment system (see Section 3.5.8.5) will be designed to minimise the risk of contamination through the collection and treatment of potentially contaminated run-off. • Groundwater monitoring to be undertaken. • Volume of fuel use to be recorded and reported on a monthly basis.
	Flooding	*Natural events, e.g., cyclonic rain and storm surge.*	Flooding and storm surge inundation	• Concrete weight-coated onshore pipeline in areas vulnerable to flooding (30 mm coating on pipeline from the onshore isolation valve for approximately 6 km). • Bulk earthworks to raise gas plant RL 0.6 m above natural grade to raise infrastructure above predicted 1-in-100-year flood level. • Design of evaporation ponds to accommodate additional inflow from 100-year ARI storm event and protect against surface flood water ingress.

Table 7.7 Summary of management measures for hydrology.

Source	Exit Velocity (m/s)	Temp (K)	NO_x (g/s)	SO_2 (g/s)	Rsmog* (g/s)
Power Gen 1	23.5	783	0.75	0	0
Power Gen 2	23.5	783	0.75	0	0
Compressor 1	16	633	0.75	0	0
Compressor 2	16	633	0.75	0	0
Elevated Flare	20	1273	0.77	0	0.1
Ground Flare	20	1273	0.77	0	0.1

Source: SKM (2008).
**Rsmog: a summary measure of volatile organic compounds.*

Table 7.8 Predicted air emissions for the DCDP under routine operating conditions.

Nitrogen oxides (NO_x) are part of the biogeochemical cycling of nitrogen (DEW, 2007a). They comprise nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O) and dinitrogen pentoxide (N_2O_5). Lightning and oxidation of ammonia can form oxides of nitrogen naturally; however, the main source is from the combustion of fossil fuels. Nitric oxide can oxidise in the atmosphere to form nitrogen dioxide. At low levels of exposure, nitrogen dioxide can irritate the eyes, nose, throat and lungs, leading to coughing, breathlessness and nausea. Eye or skin contact at high concentrations can lead to burns. Excessive levels in the atmosphere can increase the acidity of rain (the "acid-rain" effect), thereby lowering the pH of the surface water, groundwater and soil, and generally impact on ecosystems. Exposure is generally through air pollution in large cities or industrial areas.

Particulate matter (normally measured as 2.5 or 10 micrometres [$PM_{2.5}$ or PM_{10}] in diameter) is released from numerous sources, including vehicles, sea spray, wood stoves, fires, cigarette smoke, wind-generated dust, bulk material handling, combustion, minerals processing, and refineries. High levels of particulate matter in the atmosphere can represent a health hazard, particularly to people with respiratory difficulties. These health effects can include allergic reactions, fibrosis, cancer, and general irritation, depending on the composition of the particulate matter, its concentrations, the size of the particle and the duration of exposure (DEW, 2007b).

Sulphur dioxide (SO_2) is a by-product of the combustion process associated with fuel sources containing sulphur. When released into the air as sulphur dioxide, it can be converted to corrosive sulphuric acid, sulphur trioxide, and sulphates. The health effects of sulphur dioxide pollution were exposed graphically during the "Great Smog" of London in 1952. This resulted in approximately 4,000 premature deaths through heart disease and bronchitis. Since then, however, emissions have been significantly reduced through legislative controls and the introduction of clean fuel technology. Research has shown that exposure for asthmatics is significantly more damaging than for normal people. Even moderate concentrations may result in a fall in lung function in asthmatics. Tightness in the chest and coughing occur at high levels, and the lung function of asthmatics may be impaired to the extent that medical help is required. Sulphur dioxide pollution is considered more harmful when particulate and other pollution concentrations are high. Initial gas samples collected from the Reindeer gas field indicated no recordable levels of hydrogen sulphide (H_2S), a source of sulphur).

Ozone (O_3) is a colourless gas that is naturally found in the upper atmosphere. Ozone is also formed as a secondary pollutant at ground level by the reaction of nitrogen dioxide (NO_2) (a combustion product) and sunlight, which form nitric oxide (NO) and a single oxygen atom (O). This oxygen atom (O) then combines with molecular oxygen (O_2) to form ozone (O_3). Photochemical smog is characterised by the reaction of ozone, oxides of nitrogen (NO_x) and volatile organic compounds in sunlight and at high temperatures. A mixture of these chemicals forms a layer of visible, brown or white haze in the sky. Photochemical smog is a regional phenomenon; ozone is produced relatively slowly over several hours after exposure to sunlight has been sufficient for the series of reactions to be completed. Maximum ozone concentrations therefore tend to occur downwind of the main source areas of precursor emissions, and can become recirculated within local and regional circulation patterns. The health effects of ozone in the lower atmosphere include irritation of the eyes and exacerbation of respiratory problems (SKM, 2008).

Volatile Organic Compounds (VOCs) are a group of carbon-based chemicals, many with a high vapour pressure. Fuels, oil-based paints, solvents, benzene, toluene, xylene and perchloroethylene (the principal dry cleaning solvent) are all VOCs. The most common VOC is methane, a greenhouse gas. Major sources of atmospheric methane include wetlands, ruminants (such as cows), energy use, rice agriculture, landfills, and burning biomass (such as wood). Methane is the primary component of natural gas. Fugitive emissions from the storage and handling of liquid and gaseous hydrocarbons is also a source of VOCs. These chemicals can react with NO_x in the presence of sunlight to form ozone. The extent to which individual VOCs can cause health problems depends on their toxicity, concentration and the duration of exposure. Some are known to be carcinogenic, while others can cause reactions such as coughing or eye irritations. Benzene, toluene, ethylbenzene and xylenes (referred to as the BTEX group of compounds) are among a wide variety of toxic VOCs. They are of concern because of their potentially significant effects on the health of humans and the environment at low concentrations. In the ambient environment, these compounds are generally found in low concentrations. Emissions of BTEX represent a fraction of the compounds emitted from the combustion of fossil fuels (SKM, 2008).

Box 1 Air Emissions and Secondary Pollutants

Emissions from Operations: Non-routine Conditions

Non-routine conditions at the gas processing plant can lead to significantly increased emissions for short periods of time. In particular, if one or more processing trains must be shut down, then the process gas inventory must be routed to the flares for disposal, leading to very high flare emissions. Where possible, continuous flaring and venting occurrences will be avoided.

Flaring will also be required during start-up and commissioning, with emissions levels being elevated during this period. It is expected that the emission levels during commissioning will be similar to those during start-up and shut-down procedures.

Two flaring conditions have been addressed in this assessment, corresponding to a total plant shutdown (upset condition 1) and to shutdown of one gas train (upset condition 2) respectively. Total plant shutdown conditions may be expected to occur for up to 8 hours per year, with increased emissions from the elevated flare. Single train shutdown conditions may occur for up to 24 hours per year, with increased emissions from the ground flare. Flaring emissions modelled were limited to NO_x and hydrocarbons, due to the very low sulphur content of the DCDP feedstock.

The modelling of predicted ground-level concentrations of air emissions from upset conditions is considered to be conservative for the following reasons. The plant relief and blowdown system is designed to ensure that the majority of the gas inventory will be flared within the first 15 minutes of a plant shut down. For the purposes of the air emission concentration modelling, the discharge rates of predicted air emissions from the flares (**Table 7.9**) were based on their instantaneous peak discharge rate (effectively assuming this discharge rate is continuous over a 1 hour period). In reality, this peak rate will decrease rapidly over the first 15 minutes of a shutdown flaring event and as a consequence the volume of emissions will be smaller than those used to model the predicted ground-level concentrations.

Emissions characteristics for these plant upset conditions are summarised in **Table 7.9**.

Emissions Criteria

The Western Australian Environmental Protection Authority (EPA) requires that "all reasonable and practicable means should be used to prevent and minimise the discharge of waste" (EPA, 2000a). For new proposals, the EPA requires an assessment of the best available technologies for minimising the discharge of waste for the processes and a justification for the adopted technology.

The EPA has developed a guidance statement for oxides of nitrogen emissions from gas turbines, which establishes emissions limits that generally follow the Australian Environmental Council/Natural Health and Medical Research Council National Guidelines (EPA, 2000a). These limits are summarised in **Table 7.10**.

Gas-fired systems employing NO_x control technology, such as the dry-low NO_x burners specified for the DCDP power generation and sales gas compressor gas turbines, are recognised as best practice and can be expected to achieve lower emissions than 0.07 g/m^3 (EPA, 2000a).

Ambient Air Quality Standards

The National Environment Protection (Ambient Air Quality) Measure (Ambient Air Quality NEPM) was created to provide a benchmark by which to ensure that people throughout Australia have protection from the potential health effects of air pollution. This NEPM applies to both urban and regional areas and includes standards for ozone (O_3), nitrogen dioxide (NO_2), particulates (as PM_{10}), carbon monoxide (CO), sulphur dioxide (SO_2), and lead.

The EPA and Department of Environment and Conservation (DEC) routinely apply these NEPM standards and goals in Western Australia. For ambient ground-level concentrations, the EPA does not have statewide standards; however, the Ambient Air Quality NEPM

Source	Exit Velocity (m/s)	Temp (K)	NO_x (g/s)	SO_2 (g/s)	Rsmog* (g/s)	PM_{10} (g/s)
Upset Condition 1 – Total Plant Shutdown						
Power Gen 1	23.5	783	0	0	0	0
Power Gen 2	23.5	783	0	0	0	0
Compressor 1	16	633	0	0	0	0
Compressor 2	16	633	0	0	0	0
Elevated Flare	20	1273	110	0	16	198
Ground Flare	20	1273	0.77	0	0.1	0
Upset Condition 1 – Total Plant Shutdown						
Power Gen 1	23.5	783	0.75	0	0	0
Power Gen 2	23.5	783	0	0	0	0
Compressor 1	16	633	0.75	0	0	0
Compressor 2	16	633	0	0	0	0
Elevated Flare	20	1273	0.77	0	0.1	0
Ground Flare	20	1273	18	0	2.6	33

Source: SKM (2008).
*Rsmog: a summary measure of volatile organic compounds

Table 7.9 Predicted air emissions for the DCDP under non-routine conditions.

Fuel Type	Rated Electrical Output	Oxides of Nitrogen[1]	
		g/m³	ppmv (approx)
Gaseous Fuels	Less than 10 MW	0.09	44
	Greater than 10 MW	0.07	34
Other Fuels	Less than 10 MW	0.09	44
	Greater than 10 MW	0.15	73

[1]*Calculated as NO_2 at a 15% oxygen reference level, dry, at standard temperature (0°C) and pressure (1 atmosphere).*

Source: EPA (2000a).

Table 7.10 Guidelines for emissions of oxides of nitrogen from gas turbines.

standards are applied across all areas of Western Australia, excluding industrial areas and residence-free buffer zones (NEPC, 2007). As such, and in the absence of other relevant standards, the NEPM standards have been applied to the nearest sensitive receptors, determined to be the proposed DCDP accommodation facility and Gnoorea Point (to provide an indicator for the Forty Mile Beach recreational area).

The highest-risk NEPM air pollutants relevant to the DCDP are nitrogen dioxide, ozone, and sulphur dioxide. These pollutants are listed in **Table 7.11**, along with their associated NEPM standard. These specify the maximum concentrations allowed.

Impacts on Vegetation

The World Health Organization provides critical levels for concentrations for the assessment of nitrogen oxides and sulphur dioxide on vegetation. These ground-level concentration levels are 37 ppb (24 hours) and 15 ppb (annual) for NO_x and 10 ppb (annual) for SO_2.

Modelling Results

This section presents the results of computer modelling of emissions impacts for the DCDP gas plant in isolation, for existing sources, and for cumulative impacts from the combined set of sources. The modelling results are presented for the two sensitive receptor locations, the DCDP accommodation facility and Gnoorea Point, and for the maximum predicted concentration anywhere within the defined air quality assessment area (grid). The results are then compared against human health and vegetation impact assessment criteria.

DCDP Gas Plant in Isolation

Table 7.12 shows the predicted maximum ground-level concentrations of NO_2 or NO_x, SO_2 at the two receptors, the model grid maximum, and human health and vegetation assessment criteria. The predicted concentrations cannot be directly compared with air quality standards; however, they help to demonstrate that the contribution due to DCDP emissions is relatively small.

The potential emission of SO_2 from the DCDP is considered to be minimal due to the low sulphur content of the feed gas. Modelling results showed that the maximum predicted SO_2 concentrations anywhere on the model grid were a small fraction of the relevant assessment criteria; and as a result, SO_2 was not addressed any further in the air quality assessment.

Existing Sources of Air Emissions

Predicted air quality impacts due to existing and previously approved industry, including proposals that have received regulatory approval but are not yet operational (such as the Gorgon LNG Development on Barrow Island and the Austeel DRI Plant near Cape Preston), show that relevant air quality criteria for ground-level concentrations of oxides of nitrogen (one hour and annual average) are well below the assessment criteria. Ozone concentrations are higher but remain well below relevant assessment criteria at the sensitive receptors. Predicted concentrations of oxides of nitrogen are also well below criteria adopted for protection of vegetation. **Table 7.13** shows the results of the model for both human health and vegetation impacts of existing sources in the region.

Cumulative Impact of Existing Sources and DCDP: Routine Operating Conditions

Table 7.14 shows the predicted ground-level concentrations of all future air emission sources, including existing industry, current

Pollutant	Averaging Period	Maximum Concentration
Nitrogen dioxide (NO_2)	1 hour	120 ppb (246 µg/m³)
	1 year	30 ppb (62 µg/m³)
Photochemical oxidants (as ozone)	1 hour	100 ppb (214 µg/m³)
	4 hours	80 ppb (171 µg/m³)
Sulphur dioxide	1 hour	200 ppb (572 µg/m³)
	1 day	80 ppb (227 µg/m³)
	1 year	20 ppb (57µg/m³)
Particulate matter (as PM_{10})	1 day	50 µg/m³

Source: SKM (2008).

Table 7.11 Ambient Air Quality NEPM Standards.

DCDP in Isolation					
Human Health	**NO_2 1 hr (ppb)**	**NO_2 annual (ppb)**	**SO_2 1 hr (ppb)**	**SO_2 24 hr (ppb)**	**SO_2 annual (ppb)**
DCDP accommodation facility	7	0.2	9	3	0.2
Gnoorea Point	19	0.2	5	1	0.2
Grid maximum	19	1.5	15	7	2.2
Assessment criteria	**120**	**30**	**200**	**80**	**20**

Vegetation Impact	NO_x 24 hr (ppb)	NO_x annual (ppb)	SO_2 annual (ppb)
DCDP accommodation facility	2	0.3	0.2
Gnoorea Point	3	0.2	0.1
Grid maximum	4	1.5	2.2
Assessment criteria	**37**	**15**	**10**

Table 7.12 Predicted ground-level concentrations of air emissions relevant to human health and vegetation impacts for the DCDP in isolation.

Existing Sources				
Human Health	**NO_2 1 hr (ppb)**	**NO_2 annual (ppb)**	**O_3 1 hr (ppb)**	**O_3 4 hr (ppb)**
DCDP accommodation facility	26	0.7	68	59
Gnoorea Point	23	0.7	55	53
Grid maximum	36	0.9	76	66
Assessment Criteria	**120**	**30**	**100**	**80**

Vegetation Impact	NO_x 24 hr (ppb)	NO_x Annual (ppb)
DCDP accommodation facility	5	0.9
Gnoorea Point	7	0.9
Grid maximum	13	1.1
Assessment Criteria	**37**	**15**

Table 7.13 Predicted ground-level concentrations of air emissions relevant to human health and vegetation impacts due to existing sources.

proposals with regulatory approval and air emissions from the DCDP. The results show that cumulative impacts due to combined air emissions from the DCDP and other industrial sources result in only marginal increases over the impact of existing emissions.

Concentrations of nitrogen dioxide, oxides of nitrogen and ozone remain below the relevant assessment criteria during normal operating conditions with little change over the existing conditions. Ozone concentrations are predicted to increase marginally over the existing conditions and remain below the relevant assessment criteria.

Figures 7.4 and **7.5** show contour plots for averaged NO_2 and O_3 concentrations for combined future sources for the region.

Cumulative Impact of Existing Sources and DCDP: Upset Conditions

Two different upset conditions were modelled for the DCDP: total plant shutdown (upset condition 1) and a single train shutdown (upset condition 2). Modelling results are presented for short-term concentrations only, reflecting the short-term nature of upset conditions.

Upset condition 1 represents a total plant shutdown, with disposal of the complete DCDP inventory to the elevated flare. Maximum predicted ground-level concentrations at local sensitive receptors and across the model grid are presented in **Table 7.15** below. Contour plots of NO_2 and O_3 concentrations are presented in **Figures 7.6** and **7.7** respectively.

PM_{10} concentrations at the receptors are negligible (4% of the assessment criteria) with the highest concentration modelled on the grid just over 10% of the assessment criteria. NO_2 concentrations are well below the assessment criteria. The highest predicted ozone concentrations at sensitive receptors approach but do not exceed the relevant criteria at sensitive receptor locations. The highest concentrations on the model grid occur at locations distant from sensitive receptors where the assessment criteria are not applicable.

Upset condition 2 represents a shutdown of one gas processing train with gas routed to the ground flare, while normal operations continue for the rest of the plant. Maximum predicted ground-level concentrations at local sensitive receptors and across the model grid are presented in **Table 7.16**. Contour plots of NO_2 and O_3 concentrations are presented in **Figures 7.8** and **7.9** respectively.

Similar to results for upset condition 1, PM_{10} and NO_2 concentrations are well below the assessment criteria. Again, the highest predicted ozone concentrations at sensitive receptors approach but do not exceed the relevant criteria at sensitive receptor locations, while the highest concentrations on the model grid occur at locations distant from sensitive receptors where the assessment criteria are not applicable.

Air Quality Impact Assessment Summary

The air quality assessment (SKM, 2008) illustrated that the highest concentration of air pollutants due to emissions from the DCDP are small compared to the relevant air quality criteria. Cumulative impacts from the DCDP and other industrial sources show marginal increases over existing emissions, with concentrations of nitrogen dioxide, total oxides of nitrogen and ozone remaining below the air quality criteria during both routine and non-routine operating conditions.

Contribution to Climate Change

In recent times, a great deal of effort has been directed at defining the change in atmospheric greenhouse gas concentrations and

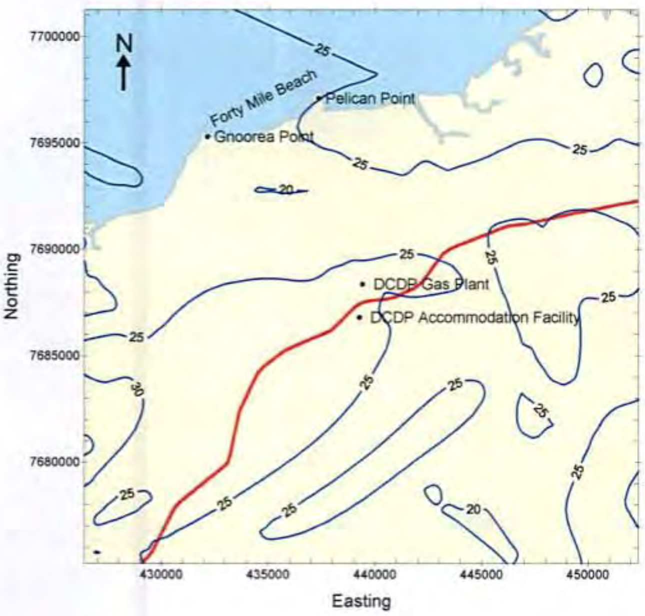

Figure 7.4 Predicted maximum 1 hour average NO_2 concentrations for all sources (ppb) – routine operating conditions.

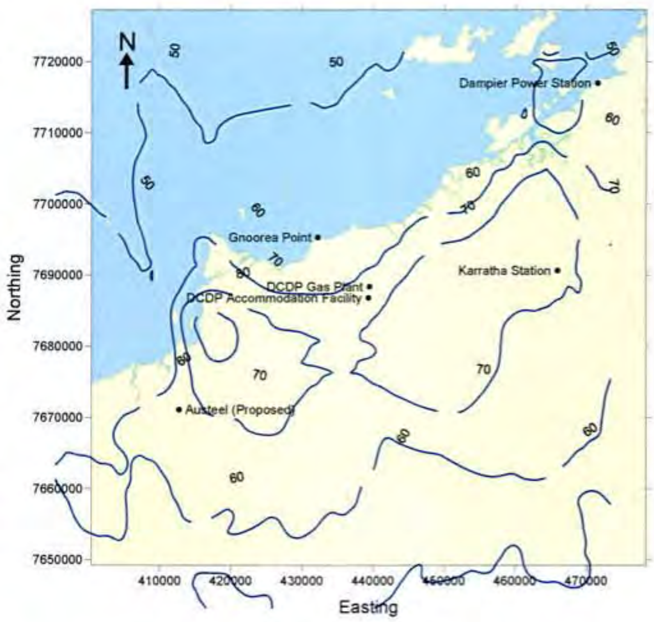

Figure 7.5 Predicted maximum 1 hour average O_3 concentrations for all sources (ppb) – routine operating conditions.

Cumulative Impacts				
Human Health	**NO_2 1 hr (ppb)**	**NO_2 annual (ppb)**	**O_3 1 hr (ppb)**	**O_3 4 hr (ppb)**
DCDP accommodation facility	29	0.7	71	63
Gnoorea Point	23	0.7	56	55
Grid maximum	39	1.3	85	76
Assessment Criteria	**120**	**30**	**100**	**80**

Vegetation Impact	NO_x 24 hr (ppb)	NO_x Annual (ppb)
DCDP accommodation facility	6	1.0
Gnoorea Point	5	1.0
Grid maximum	13	2.3
Assessment Criteria	**37**	**15**

Table 7.14 Predicted ground-level concentrations of air emissions relevant to human health and vegetation impacts for cumulative impacts (routine operating conditions).

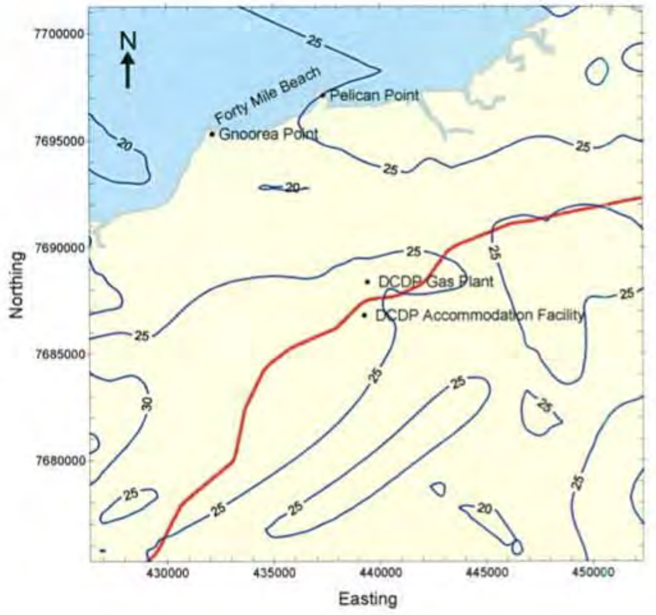

Figure 7.6 Predicted maximum 1 hour average NO_2 concentrations for all sources (ppb) – Upset 1: Total Plant Shutdown.

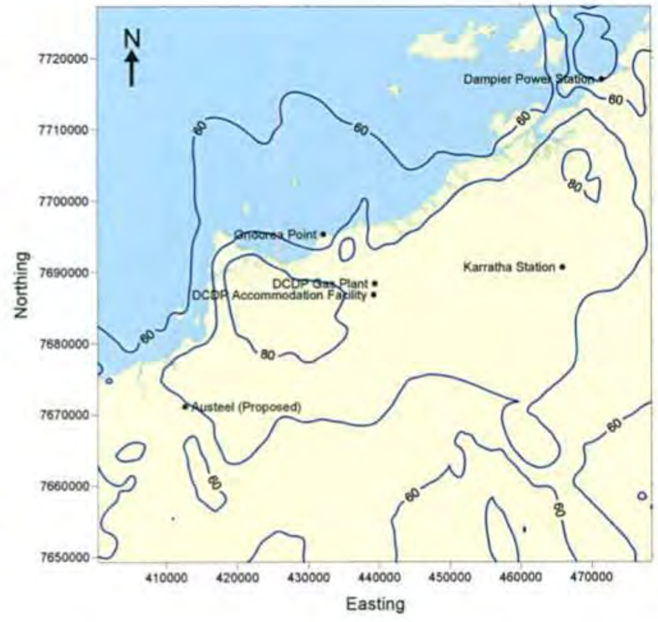

Figure 7.7 Predicted maximum 1 hour average O_3 concentrations for all sources (ppb) – Upset 1: Total Plant Shutdown.

Averaging Period Units	NO_2 1hr ppb	O_3 1hr ppb	O_3 4hr ppb	PM_{10} 24hr µg/m³
DCDP accommodation facility	27	78	71	1.9
Gnoorea Point	23	68	64	1.4
Grid maximum	36	89	83	6
Assessment criteria	**120**	**100**	**80**	**50**

Table 7.15 Predicted ground-level concentrations of air emissions relevant to human health for upset condition 1 (total plant shutdown).

mean global temperature. Since the Third Assessment Report (IPCC, 2001), a succession of unusually warm years, heatwaves, droughts, floods and cyclones has brought global warming and climate change to the forefront of public debate (AGO, 2006). In its Fourth Assessment Report in 2007, the Intergovernmental Panel on Climate Change (IPCC) stated that: "Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations" and "Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns" (IPCC, 2007a)

Greenhouse gases are a natural part of the atmosphere. The atmosphere allows most sunlight (solar short-wave radiation) to enter and warm the earth. As the surface of the earth cools, it emits infrared radiation (heat), some of which is absorbed by gases in the atmosphere and radiated back to earth. This is called the greenhouse effect. The main gases responsible for this effect are water vapour, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Other greenhouse gases include perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6).

The global warming potential of these gases varies, depending on their particular physico-chemical structure and the time span over which the effect is being considered. To be able to compare the effect of different gases, the global warming potential of a gas is expressed relative to CO_2 over a time horizon (100 years is the most usual) and is referred to as its carbon dioxide equivalent, or CO_2-e. The global warming potential of the six main greenhouse gases is provided in **Table 7.17**.

The construction and operation of the DCDP will result in the emission of greenhouse gases, with the vast majority emitted during the operational phase of the development. Emissions of greenhouse gases during the construction phase will be limited to the combustion of fuel in plant and equipment. Fuel gas (conditioned natural gas recovered from the production wells) will be used as the primary fuel during operations for generating the power and processing requirements at the gas plant. Diesel will be used as a back-up fuel source. The main sources of greenhouse gas emissions associated with the operation of the DCDP (in descending order) are:

- Gas turbine sales gas compression.
- Gas turbine power generation.

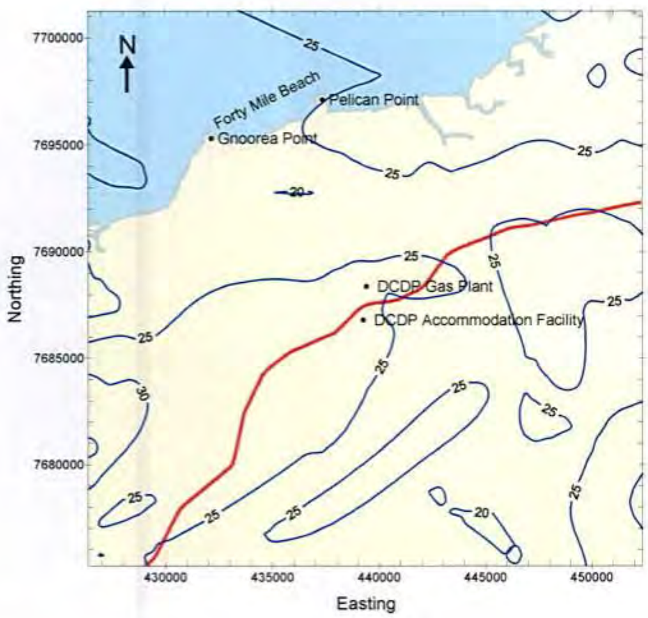

Figure 7.8 Predicted maximum 1 hour average NO_2 concentrations for all sources (ppb) – Upset 2: Single Train Shutdown.

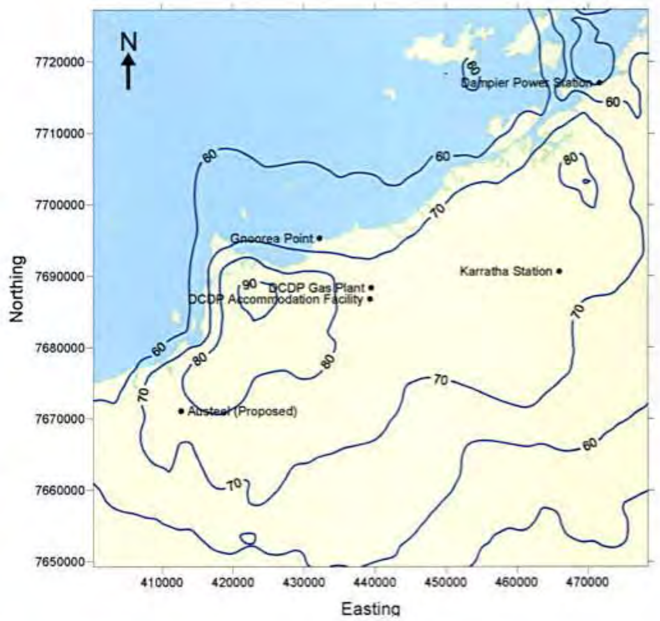

Figure 7.9 Predicted maximum 1 hour average O_3 concentrations for all sources (ppb) – Upset 2: Single Train Shutdown

Averaging Period Units	NO_2 1hr ppb	O_3 1hr ppb	O_3 4hr ppb	PM_{10} 24hr µg/m^3
DCDP Accommodation facility	28	78	69	1.5
Gnoorea Point	23	64	62	0.7
Grid maximum	36	93	87	2.1
Assessment criteria	**120**	**100**	**80**	**50**

Table 7.16 Predicted ground level concentrations of air emissions relevant to human health for upset condition 2 (single train shutdown).

- Flaring.
- Road transport of condensate.
- Fugitive emissions (non-point source emissions).

Greenhouse gas emissions for the DCDP have been estimated based on agreed standards for the oil and gas industry (E&P Forum, 1994). Of the six main greenhouse gases, there will be no emissions of perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) or sulphur hexafluoride (SF_6) from the DCDP, and these have not been discussed further. Greenhouse gases that apply to the project include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

For the 100-MMSCFD production case, greenhouse gas emissions from the DCDP and associated road transport of condensate were estimated to range from 76,818 tonnes to 79,674 tonnes of CO_2-e per annum.

For the 200-MMSCFD production case, greenhouse gas emissions from the DCDP and associated road transport of condensate were estimated to range from 121,985 tonnes of CO_2-e to 124,840 tonnes of CO_2-e per annum.

Gas	Global Warming Potential (CO_2-e)
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Perfluorocarbons (PFCs)	6,500 to 9,200
Hydrofluorocarbons (HFCs)	140 to 11,700
Sulphur hexafluoride (SF_6)	23,900

Source: IPCC (2007b)

Table 7.17 Global warming potential of the six main greenhouse gases relative to CO_2 (over 100-year time horizon).

Tables 7.18 and **7.19** details the breakdown of the calculated greenhouse gas emissions for the 100-MMSCFD and 200-MMSCFD production rates respectively.

In Australia, in 2005, it was estimated that 559.1 million tonnes (Mt) of CO_2-e were emitted, representing a 2.2% increase on emissions generated in 1990 (AGO, 2007b). Of the 2005 total, oil and gas extraction comprised 16.5 Mt of CO_2-e, or 3% (a 16% increase on the 1990 emissions of 12.5 Mt) (APPEA, 2006). This compares with a 47.6% increase for coal mining and a 46.8% increase for the electricity, gas and water industry sectors over the same period (AGO, 2007a).

Compared to the 2005 oil and gas industry greenhouse gas emissions figure, the annual greenhouse gas emissions from the DCDP will contribute an additional 76,818 tonnes to 124,840 tonnes (0.5% to 0.8% of the 16.5-Mt 2005 total) equating to about 0.01% to 0.02% of Australia's total greenhouse gas emissions.

The main impact of the emission of greenhouse gases from the DCDP will be a contribution to the incremental build-up of these gases in the atmosphere, which, when combined with greenhouse gases released from other sources, is considered to be the main contributor to global warming.

Dust impacts on Safety, Amenity, Health and Vegetation

Dust emissions from the DCDP are expected to be mostly generated during the construction phase of the project with sources including:

- Vegetation clearing.
- Earthworks, including material conditioning, and excavations.
- Traffic movements on unsealed roads.
- Wind action over cleared areas and material stockpiles.
- Handling of dusty materials, such as during concrete batching.
- Grinding and welding.

Maintenance activities during the operational phase of the DCDP, such as the mercury guard bed and molecular sieve material change-outs, also have the potential to create dust.

Dust may have a temporary impact on local air quality during construction. Dust in the atmosphere can reduce visibility (potentially affecting safety and amenity) and can irritate respiratory systems, and dust deposition on plants can increase thermal stress and reduce growth rates by affecting the photosynthetic efficiency of plants.

Dust emissions are expected to vary depending on a number of factors, including weather conditions (wind speed and humidity), operations being undertaken, and amount of project traffic.

7.4.3.2 Management

The design and management measures that will be implemented to manage air emissions are summarised in **Table 7.20**.

Combustion emissions will be minimised through the design and selection of processing equipment to maximise energy efficiency. Notably the DCDP gas plant has been effectively designed to capture waste heat from the sales gas compressors' gas turbine exhausts using waste heat recovery units (WHRUs), in place of conventionally fired heaters, to provide the required utility heat for the following process users:

Operation	CO_2	N_2O	CH_4	CO_2-e*	%
Sales gas compression	37,749	3.02	5.76	38,806	49 to 51
Power generation	18,116	1.45	2.76	18,623	23 to 24
Flare emissions	3452 to 4025	0.38 to 0.44	164 to 192	17,189 to 20,044	22 to 25
Condensate road transport	2135	0.14	0.92	2200	3
Fugitive emissions	-	-	0.0006	0.01	<0.0002
Total (tonnes)				**76,818 to 79,674**	
*IPCC Global Warming Potential factors (IPCC, 2007b): CO_2 equivalents: $CO_2 = 1$, $CH_4 = 21$, $N_2O = 310$.					

Table 7.18 Calculated greenhouse gas emissions for 100-MMSCFD production rate (tonnes per annum).

Operation	CO_2	N_2O	CH_4	CO_2-e*	%
Sales gas compression	75,498	6.02	11.4	77,612	62 to 64
Power generation	22,163	1.76	3.37	22,783	18 to 19
Flare emissions	13,619 to 15,881	0.37 to 0.43	164 to 192	17,189 to 20,044	14 to 16
Condensate road transport	4271	0.28	1.87	4401	4
Fugitive emissions	-	-		0.02	<0.0002
Total (tonnes)				**121,985 to 124,840**	
*IPCC Global Warming Potential factors (IPCC, 2007b): CO_2 equivalents: $CO_2 = 1$, $CH_4 = 21$, $N_2O = 310$.					

Table 7.19 Calculated greenhouse gas emissions for 200-MMSCFD production rate (tonnes per annum).

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Air Quality	Emission of combustion products and atmospheric pollutants	*Gas turbine emissions.* *Flaring.* *Road transport.* *Fugitive emissions.*	Deterioration of local and regional air quality (with potential adverse human health and vegetation impacts).	• Use of dry low NO_x burners with natural gas as principal fuel source. • Energy conservation measures in gas plant design (e.g., WHRUs to provide utility heat and thermal insulation of piping and buildings). • Process control to minimise flaring. • Regular maintenance on combustion and other energy-intensive equipment. • Full gas train recycle capability to reduce flaring on start-up. • Fugitive emission controls and thermal destruction of captured volatile organic compounds. • Fugitive emissions of volatile organic compounds. will be minimised through design and selection of processing and storage equipment: – Stabilised condensate storage tanks are an internal floating roof design. – Off-specification condensate tank, fixed roof, is to be blanketed with low-pressure fuel gas and is to out-breathe to the low-pressure flare tip for vapour destruction. – Condensate road tanker load-out system will include a vapour recovery system with collected vapour routed to the low-pressure flare tip for destruction. • Thermal destruction of the captured volatile organic compounds is considered preferable to fugitive emissions from a greenhouse gas management point of view due to the smaller (approximately six times less per tonne) greenhouse gas impact of the combustion gases. In addition, volatile organic compounds' emissions can be viewed to be more damaging than their combustion products, due to their higher potential to cause adverse health impacts and create secondary pollutants, such as low-level ozone, through photochemical reactions. • Generally, compressor seals are a significant source of fugitive emissions in gas processing facilities. The DCDP will utilise dry-gas compressor seals that virtually eliminate fugitive emissions from this source. • Once operational, power will be supplied from the gas plant's gas-fired power generation to the accommodation facility, replacing the diesel-powered generation to be used prior to gas plant commissioning. • Metering equipment will be installed on all process equipment (including composition analysis as required) at the DCDP so that atmospheric discharges can be quantified. • Habitable buildings to comply with energy efficiency requirements as per the Building Code of Australia. • Corporate participation in Greenhouse Challenge and Energy Reporting program will continue.
	Emission of combustion products and atmospheric pollutants	*Gas turbine emissions.* *Flaring.* *Road transport.* *Fugitive emissions.*	Contribution to climate change.	As above.
	Dust	*Vegetation clearing.* *Earthworks, material conditioning, and excavations.* *Traffic movements.* *Wind action on cleared areas and material stockpiles.* *Concrete batching.* *Grinding and welding.* *Maintenance activities during operation of the DCDP.*	Dust impacts on safety, amenity, health and vegetation.	• The CEMP includes dust suppression measures, such as: – Watering of unsealed roads, access tracks, cleared areas and stockpiles. – Stabilisation of surfaces as soon as possible following clearing. – Covering loads of dusty materials for transportation on public roads. – Controlling concrete batching in accordance with applicable regulations. – Traffic speed limits as per the DCDP Traffic Management Plan. – Enclosing grinding operations where practicable in higher sensitivity areas, such as at the HDD construction site at Gnoorea Point. – Daily visual dust monitoring. • Measures to manage dust during the operational phase will include: – Sealed road ways. – The undertaking of 'dusty' jobs will use working methods such as encapsulation to reduce emissions from the handling of dusty materials.

Table 7.20 Summary of air emissions management measures.

- Molecular sieve dehydration.
- Condensate stabilisation (condensate preheater and stabiliser reboiler).
- Fuel gas bath heater.

The WHRUs exchange heat from the gas turbine exhaust streams with a recirculated heating medium (hot oil). The WHRUs will provide approximately 3.6 MW of heat energy during the 100-MMSCFD sales gas production case, effectively doubling for the 200-MMSCFD production case. The use of WHRUs instead of conventional gas-fired heating will result in a saving of approximately 9,165 to 18,330 tonnes of CO_2-e per annum depending on the rate of sales gas production.

7.4.3.3 Residual Risks

The results of the air emissions modelling study for the DCDP concluded that the highest concentration of air pollutant species (NO_2, NO_x and O_3) are small relative to relevant air quality standards and that cumulative impacts due to combined emissions from DCDP and other industrial sources show only marginal increases over the impact of existing emissions (SKM, 2008). The potential emission of SO_2 from the DCDP is considered to be minimal due to the negligible sulphur content of the feed gas.

Fugitive emissions of volatile organic compounds from storage tanks, the produced water treatment system and the condensate load-out facility will be captured and diverted to the low-pressure flare tip for destruction.

The residual environmental impacts of the emission of combustion products and atmospheric pollutants are predicted to be "negligible", with combustion emissions not expected to result in any significant impact on human health or the environment.

With the implementation of the proposed dust management controls, the residual environmental risks of dust emissions are predicted to range from "B" to "negligible". The higher level of risk rating applies to the potential dust generation at the HDD construction site, taking into account the higher sensitivity of the receptors in this area (the Forty Mile Beach recreational area).

7.3.5 Noise Emissions

Noise hazards associated with the DCDP include:

- Noise emission from construction activities.
- Noise emissions from operations.

7.3.5.1 Impacts

The potential impacts of the noise hazards identified above include:

- Reduction in amenity.
- Fauna disruption.

Reduction of Amenity

Noise emitted by the DCDP during the construction and operational phases has the potential to reduce amenity at sensitive receptors.

Sensitive Receptors

An initial screening of the DCDP area and potential noise sources during the construction and operational phases identified two sensitive receptors that may be impacted by noise:

- Recreational users in the Forty Mile Beach area that may be impacted by HDD noise during the construction of the shore crossing.
- Residents of the DCDP accommodation facility that may be impacted by operational noise from the gas plant.

Operational noise from the gas plant is not expected to impact upon the recreational users of the Forty Mile Beach area due to the separation distance (approximately 10 km) between the two locations. Operational noise emissions from the shore crossing and onshore sections of the supply gas pipeline are expected to be non-existent.

Existing Noise Levels

An assessment of existing ambient noise levels in the vicinity of the proposed development was undertaken from 23 October to 6 November 2007. Noise monitors were deployed at the locations of the two identified sensitive receptors.

The noise monitoring equipment was set to continuously record L_{A1}, L_{A10} and L_{A90} noise levels (levels that are exceeded 1%, 10% and 90% of

Period	Average L_{A10} (dB(A))	Average L_{A90} (dB(A))	L90 of L_{A90} (dB(A))
Shore Crossing – Forty Mile Beach			
Day (0700 to 1900 hrs)	48.7	41.2	30.5
Evening (1900 to 2200 hrs)	47.9	41.5	36.5
Night (2:00 to 0700)	43.0	36.7	23.5
All Data	46.6	39.7	27.5
DCDP Accommodation Facility			
Day (0700 to 1900 hrs)	45.6	34.0	25.0
Evening (1900 to 2200 hrs)	42.3	34.2	22.8
Night (2200 to 0700)	33.5	20.1	<20
All Data	40.2	28.6	<20

Table 7.21 Summary of ambient noise levels for DCDP noise receptor areas.

the time respectively) at 15-minute intervals. The L90 (90th percentile) of the L_{A90} noise levels (that is, the noise level that is exceeded for 90% of the monitoring period) provides a good indication of the lowest ambient noise levels recorded at the two sites. A summary of the results are provided in **Table 7.21**.

Results show that ambient noise at the supply gas pipeline shore crossing (Forty Mile Beach) is very low, with an overall average L_{A10} of 46.6 dB(A) and L_{A90} of 39.7 dB(A). The lowest ambient noise levels were experienced during the night period of 2200 to 0700 hours (L_{A10} of 43.0 dB(A) and L_{A90} of 36.7 dB(A)). Noise levels were mostly influenced by ocean- and wind-generated noise.

The ambient noise at the proposed DCDP accommodation facility is also very low with an overall average L_{A10} of 40.2 dB(A) and L_{A90} of 28.6 dB(A). The lowest ambient noise levels were experienced during the night period of 22.00 to 07.00 hours (L_{A10} of 33.5 dB(A) and L_{A90} of 20.1 dB(A)). Daytime and evening ambient noise levels were influenced by traffic noise on the North West Coastal Highway, and this is reflected in the increased noise levels during these time periods.

Table 7.22 provides descriptions of typical sound pressure levels for comparison with existing (ambient) and predicted noise levels.

Construction Noise

A range of construction activities will be undertaken that will generate noise. These are described in **Section 3.6** and include:

- Clearing and earthworks.
- HDD.
- Running of generators and pumps.
- Civil engineering works.
- Mechanical construction activities.
- Metal grinding.

Preliminary geotechnical and construction reviews have indicated that there will not be a requirement for blasting along the onshore section of the supply gas pipeline route, thus reducing potential construction-related noise impacts.

The pipeline shore crossing will be completed by horizontal directional drilling, which is expected to take 3 to 4 months to complete, with activity occurring 24 hours, 7 days a week. Typical high noise emitters from HDD activities will include:

- Drilling rig.
- Power packs.
- Mud pumps.
- Mud recycling.
- Generator.
- Mixing tank.
- Crane.

Operational Noise

During operation of the DCDP, noise emissions will be generated from equipment on the gas plant site. In particular, the main noise sources will include:

- Sales gas compressors.
- Stabiliser compressors.
- Gas coolers/aftercoolers.

Sound Pressure Level (dB)	Typical Environment	Average Subjective Description
140	30 m from jet aircraft	Intolerable
130	Pneumatic chipping and riveting (operator's position)	
120	Boiler shop (maximum levels)	
110	Chainsaw	Very noisy
100	Disco	
90	Heavy lorries at 6 m	
80	Kerbside of busy road	Noisy
70	Loud radio	
60	Restaurant	
50	Conversational speech at 1 m	Quiet
40	Residential area at night	
30	Quiet bedroom at night	
20	Background in TV and recording studios	Very quiet
10		
0	Threshold of hearing	

Source: WEL (2007)

Table 7.22 Description of typical sound pressure levels.

- Condensate loading pumps.
- Other pump systems (hot oil, skimming, water).
- Gas turbine driven generators.
- Diesel driven emergency generator.
- Emergency flare.

Noise Criteria

Noise management in Western Australia is implemented through the Environmental Protection (Noise) Regulations 1997, which operate under the *Environmental Protection Act 1986*. The regulations specify maximum noise levels (assigned levels) that are the highest noise levels that can be received at noise-sensitive premises, commercial premises and industrial premises.

Assigned noise levels have been set differently for noise-sensitive premises, commercial premises, and industrial premises. For noise-sensitive premises (e.g., residences), an "influencing factor" is incorporated into the assigned noise levels. The influencing factor depends on land use zonings within circles of 100 m and 450 m radius from the noise receiver, including:

- The proportion of industrial land use zonings.
- The proportion of commercial zonings.
- The presence of major roads.

For noise-sensitive premises, the time of day also affects the assigned levels. The regulations define three types of assigned noise level:

- $L_{A\,max}$ assigned noise level means a noise level that is not to be exceeded at any time.
- L_{A1} assigned noise level means a noise level that is not to be exceeded for more than 1% of the time.
- L_{A10} assigned noise level means a noise level that is not to be exceeded for more than 10% of the time.

The L_{A10} noise level is the most significant for the DCDP as it is representative of continuous noise emissions from the gas plant and HDD drilling operations.

The area surrounding the proposed shore crossing is designated as an area for "Conservation, Recreation and Natural Landscapes" and does not comprise any permanent buildings (camping, however, is permitted and managed by the Shire of Roebourne). Although the noise levels prescribed in the Environment Protection (Noise) Regulations 1997 do not apply, as no actual premises exist in the area, the EPA recognises that "some areas need to be protected from noise to a standard commensurate with their status as important places of quiet" (EPA, 2007b). In this context, a noise management plan would be required for HDD construction activities associated with the shore crossing.

The proposed DCDP accommodation facility, to be located approximately 1 km from the southern boundary of the gas plant site, will be considered a noise-sensitive premises under the EPA designation that determines that camps for operational staff should be "located and designed so as to achieve compliance with assigned noise levels" (EPA, 2007b). Since the facility is more than 450 m from any industrial or commercially zoned land and there are no major or secondary roads (i.e., traffic levels of more than 6,000 vehicles per day) in the area, the relevant assigned noise levels at the accommodation facility will not include an influencing factor. The gas plant is a 24-hour operation; and consequently, the most stringent of the assigned noise levels is the L_{A10} level of 35 dB(A), which applies during night-time hours.

Noise Modelling

A preliminary environmental noise assessment of the DCDP was undertaken to predict the likely noise emissions associated with the HDD construction activities in the vicinity of the shore crossing and the operational activities at the gas plant. An acoustic model was produced using the SoundPlan noise modelling program, which calculates sound pressure levels at nominated receiver locations. The model also produced L_{A10} noise contours (noise levels) at the two specified receiving locations for specific meteorological conditions.

The acoustic model was used to predict noise levels for the following scenarios:

- Construction activities associated with HDD at the shore crossing, including differing noise reduction scenarios.
- Normal gas plant operation.
- Emergency flaring conditions at the gas plant.

The sources of noise used in the acoustic models were identified from:

- Preliminary HDD shore crossing construction plans and typical HDD equipment noise emissions data supplied by a pipeline engineering specialist.
- Preliminary gas plant plot plans, equipment list and generic sound power information for equipment accessible to the acoustic specialist.

Predicted Noise Levels: HDD Shore Crossing Construction

The predicted L_{A10} noise levels for the HDD drilling operations at the shore crossing for varying metrological conditions ranged from 40 dB(A) to 65 dB(A) in the surrounding recreational camp sites to higher levels of 65 dB(A) to 70 dB(A), potentially experienced directly adjacent to the construction site boundaries. Noise levels reduce to 35 dB(A) at approximately 1 km from the construction site under calm conditions and 1.5 km under worst-case weather conditions. **Figure 7.10** shows the predicted noise contours for the HDD operations (with no noise attenuation in place) for calm and worst-case weather conditions.

The model was also run to account for different noise attenuation scenarios, including:

- Noise reduction at source (such as mufflers and noise-absorbing panels) for the major noise-emitting equipment.
- Noise reduction at source and three different noise wall configurations.

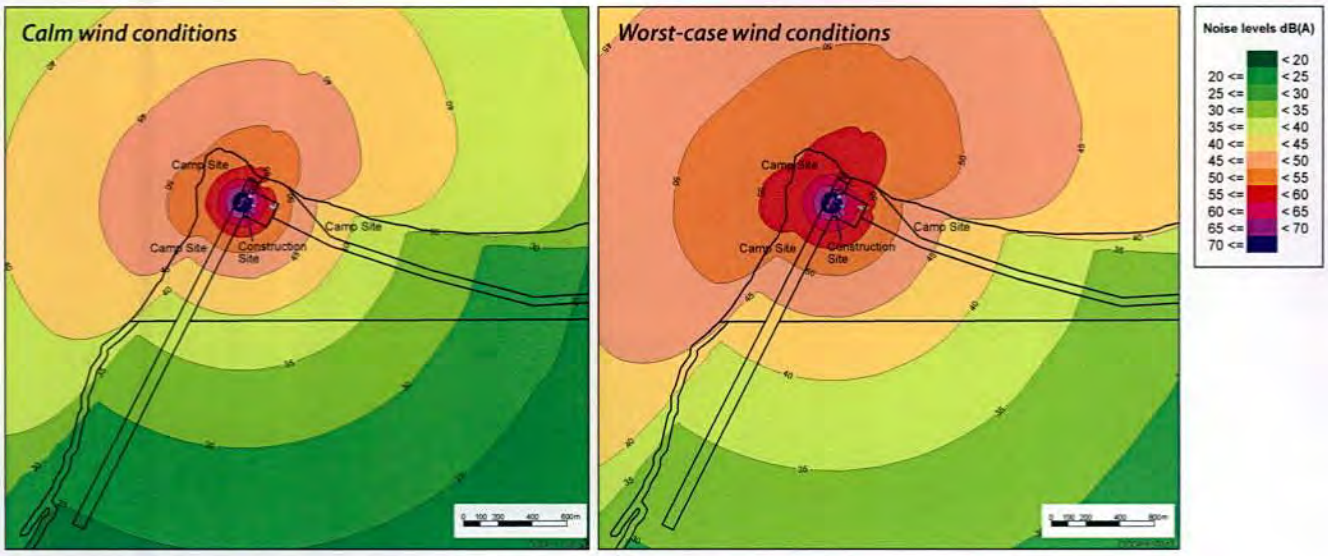

Figure 7.10 HDD Construction Noise Contours - No Noise Attenuation.

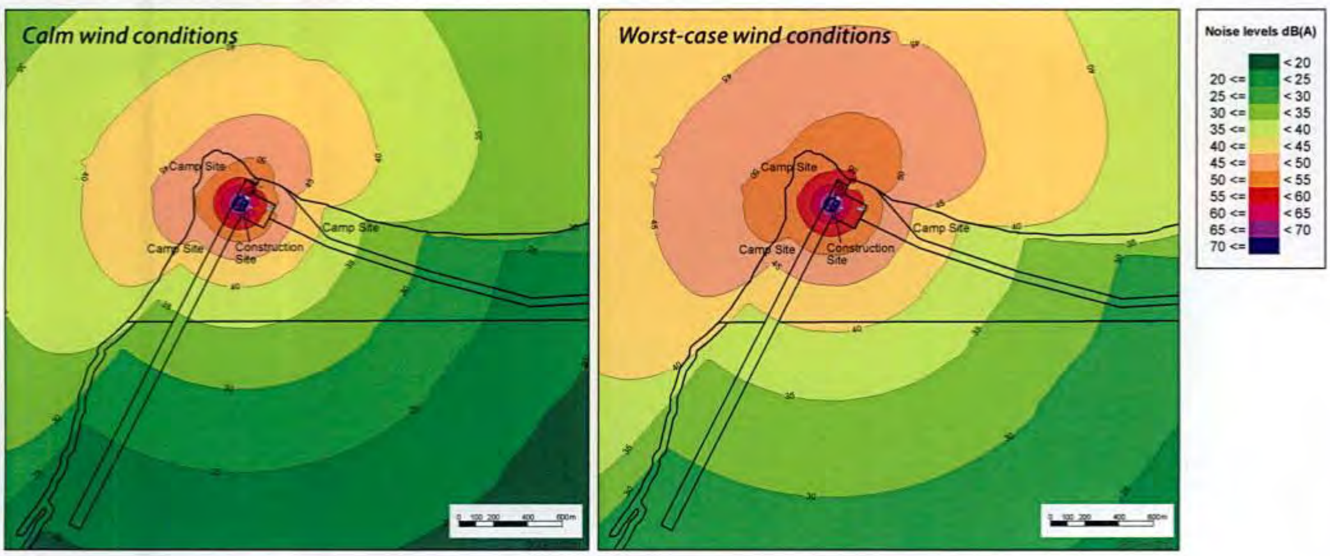

Figure 7.11 HDD Construction Noise Contours - Noise Attenuation at Source.

Figure 7.11 shows noise contours for calm and worst-case weather conditions for the application of noise reductions at source. For this scenario, noise levels reduce to 35 dB(A) at approximately 750 m from the HDD construction site under calm conditions and 1,200 m under worst case weather conditions.

Figure 7.12 shows noise contours for noise reduction measures at source coupled with a noise barrier. Three noise barrier configuration options were considered as shown in **Figures 7.13** to **7.15**. All three options perform similarly with regards to noise propagation towards the beach to the west and south of the HDD construction site, with noise levels reducing to 35 dB(A) at approximately 700 m under calm conditions and 1,100 m under worst-case conditions. However, options 2 and 3 provide greater reduction of noise propagation towards the beach to the north and east of the HDD construction site. Option 3 provides the greatest reduction in this direction, with noise levels reducing to 35 dB(A) at approximately 600 m under calm conditions and 900 m under worst-case conditions.

Noise modelling of the HDD activities at the shore crossing demonstrates that visitors to the beach (including campers) will be impacted by noise levels from these operations during the 3- to 4-month drilling period.

Predicted Noise Levels: Gas Plant Operations

The predicted noise levels for routine gas plant operation received at the proposed accommodation camp for a range of metrological conditions ranged from less than 35 dB(A) for calm conditions and between 35 dB(A) to 40 dB(A) for worst-case meteorological conditions. **Figure 7.16** shows the noise contours for normal operations under calm and worst-cast wind conditions.

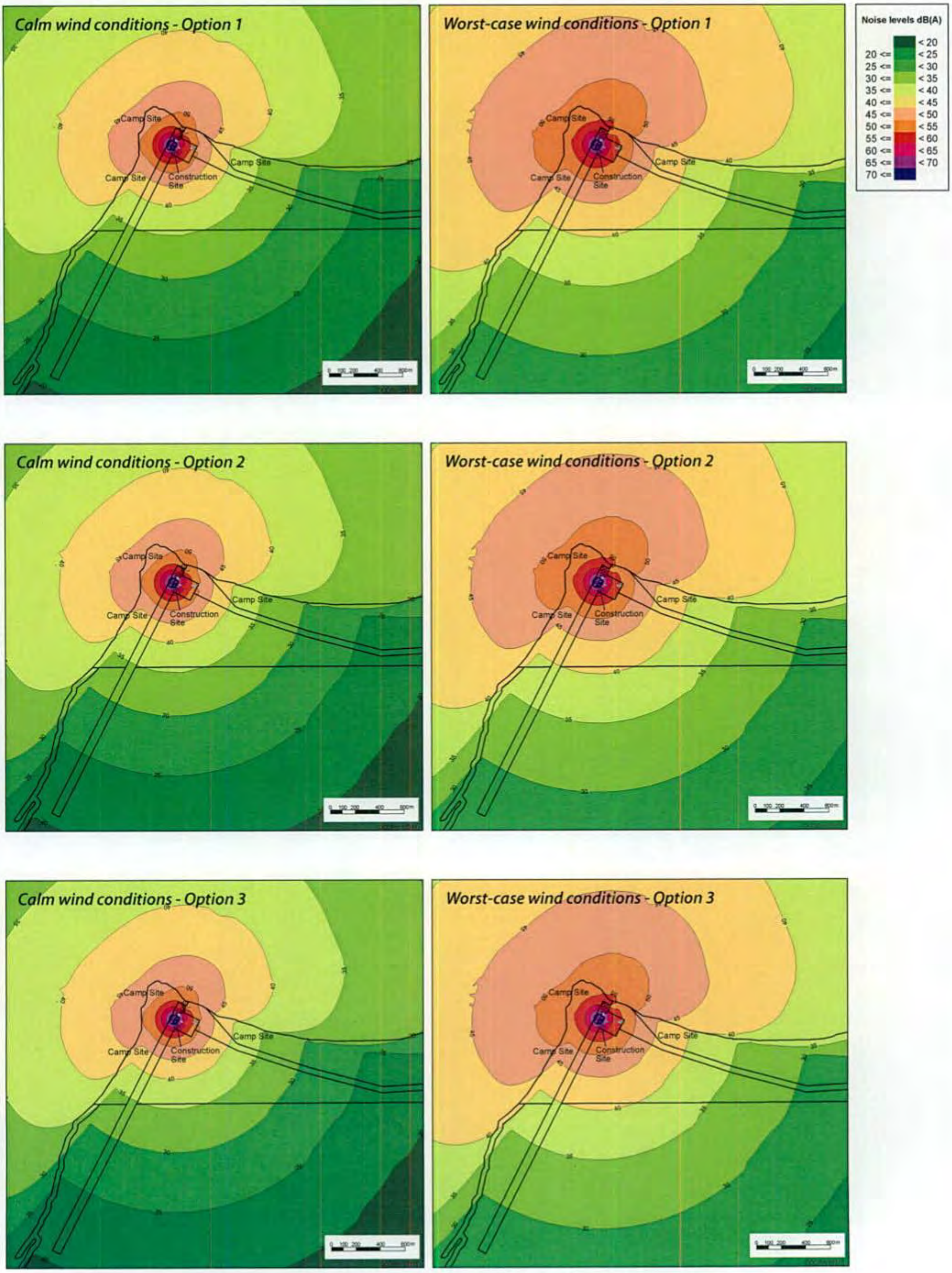

Figure 7.12 HDD Construction Noise Contours - Noise Attenuation at Source and Near Source Noise Barriers.

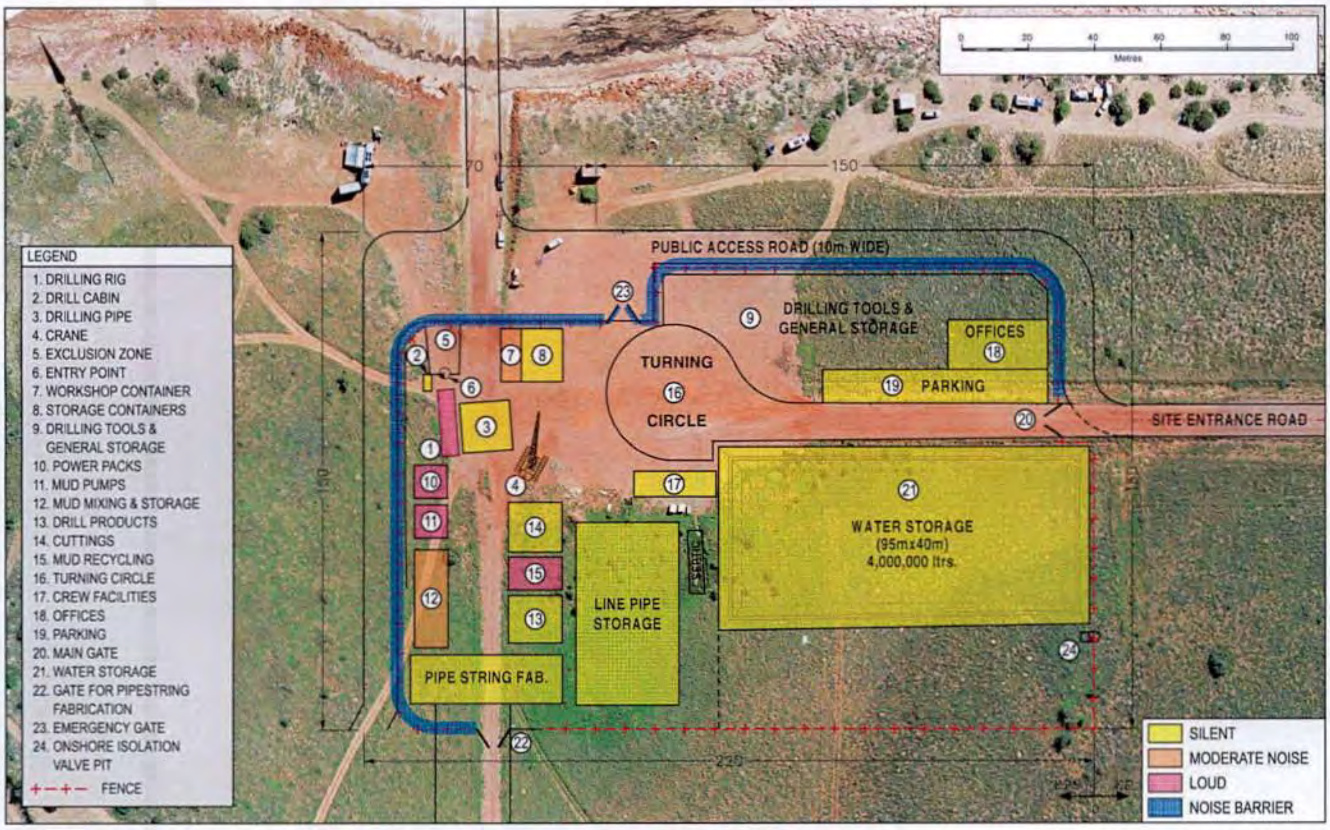

Figure 7.13 HDD Construction Site Noise Barrier – Option 1.

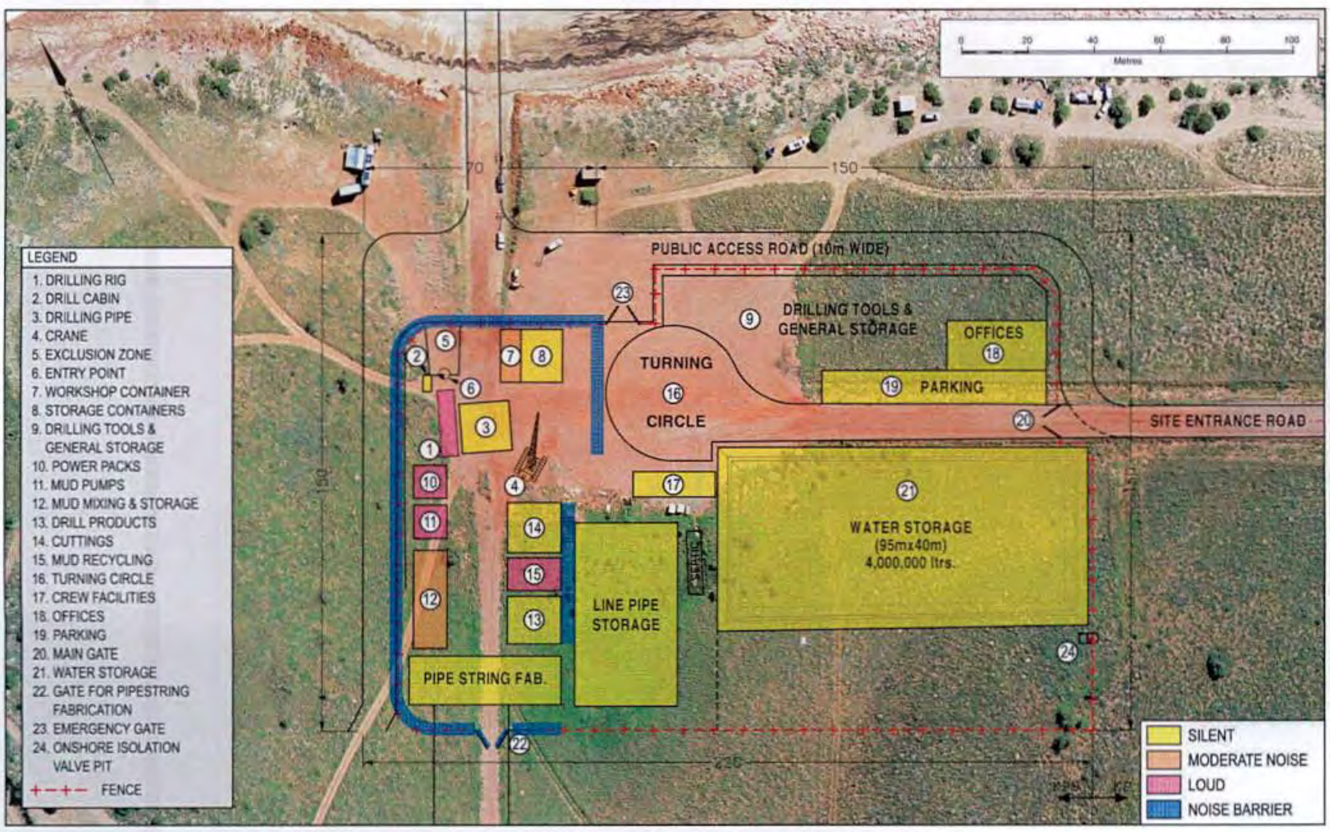

Figure 7.14 HDD Construction Site Noise Barrier – Option 2.

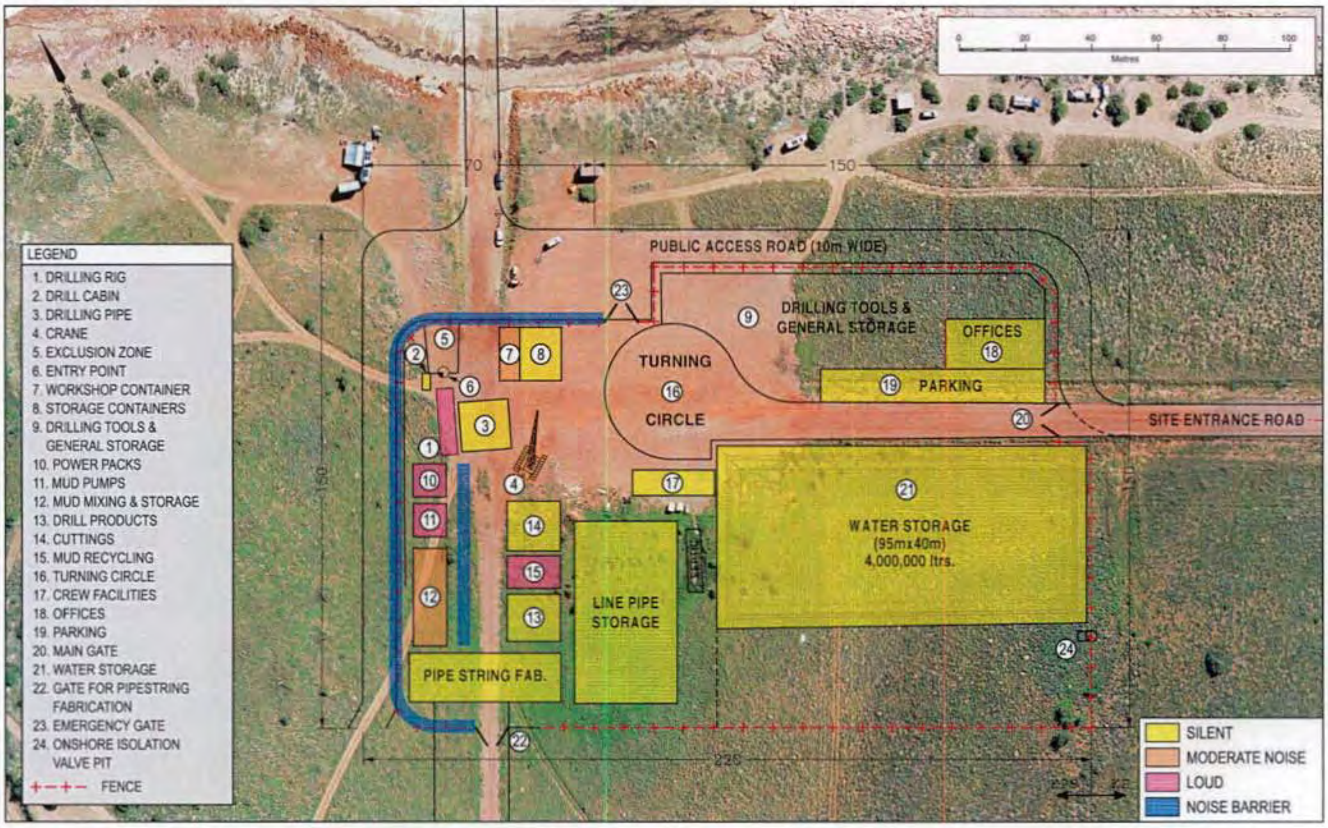

Figure 7.15 HDD Construction Site Noise Barrier – Option 3.

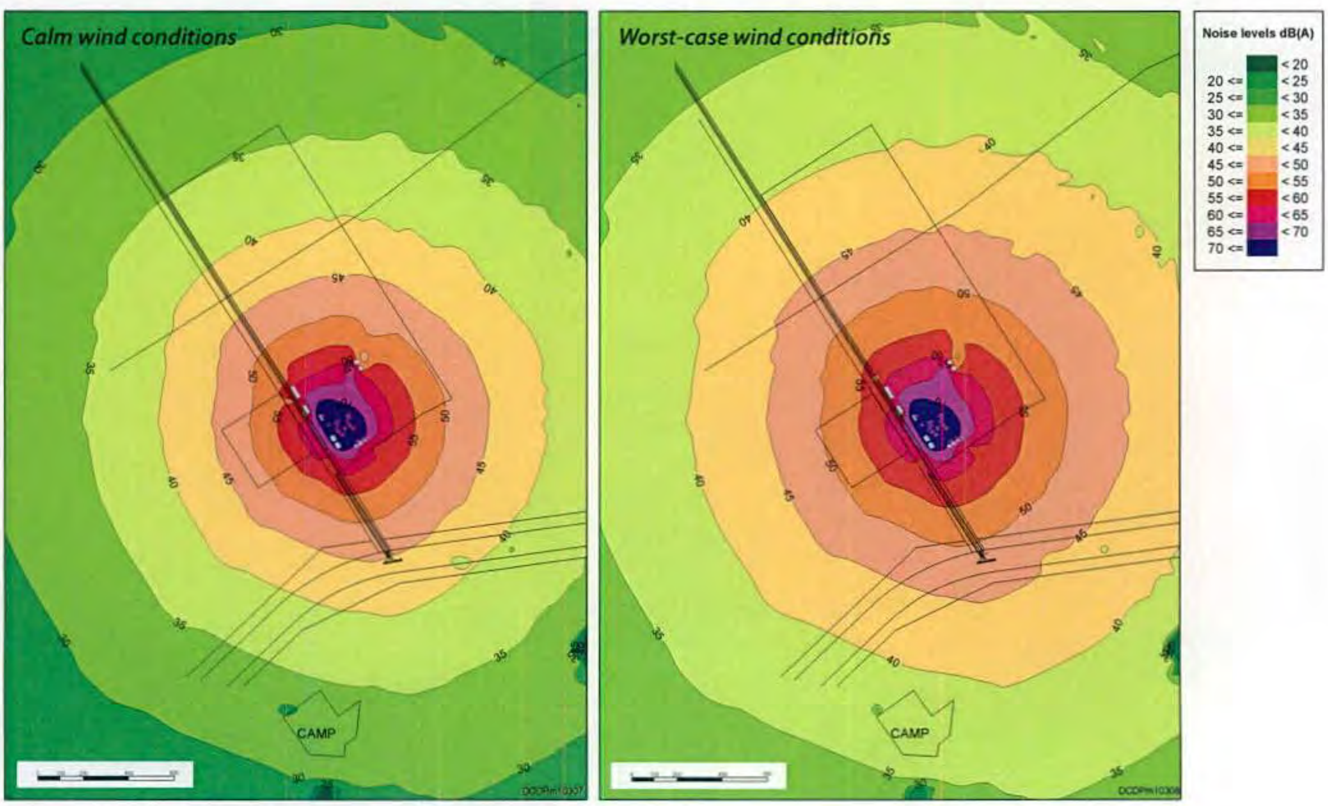

Figure 7.16 DCDP Gas Plant Noise Contours - routine operations.

Noise modelling of the gas plant in its current form has shown that noise received at the accommodation camp can comply with applicable limits during normal operating conditions, except at night-time under worst-case conditions for sound propagation, where noise levels marginally exceeded the limit of 35 dB(A). However, it should be noted that the model is based on preliminary layout and generic noise emission data for gas plant equipment.

The most significant noise-generating non-routine operation will be high-pressure flaring during emergency shutdown or for the purposes of pressure relief. The sound power level used for the model was conservatively estimated based on a flare sized for 280 MMSCF and choked at 3 bar.

Noise contours for emergency flaring at the gas plant were determined for calm and worst-case weather conditions. The resultant noise levels received at the accommodation camp are between 65 dB(A) and 70 dB(A). These predicted levels exceed the assigned level of 35 dB(A) for night-time hours and are above the $L_{A\ max}$ of 55 dB(A) and 65 dB(A) (varying on time of day and which day) for short periods of time, exceeding appropriate assigned noise levels.

Fauna Disruption

Fauna in the area may be disturbed by noise and vibration associated with vehicular movement, earthworks and other human activities during construction. Displacement will occur within the DCDP area as clearing and earthwork activities are undertaken and will potentially occur in the area adjacent to the DCDP area; however, this displacement is likely to only be short term, and fauna are expected to return to the area once the activities have ceased. It is likely that species will become habituated to operational noise once the gas facility is established.

7.3.5.2 Management

Noise management measures proposed for the construction and operational phases of the DCDP are summarised in **Table 7.23**.

Construction

Management of noise associated with construction activities (typically intermittent and variable in intensity) will be addressed in the CEMP that will be developed with reference to Regulation 13 of the Environmental Protection (Noise) Regulations 1997. The plan will cover all construction activities in all project areas, including site preparation, traffic movements, and noisy activities such as grinding, as well as the operation of the HDD construction equipment. As a minimum requirement, all construction activities will be undertaken in line with the noise control practices within Australian Standard AS 2436-1981, Guide to Noise Control on Construction, Maintenance and Demolition Sites.

It is evident from the modelling that visitors to and users of the Forty Mile Beach camp sites will be affected by noise from the HDD drilling operations. With regard to noise control of the activities in this

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Noise	Construction noise	*HDD construction operations.* *Pipeline installation.* *Gas plant construction.*	Reduction in amenity. Fauna disruption.	• CEMP includes noise management measures covering: – Details of and reasons for construction work on the construction site that is likely to be carried out other than between 0700 hours and 1900 hours, or on at anytime on a Sunday or public holiday. – Types of activities that could be noisy. – Predictions of noise emissions on the construction site. – Details of measures to be implemented to control noise emissions. – Noise monitoring at HDD construction site to be undertaken. • Construction activities to comply with noise control practices in AS 2436-1981, Guide to Noise Control on Construction, Maintenance and Demolition Sites. • Equipment to be used quietest reasonably available. • Mitigation measures to consider include: – Selection of the quietest equipment reasonably available. – Use of mufflers. – Use of noise-absorbing enclosures. – Use of noise-absorbing walls in close proximity to noisy equipment. – Strategic positioning of equipment to act as a noise barrier. – Maintenance at off-site workshop or carried out in daylight hours where practicable. – Scheduling the delivery of equipment for daytime hours.
	Operational noise	*Gas plant operations (compressors, gas turbines, pumps).* *Emergency plant blowdown and flaring.*	Fauna disruption.	• Reassessment of noise impacts from the gas plant during detailed design. • Further noise reduction mitigation measures for sales gas compressor packages if required.

Table 7.23 Summary of noise management measures.

area, a combination of options for the major high-noise equipment associated with the drilling operations will be investigated to minimise noise emissions.

Operational noise from the gas plant is not expected to impact upon the recreational users of the Forty Mile Beach area due to the separation distance (approximately 10 km) between the two locations. Operational noise emissions from the shore crossing and onshore sections of the supply gas pipeline are expected to be non-existent.

Operations

Apache will reassess noise impacts from the project as detailed design progresses. Once the gas plant layout is finalised and detailed noise emissions data for equipment is obtained, remodelling may show that noise limits are met at the accommodation facility during worst-case noise propagation conditions during normal operating conditions. However, should noise levels be shown to continue to breach the night-time limit of 35dB(A) at the accommodation facility during worst-case noise propagation conditions, further noise reduction mitigation measures will be implemented. As the most significant contributors to the noise received at the accommodation facility are the sales gas compressor packages, these measures may include restricting the overall sound power level for each sales gas compressor package or, alternatively, the erection of noise barriers near the compressor packages.

Noise received at the DCDP accommodation facility is expected to breach the assigned noise limits during emergency blowdown to the high-pressure flare. However, it should be noted that such events are expected to be extremely rare, for instance, only in the event of a failure of primary and back-up power supplies or in the event of a confirmed fire or loss of containment. Automatic plant blowdown will not occur immediately on the tripping of an emergency shutdown, with initiation required by an operator in the central control room following confirmation of the emergency. The events will also be short in duration, with the emergency blowdown system specified to reduce pressure to 690 kPag or 50% of design pressure (whichever is lower) within 15 minutes. It is therefore reasonable to expect that the duration of the predicted 65 dB(A) to 70 dB(A) at the accommodation facility would occur for less than 15 minutes per event. High-pressure flaring may occur for longer than this period; however, the discharge pressure will have fallen sufficiently to reduce noise levels (noise levels are typically reduced by four as pressure is halved). Taking these issues into consideration, it would be reasonable to expect noise impacts at the accommodation facility due to plant blowdown would be likely to occur for less than two hours a year. During the consideration of these events, it should also be borne in mind that the residents of the accommodation facility are DCDP gas plant staff. As they are likely to be involved in emergency response activities, the increased noise levels are not seen to be a significant issue.

7.3.5.3 Residual Risks

Taking into account the management measures described above, the residual risks from noise emissions during construction have been ranked from "B" to "negligible", with the higher residual risks connected to the HDD program. Residual noise risks associated with the operation of the gas plant have been ranked as "negligible".

7.3.6 Artificial Lighting

Artificial light hazards associated with the construction and operational phases of the DCDP include:

- Lighting to enable 24-hour a day activities at the HDD construction site.
- Potential lighting on the gas plant site during construction (should construction hours be extended beyond daylight hours).
- Lighting on the gas plant site during night-time operations.
- Light emissions from flaring.
- Lighting at the accommodation facility.

7.3.6.1 Impacts

Artificial lighting will attract insects, which subsequently provides an increased source of food for birds and bats. The potential impacts to fauna from artificial lighting are discussed in full in **Section 7.7.3**.

Potential impacts on, and proposed management measures for marine fauna, specifically sea turtles, from artificial lighting at the HDD construction site are discussed in **Section 8**.

There is also potential for a reduction in the amenity value of the Forty Mile Beach recreational area over the 3- to 4-month HDD drilling period due to light over-spill in an otherwise undeveloped area. Artificial lighting at the HDD construction site will be minimised and will only be used during 24-hour drilling operations.

7.3.6.2 Management

Lighting management measures for the DCDP are summarised in **Table 7.24**.

The CEMP will address lighting management. Particular emphasis will be given to the control of lighting during works in close proximity to light-sensitive areas. These areas include:

- Shore crossing.
- Shore-based marine facility (Reserve 46694).
- Forty Mile Beach Road Reserve (limited section running east–west, parallel to Forty Mile Beach).

External lighting will be minimised wherever possible, without compromising safe working. In the vicinity of the coast, lights should be shielded to prevent overspill onto the sea.

Permanent artificial lighting will be designed to be reduced to the least practicable level for the safe conduct of operations. Considerations will include:

- Need for the light.
- Timing requirement for the light, such as timers to turn off lights.

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Light	Construction Artificial Lighting	*HDD construction operations.* *Pipeline installation.* *Gas plant construction.*	Reduction in amenity. Attraction of fauna.	CEMP includes lighting management covering: • Lighting will be minimised wherever possible, without compromising safe working. • Lights will be shielded to prevent overspill onto the sea.
	Operational Artificial Lighting	*Facility lighting.* *Flares.*	Attraction of, or disturbance to fauna.	Lighting design considerations include: • Timers to turn-off lights. • Shielding light spill to the site boundary. • Light positioning (reducing height, use of screening). • Orientation of the light away from the site perimeter. • Type of lighting (e.g. low-profile fluorescent luminaries) / reducing wattages. • No tower-mounted flood lighting. • Enclosed ground flare.

Table 7.24 Summary of light management measures.

- Shielding light spill to the site boundary.
- Light positioning (reducing height, use of screening).
- Orientation of the light away from the site perimeter.
- Type of light / reducing wattages.

Tower-mounted floodlights will not be used within the gas plant.

Light emission from flares will be minimised as far as practicable through the provision of an enclosure around the ground flare.

7.3.6.3 Residual Risks

Lighting impacts from the construction phase of the DCDP are expected to be negligible and temporary in nature.

As a result of the light spill minimisation design philosophy for lighting at the gas plant and the distance from the plant to the Forty Mile Beach recreational area (approximately 10 km), the light impact to users of this area is expected to be minimal.

Based upon the implementation of the above management measures, the residual risks of artificial lighting during both construction and operations are predicted to be "negligible".

7.3.7 Visual Amenity

Impacts to visual amenity associated with the construction and operational phases of the DCDP include:

- Presence of construction equipment for the HDD shore crossing site, onshore pipeline installation and gas plant construction.
- Presence of gas plant infrastructure.
- Presence of the accommodation facility.

The presence of construction equipment will be temporary and therefore has not been included within the visual impact assessment.

7.3.7.1 Impacts

Five critical viewpoints that could be impacted by the DCDP were selected for assessment:

- From Gnoorea Point, looking in the direction of the gas plant (Viewpoint 1).
- Approaching on the North West Coastal Highway from the east, looking toward the gas plant (Viewpoint 2).
- Approaching on the North West Coastal Highway from the west, looking toward the gas plant (Viewpoint 3).
- Approaching on the North West Coastal Highway from the east, looking toward the accommodation facility (Viewpoint 4).
- At the intersection of the North West Coastal Highway, looking toward the accommodation facility (Viewpoint 5).

Figure 7.17 shows the location of the viewpoints in relation to the DCDP area.

A visual impact assessment of the permanent DCDP infrastructure (WorleyParsons, 2008) was commissioned following the general process of The Landscape Institute (2002), Guidelines for Landscape and Visual Impact Assessment.

Visual Impact Assessment

The evaluation criteria (covered in **Box 2**) were applied to each viewpoint, and a final assessment was made on the severity of the visual impact. The categories for the overall visual impact are as follows:

- Low Visual Impact.
- Moderate Visual Impact.
- High Visual Impact.

The categorisation is based on the individual criteria applied, whereas the highest rating for any given criteria defines the final visual impact category, i.e., if the magnitude of the impact is "moderate" but the significance of the impact is only "slight adverse impact", the final visual impact can be no less than "moderate visual impact". The final

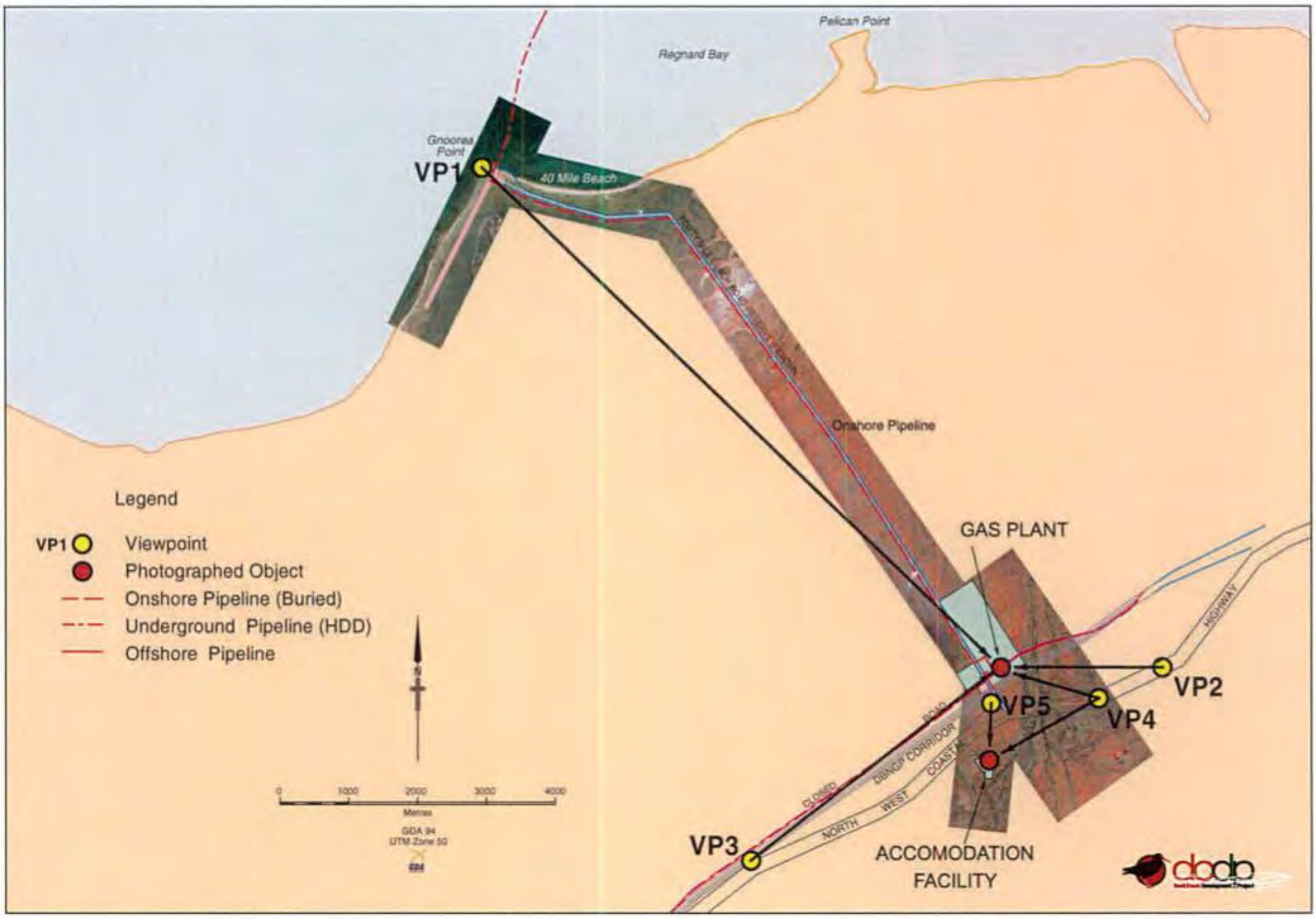

Figure 7.17 Critical Viewpoint Locations.

Methodology

A field visit was undertaken and information collected included visual amenity and baseline information for the viewshed (extent of potential visibility to or from a specific area or feature) from each viewpoint. Digital photographs were taken for subsequent viewshed analysis. GPS readings, for positioning the viewpoint, determining the distance to the development, and to collect approximate elevation information were also recorded at each viewpoint.

3-D models of the gas plant and accommodation facility uploaded into PDMS® modelling software. Virtual camera points (equalling the viewpoints) were set within the modelling software using the GPS location readings and the locations provided in the layout plan for the development area. Once the camera points were set at the proper locations and the viewing directions were assigned, the model was run to create a distance-based, scaled model of the gas plant and accommodation facility. The model was subsequently extracted from as digital image files.

Digital photographs taken in the field were imported into a graphics software package and the location of the proposed development (either the gas plant or the accommodation facility, or both, depending on the viewpoint) identified. The development model from PDMS® was then uploaded into the graphics software and merged with the digital photograph at the identified location(s) to produce a series of photomontages of the proposed development.

The visual impact assessment for each viewpoint was then undertaken, taking into consideration the baseline information collected and the visual impacts modelled. The assessment of the actual visual impact was based on the prominence and visual dominance of the proposed development relative to the surrounding landscape. The following main criteria were applied to assess the visual impact.

Box 2 Visual Impact Assessment Evaluation Criteria.

- *Distance* – The greater the distance the less detail is observable and the more difficult it is to distinguish the development from the surrounding area.
- *Elevation* – Lower elevation of a proposed development has a lower impact due to the surrounding features and a backdrop.
- *Size* – The smaller the development the less impact.
- *Context* – The degree to which the development is in character with the surrounding landscape.
- *Activity* – The more movement of vehicles and activities, the more visible the development.
- *Change* – The degree and rapidity of change associated with the development.

The assessment, taking these evaluation criteria into consideration used three main impact criteria (magnitude, significance and landscape value) to evaluate the visual impact. The criteria definitions are based on guidance from The Landscape Institute (2002).

The following describes the terminology used to describe the magnitude and significance of visual impacts and the landscape value.

Magnitude of Impact or Degree of Effect on Visual Amenity (based on Terence O'Rourke plc):

None	No part of the proposed development or work or activity associated with it is discernible.
Negligible	Only a very small part of the proposed development is discernible and/or it is at such distance that it is scarcely appreciated. Consequently, it has very little effect on the scene.
Slight	The proposed development constitutes only a minor component of the wider view, which might be missed by the casual observer or receptor. Awareness of the proposed development would not have a marked effect on the overall quality of the scene.
Moderate	The proposed development may form a visible and recognisable new element within the overall scene and may be readily noticed by the observer or receptor.
Substantial	The proposed development forms a significant and immediately apparent part of the scene that affects and changes its overall character.
Severe	The proposed development becomes the dominant feature of the scene to which other elements become subordinate, and it significantly changes and affects the character of the scene.

Significance of Impact (based on Nicholas Pearson Associates)

The significance of the impact can be positive (improvement of view) or negative (deterioration of view).

No Change	No discernible deterioration or improvement in existing view.
Substantial Beneficial Impact	Significant improvement in the existing view.
Moderate Beneficial Impact	Noticeable improvement in the existing view.
Slight Beneficial Impact	Barely perceptible improvement in the existing view.
Slight Adverse Impact	Barely perceptible deterioration in the existing view.
Moderate Adverse Impact	Noticeable deterioration in the existing view.
Substantial Adverse Impact	Significant deterioration in the existing view.

Landscape Value (based on Jeff Stevenson Associates) *Source: WorleyParsons (2008).*

Exceptional/Very Good	Areas exhibiting a strong positive character with valued features that combine to give the experience of unity, richness and harmony. Areas that may be considered of particular importance to conserve and that may be sensitive or very sensitive to change.
Good/Medium	Areas exhibiting positive character but that may have evidence of degradation or erosion of some features. Change may be unlikely to be detrimental.
Poor/Very Poor	Areas generally negative in character, with few, if any, valued features. Often scope for positive enhancement or improvement.

Box 2 Visual Impact Assessment Evaluation Criteria. *(continued)*

visual impact assessment matrix (**Table 7.25**) outlines the various final impact assessments based on combinations of magnitude of impact and significance of impact.

The landscape value criterion is applied primarily when the landscape value is considered "exceptional/very good" (i.e., in areas that contained valuable landscape components), in which case the impact can be no less than "moderate visual impact", even though the remaining criteria might be "negligible" or "slight". However, for a landscape value of "good/medium" or "poor/very poor", the landscape value is secondary to the significance and magnitude of the impact.

Model Results

Plates illustrating the viewshed for the five critical viewpoints, current status, and photomontage to illustrate the impact of the proposed development are presented in **Appendix 7**.

Viewpoint 1. The proposed development is only slightly visible within this viewshed and could be missed by the casual observer. This is due to the distance of Viewpoint 1 from the development, the elevated ridges and higher-growing vegetation providing a backdrop to the development, the insignificant change in elevation between the viewpoint and the development, and the overall low height of the gas plant and the accommodation facility infrastructure.

Although the size of the gas plant and accommodation facility is significant and the development does not fit the context of its surrounding, the impact is mitigated by the distance and the almost equal elevation between this viewpoint and the development area, which offset the size of the development.

The magnitude of the visual impact from Gnoorea Point is considered negligible with a slight impact to the significance of the area. As a result, the final visual impact from Gnoorea Point is considered low.

Viewpoint 2. The proposed development is located in an area of decreased vegetation cover and at a lower elevation than Viewpoint 2. Thus, the plant site is clearly noticeable from this viewpoint. However, the surrounding area and features serve as a backdrop and limit the visual impact of the site. The plant is, however, out of context with its surrounding; and the plant size defines the development as a noticeable feature. The visual impact is partially mitigated by the distance of the plant from the viewpoint and the screening effect of the semi-continuous, near-distance vegetation, primarily higher-growing trees.

The magnitude of the impact to this viewshed is considered slight with a slight impact to the visual significance of the area. As a result, the final visual impact from Viewpoint 2 is considered low.

Viewpoint 3. The proposed plant site is located at a slightly lower elevation than Viewpoint 3. The development is clearly visible in the viewshed; however, the surrounding area and the mountainous ridge in the background serve as mitigative features to limit the visual impact of the plant site. Furthermore, although the vegetation cover is sparse and low-profile, the vegetation close to and in front of the development serves as a partial mitigative feature to the visual impact of the plant. The visual impact is also minimised by the low development height.

The magnitude of the visual impact is considered slight with a slight impact to the visual significance of Viewpoint 3. As a result, the final visual impact to the viewshed is considered low.

Viewpoint 4. Due to the increase in elevation in the near viewshed (and the subsequent blocking of the view in the farther distance) and the continuous band of shrubs and trees in the near distance, the accommodation facility will not be visible from Viewpoint 4. Therefore, there is no visual impact to this viewpoint.

Viewpoint 5. The proposed accommodation area is located at a similar elevation as Viewpoint 5 and in relatively close proximity to continuous high-growing vegetation (along Devil Creek) and several mounts. The high-growing vegetation, the proximity to the mounts

Visual Impact		Magnitude of Impact		
		None, Negligible, or Slight	Moderate	Substantial or Severe
Significance of Impact	Slight*	Low	Moderate	High
	Moderate*	Moderate	Moderate	High
	Substantial*	High	High	High

*adverse or beneficial

Table 7.25 Final visual impact assessment matrix.

Viewpoint	Magnitude	Significance	Landscape Value	Final Visual Assessment
1	Negligible	Slight Impact	Medium	Low
2	Slight	Slight Impact	Medium	Low
3	Slight	Slight Impact	Medium	Low
4	None	No Change	Medium	None
5	Moderate	Moderate Impact	Medium	Moderate

Table 7.26 Summary of impact to the critical viewpoints.

and the mountainous ridge in the background serve as mitigative features to limit the visual impact of the development. In addition, a mount to the west of the accommodation facility blocks some of the westernmost development. The model also indicates that the proposed landscaping around the perimeter of the accommodation facility will mitigate some of the visual impact.

The accommodation facility remains out of context with its surroundings, even with the mitigating natural features. The relatively short distance from the viewpoint does not allow for a significant decrease in visual impact, and the low-growing natural vegetation does not provide any screening. The accommodation area is therefore a noticeable feature of the viewshed.

The magnitude of the visual impact is considered moderate due to the proximity of the viewpoint to the accommodation facility, with a moderate impact to the visual significance of the area. As a result, the final visual impact to the viewshed is considered moderate.

7.3.7.2 Management

Management measures that will assist to mitigate the visual impact of the DCDP include perimeter landscaping. The photomontages in **Appendix 7** show the landscaping proposed for the accommodation facility but do not show the landscaping proposed for the gas plant. It is envisaged that visual impact will be reduced further by the inclusion of perimeter landscaping for the gas plant.

7.3.7.3 Residual Risks

The overall visual impact from the proposed development of the gas plant and accommodation facility to the five critical viewpoints is considered low with a slight adverse impact. The rationale for the low impact is:

- Distance to the proposed development from three viewpoints (1, 2 and 3).
- Screening of proposed development by existing relief and vegetation (complete screening of the accommodation facility from Viewpoint 4).
- Overall low height of the proposed development and minimal change in elevation within the viewsheds.
- Overall Medium landscape value of the assessed area.

The final visual impact of the gas plant was found to be low for Viewpoints 1, 2 and 3. In all three cases, the development will be visible; however, the final impact to the viewshed was deemed to be low as the magnitude of the impact was considered to be negligible to slight and the landscape value was considered to be medium with no particularly valued landscape features. Furthermore, the development is partially screened by natural vegetation or too distant (particularly from Viewpoint 1) to be significantly appreciated.

The final visual impact of the proposed accommodation facility was found to be moderate at Viewpoint 5; however, the proposed landscaping of the perimeter will mitigate some of the visual of the accommodation facility. Furthermore, the accommodation facility will be sited against the backdrop of several elevated ridges and in close proximity to existing vegetation and several natural mounds, which minimise the visual impact. The residual risk of the proposed DCDP amenity of the area is predicted to be "negligible".

7.4 ROUTINE SOLID WASTES

Routine solid wastes will be generated during all phases of the proposed DCDP. These wastes will be produced in relatively small amounts and will consist of both hazardous and non-hazardous materials.

Hazardous waste material are materials whose characteristics pose a threat to public health, safety or the environment, including substances that are toxic, infectious, mutagenic, carcinogenic, teratogenic, explosive, flammable, corrosive, oxidising and radioactive (DoE, 2005).

7.4.1 Impacts

Handling and Storage

Potential impacts from the inadequate handling and storage of both hazardous and non-hazardous solid waste include:

- Potential contamination of soil and groundwater.
- Impacts to fauna (attraction, entanglement or ingestion).
- Visual amenity reduction from windblown rubbish.

Potential Contamination of Soil and Groundwater

Solid waste materials can cause soil or groundwater contamination if they either come in contact with the ground surface directly, such as through spillage or inappropriate storage practices, or if rainwater filters through uncovered waste containers producing contaminated water, known as leachate, that can infiltrate into, and contaminate the underlying soil and groundwater.

Impacts to fauna

These are discussed in **Section 7.7.3**.

Windblown Rubbish

Waste materials not securely stored may become windblown over the site or throughout the wider environment. This is particularly problematic for light materials, such as plastics and paper. Windblown rubbish:

- Reduces the visual amenity of an area.
- May pose injury risks to fauna.

7.4.2 Management

Both the CEMP and OEMP include management measures for mitigating against potential impacts from waste materials, providing minimum requirements for storing, and disposing of all wastes, summarised in **Table 7.27**.

7.4.3 Residual Risk

Taking into account the proposed management measures, the residual environmental risk of the generation and disposal or recycling of solid waste is predicted to be "negligible".

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Solid Waste	Potential soil and groundwater contamination	*Construction and operational activities.*	Reduction in soil and groundwater quality. Impacts to fauna. Windblown rubbish.	• The CEMP and OEMP address waste management, defining methods for handling, storing and disposing of all wastes, including: – Efforts will be made to minimise waste generation and to reuse or recycle materials. – Waste disposal will be to an appropriately licensed landfill or waste disposal facility. – All non-hazardous solid wastes will be segregated from hazardous wastes. – Waste will be stored in clearly marked, covered containers, secured to prevent contamination of the environment, attraction of fauna and windblown litter. – All hazardous waste generated will be measured, documented and tracked to assess the quantity of waste and its fate. – The creation of hazardous solid wastes will be avoided through all phases of the project wherever practicable. Non-hazardous materials that serve the same purpose and are as cost-effective as hazardous materials will be given preference. – Volume of waste material will be recorded and reported on a monthly basis. • Molecular sieve material will be regenerated prior to the change-out and disposal of spent sieve media to reduce hydrocarbon contamination as far as practicable. Molecular sieve material will be disposed of at an approved hazardous waste facility. • Mercury guard bed material will either be returned to the supplier for recycling or disposed of at an approved hazardous waste facility.

Table 7.27 Summary of solid waste management measures.

7.5 ROUTINE LIQUID WASTES

Routine liquid wastes will be generated during all phases of the DCDP. These wastes will be produced in significant quantities and will consist of both hazardous and non-hazardous materials. The routine liquid wastes expected to be produced during the construction or operational phases include:

- Hydrotest fluid.
- Produced formation water.
- Sewage and greywater.
- Desalination brine.
- Hazardous liquids (such as used chemicals and lubricating oils and specialised cleaning fluids).
- Washdown effluent.

7.5.1 Impacts

The inappropriate handling and storage of liquid wastes can lead to various adverse impacts including:

- Potential contamination of soil and groundwater.
- Generation of odour.
- Attraction of fauna.
- Fire hazard.

The impacts vary according to liquid waste stream as discussed below.

Hydrotest Water

Hydrotest water requirements and disposal proposals are discussed in **Section 3.6**. Hydrotest water used for the onshore pipeline will probably be treated with oxygen scavengers and corrosion inhibitors. The base case for the disposal of this water is evaporation in either the HDD water storage basin or the gas plant evaporation ponds. Hydrotest water used for tanks and equipment at the gas plant will be untreated freshwater. This water will either be reused, where possible, or routed to the evaporation ponds.

Produced Water

Produced water will be disposed of via the evaporation ponds (**Section 3.5.5**). The design of these ponds has been specified to provide sufficient capacity to prevent overtopping and to prevent seepage into the underlying ground.

As an open water body, the evaporation ponds will attract birds and other fauna that could potentially become trapped in the ponds and drown. The ponds will be fenced to limit terrestrial fauna access; however, they will also include crawl ladders to facilitate escape in the event that an animal gets into the pond area. Measures to discourage birds from the ponds will be investigated for implementation.

Sewage and Greywater

Disposal arrangements for sewage and greywater produced during the construction phase of the DCDP are discussed in **Section 3.6.5.3**. Facilities will be provided at the worksite in accordance with health and environmental legislative requirements.

Sewage disposal arrangements for the operational phase of the DCDP (**Section 3.5.8.6**). Odours will be minimised by the construction of enclosed, in-ground; processing tanks.

The accommodation facility wastewater treatment plant treatment processes (including secondary treatment, nutrient (phosphorous) removal (alum dosing), disinfection and filtration) exceed the Australian Guidelines for Sewerage Systems – Effluent Management

(ARMCANZ/ANZECC, 1995) for the minimum level of treatment required for irrigation onto landscape. The final effluent quality specifications will meet the Department of Health's "Class A" recycled water standards. Routine inspection and maintenance of the system will be undertaken to ensure it is operating properly, and groundwater quality will be monitored on a quarterly basis.

Treated effluent will be disposed of via reticulation to landscaped areas. Vegetation survival and health will be monitored for the first two years, following which the vegetation should be self-sustaining. Monitoring will include visual assessment, survival count and soil pH testing on a quarterly basis.

Sewage sludge will be periodically removed from the treatment tanks and disposed of at a licensed waste disposal facility.

Nutrient enrichment of groundwater is not expected, as water infiltration rates will be low, nutrients loads will be reduced through the treatment processes, plants within the reticulation area will take up the nutrients, and the soils within and under the proposed disposal windrows have a high phosphorous retention index.

Desalination Brine

Groundwater to be used during the construction and operation of the DCDP is of marginal freshwater to brackish quality. A package reverse osmosis unit will be used to desalination the water for potable use. The reject brine from the reverse osmosis unit will be disposed of with the produced water stream to the evaporation ponds.

Hazardous Liquids

Hazardous liquid waste stored on the site will include used oils and cleaning solvents and, potentially, out-of-specification process chemicals, such as methanol, biocide, and emulsion breakers. Leakage of these materials could result in soil and groundwater contamination.

Washdown Effluent

Washdown effluent from the cleaning of plant and equipment will be contaminated with traces of oils, greases, suspended solids and detergents.

7.5.2 Management

Both the CEMP and OEMP include management measures for mitigating potential impacts from liquid wastes, providing minimum requirements for storing, and disposing of all wastes, as summarised in **Table 7.28**.

7.5.3 Residual Risks

Taking into account the proposed management measures, the residual environmental risk of the generation and disposal or recycling of liquid waste is predicted to be "negligible".

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Liquid Waste	Potential soil and groundwater contamination	*Construction and operational activities.* *Equipment washdown.*	Reduction in soil and groundwater quality. Attraction of fauna. Odour. Fire risk.	• The CEMP and OEMP address waste management, defining methods for storing, treating and disposing of all wastes, including:Efforts will be made to minimise waste generation and to reuse or recycle materials. – Waste disposal will be to an appropriately licensed landfill or waste disposal facility. – All non-hazardous liquid wastes will be segregated from hazardous wastes. – Waste will be stored in clearly marked containers, secured to prevent leakage, or in bulk tanks provided for storage. – Liquid waste containers will be stored within bunded areas and segregated from incompatible materials. – All hazardous waste generated will be measured, documented and tracked to assess the quantity of waste and its fate. – The creation of hazardous liquid wastes will be avoided through all phases of the project wherever practicable. Non-hazardous materials that serve the same purpose and are as cost-effective as hazardous materials will be given preference. – Washdown will only take place in designated areas with facilities provided to collect and treat (or store awaiting off-site disposal at an appropriate facility) the washdown effluent. – Volume of waste material will be recorded and reported on a monthly basis. – Regular groundwater quality monitoring will occur. • The gas plant will include a purpose-built covered store for liquid wastes to provide protection from the elements. • Hydrotesting water will be disposed of via evaporation, with the exception of the final testing of the entire pipeline length from the gas plant to the offshore platform. This water will be disposed of offshore at the Reindeer Platform location in accordance with the requirements of an Environmental Management Plan to be agreed with the Department of Industry and Resources. Impacts of this disposal will be minimised by selecting low-toxicity chemicals and ensuring that the concentrations of these chemicals within the hydrotest water are ALARP without compromising the integrity of the testing.

Table 7.28 Summary of liquid waste management measures.

7.6 NON-ROUTINE LIQUID WASTES

In the context of the DCDP, non-routine liquid waste is defined as spills of chemicals and hydrocarbons (condensate, oil and diesel) and the generation of accidentally oil-contaminated water.

7.6.1 Impacts

The impacts from the generation of non-routine liquid wastes includes:

- Soil and groundwater contamination.
- Fire risk.
- Impacts to fauna (attraction or ingestion) (discussed in **Section 7.7**).

Soil and Groundwater Contamination

Produced water will be disposed of via the evaporation ponds (**Section 3.5.5**). Damage to the liner of these ponds could result in the seepage of produced water (saline and hydrocarbon contaminated) into the underlying soil and groundwater. Soil and groundwater contamination impacts could also arise from the spillage of liquid waste and its subsequent infiltration into soil and underlying groundwater.

Fire Risk

The spillage of flammable materials (such as chemicals, solvents, or fuels) could present a fire risk if an ignition source was present.

7.6.2 Management

The management measures to minimise the impacts of soil and groundwater contamination and impacts to fauna from non-routine liquid wastes have been discussed in **Sections 7.3.2** and **7.7** and are summarised in **Table 7.29**.

7.6.3 Residual Risks

Taking into account the management measures proposed to minimise and mitigate the impacts from non-routine liquid wastes, the residual environmental risks have been predicted to range from "negligible" to "B" inferring an acceptable level of risk.

7.7 TERRESTRIAL ECOLOGICAL IMPACTS

The construction, operation and physical presence of the proposed DCDP may potentially result in environmental impacts to:

- Vegetation and flora.
- Weeds.
- Fauna habitats and species.
- Subterranean fauna.

7.7.1 Vegetation and Flora

Key hazards that have the potential to impact vegetation and flora in the DCDP area include:

- *Clearing and earthworks:* Vegetation clearing is required as part of site preparation activities for the DCDP. Approximately 120 ha of clearing is proposed for the DCDP to facilitate construction of the onshore pipelines, gas plant and ancillary areas. Clearing will have a direct impact through vegetation loss.
- *Fire:* Accidental fire caused by activities on site can potentially impact vegetation through loss of or modification to sensitive communities and loss of key species.

A number of other hazards can potentially cause indirect impacts to vegetation and flora. These have been discussed in other sections of this chapter.

7.7.1.1 Impacts

The impacts of the hazards to vegetation and flora from clearing and earthworks and from fire include:

- Loss of regional vegetation with conservation significance.

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Liquid Waste	Potential soil and groundwater contamination	*Spillages of liquids during construction or operational activities.* *Accidentally oil contaminated water.* *Leakage of produced water from evaporation ponds.*	Reduction in soil and groundwater quality. Impacts to fauna. Fire risk.	• The CEMP and OEMP address spillage control and liquid waste management, defining methods for storing, treating and disposing of all wastes, including: – A spill response plan will be developed, and control and clean-up equipment will be provided. – Liquid waste containers will be stored within bunded areas and segregated from incompatible materials. – Washdown will only take place in designated areas with facilities provided to collect and treat (or store awaiting off-site disposal at an appropriate facility) the washdown effluent. • Gas plant facilities where liquids are stored or handled will be provided with secondary containment. These include storage buildings for chemicals, bulk tanks, and the condensate load-out facilities. • The produced water evaporation ponds (Section 3.5.5) will be provided with a robust lining system to protect against leakage. • Regular groundwater quality monitoring will occur.

Table 7.29 Summary of non-routine liquid waste management measures.

- Loss of flora of conservation significance.
- Accidental disturbance of vegetation outside of the project footprint.
- Potential introduction and spread of weeds (this is discussed in **Section 7.7.2**).

Loss of Regional Vegetation with Conservation Significance

The clearing and earthworks associated with the DCDP includes the removal of approximately 120 ha of vegetation from 41 identified communities as shown in **Figures 4.6a** to **4.6g.**

Proposed Area to be Cleared

Without fully surveying the wider region, a comparative analysis of the area to be cleared against the regional extent of each of these communities is not possible. However, the proposed clearing area of each vegetation community has been calculated and presented in **Table 7.30**.

A large proportion of the proposed project area has undergone previous disturbance and is subsequently in a poor or degraded condition, particularly in the nearshore area and along the onshore section of the supply gas pipeline route. It is proposed that the majority of the nearshore works and onshore pipeline installation will be undertaken within the disturbed road reserve and the semi-disturbed area adjacent to it. The area proposed for the gas plant site, adjacent to the North West Coastal Highway, is in better condition, with greater than 80% native flora composition and vegetation fairly intact, although there are minor signs of disturbance as a result of pastoral use.

Given the existing level of disturbance of the area, the relatively small amount of clearing and the likelihood that vegetation communities included in the clearing footprint are well represented in the area, the regional impact on vegetation communities is negligible.

Roebourne Plains Communities

There are no threatened ecological communities in the Roebourne Subregion of the Pilbara Craton in which the DCDP is located; however, there are two communities that have been listed on the Priority Ecological Communities (PEC) for Western Australia list, the Roebourne Plains coastal grassland and the Roebourne Plains stony chenopod associations. The significance of these vegetation associations is described in **Section 4.3.2**.

Site preparation activities will include the removal of 98.51 ha of Roebourne Plains coastal grassland and Roebourne Plains stony chenopod associations. This includes 89.01 ha of vegetation that is considered to be in excellent condition, primarily on the gas plant and gas plant ancillary area, and 9.51 ha that is considered to be in poor or fair condition along the onshore gas supply pipeline route. These communities are, however, represented relatively widely in the area from Forty Mile Beach to Sherlock Station; and the proposed area of clearing is unlikely to have a significant impact on the Roebourne Plain communities from a regional perspective.

Eremophila forrestii **subsp forrestii**

The significant vegetation association (*Ipomoea costata, Acacia bivenosa shrubland* (10% to 30% 1 to 2m) over *Eremophila forrestii* subsp *forrestii* low heath (30% to 70% less than 1m) over *Triodia wiseana* hummock grassland (30% to 70%) on undisturbed red-brown alluvial soils with sparse to moderate stones) was mapped near the northeastern boundary of the accommodation facility (**Section 4.3.2.1**). **Figure 7.18** indicates the location of this vegetation association in relation to the footprint of the accommodation facility. The establishment of the accommodation facility has been excluded from the scope of this PER (**Section 3.5.7**), however, the following information has been provided for completeness. The vegetation association (vegetation association Rf2 on **Figure 4.6g**) occurs on the northeastern boundary of the accommodation facility (marked as 'No Access Area' on **Figure 3.10**). Recognising the significance of this vegetation, Apache excluded this area from the native vegetation clearing permit application submitted to the DEC for the purpose of establishing the accommodation facility. Additionally, Apache will erect a fence to protect this vegetation association from potential damage from accidental clearing during construction. This boundary fence will remain throughout operations to ensure that access to this area is prevented during the operations phase of the DCDP. Information on the significance of the vegetation in this area and the need to prevent disturbance to it will be included within DCDP environmental awareness and induction materials.

Loss of Flora of Conservation Significance

No Declared Rare Flora as per the *Wildlife Conservation Act 1950 (WA)* or any Protected Plant Taxa as listed under Section 179 of the EPBC Act (Cwlth) were identified during the site surveys or expected to occur in the DCDP area.

Six Priority species as listed on CALM's declared Rare and Priority Flora List are known to occur in the development area. All six species are classified as Priority 3, which implies that they are not under immediate threat and are in need of further survey through the region. Only one of these Priority species, the perennial herb *Hibiscus brachysiphonius*, was located during the site surveys in the disturbed verge along the Forty Mile Beach Road (eastern side) on the non-gilgai plain. It is not envisaged that this side of the road will be impacted by construction, as the pipeline easement is to be located on the western side of the road.

Accidental Disturbance of Vegetation Outside of the Project Footprint

In the vicinity of the DCDP is riparian vegetation at Devil Creek, which is outside of the proposed project footprint and should be protected from accidental disturbance. Accidental disturbance of vegetation outside the planned project footprint could occur through vehicle and personnel movement outside designated areas, dust deposition or accidental fire. The extent of such impacts could include minor damage to individual plants or damage to a vegetation community. Measures will be in place to minimise the risk of accidental disturbance to areas of vegetation outside the project footprint.

7.7.1.2 Management

The CEMP includes a number of management measures to reduce the impact to vegetation and flora of the area from the key hazards described. The proposed prevention and management measures are summarised in the **Table 7.31**.

Vegetation Community	Condition	Total Area in Survey (ha)	Total Area to be Cleared (ha)	Total to be Cleared of Area in Survey (%)
LITTORAL				
Lb1	4: Poor/partially degraded	7.22	0	0.00
Lb2	4: Poor/partially degraded	8.69	3.11	35.80
Lb3	4: Poor/partially degraded	32.15	0	0.00
Lb4	4: Poor/partially degraded	1.75	0	0.00
Lb5	4: Poor/partially degraded	7.17	2.35	32.83
Lb6	4: Poor/partially degraded	3.96	0.15	3.71
Lb7	4: Poor/partially degraded	17.09	0.61	3.58
Lb8	4: Poor/partially degraded	4.61	0.24	5.17
Lb9	4: Poor/partially degraded	0.84	0.12	14.54
LbD1	4: Poor/partially degraded	1.06	0.07	6.72
LbD2	4: Poor/partially degraded	3.88	0.26	6.73
Lp1	4: Poor/partially degraded	15.29	3.18	20.81
Lp2	4: Poor/partially degraded	8.66	0.20	2.27
Lp3	4: Poor/partially degraded	1.59	0.04	2.40
Lp4	4: Poor/partially degraded	19.25	1.99	10.36
Lp5	4: Poor/partially degraded	5.66	1.87	33.07
LpD1	4: Poor/partially degraded	1.22	0.97	79.18
LpD2	4: Poor/partially degraded	0.28	0.28	100.00
LpD3	4: Poor/partially degraded	1.47	0.50	33.79
CHEERAWARRA				
Csp1	4: Poor/partially degraded	5.59	0.06	1.16
Csp2	4: Poor/partially degraded	0.77	0	0.00
Csp3	4: Poor/partially degraded	8.43	0.59	7.02
Csp4	4: Poor/partially degraded	0.66	0	0.00
Csp5	4: Poor/partially degraded	2.65	0.40	15.07
Csp6	4: Poor/partially degraded	2.30	0.28	12.28
CspD1	4: Poor/partially degraded	4.25	0.77	18.13
CspD2	4: Poor/partially degraded	0.32	0	0.00
Css1	3: Fair	7.37	0.43	5.81
HORSEFLAT				
Hng1*	3: Fair	7.74	0.89	11.50
Hng2*	1: Excellent	61.86	45.50	73.55
Hng3*	1: Excellent	7.07	7.04	99.61
Hng4*	1: Excellent	6.55	4.54	69.30
Hng6*	1: Excellent	0.76	0.18	24.07
HngD1*	4: Poor/partially degraded	5.16	0.26	5.04
Hm1*	3: Fair	36.09	5.98	16.56
Hm2*	1: Excellent	14.82	0.54	3.62
Hm3*	1: Excellent	14.65	9.67	66.01
Hm4*	1: Excellent	7.09	7.09	100.00
Hg1*	3: Fair	0.30	0.30	100.00
Hg2*	3: Fair	2.15	2.08	97.12
Hss1*	1: Excellent	22.60	14.45	63.96
RIVER				
R1	3: Fair	1.52	0	0.00
	BARE SALINE FLAT	12.37	1.42	11.50
	DEGRADED OR DESTROYED	6.57	2.16	32.88
	TOTAL AREA	381.48	120.58	

** Vegetation associations that may represent Roebourne Plains coastal grassland and Roebourne Plains stony chenopod associations.*

Table 7.30 Vegetation community clearance areas.

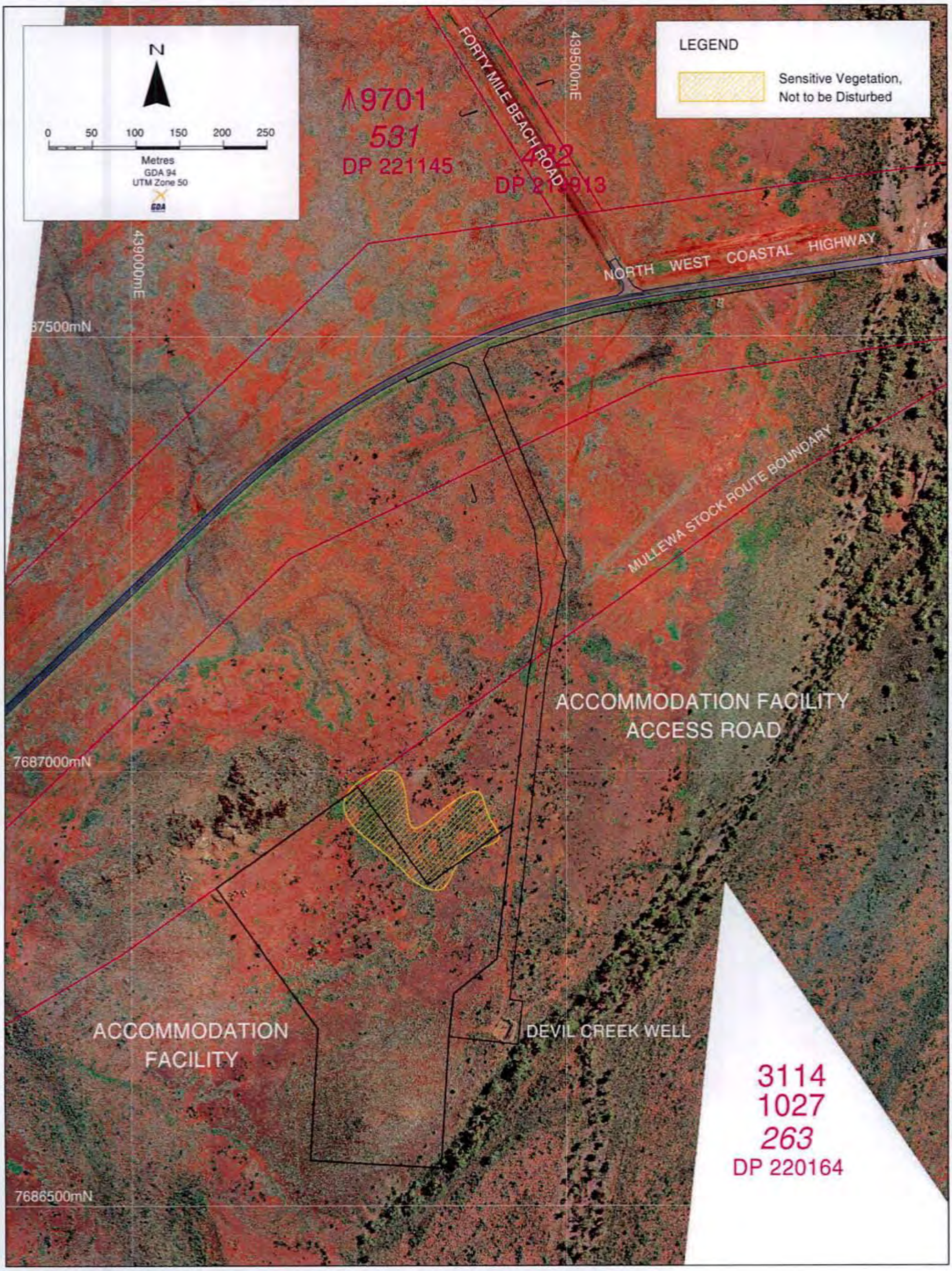

Figure 7.18 Sensitive vegetation adjacent to the accommodation facility.

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Vegetation and flora	Vegetation clearing and earthworks	*Site preparation, access tracks.*	Loss of regional vegetation and flora of conservation significance. Disturbance of vegetation outside of the project footprint. Potential introduction and spread of weeds.	The boundary of the project footprint will be clearly marked on all drawing and physically marked-out on the ground to ensure disturbance does not go beyond it. • Access for vehicles and personnel will be along designated access routes. • Control measure will be in place to manage the introduction and spread of weeds (Section 7.4.2). • Control measures will be in place to manage the generation of dust (Section 7.5.3). • The site induction will cover the measures to be implemented for vegetation and flora protection. • Rehabilitation of temporary areas will be implemented following the completion of construction. • Vegetative matter and topsoil will be separately stockpiled for use in rehabilitation.
Vegetation and flora	Fire	*Accidental ignition (hot work) during project activities.*	Loss of regional vegetation and flora of conservation significance. Disturbance of vegetation outside of the project footprint.	Fire control measures in the CEMP and OEMP, including: • Fire response equipment stationed nearby during hot-work.

Table 7.31 Summary of vegetation and flora management measures.

7.7.1.3 *Residual Risks*

Given the relatively small area of clearing, the fact that the vegetation communities are relatively well represented in the area and the existing level of disturbance to the region, it is not anticipated that the impacts to vegetation and flora will be significant on a regional scale. In the risk assessment process, the residual impact of vegetation clearing has been ranked as "negligible" during all stages of the development. Vegetation clearing and a loss of cover is expected to occur; however, the measures within the CEMP will serve to minimise the extent of this area and associated indirect impacts. The CEMP and OEMP also include measures to manage the risk of impacts to vegetation from accidental fires.

7.7.2 Introduction and Spread of Weeds

No Declared Weeds (Department of Agriculture WA, 2006 cited by Astron Environmental Services, AES 2007a and 2007c) were found within the DCDP area during site surveys; however, five species of environmental weeds were recorded (**Section 4.3.7**):

- Buffel grass (*Cenchrus ciliaris*).
- Birdwood grass (*Cenchrus setiger*).
- Feathertop Rhodes grass (*Chloris virgata*).
- Kapok (*Aerva javanica*).
- Caribbean stylo (*Stylosanthes hamata*).

Environmental weeds are plants that establish themselves in natural ecosystems and proceed to modify natural processes, usually adversely, resulting in the decline of the communities they invade (CALM, 1999). Environmental weeds compete for resources (water, nutrients and light) with native plants and can result in changes to fauna habitat and loss of biodiversity.

The key hazard likely to impact on the distribution of weed species is clearing and earthworks required as part of site activities for the construction of the DCDP.

7.7.2.1 *Impacts*

The impacts of the hazards to vegetation and flora from clearing, earthworks and general ground disturbance are the potential introduction of new, and spread of existing and new weeds.

The site surveys found that buffel grass and kapok were dominant species on the coastal dunes and the coastal sand plain and extended abundantly onto the saline clay plain. Kapok was not recorded on the non-gilgai and gilgai clay plains and buffel grass only occurred in this habitat on disturbed areas. Birdwood grass and feathertop Rhodes grass were only recorded occasionally on the coastal sand plain in the road verge. Carribean stylo was recorded at various locations along the Forty Mile Beach Road. **Figures 4.8a** to **4.8g** show the current distribution of weeds in the project area.

The site activities required for the project pose a risk of introducing new weeds to and spreading existing weeds within the project area. The clearing and earthworks require construction machinery and vehicles that will move throughout the project area and have the potential to spread weeds and propagules. General ground disturbance, for example, vehicle movements along access tracks, will create conditions that promote the establishment and proliferation of weed species.

Buffel grass is present in most vegetation associations, and its control is difficult. Caribbean stylo, kapok, feathertop Rhodes grass and birdwood grass have restricted patterns within the project area, and measures will be implemented to prevent their further spread.

7.7.2.2 *Management*

The CEMP will include a number of management measures to prevent the introduction of new weeds into the project area and the proliferation of existing weed species. The OEMP will include weed management measures applicable to the operations phase of the DCDP. These are outline in **Table 7.32**.

7.7.2.3 *Residual Risks*

Given the existing status of weed distribution in the development area, the residual risk of the introduction and spread of weeds has been ranked as "negligible" during all stages of the development.

7.7.3 *Fauna Habitats and Species*

There are a number of activities associated with the DCDP that have the potential to impact terrestrial fauna habitats and fauna species. The key hazards to terrestrial fauna and their habitat, for which impacts have been predicted and ranked through the risk assessment process, include:

- *Physical interaction:* The general presence of personnel, vehicles and plant during all stages of the development has the potential to impact fauna through direct physical interaction.
- *Clearing and earthworks:* The clearing and earthworks associated with the DCDP has the potential for direct loss or fragmentation of habitat. The majority of clearing and earthworks will be in association with the preparation of the site for the terrestrial components, including shore crossing facility, onshore section of the supply gas pipeline route, gas plant and all ancillary areas and access tracks.
- *Excavation and trenching:* Potential risk to fauna through accidental capture in excavations, such as the onshore pipeline trench. The onshore section of the supply gas pipeline route extends 10.9 km from the onshore HDD entry point to the gas plant and will be within the Forty Mile Beach Road reserve. The pipeline is to be buried to a nominal depth of 1,500 mm below ground level in a trench approximately 1000 mm wide. During pipeline installation, the open section of trench will be limited to a maximum of 2,500m at a time.
- *Noise:* The major sources of noise and vibration during the construction activities of the DCDP will be associated with earthworks for the site preparation, HDD activities and vehicle movements. Construction and commissioning activities will generate occasional peaks in noise and vibrations, while operations will tend to generally produce a constant source of noise.
- *Light:* Light emissions can cause modifications to fauna behaviour patterns. Light sources include temporary lighting to support construction activities and HDD activities, as well as permanent lighting of the operational plant, accommodation facility and the light from the flare.
- *Waste (solid and liquid):* Fauna may be attracted to waste materials or containers.

The likelihood that impacts to fauna will occur is largely based on the potential for a particular species to occupy the project area. Chapter 4 lists the terrestrial fauna species expected to occur in the project area and the species recorded during the field surveys. Of the 283 species likely to occur, there are potentially 54 species of conservation significance, although the habitats represented in the project area are not necessarily ideal habitats for the majority of these species (**Section 4.4.3**). In addition, the fauna habitats are well represented outside of the project area, and there is no indication that these are habitats of critical importance to terrestrial fauna.

7.7.3.1 *Impacts*

The impacts of these hazards include direct impacts, such as:

- Injury or death.
- Disturbance to fauna.
- Habitat loss or modification.

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Weeds	Clearing and earthworks	*Site preparation, access tracks.*	Introduction and spread of weeds.	• The CEMP includes procedures to: – Identify, mark out and assess controllability of existing weed infestations. – Establish and maintain plant, vehicle and equipment hygiene to prevent introduction and transfer of weeds. – Restrict vehicle and personnel movement to designated access tracks and working areas. – Stockpile topsoil in weed infested areas locally for use in rehabilitation to prevent the spread of weeds. – Monitoring throughout construction to identify introductions or the spread of weeds and to manage any new infestations, where they can be effectively controlled. • The OEMP includes measures to manage weeds throughout operations including: – Regular weed monitoring – Remedial weed control measures where necessary and practicable.

Table 7.32 Summary of weed management measures.

Injury or Death

The main impact associated with physical interaction between the workforce, vehicles and process facility and the local fauna will be injury and death through accidental road kill. Vehicular traffic is currently limited to recreational users of the area, who utilise the existing unsealed Forty Mile Beach Road to access the coast. During construction of the DCDP, there will be considerable heavy and light vehicle traffic, and some fauna deaths or injuries are likely to occur.

A range of species may potentially be impacted by death or injuries. Species that are most likely to be affected by road traffic are the reptiles, mammals and marsupials that inhabit the area. This includes a small number of species of conservation significance, including the skink lizards *Lerista quadrivinclua* and *Ctenotus rufescens*, as well as the Kerakenga/Lakeland Downs mouse (*Leggadina lakedownensis*). Although the project area is not known to be suitable habitat for the significant reptiles, the Lakeland Downs mouse, which is classified as Priority 4 by the DEC, does have a preference for shady and cracking clay or gilgai soils, such as those found within the project area. However, the potential impact to the regional populations of this species is low due to this habitat being well represented outside the project area.

The impacts of physical interaction will be highest in areas of most activity during the construction phase. Construction activities are scheduled in accordance with **Table 7.33**.

During the operational phase of the DCDP, vehicle numbers will be reduced. However, road fatalities will have an ongoing impact on terrestrial fauna of the area for the life of the project. Internal roads within the DCDP boundaries and the 1.2-km sealed section of the Forty Mile Beach Road proposed between the North West Coastal Highway and the gas plant will provide greater visibility of fauna, particularly reptiles, and will provide improved stopping distances; however, the warm, dark sealed roads can potentially attract reptiles and thus increase their risk of encountering a vehicle.

Injury or death of fauna may also result from terrestrial fauna becoming accidentally trapped in excavations, particularly the trench associated with the installation of the onshore section of the supply gas pipeline. Animals that are trapped in trenches are exposed to various factors, such as stress, predators, effects from the sun and subsequent dehydration. Species that are particularly susceptible to entrapment include reptiles and small mammals, and measures to prevent fauna falling into the trench, as well as to facilitate their escape or removal, will be put in place.

The evaporation ponds can also pose a risk to fauna, particularly birds that are likely to be attracted to sources of open water. The evaporation ponds are required for the disposal of produced water, which is a by-product of gas processing. Off-specification water quality resulting from a loss in control in the processing train or water treatment system could result in injury or death to birds and other fauna through, for example, high hydrocarbon content. Measures to protect birds and other fauna will be put in place for the operational phase of the project.

Fauna may be attracted to waste containers, especially if food materials are present, seeking food, water or shelter. Adverse impacts may result including injury or death through fauna ingesting materials that are toxic or from becoming trapped within containers.

An accidental fire within the project area could also cause injury or death to fauna, in particular land restricted, slow moving species.

Disturbance to Fauna

Fauna in the area may be disturbed by the general presence of personnel and equipment, as well as by noise and vibration associated with vehicular movement, earthworks and other human activities. Displacement will occur within the DCDP area as clearing and earthwork activities are undertaken and will potentially occur in the area adjacent to the project area; however, this is likely to only be short term, and fauna are expected to return to the area once the disturbance has ceased. It is likely that species will habituate to operational noise once the gas plant is operational.

The greatest potential for impacts are to species that nest or burrow in the project area. For example, the peregrine falcon, which could potentially breed in the project area, may be affected by the increased traffic; and this could subsequently lead to abandonment of nests. Similarly, although the beach is not known to be a significant area for turtles, those that utilise the area in the vicinity of the project could potentially be discouraged from using the beaches for nesting, particularly during the shore crossing and other construction activities in the coastal area.

Behavioural disturbance may also result from vehicular and pedestrian traffic or the presence of personnel outside of the project area during construction and operations; however, this will be minimised by restricting any access to areas outside the proposed project area.

Major activity	Timing
Gas plant and ancillary areas (earthworks and civils)	November 2008 to May 2009
Onshore section of the supply gas pipeline installation	November 2008 to May 2009
Shoreline crossing using HDD	April 2009 to July 2009
Gas plant (plant construction)	May 2009 to May 2010
Commissioning	January 2010 to May 2010

Table 7.33 Schedule of major construction activities.

The potential impact of the introduction of light sources includes the attraction of insects to light, which in turn increases the availability of food for other animals, including birds and bats. This potentially puts species at risk of other hazards associated with the project, including hazardous substances, and the flares.

There have been no indications of turtle nesting on the section of Forty Mile Beach adjacent to the HDD has site. Therefore it is highly unlikely that the lighting associated with the construction of the shoreline crossing could potentially affect the behaviour of nesting and hatching turtles.

Habitat Loss or Modification

The removal of breeding, nesting and foraging habitats will result in decreased resources for fauna and may result in habitat fragmentation. The loss of habitat resulting directly from the clearing of the project area has the potential to impact local terrestrial fauna, including some species of conservation significance.

Approximately 120 ha of the project area is proposed to be cleared for the DCDP. This includes areas previously subjected to disturbance and clearing. The area to be cleared includes six key terrestrial habitat types as shown in **Figure 4.10** and detailed in **Table 7.34** along with the total area of each to be cleared.

These terrestrial habitats are well represented throughout the Pilbara Region, and the total area to be cleared represents a negligible proportion of total habitat. Most of the habitats in the project area have been degraded due to the grazing activity of cattle and the incursion of weeds, such as *Cenchrus* spp.; and native fauna in the project area is also likely to have suffered localised extinction due to predation from feral cats and foxes (AES, 2007b). Thus, it is likely that these habitats only support a portion of the original fauna assemblage that would have occurred there prior to any disturbance.

There are more sensitive habitats in the vicinity of the DCDP, including mangroves west of Gnoorea Point and riparian vegetation supported by Devil Creek. The Gnoorea Point mangroves can be considered a sensitive habitat, and measures are required to minimise risks from project activities to this area. Devil Creek and its associated riparian vegetation, although outside the development area, may be indirectly affected by the project, and measures should also be considered to minimise impacts in this area.

The riparian vegetation adjacent to Devil Creek is potentially at risk of impact in the event that the habitat is modified through activities conducted in association with the proposed project. Habitats along this watercourse are locally significant for fauna, including fauna species of conservation significance; and changes in hydrology due to earthworks may impact on the riparian habitats and thus the fauna that utilise them. Changes in the groundwater levels or condition may affect any groundwater-dependent ecosystems, which may consequently impact on fauna utilising such areas. Risks to hydrology are discussed in **Section 7.3.3**, and risks to groundwater are discussed in **Section 7.3.2**.

Given the level of existing disturbance, the relatively small area of clearing and the fact that these habitat types are well represented in the region, it is likely that impacts of loss of habitat will be minor and localised. However, in terms of protecting key habitat that supports species of conservation significance, special consideration should be given to the protection of areas adjacent to the project area, including the mangrove areas west of Gnoorea Point and the riparian vegetation along Devil Creek.

An accidental fire within the project area could also cause damage to fauna habitat. During the environmental HAZID, the most credible fire event was judged to be a spot fire associated with hot work.

7.7.3.2 Management

The CEMP will include a number of management measures to reduce the impact to terrestrial fauna habitats and species from the key hazards described. The proposed prevention and management measures are summarised in the **Table 7.35**.

7.7.3.3 Residual Impacts

In the risk assessment process, the residual risk to fauna habitat and species was determined to range from "negligible" to "B" which infers an acceptable level of risk. The most significant risks to fauna is associated with open excavations and potential contamination in the produced water evaporation ponds.

7.7.4 Subterranean Fauna

The subterranean environment beneath the DCDP area contains fresh groundwater with a neutral pH and is known to support stygofauna communities dominated by crustaceans (ostracods, copepods and amphipods). There is little likelihood of troglofauna occurring, as the

Habitat Type	Approximate Area to be Cleared (ha)
Beach	None
Coastal dunes with mixed open shrubland	0.83
Sandy coastal plain with mixed open shrubland	13.85
Mosaic grassland with isolated shrubs on gilgai and non-gilgai flats	97.97
Saline inlet	2.80
Stony low rises	0.36

Table 7.34 Proposed clearance areas for each habitat type.

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Fauna	Physical interaction	*Presence of personnel, vehicles, plant and other equipment during all phases of the project.* *Water storage bunds and evaporation ponds.*	Injury or death. Disturbance to fauna.	• Controlling vehicles and plant movement along designated access routes where site speed limits will apply managed under the DCDP Traffic Management Plan. • The site induction will cover fauna interaction rules, such as no feeding or interference. • Measures will be put in place to assess and manage any injured fauna. • Dead animals found in construction or operations areas will be removed to reduce the risk of attracting other fauna and potentially creating further deaths or injuries. • Fencing will be installed around water storage areas during the construction and operations phases of the DCDP. • Measures will be put in place to deter birds from water storage areas. • Alarms and monitoring systems will be put in place for process trains and water treatment systems to indicate off-specification water quality conditions. Remedial measures will be implemented to limit the discharge of off-specification water to the ponds. • Daily inspections of the water storage and evaporation ponds will be conducted to check for injured or dead fauna.
	Clearing and earthworks	*Site preparation, access tracks.*	Injury or death. Disturbance to fauna. Habitat loss or modification.	• Clearing will only occur within the marked out project boundaries. • Rehabilitation of temporary areas will be implemented following the completion of construction (vegetative matter and topsoil will be separately stockpiled for use in rehabilitation).
	Excavation and trenching	*Pipeline installation.* *Foundation excavations.*	Pipeline installation. Foundation excavations	• The extent of open pipeline trench will be limited to 2,500 m at any one time. • Daily inspections of all excavations and trenches will be undertaken by trained fauna handler, with observed fauna removed and recorded, in accordance with the following timing requirements: – 1st April to 31st October: no later than 4.5 hours after sunrise. – 1st November to 31st March: no later than 3 hours after sunrise (unless temperature is forecast to be >35°C then no later than 2.5 hours after sunrise). • A means of escape, such as fauna ladders (branches, hessian sacks, ranked gangplanks or similar) will be provided within the pipeline trench and other excavations. • Trench plugs will have slopes no greater than 50% to allow fauna to exit the trench. • During construction of the pipeline, the open end of the pipeline will be plugged with 'night caps' at the cessation of work to prevent fauna from entering into the pipeline. • Fauna shelters, such as cardboard boxes or hessian sacks, will be provided in open trenches and inspected during daily trench inspections. • Should water ingress (groundwater) or collection (rainfall) result in ponding within an excavation, measures will be taken to either remove the water (dewatering) or limit the amount of time the trench is open to not more than 7 days. • Trenches will be inspected by a trained fauna handler half an hour prior to backfilling.
	Noise	*Gas plant construction, pipeline installation, HDD activities, operations of plant, flaring (routine and no- routine).*	Disturbance to fauna.	• Measures will be put in place to control noise emissions (see Section 7.3.5.2).
	Light	*Gas plant construction, HDD activities, operators camp, operating plant, flare, traffic.*	Disturbance to fauna.	• Construction and operational lighting will be designed to minimise impacts on fauna, while maintaining lighting levels required for safety.
	Waste	*Construction and operations activities.*	Injury or death.	• Storage of waste within enclosed containers, and provision of secondary containment for liquid waste.
	Fire	*Accidental ignition (hot work) during project activities.*	Injury or death. Damage to habitat.	Fire control measures in the CEMP and OEMP, including: • Fire response equipment stationed nearby during hot-work.

Table 7.35 Summary of fauna management measures.

humid, small voids that these animals require are very unlikely to occur within the project area. The soil profile above the watertable is sufficiently shallow (maximum of 10 m) that plant roots will be able to take up the soil moisture through most of it. Furthermore, the clayey alluvial substrates are unlikely to contain pore spaces that are large enough for troglofauna.

The stygofauna communities could potentially be impacted by the activities proposed for the DCDP. The hazards to stygofauna include:

- Clearing and earthworks.
- Alteration of hydrogeological conditions through groundwater use.
- Groundwater contamination.

7.7.4.1 *Impacts*

Key potential impacts to stygofauna are:

- Localised loss of stygofauna.
- Loss of stygofauna habitat through drawdown of aquifer levels.
- Toxic effects on stygofauna through a reduction in groundwater quality.

Generally, the risk to stygofauna populations for the region are considered negligible as all species found in the surveys are known to occur elsewhere.

Localised Loss of Stygofauna

Site preparation activities (including compaction and excavation) have the potential to cause direct impacts to stygofauna in the immediate vicinity of works a result of the physical destruction of habitat and shock waves. For the DCDP, given there will be no planned disturbance below the watertable, which stygofauna are known to inhabit, nor any blasting that could result in lethal impacts to stygofauna from shock waves, it is expected that direct impacts to stygofauna will be negligible.

Loss of Stygofauna Habitat through Drawdown of Aquifer Levels

Groundwater will be the single source of water for the DCDP throughout all phases of the project. Water will be obtained from up to four bores located within the project footprint (see **Section 3.5.8**). Abstraction of groundwater has the potential to draw down aquifer levels and subsequently impact upon groundwater-dependent stygofauna that exist within the saturated interstitial spaces within an aquifer.

Apache commissioned a hydrogeological investigation of the aquifer characteristics at the DCDP site to determine aquifer response to the proposed groundwater extraction during the construction and operational phases of the development (Coffey Geotechnics, 2007). This is outlined in **Section 7.3.2.1**.

To support the potential impact assessment on groundwater-dependent habitat, aquifer drawdown during construction in the vicinity of the DCDP wells was estimated and found to be extremely localised in the vicinity of the bore (see **Section 7.3.2.1**), in the order of 4 to 5 m in the bore and less than 1.2 m beyond a 100-m radius.

Groundwater requirements during the operational phase of the DCDP are relatively small, and it is expected that water abstraction, from up to two wells, will not have a significant impact on any groundwater-dependent habitat, including stygofauna habitat.

Toxic Effects on Stygofauna through a Reduction in Groundwater Quality

Both the construction and operational phases of the DCDP have the potential to cause groundwater contamination from leaks or spills of fuels, chemicals or waste material. These have been discussed in **Section 7.3.2.1**. Groundwater hazards associated with the disturbance of ASS or PASS have been discussed in **Section 7.3.1**.

There is associated potential for an effect through potential contamination of subterranean habitat and acute toxicity to stygofauna. In the absence of definitive data on the toxicity of various chemicals to subterranean fauna and the lack of information on the sensitivity of such fauna to changes in water chemistry (e.g., salinity), the input of potential contaminants into the ecosystem should be assumed to cause adverse impacts.

7.7.4.2 *Management*

The CEMP and OEMP include a number of measures to be implemented to reduce the localised loss of stygofauna and the impacts to groundwater and subsequent impacts to stygofauna. These measures are discussed in **Section 7.3.2.2** and summarised in the **Table 7.36**.

Based upon the results of hydrogeological investigations undertaken at the project site, it is expected that the extraction of groundwater will not have an adverse impact on any groundwater-dependent ecosystems. The residual risk of groundwater use to subterranean fauna has been ranked "negligible".

The subterranean fauna investigation of the DCDP concluded that all species of subterranean fauna within the area appear to be widespread. Thus, even in the event that impacts of clearing or earthworks and groundwater drawdown caused local extinction, the overall species population would not be affected.

Taking into account the proposed controls for managing clearing and earthworks, groundwater extraction, and the risk of groundwater contamination, the residual risk has been ranked ranging from "B" to "negligible". Spills are, however, unlikely to occur and would need to be of a significant volume in order to infiltrate the surface soils and affect the subterranean environment.

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Subterranean fauna	Clearing and earthworks	*Site preparation activities.*	Localised loss of stygofauna.	• No excavation below the water table expected during construction.
Subterranean fauna	Alteration of hydrogeo-logial conditions through groundwater use	*Construction and operations water (HDD, bulk earthworks, civil works, dust suppression, hydrotesting, potable and domestic use).*	Loss of stygofauna habitat through drawdown of aquifer levels.	• Further hydrogeological investigation will be undertaken to establish sustainable rates of groundwater extraction following the installation of new water supply wells. • Groundwater abstraction rates will be agreed with the DoW prior to the commencement of construction. • Groundwater abstraction will be undertaken in accordance with agreed DoW licence conditions (quantity and rate). • Aquifer drawdown levels will be monitored during all phases of the DCDP. • Groundwater monitoring records will be subject to verification audit and annual environmental performance reporting.
Subterranean fauna	Groundwater contamination	*Leaks or spills of fuels, chemicals or waste material.*	Toxic effects on stygofauna through a reduction in groundwater quality. Localised loss of stygofauna.	• The CEMP includes a series of requirements to reduce the likelihood of spillages, including: – Minimum requirements for fuel, oil, and chemical storage, including provision of secondary containment and access control. – Storage of waste within enclosed containers, and provision of secondary containment for liquid waste. – Provision of designated washdown areas with effluent management controls – Procedures for refuelling operations. – A site evacuation procedure, covering the requirement to secure storage areas, in the event of an approaching cyclone. – Design of temporary containment bunds to ensure sufficient capacity. – Spillage response procedure • Design measures will reduce the risk from operations phase spills and leaks • Groundwater monitoring (levels and quality) will be conducted during all phases of the project.

Table 7.36 Summary of subterranean fauna management measures.

This chapter provides an environmental impact assessment of the known and potential environmental impacts to the nearshore marine environment as described in Chapter 5 of this Draft PER.

The reports from environmental impact assessment studies are provided on a CD, accompanying this PER.

8.1 MARINE IMPACT ASSESSMENT METHOD

The environmental impact assessment method is described in **Section 7.2**.

8.1.1 Key Marine Environmental Risks

The key marine environmental risks were identified as resulting from the discharges associated with the drilling activity associated with the HDD program. Achieving the shoreline crossing using HDD results in far less physical disturbance to the nearshore marine environment than the alternative techniques of blasting and digging a trench through hard limestone pavement; however, there are some real and potential impacts from the HDD program that must be considered.

As described in **Section 3.6.1**, the proposed design of the HDD program involves delaying the punch out of the hole until the final 150 m of drilling, thus reducing the volume of drilling discharges that would be released to the marine environment compared to a simpler, more reliable engineering solution of an immediate punch out.

For the purpose of comparing potential impacts, however, three engineering cases for the HDD program have been modelled to assist with the environmental assessment process. The three cases are summarised in **Table 8.1** and described below:

- *Planned case:* intended HDD program for DCDP with delayed punch out as described in **Section 3.6.1**.
- *Contingency case:* intended HDD program with delayed punch out but with contingency built in should there be technical problems encountered during the HDD program requiring an additional cleaning pass, which would result in additional discharges to the marine environment.
- *No mitigation case*: no delay in punch out, representing the worse-case HDD program, due to maximum discharges to the marine environment. Note that this case is presented for comparison only and will not be undertaken for the DCDP.

For these three cases, the impact of the discharge of the cuttings and bentonite to the marine environment was predicted using numerical modelling to describe the hydrodynamic conditions influencing the discharge point and to quantify the concentrations of suspended sediment and sedimentation expected over benthic habitats at and adjacent to the HDD exit point.

Additional disturbance to the benthic habitats will occur through the preparation of the seabed around the HDD exit point to ensure that the emergent pipeline is adequately supported (**Section 3.6.1.3**). This may involve jetting loose sediments from beneath the pipeline or placing cement-filled grout bags under the pipeline, depending on the nature and contour of the seabed at the HDD exit point. In addition, anchoring of HDD support vessels will be necessary to support diving activities. The areas of seabed disturbance associated with these activities are estimated in **Table 8.2**.

8.1.2 Numerical Modelling

Numerical modelling to support the marine impact assessment for the DCDP was carried out by Asia Pacific Applied Science Associates (APASA, 2008a, b). The method and validation for the numerical modelling are described in technical detail in **Appendix 5**, and the results are given throughout this chapter. There were three main components to the numerical modelling:

Case	HDD length (km)	Timing of punch out	Drilling fluids	Materials released	Period of release
Planned	1.8	Delayed, last 150 m only	100% bentonite	70 m^3 of cuttings 60 m^3 of bentonite	~2 weeks
Contingency	1.8	Delayed, last 150 m only but additional reaming pass required	100% bentonite	80 m^3 of cuttings 100 m^3 of bentonite	~3 weeks
No mitigation	2.26	No delay	100% bentonite	500 m^3 of cuttings 180 m^3 of bentonite	~12 weeks

Table 8.1 Attributes of the three cases for the HDD program.

Activity	Timeframe	Footprint	Sediment volume
Modification to seabed – air jetting of loose sediments at HDD exit point	Short-term - several hours	1 m x 10 m = 10 m^2	10 m^3
Modification to seabed – grout bags to support pipeline at HDD exit point	Long-term - years	1.5 m x 1.5 m = 2.25 m^2 per grout bag	Insignificant
Vessel support – 4 to 8 anchors on pipelay barge	Short-term – several days	20 m^2 for 8 anchors	Insignificant

Table 8.2 Estimated area of seabed disturbance from non-drilling activities associated with the HDD program.

- Hydrodynamic and wave modelling, using the models HYDROMAP and SWAN, to model water movement within Regnard Bay considering ocean currents, astronomical tides, wind stress, bottom friction and waves.
- Trajectory and fate of HDD drilling discharges, using the model SSFATE to simulate the release of drill cuttings and fluids from the HDD exit point under the three cases described in **Table 8.1**.
- Trajectory and fate of diesel, using the model SIMAP to simulate three scenarios representing accidental spills of diesel from vessels used to support the HDD program.

The hydrodynamic and wave models were used as inputs into the trajectory and fate modelling for both the HDD discharges and the accidental diesel spills. A technical peer review of the hydrodynamic, wave, and trajectory and fate of HDD discharges modelling was undertaken by Dr Peter Ridd of James Cook University.

The trajectory and fate modelling of the HDD drilling discharges considered both the short-term (initial transport, sinking and deposition) and longer-term (subsequent cycles of resuspension and deposition) fates of sediments derived from the cuttings and fluids discharged during HDD operations. The model provided estimates of above-background levels of suspended sediment concentrations and sedimentation concentrations (APASA, 2008a). In accordance with EPA Guidance Statement No. 29 (EPA, 2004a), RPS (2008b) used this information in conjunction with threshold values for benthic primary producers to map zones of impact, effect and influence, indicating where the defined thresholds of suspended sediment and sedimentation concentrations were exceeded.

The trajectory and fate of accidental diesel releases was calculated using stochastic modelling using repeated simulations of a given spill scenario (hydrocarbon type, volume, duration of release and release location) under randomly selected sets of environmental conditions (air and sea temperature, wind and current) (APASA, 2008b). The study examined three scenarios to represent the potential incidents that could occur albeit very unlikely. These three scenarios are detailed in **Table 8.3**.

Results of the multiple stochastic simulations were then analysed to estimate risks to the coastline and shallow subtidal habitats in terms of the probability of contact by diesel, the quantities that could come ashore and the concentrations of oil that could become entrained in the shallow subtidal zone. A minimum threshold of 0.01g/m^2 was used to define contact for the calculation of probabilities. This concentration equates to a film of oil that would appear as a coloured sheen.

8.2 MARINE PHYSICAL IMPACTS

The construction, operation and physical presence of the DCDP may potentially result in environmental impacts to:

- Water quality.
- Geology and geomorphology.

8.2.1 Water Quality

Key hazards that have the potential to impact water quality in the vicinity of the DCDP include:

- Modifications to the seabed around the HDD exit point either through jetting away loose sediments and exposing hard substrate or placement of grout bags under the pipeline for support. These modifications may be temporary (jetting away sediments) or more permanent (placement of grout bags) (see **Table 8.2**).
- Discharges associated with the HDD program in the form of suspended sediment concentrations above background levels.
- Support vessel discharges, including accidental release of diesel.
- Disposal of hydrotest water.

The management objective for water quality as stated in the Draft Management Plan for the Dampier Archipelago Marine Park and Regnard Marine Management Area is to ensure that the water quality of the proposed reserves is not significantly impacted by the input of contaminants. The long-term target for unzoned areas within the Marine Management Area is "maintained in a natural state, except for areas where some level of acceptable change is approved by the appropriate government regulatory authority".

Discharges from HDD Elevating Suspended Sediment Concentrations. The following predictions of suspended sediment concentrations from HDD discharges were derived from numerical modelling of the three HDD cases described in **Table 8.1**.

Spill Scenario	Assumed volume (m^3)	Assumed release duration (hours)	Simulation period for each spill (days)
Small diesel spill at the HDD exit point onto the water surface, representing a refuelling accident	2.5	1	3
Diesel spill from a random site within a 500-m radius of the HDD exit point onto the water surface, representing a storage tank rupture from a supply vessel	25	6	3
Larger diesel spill from a random site within a 500-m radius of the HDD exit point onto the water surface, representing a storage tank rupture from a supply vessel	80	12	3

Table 8.3 Summary of diesel spill scenarios for numerical modelling and risk assessment.

In general, modelling indicated that the discharge of cuttings and drilling fluid would generate elevations to the background levels of suspended sediments over a relatively limited area. Concentrations greater than 1 mg/L above background were generally limited to less than 1,000 m from the HDD exit point. The plume was predicted to affect the full water column immediately around the discharge point, however, plumes would be concentrated near the seabed over wider extents. Examining the outcomes by individual particle classes indicated that the coarse and fine sand particles would settle locally (less than a few hundreds of metres), while the clay and silt-sized particles would tend to migrate away from the source and thus would be the particles generating suspended sediment concentrations above background. Numerical modelling indicated that plumes would disperse relatively quickly, within hours, after cessation of discharge. This was attributed to a combination of the rapid dispersal of fines (clay and silt-sized particles) and the rapid settling of coarser particles and suggests that flushing of the HDD-induced turbidity will be effective.

More specific predictions for each HDD case are given below:

Planned Case:

- Examples of the predicted plume distributions are shown in plan and cross-sectional view in **Figure 8.1**. Images are randomly selected in chronological order from the extent of the simulation to illustrate the variation in plume shapes over time. Smaller extents were indicated where discharge rates were lower or where the tide was turning. One implication of this variability is that the surrounding seabed locations would not tend to be chronically affected by elevated suspended sediments, with associated influences on light penetration to the seabed.
- Plumes were predicted to move with the prevailing current and did not stream over the same locations constantly. The variations in the discharge rates and particle size distributions during drilling resulted in the plume extents varying over time by one or two orders of magnitude. Plumes dissipated from the discharge area rapidly, and there was no evidence of secondary plumes of fine sediments being generated due to resuspension or subsequent return of plumes that migrated past the HDD exit point. This result indicates that the fines will remain suspended for sufficient time to be effectively dispersed.
- Estimates of the above-background elevations in suspended sediments surrounding the discharge point are predicted to be variable over time, as shown in **Figure 8.2.** Within 50 m of the exit point along the main tidal axis to the southeast, concentrations are predicted to range from 1 to 60 mg/L above background, with the extreme concentrations lasting only a few hours. At 400 m from the HDD exit point, the peak elevations were predicted at 5 to 10 mg/L over durations of several hours at most.
- The median and maximum suspended sediment concentrations in any direction from the discharge point were 3 mg/L and 90 mg/L at 50 m, 2 mg/L and 60 mg/L at 100 m, 0 mg/L and 85 mg/L at 200 m, and 0 mg/L and 35 mg/L at 400 m.

Contingency Case:

- The patterns of plume distribution for the contingency case were similar to those for the planned case (**Figure 8.3**). There were no above-background elevations in suspended sediment concentrations after the drilling operations were completed.
- Within 50 m of the exit point along the main tidal axis to the southeast, concentrations are predicted to increase by 20 to 30 mg/L over durations of no more than 6 to 12 hours (i.e., up to one tidal cycle), and continuous elevations in the order of 5 to 10 mg/L are expected (see **Figure 8.2**). With increasing distance from the HDD exit point, there was a reduction in the expected increases of suspended sediment concentrations during the peaks and increasing proportions of the time where concentrations were not expected to increase by more than 1 mg/L. At 400 m from the HDD exit point, the peak elevations were predicted at 10 to 30 mg/L over durations from one to a few hours.
- The median and maximum suspended sediment concentrations in any direction from the discharge point were 7 mg/L and 90 mg/L at 50 m, 4 mg/L and 60 mg/L at 100 m, 2 mg/L and 85 mg/L at 200 m, and 0 mg/L and 35 mg/L at 400 m.

No Mitigation Case:

- The patterns of plume distribution for the no mitigation case are given in **Figure 8.4**.
- Concentrations of suspended sediments are predicted to be variable over time, with a number of higher peaks (greater than 20 mg/L above background) occurring over the scale of one or a few hours. Concentrations of up to 15 to 20 mg/L were predicted to persist for the duration of a tidal period (approximately 6 hours), with sharp fluctuations due to movement of the plume with each tidal reversal. Relatively small increases of 2 to 4 mg/L above background were predicted to occur more constantly within 50 m of the discharge point (see **Figure 8.2**). With increasing distance from the HDD exit point, there was a reduction in the expected increases of suspended sediment concentrations during these peaks and increasing proportions of the time where concentrations were not expected to increase by more than 1 mg/L. At 400 m from the HDD exit point, the peak elevations were predicted at 1 to 2 mg/L over durations of 1 to 2 hours.
- The median and maximum suspended sediment concentrations in any direction from the discharge point were 3 mg/L and 75 mg/L at 50 m, 1 mg/L and 40 mg/L at 100 m, 0 mg/L and 23 mg/L at 200 m, and 0 mg/L and 16 mg/L at 400 m.

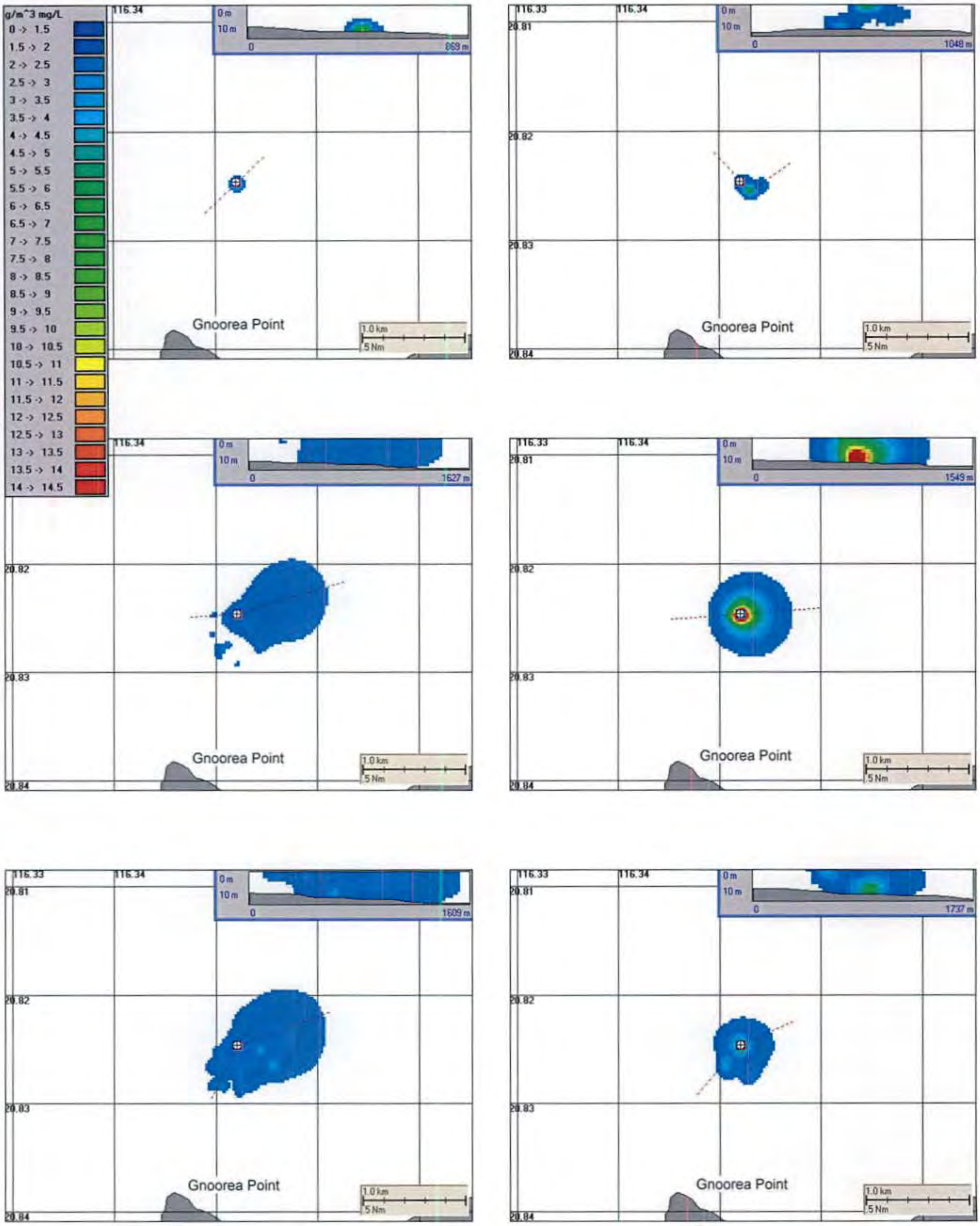

Figure 8.1 Predicted suspended sediment concentrations (mg/L) at points in time from simulation of HDD discharge (Planned Case). Main panels show plan-view. Cross-sectional view along the dotted line is given in top right corner of each main panel. White circle with cross hairs indicates HDD exit point. Example times were randomly selected.

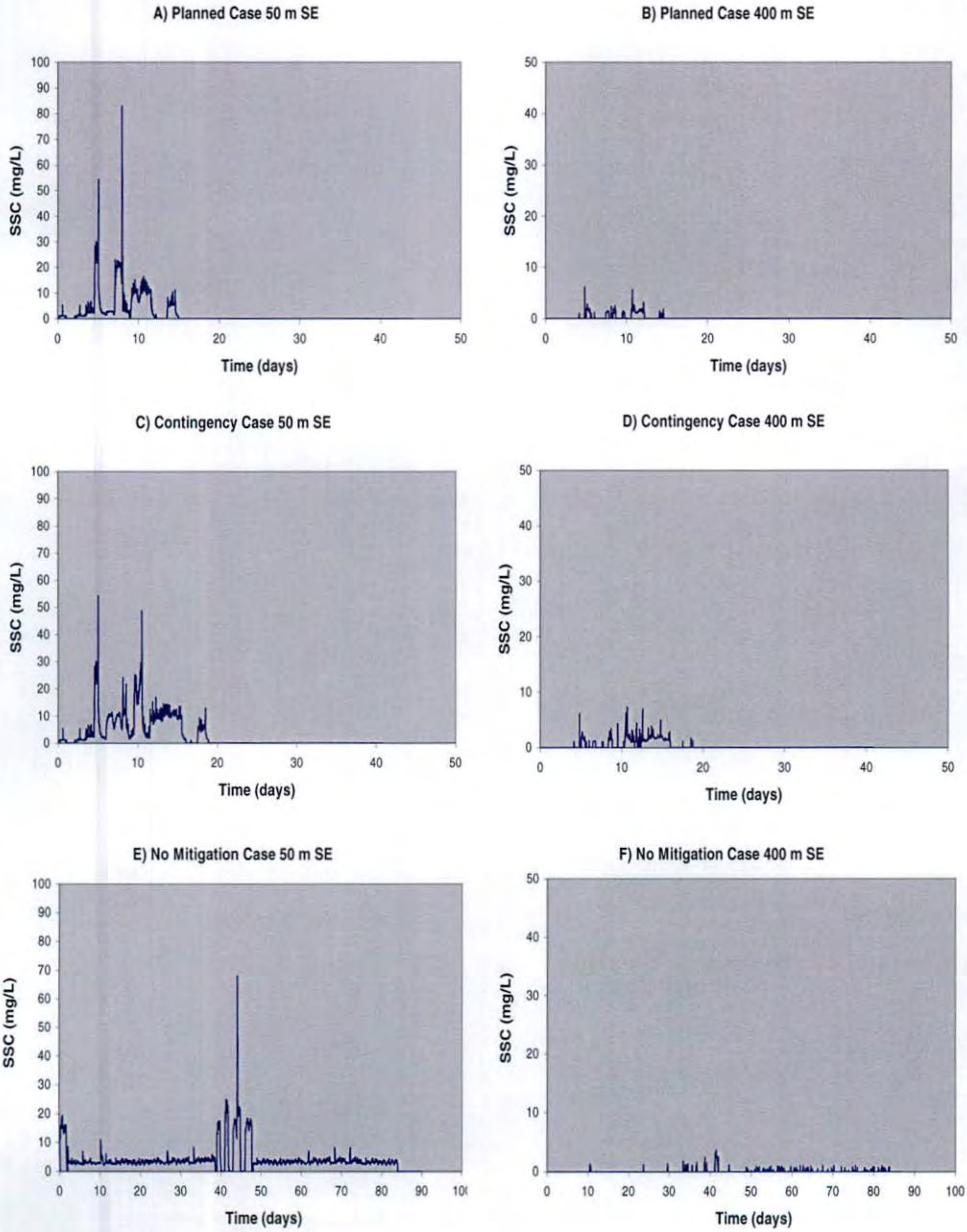

Figure 8.2 Suspended sediment concentrations (SSC; mg/L) through time at 50 m and 400 m to the south east of the HDD discharge location for 3 cases for HDD program.

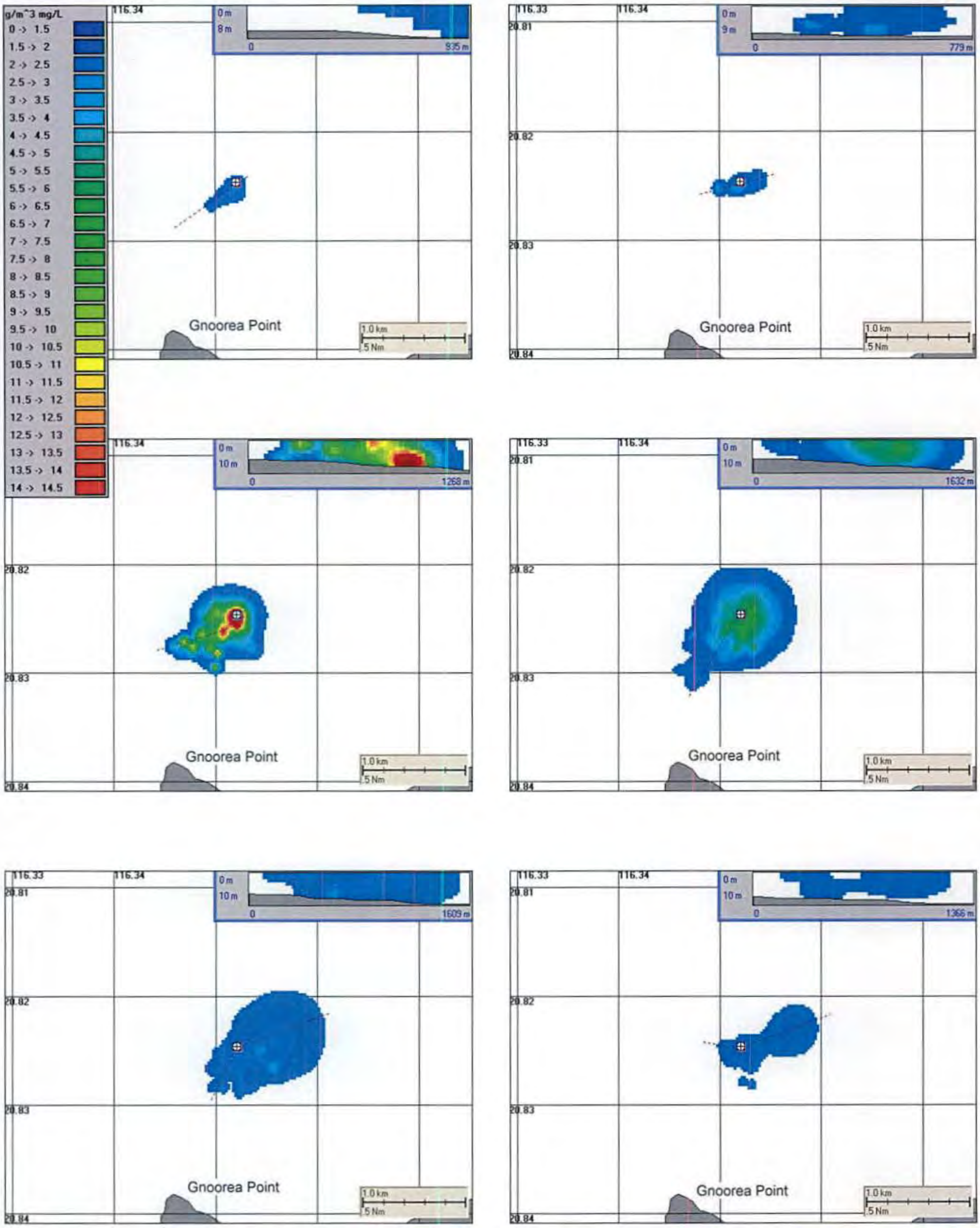

Figure 8.3 Predicted suspended sediment concentration (mg/L) at points in time from simulation of HDD discharge (Contingency Case). Main panels show plan-view. Cross-sectional view along the dotted line is given in top right corner of each main panel. White circle with cross hairs indicates HDD exit point. Example times were randomly selected.

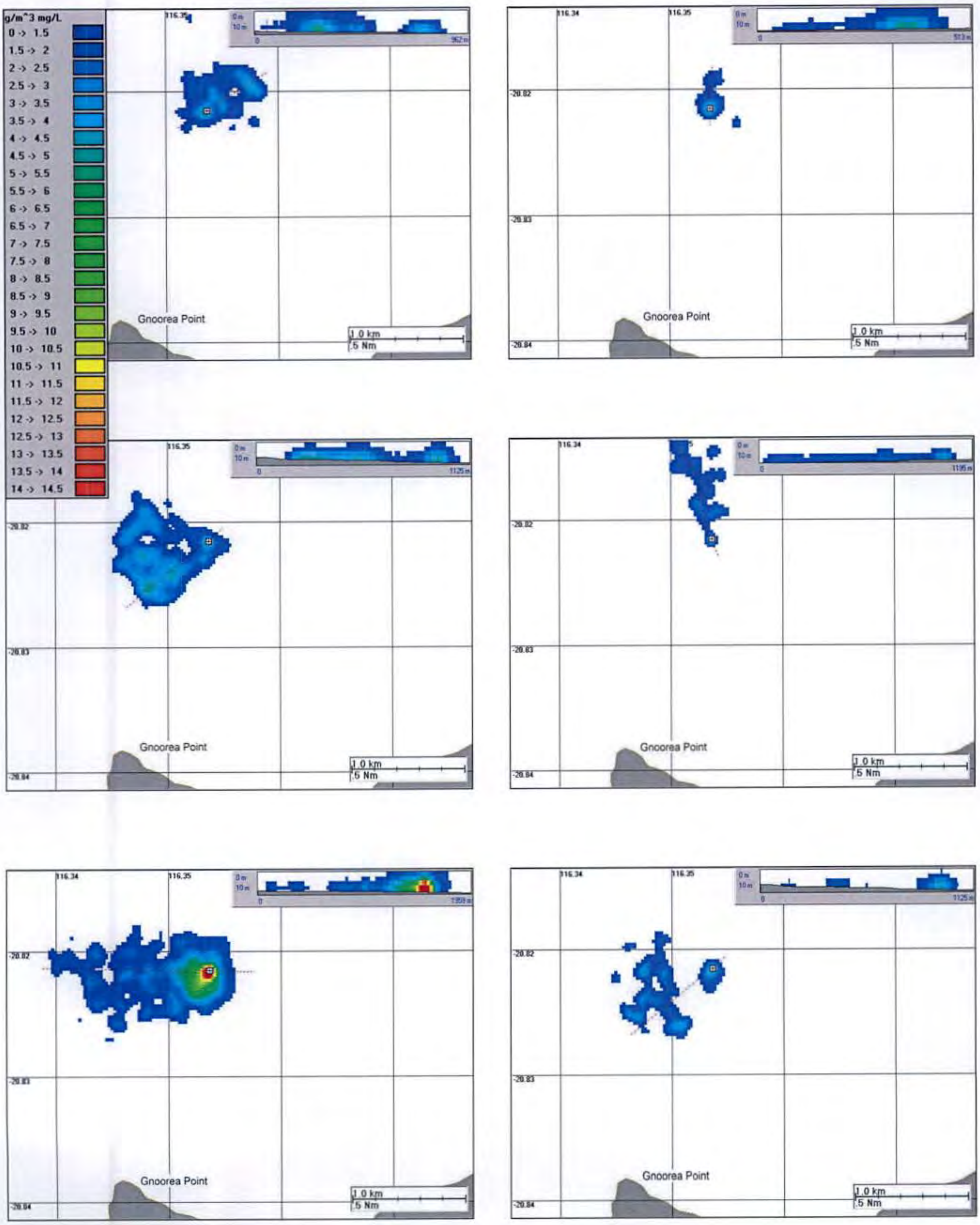

Figure 8.4 Predicted suspended sediment concentration (mg/L) at points in time from simulation of HDD discharge (No Mitigation Case). Main panels show plan-view. Cross-sectional view along the dotted line is given in top right corner of each main panel. White circle with cross hairs indicates HDD exit point. Example times were randomly selected.

Background Suspended Sediment Concentrations. Model predictions indicated that HDD discharges will generate relatively low concentrations of suspended sediments compared to the limited available background data derived from field deployment of 2 calibrated acoustic-doppler current profilers (ADCPs) deployed as part of the model validation work. In the vicinity of Gnoorea Point, the minimum concentration of suspended sediment was 2 to 3 mg/L, with constant fluctuations up to 2 orders of magnitude above these levels over irregular, short-term events.

Model predictions indicated that HDD discharges would generate fluctuating concentrations over any given location in the immediate proximity of the discharge. At a distance of 50 m along the main current axis, the minimum contribution to suspended sediment concentrations from all HDD cases was 0 mg/L, hence discharges would not add a constant suspended sediment load at this distance, irrespective of the HDD case. Suspended sediment concentrations were predicted to decrease and become more intermittent with distance from the discharge. Median contributions at 50 m were estimated to be 0 mg/L for the planned and contingency cases and 3.2 mg/L for the no mitigation case. Hence, most frequently, the contribution from HDD discharge in all cases was predicted to be less than or equal to the minimum background suspended sediment concentration.

The combined median concentration for suspended sediments, that is, the sum in the background and HDD discharge sources would most frequently be of the order of 12 mg/L or less for the no mitigation case as that generated the highest median suspended sediment values. This would be lower than the 80th percentile background suspended sediment concentration observed in the vicinity of Gnoorea Point. More extreme combined concentrations would be expected for short periods (less than a few hours) if more extreme background values coincided with more extreme concentrations generated by HDD. Summing the 80th percentile background concentration and the 80th percentile contribution to suspended sediment concentration predicted at 50 m for the no mitigation case for HDD, combined concentrations would be of the order of 18 mg/L, which would be less than the 95th percentile estimate for background suspended sediment concentration and an order of magnitude lower than maximum background suspended sediment concentration.

Vessel Discharges. The use of a number of diesel-powered support vessels is required for the nearshore HDD operations as described in **Section 3.6.5.5**. Vessels can potentially contribute contaminants to the marine environment via discharges, such as domestic wastes and deck drainage. However, the key risk associated with vessel activity is the accidental discharge of hydrocarbons (e.g., diesel) during refuelling or from a storage tank rupture resulting from a collision or grounding of the vessel.

Domestic Wastes and Deck Drainage. Support vessels working in the nearshore marine environment will generate domestic wastes, including sewage, greywater and food scraps. When disposed of into the marine environment, these wastes have the potential to cause nutrient enrichment and contamination of the surrounding waters. Legislation requires that none of these wastes are to be discharged within 12 nautical miles of the coastline. In accordance with this legislation, no domestic wastes will be disposed of in the nearshore marine environment in which the HDD activities are to take place.

Support vessels have main deck work areas that, under routine operations, drain freely. Water that reaches the deck through condensation, precipitation, sea spray, wash down and fire drills will drain directly to the marine environment. To minimise the impacts of this, when deck drainage is contaminated with oils, greases and other contaminants, it is redirected to a sump or oily water separator to prevent discharge of the contaminants into the marine environment. Depending on the type and volume of pollutants on deck, contaminated deck drainage that is not redirected and is discharged has the potential to create surface sheens and short-term, localised reductions in water quality.

Accidental Discharge of Diesel. The key impacts associated with the accidental discharge of diesel from vessels into the marine environment are either:

- Physical impacts, including coating and/or smothering leading in some instances to contamination or mortality.
- Chemical and biological impacts, including sublethal and lethal impacts on marine organisms caused mainly by the water-soluble components of hydrocarbons, such as benzene.

The consequences of a diesel discharge are determined by taking into consideration the size, type and location of the spill and how susceptible the individual species are to the hydrocarbons.

Based on the diesel spill prediction modelling for each of the three spill scenarios detailed in **Table 8.3**, diesel slicks were predicted to migrate inshore and offshore with the tide, which generally flows from the northwest to the southeast in the study area and to undergo net drift depending upon the prevailing wind. The modelling indicated that the slicks would most commonly drift alongshore to affect the waters of Regnard Bay.

The predictive modelling showed slicks are most likely to affect locations east of the discharge during the early part of the operation (in summer) but to the west of the discharge during the latter part of the operation (in winter). Overall, there was a higher risk predicted for the western end of the bay. The probability of surface oil exceeding the 0.01 g/m^2 threshold (indicating a rainbow sheen) for each of the modelled scenarios is illustrated in **Figures 8.5**, **8.6** and **8.7**.

Lighter end hydrocarbons tend to weather quickly in warm conditions. However, weathering analysis for diesel fuel oil under the ambient conditions of temperature, wind and currents indicate that the evaporation of diesel will be limited to approximately 40% of the volume (APASA, 2008b) with the remaining proportions being contributed by oil with a lower volatility (heavy end hydrocarbons). Based on the weathering properties of the diesel fuel oil and the effects of wind and current, at least some part of the slick has a high probability (95% to 100% depending upon the scenario) of coming ashore. The minimum time for first exceedence of the threshold for surface oil (i.e., exceeding 0.01 g/m^2) is shown in **Figures 8.8**, **8.9** and **8.10**.

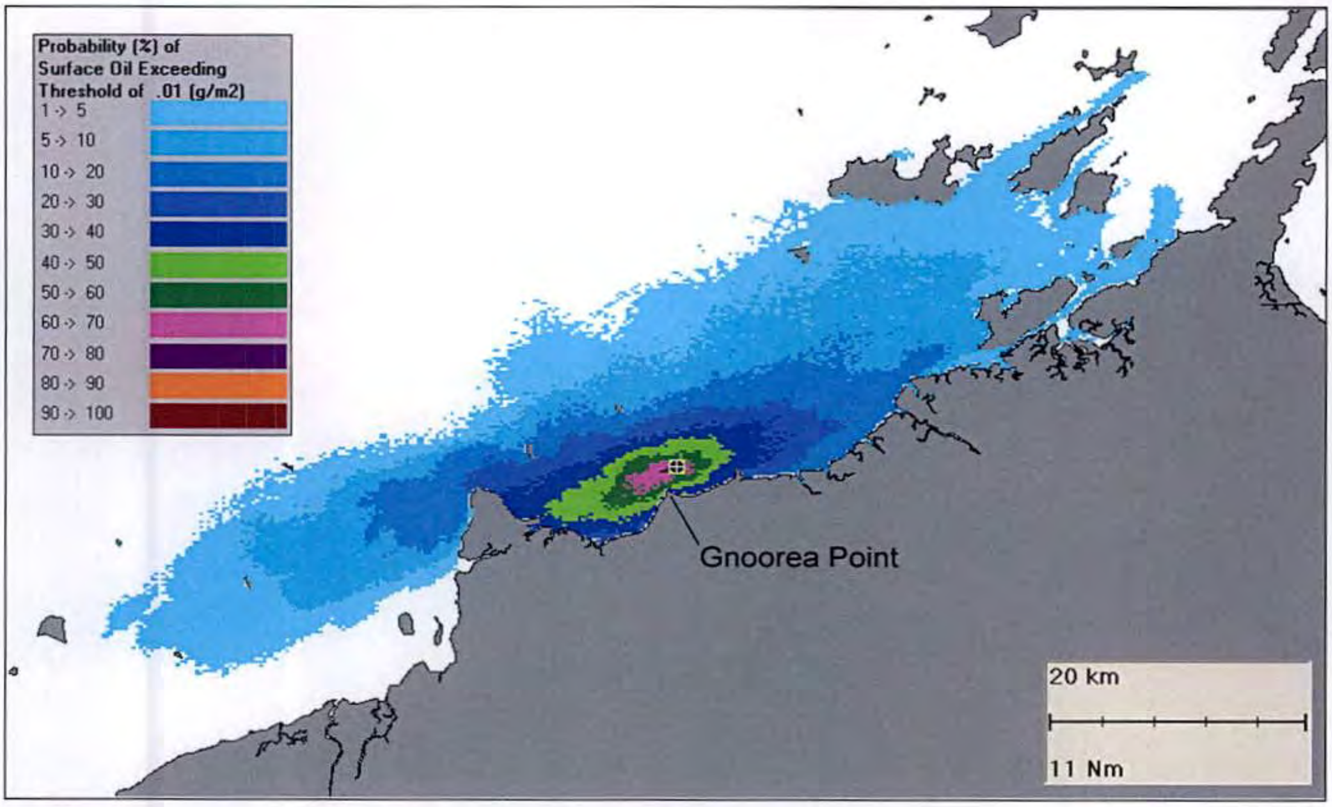

Figure 8.5 Probability of surface oil exceeding 0.01 g/m² (rainbow sheen) from surface spill of 2.5 m³ of diesel released over 1 hour at the HDD exit point (black circle).

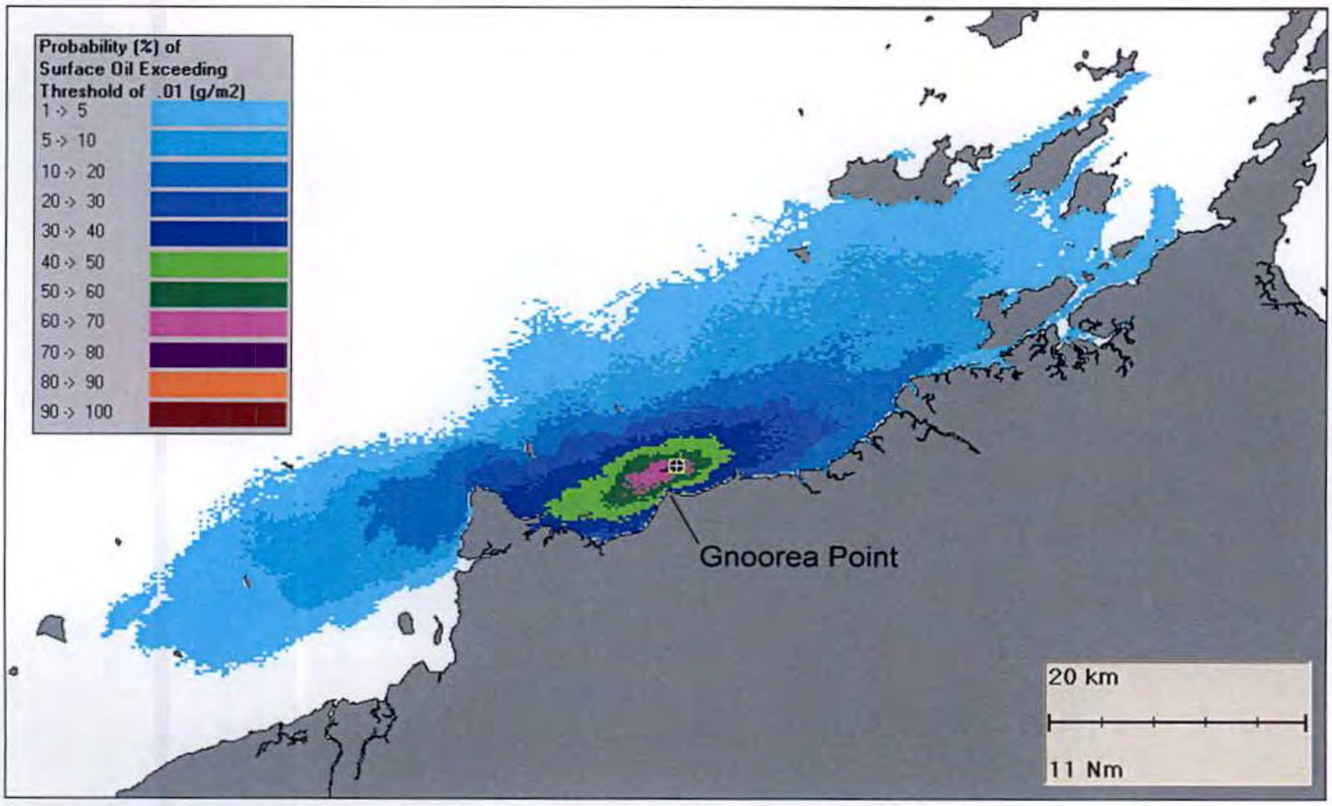

Figure 8.6 Probability of surface oil exceeding 0.01 g/m² (rainbow sheen) from surface spill of 25 m³ of diesel released over 6 hours from random locations around the HDD exit point (black circle).

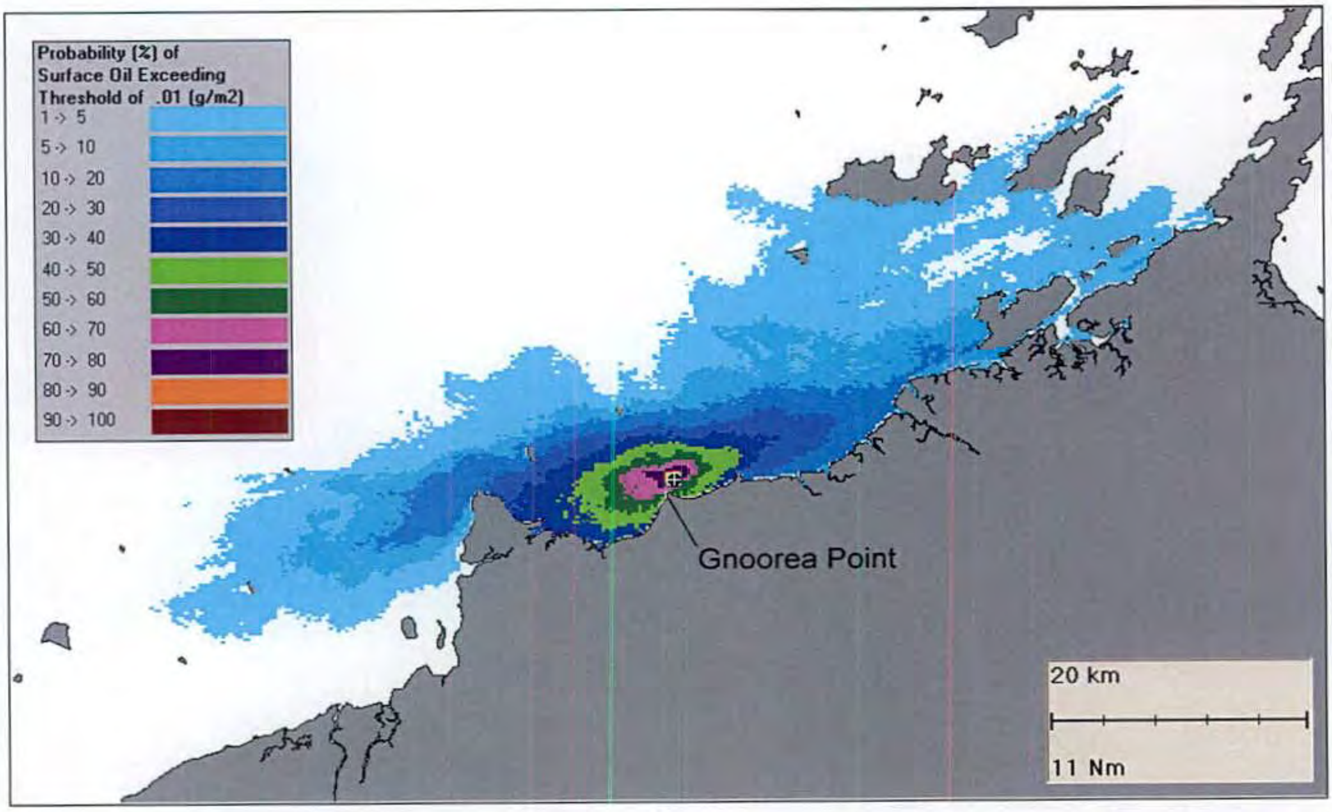

Figure 8.7 Probability of surface oil exceeding 0.01 g/m^2 (rainbow sheen) from surface spill of 80 m^3 of diesel released over 12 hours from random locations around the HDD exit point (black circle).

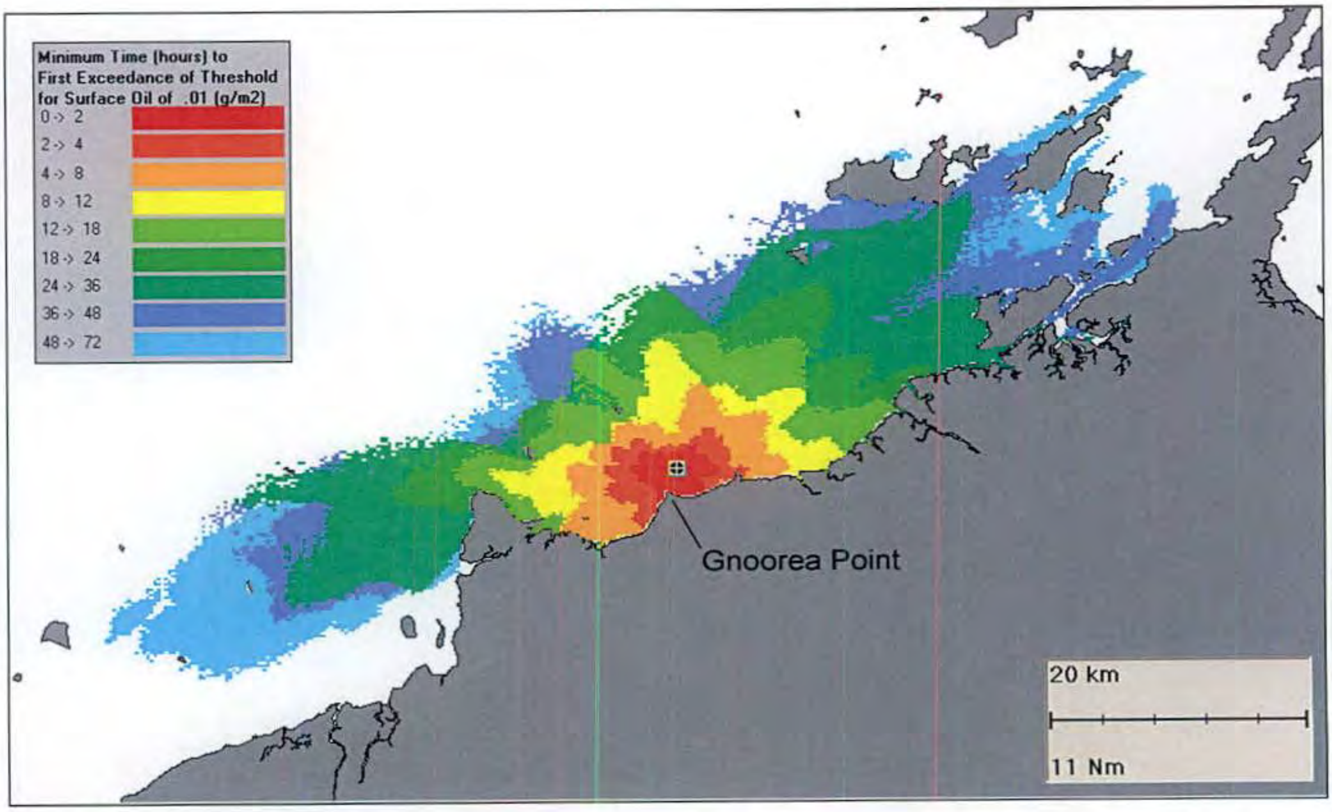

Figure 8.8 Minimum time of surface oil exceeding 0.01g/m^2 from surface spill of 2.5 m^3 of diesel released over 1 hour from the HDD exit point (black circle).

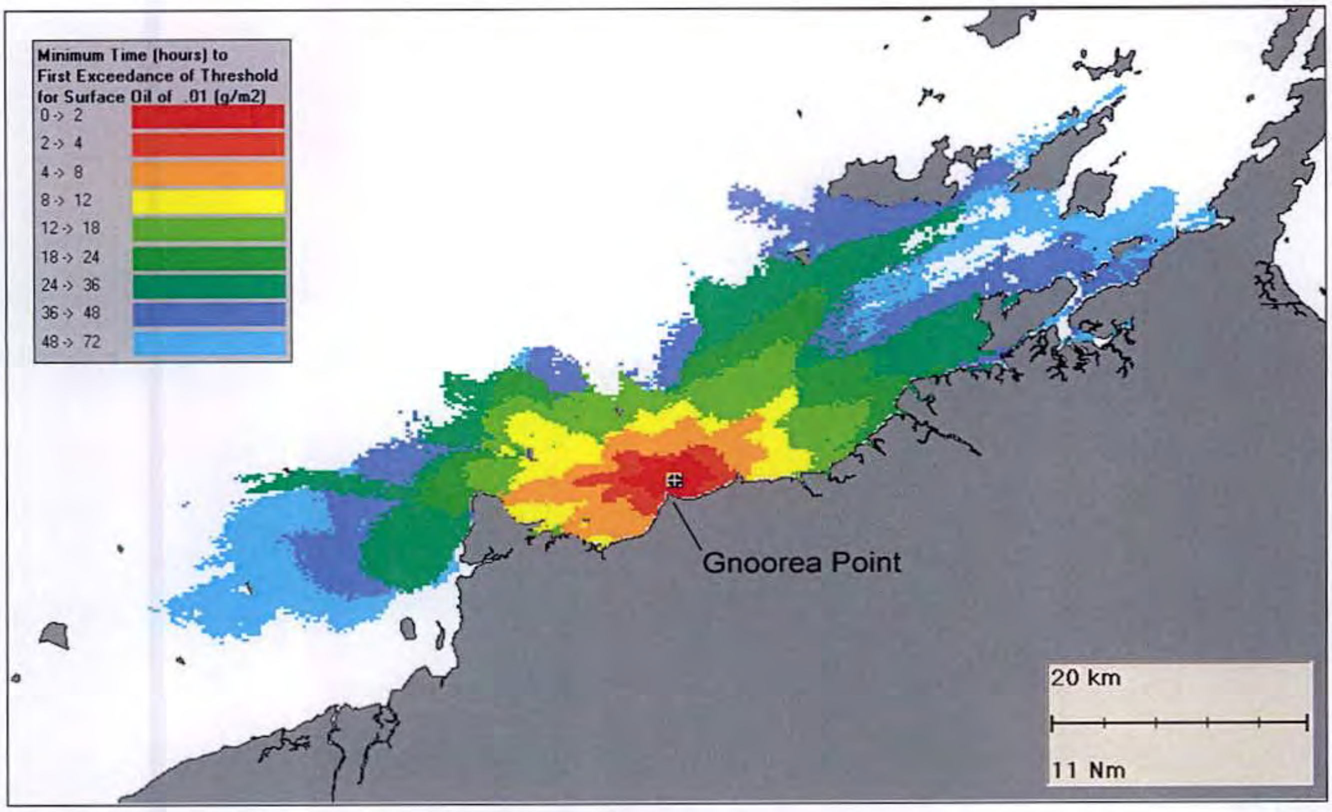

Figure 8.9 Minimum time of surface oil exceeding 0.01g/m^2 from surface spill of 25 m^3 of diesel released over 6 hours from random locations around the HDD exit point (black circle).

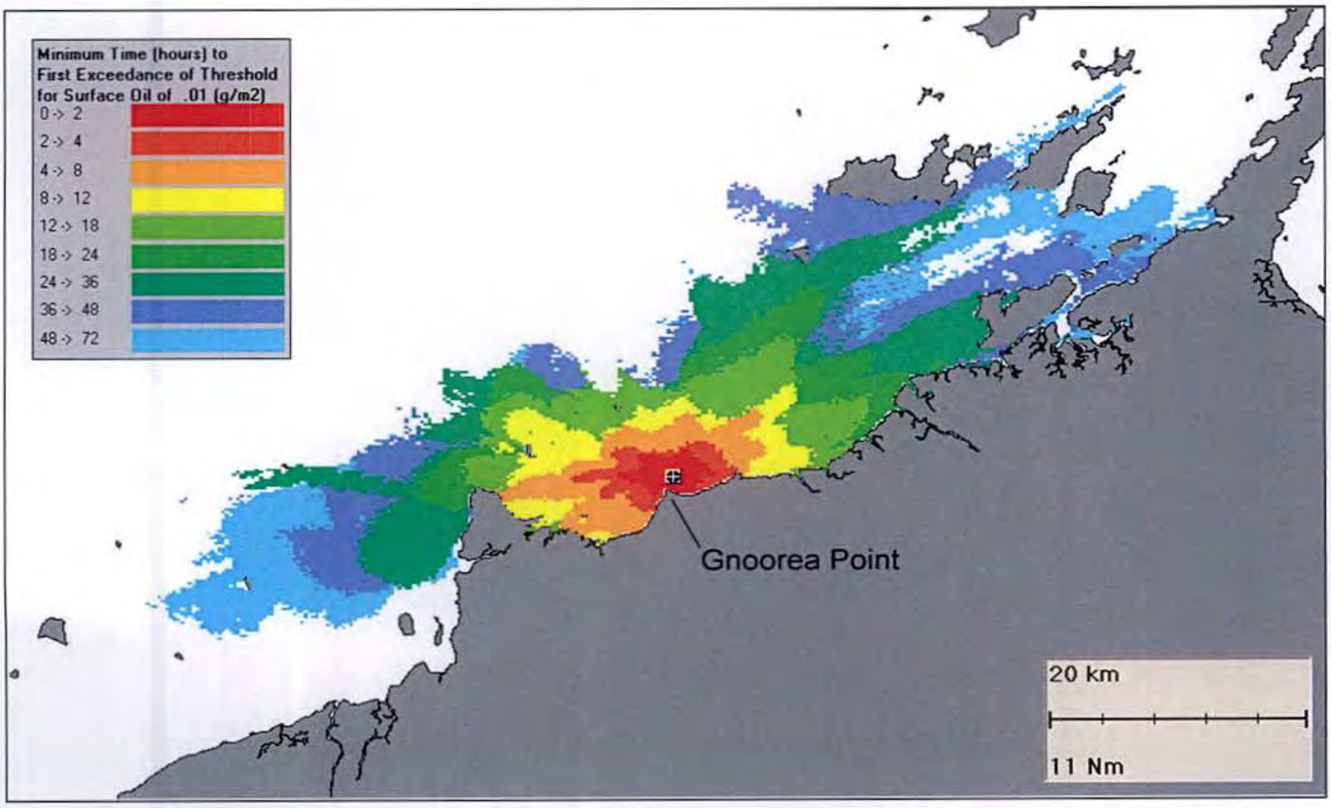

Figure 8.10 Minimum time of surface oil exceeding 0.01g/m^2 from surface spill 80 m^3 of diesel released over 12 hours from random locations around the HDD exit point (black circle).

Travel times for the slick to reach the shore were estimated to be as short as 2 hours; hence, diesel could arrive after relatively short weathering times for all spill scenarios. This is summarised in **Table 8.4**, along with the average volumes and the worst-case volumes of oil predicted to come ashore.

The highest likelihood of shore contact was predicted for Gnoorea Point and the adjacent shoreline. This area supports a range of intertidal habitats, including rocky shores, sandy beaches, mangroves and sand flats as described in **Section 5.2.3**. Slicks were also predicted to potentially reach the western half of the Dampier Archipelago or the western side of Cape Preston before dispersing and entraining to a thin rainbow sheen. In these areas, the highest volumes predicted to come ashore were a relatively small percentage of the initial spill volumes (less than 5%) based on the time taken to reach these areas and the greater degree of weathering.

Subsurface plumes can result from the entrainment of oil within the water column and can cause chemical and biological impacts, including lethal and sublethal impacts on marine organisms. Entrainment is expected to affect a variable proportion of any spill, depending upon the conditions and the size of the spill. The maximum proportion of diesel that was entrained during each simulation for each spill size is shown in **Figure 8.11**. This shows that an increasing proportion of oil is expected to be entrained when the simulated spill increases in size from 2.5 to 25 m³. This is because, for the larger spill, evaporation will account for a smaller volume in the time required for the slicks to enter the nearshore wave zone, and thus higher proportions of oil would be available for entrainment. Similar proportions were expected for the 25 and 80 m³ spill size. Stochastic modelling indicates that average concentrations of entrained diesel could reach up to 100 ppb at isolated spots along the inshore edge of Regnard Bay from the smallest spill scenario (**Figure 8.12**).The maximum instantaneous concentrations of entrained diesel for the 2.5 m³ scenario were up to 1,000 ppb, with most of Regnard Bay receiving over 100 ppb (**Figure 8.13**). For the two larger scenarios the average concentrations at 20 to 200 ppb (**Figures 8.14** and **8.16**) and the maximum instantaneous concentrations were predicted to peak at 20,000 ppb (**Figures 8.15** and **8.17**).

Disposal of Hydrotest Water. Following installation, the entire HDD section of the pipeline will be hydrotested by either filling with sea water with additives from an offshore source and discharging the hydrotest water onshore in the HDD water storage basin or by filling with borewater with additives from an onshore source and discharging to suitable offshore vessel ballast tanks for eventual onshore disposal. Regardless of the chosen method, no hydrotest water will be released into the nearshore marine environment. It is expected that 500 m³ of water will be used for the hydrotesting.

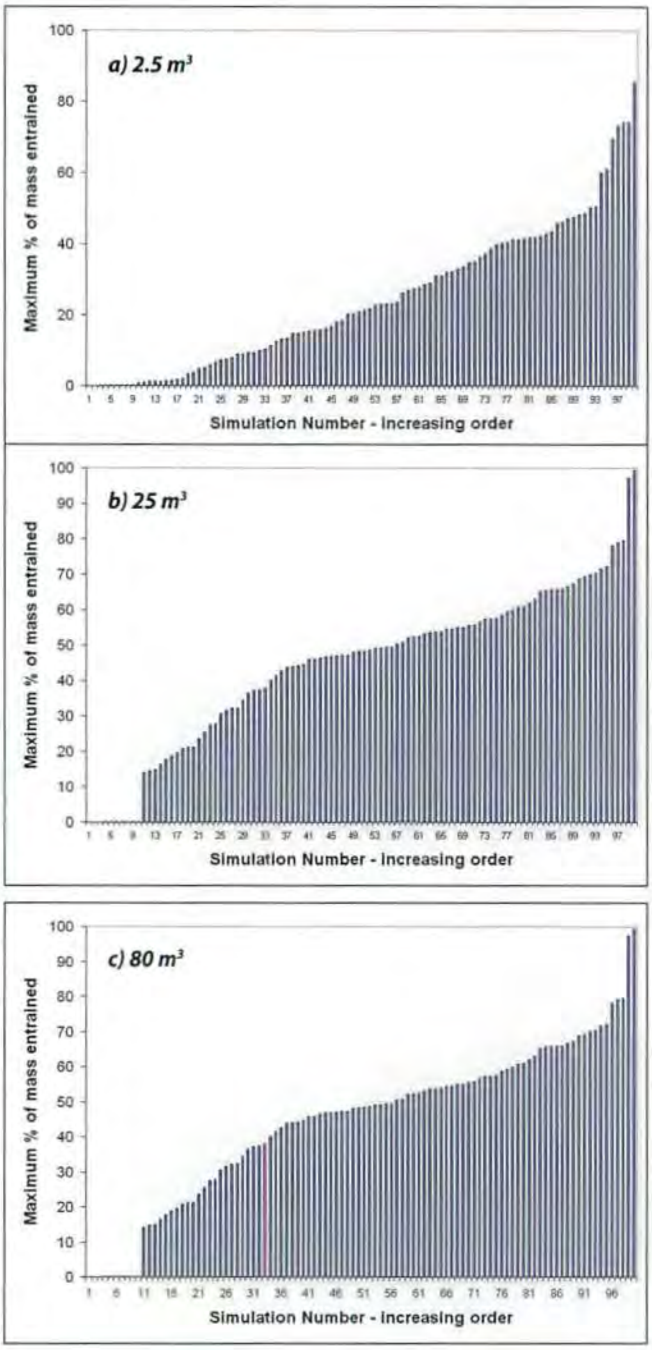

Figure 8.11 Maximum proportion of diesel that entrained during each simulation for each diesel spill size. Proportion values have been ranked in ascending order.

Diesel spill scenario	Peak probability of contact for any section (%)	Earliest time before contact (hours)	Average volume (L)	Worst-case volume (L)
2.5 m³	44	2	3	124
25 m³	64	2	366	1,204
80 m³	65	2	1,172	3,852

Source: APASA (2008b)

Table 8.4 Summary of stochastic modelling results for exposure by surface slicks (greater than 0.01 g/m²) on any section of shoreline for the three diesel spill scenarios.

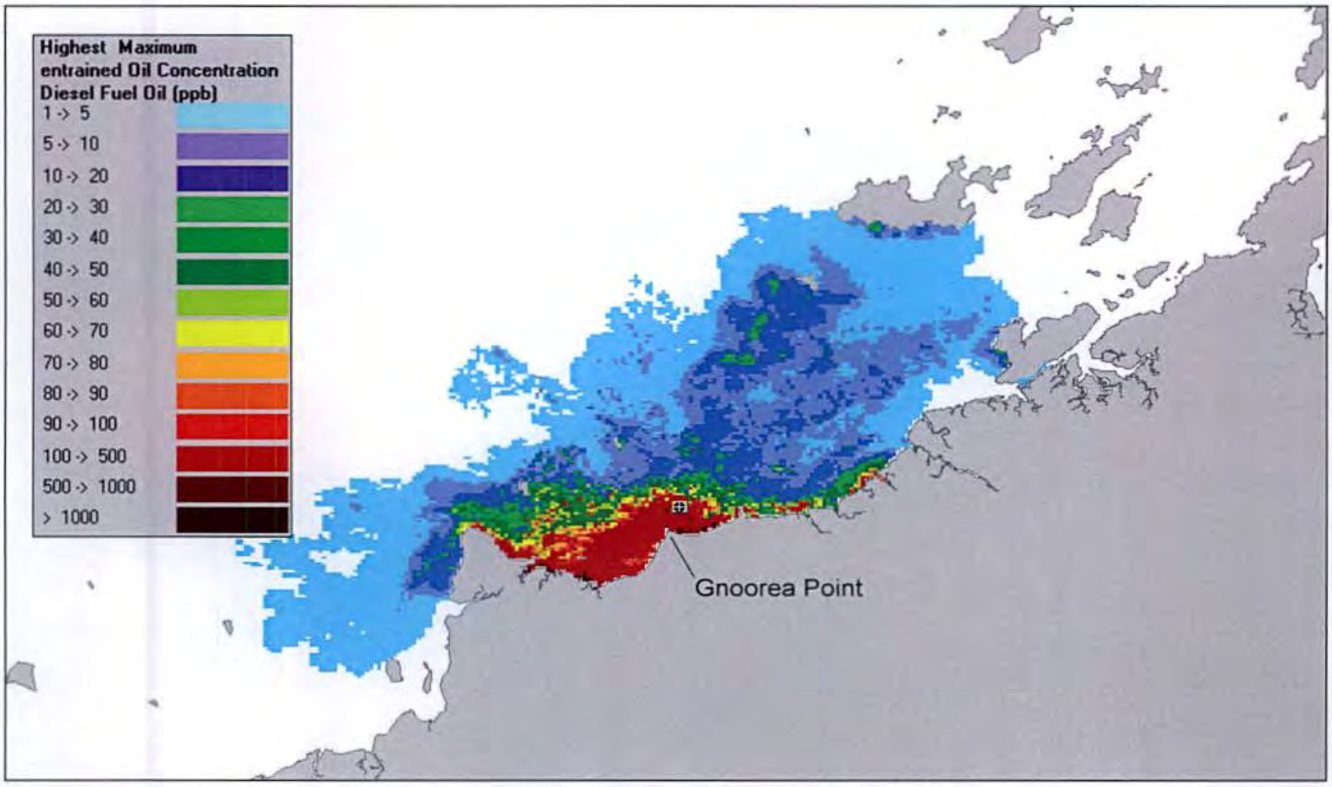

Figure 8.12 Average potential entrained diesel concentration for the 2.5 m^3 diesel spill scenario. Values are the highest instantaneous concentrations predicted at any time for each model cell, averaged among replicate simulations. Black circle with cross hairs indicates HDD exit point.

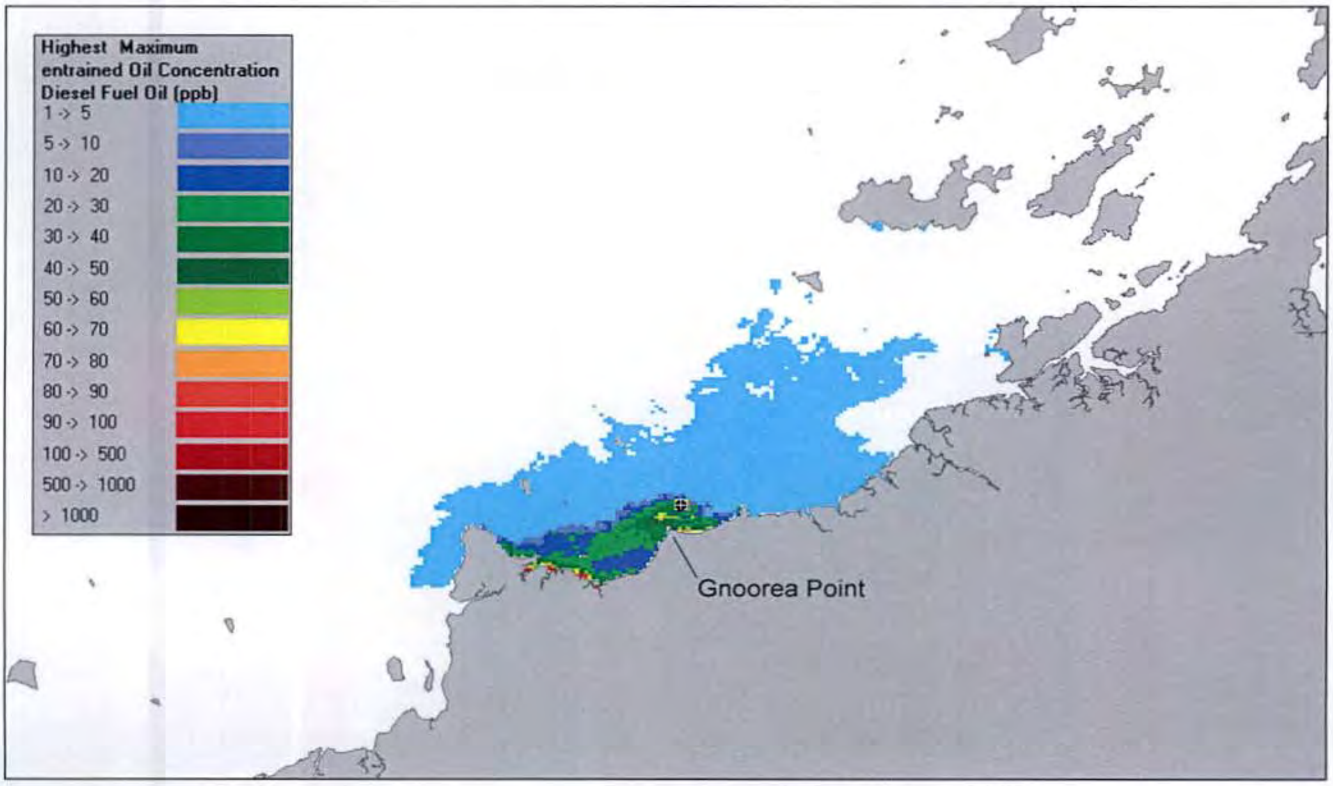

Figure 8.13 Maximum potential entrained diesel concentration for the 2.5 m^3 diesel spill scenario. Values are the highest instantaneous concentrations predicted at any time for each model cell during 100 simulations. Black circle with cross hairs indicates HDD exit point.

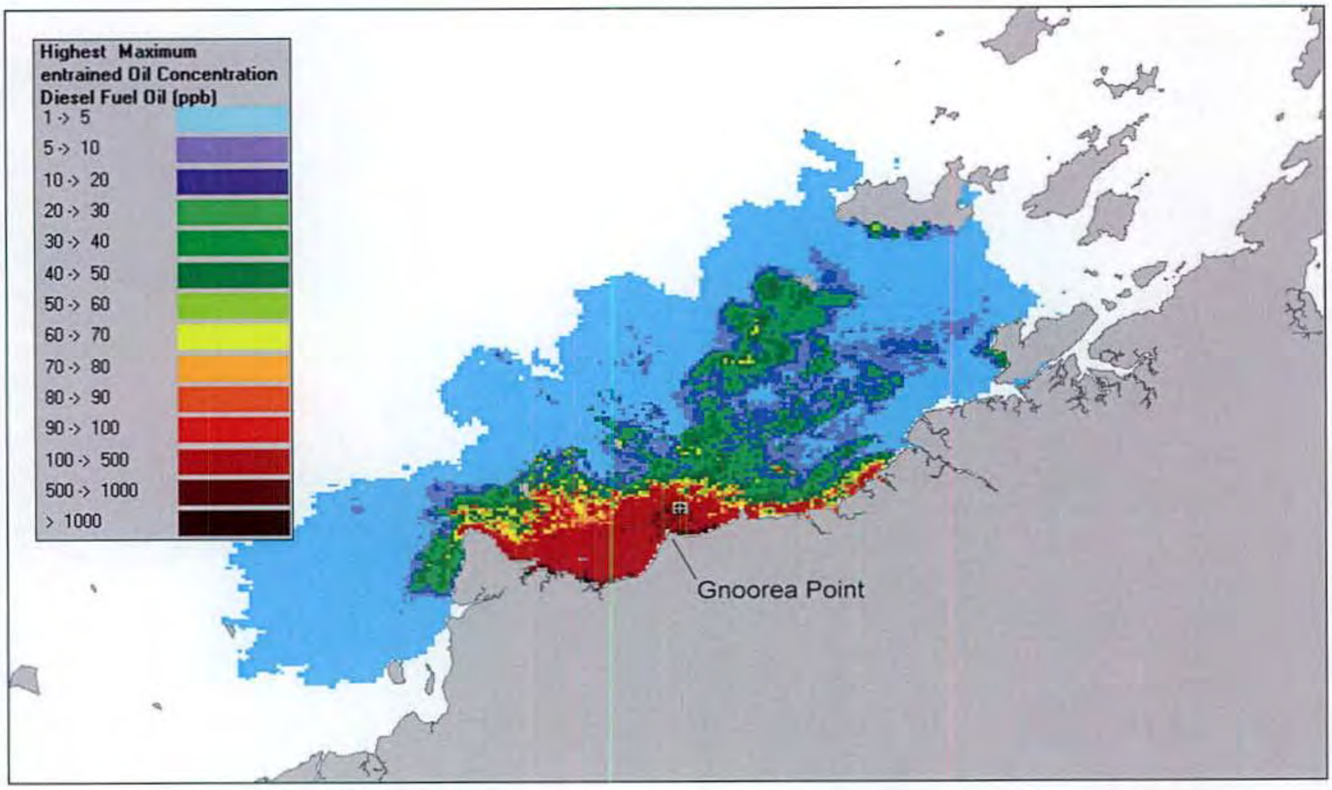

Figure 8.14 Average potential entrained diesel concentration for the 25 m³ diesel spill scenario. Values are the highest instantaneous concentrations predicted at any time for each model cell, averaged among replicate simulations. Black circle with cross hairs indicates HDD exit point.

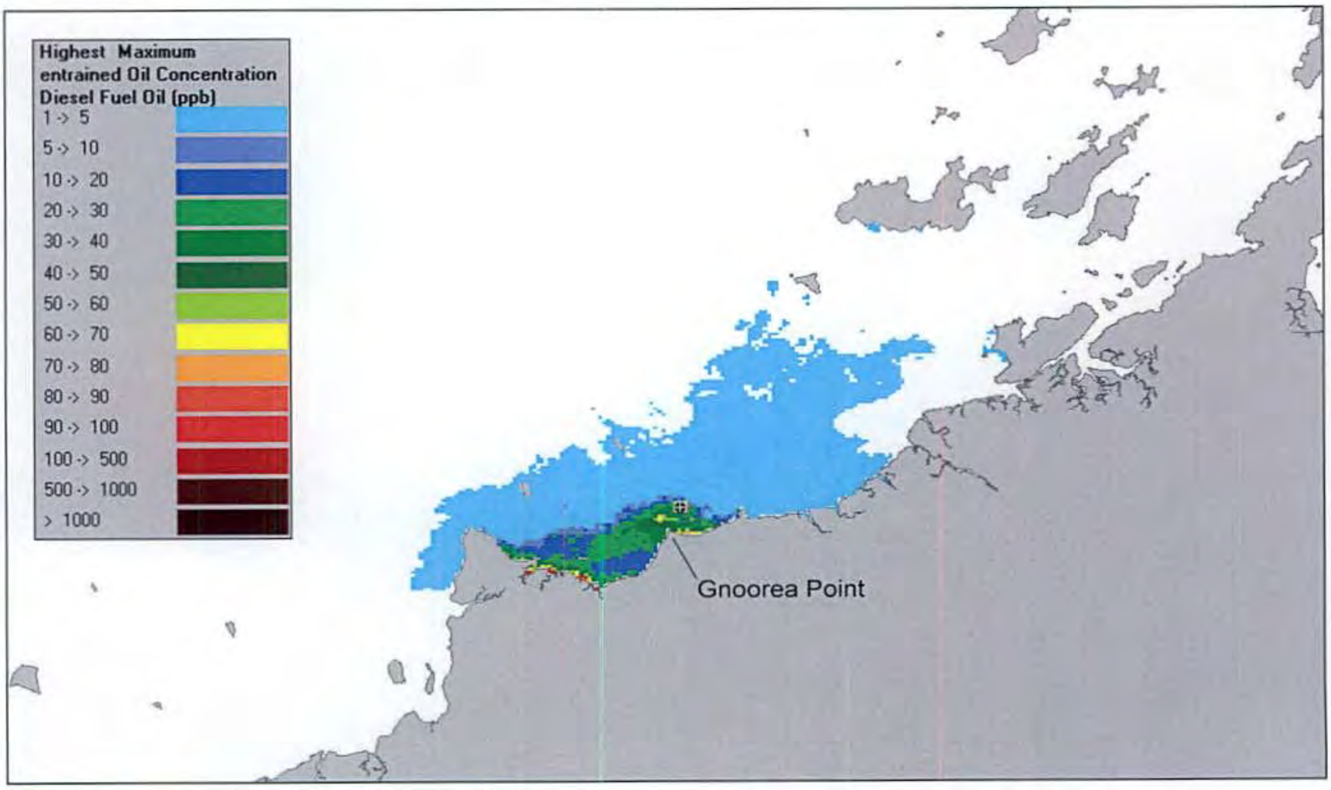

Figure 8.15 Maximum potential entrained diesel concentration for the 25 m³ diesel spill scenario. Values are the highest instantaneous concentrations predicted at any time for each model cell during 100 simulations. Black circle with cross hairs indicates HDD exit point.

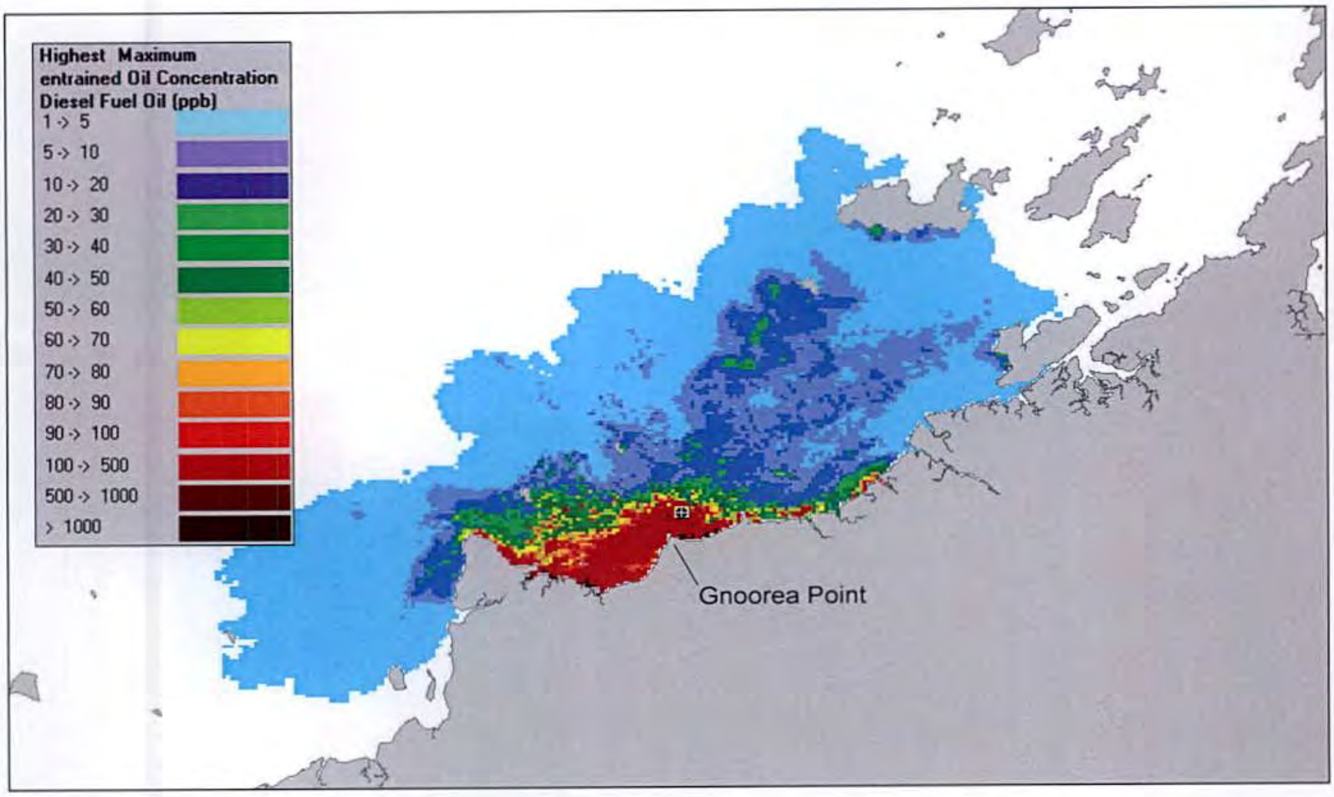

Figure 8.16 Average potential entrained diesel concentration at any location for the 80 m^3 diesel spill scenario. Values are the highest instantaneous concentrations predicted at any time for each model cell, averaged among replicate simulations. Black circle with cross hairs indicates HDD exit point.

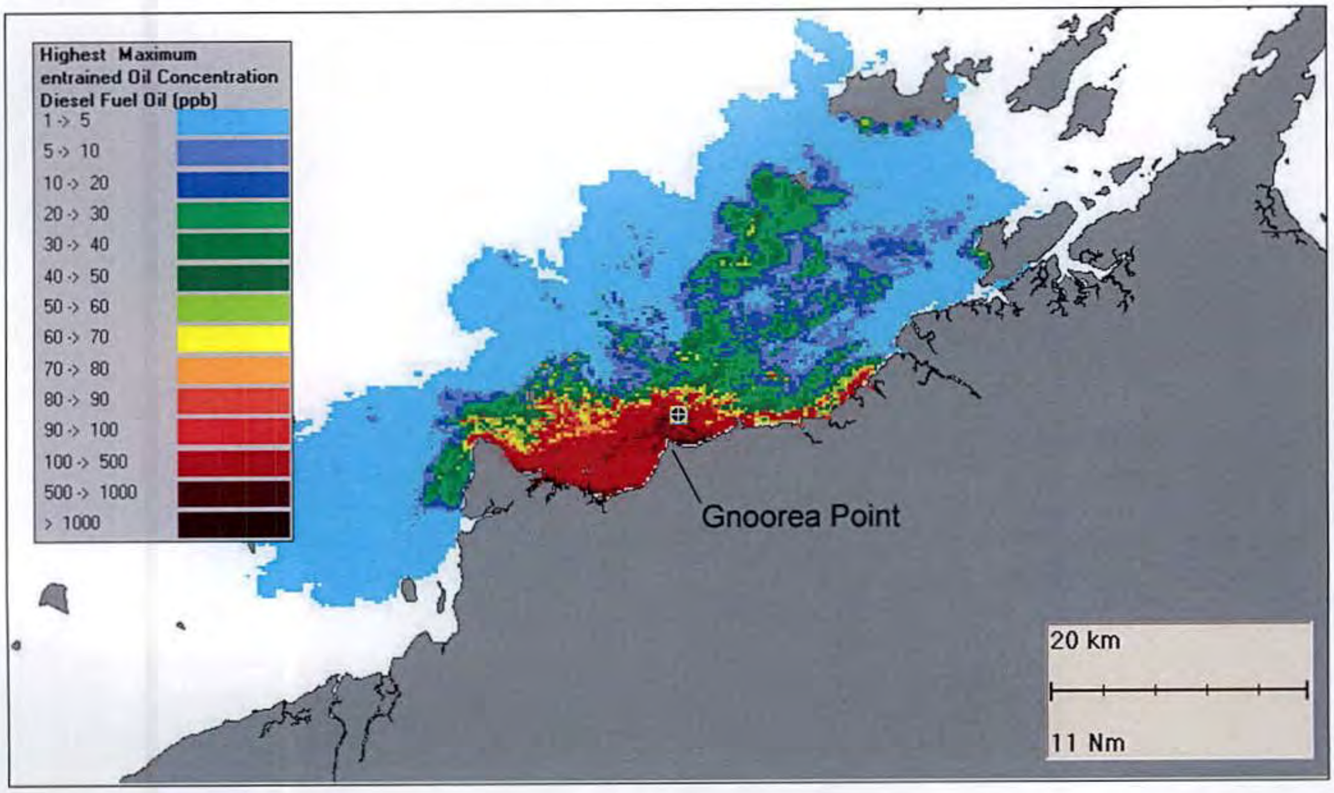

Figure 8.17 Maximum potential entrained diesel concentration at any location for the 80 m^3 diesel spill scenario. Values are the highest instantaneous concentrations predicted at any time for each model cell during 100 simulations Black circle with cross hairs indicates HDD exit point.

8.2.1.1 *Impacts*

The potential impacts of the hazards to water quality include:

- Elevated suspended sediment concentrations.
- Nutrient enrichment in receiving waters.
- Toxicity to marine biota.
- Hydrocarbon tainting of commercial fish species.
- Adverse impacts on visual amenity of area.

8.2.1.2 *Management*

The construction environmental management plan (CEMP) will include a number of measures to manage the impacts to water quality so that the management objective and long-term target of the Regnard Marine Management Area will be met. These measures are summarised in **Table 8.5**.

8.2.1.3 *Residual Risks*

Based upon the implementation of the above management measures, the residual risks to water quality for all of the identified hazards are ranked from "B" to "negligible", with the higher residual risks associated with drilling discharges from the HDD program and accidental release of diesel.

Compared to the no mitigation case, the planned case for the HDD program actually showed greater but short-lived values for suspended sediment concentrations near the discharge point (up to 60 mg/L above background for 1 to 2 hours). This was because the proportion of fine particles was greater due to more bentonite being used intermittently during some drilling operations in the planned case. As for the no mitigation case, variable plume directions were predicted; hence, individual locations away from the immediate discharge are unlikely to be constantly exposed to elevated turbidity or light reduction, and concentrations are expected to decrease fairly rapidly with distance due to settlement of coarser sediments (sand and larger-sized particles) and dispersal of fine sediments (clay and silt-sized particles). The suspended sediment concentration was not predicted to elevate above background within hours of the HDD discharge ceasing due to dispersal of the fines from the area. With the significantly shorter discharge period for the planned case (approximately 2 weeks compared to approximately 12 weeks for the no mitigation case), the suspended sediment dosage (i.e., concentration x time of exposure) would be much reduced compared to the no mitigation case.

The results of the numerical modelling for the fate and trajectory of HDD discharges indicates that, under the planned case, in which the volume of cuttings and fluids is reduced to as low as reasonably practicable, the residual risk to water quality was considered to be acceptable due to the localised and transient elevations in suspended sediment concentrations.

The potential risks from the accidental release of diesel from HDD support vessels into the marine environment was considered as having a moderate consequence for all three spill scenarios modelled; however, the likelihood of such events occurring was considered as highly unlikely given the proposed management measures, therefore, the residual risk of impacts to water quality is considered acceptable.

The risk to the marine environment from disposal of hydrotest water is negligible. In the unlikely event of a leak in the pipeline during hydrotesting, the volume discharged is unlikely to be of a sufficient quantity to cause impacts to water quality. The impact in the event of a unplanned release of hydrotest water will be minimised by selecting low-toxicity chemical additives and ensuring that the concentration of these chemicals within the hydrotest water is ALARP without compromising the integrity of the testing.

8.2.2 Geology and Geomorphology

Key hazards that have the potential to impact geology and geomorphology in the DCDP area include:

- Modifications to the seabed around the HDD exit point either through jetting away loose sediments and exposing hard substrate or by placement of grout bags under the pipeline for support. These modifications may be temporary (jetting away sediments) or more permanent (placement of grout bags).
- Discharges associated with the HDD program in the form of deposited sediments over the seabed.

The management objectives for geomorphology as stated in the Draft Management Plan for the Dampier Archipelago Marine Park and Regnard Marine Management Area is to ensure that the structural complexity of the geomorphology is not significantly reduced by human activities and that coastal landforms are not degraded by access and use. The long-term target for unzoned areas within the Marine Management Area is "maintained in a natural state, except for areas where some level of acceptable change is approved by the appropriate government regulatory authority".

Numerical Modelling of Sedimentation Concentrations from HDD. The following predictions of sedimentation concentrations from HDD discharges were derived from numerical modelling of the three HDD cases described in **Table 8.1**.

In general, the concentration estimates for suspended sediments indicated that the clay and silt-sized particles would contribute less than 1 mg/L to background suspended sediment concentrations once they had left the immediate discharge area, and there was no evidence of accumulation of these size classes in relatively calm or deeper depressions in the bathymetry. In contrast, particles in the fine sand and larger classes were predicted to settle quickly and resist resuspension and hence to accumulate around the discharge point.

The clay and silt-sized particles tended to remain suspended during the simulations or else to be quickly resuspended after periods of short-term (hours) settlement during periods of calm environmental conditions (e.g., neap tides, calm seas). These particle sizes were

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Water Quality	Seabed disturbance	*Modification to seabed at HDD exit point (see Table 8.2).*	Localised and temporary elevation in suspended sediment concentrations. Localised and temporary impacts on visual amenity.	• Required for span correction of pipeline at HDD exit. • Modifications to the seabed will only occur after the HDD exit hole is made, thereby restricting the disturbed area to that which is necessary given the specific conditions at the exit point.
	HDD discharges	*Cuttings and drilling fluids discharged during drilling.*	Elevated suspended sediment concentrations, quantified in Section 8.2.2. Toxicity to marine biota. Adverse impacts on visual amenity.	• Planned case for HDD with delay in punch out selected on basis of reducing volume of discharge to as low as reasonably practicable (ALARP). • Bentonite, a low toxicity drilling fluid, will be used. • Solids separation equipment will be functioning to maximise the volume of drilling fluid removed from cuttings.
	Support vessel discharge – domestic waste	*Support vessel use during HDD operations.*	Toxicity to marine biota. Nutrient enrichment in receiving waters.	• No domestic wastes will be disposed of in the nearshore marine environment in which the HDD activities are to take place. • Vessel wastes will be either brought to shore or disposed of in deeper waters in accordance with the legislative requirements and MARPOL and AMSA regulations. • CEMP documents waste management practices that will be implemented during all phases of the proposed works, including on support vessels during the HDD operations, by Apache and its appointed contractors. • All domestic waste will be stored in clearly marked skips, and waste containers will be provided on all vessels.
	Support vessel discharge – deck drainage	*Support vessel use during HDD operations.*	Physical impacts of hydrocarbons to marine habitat and organisms. Toxicity to marine biota.	• Areas on vessels where hazardous materials will be stored, including fuels, oils and lubricants, will be bunded, and drainage from these areas will be directed to a sump (or similar) that is connected to an oily water separator or containment tank for disposal onshore. • Scupper plugs will be fitted at drainage points to prevent discharge of deck wash into the marine environment. These will only be removed before or during heavy rain storms to prevent the deck flooding. • No contaminated waste will be intentionally discharged via deck washdown. • Contaminated drainage will be contained and diverted to the slops tank or sump or will be mopped up to prevent overboard discharge. • Vessels will have absorbent booms and clean-up materials readily available so that any spill on deck can be rapidly contained. • Drip trays will be used to capture oily material. • Routine maintenance and monitoring of vessels and equipment will allow for early detection of leaks, minimising the potential for discharge of hydraulic oils and other hydrocarbons and ensuring a quick response to repair leaks and clean up spills.
	Support vessel discharge - diesel spills	*Support vessel use during HDD operations.*	Physical impacts of hydrocarbons to marine habitat and organisms. Toxicity to marine biota.	• Apache's bunkering management procedures will be followed. • No vessel-to-vessel refuelling will occur in shallow waters. • Compliance with the legislative requirements and MARPOL and AMSA regulations. • Oil Spill Contingency Plan (OSCP) and Shipboard Oil Pollution Emergency Plan (SOPEP) to be developed and implemented. These plans will: – Ensure effective and timely management of spills of hydrocarbons. – Describe the procedures to deal with an oil spill. – Define the roles and responsibilities of response personnel. – Describe the external resources available for use in combating oil spills and how these resources will be coordinated. – Be integrated with State and Commonwealth government and industry response plans.
	Hydrotest water	*Hydrotesting of onshore and offshore pipeline.*	Toxicity to marine biota.	• No planned discharge will be made to the nearshore marine environment. • Low-toxicity chemical additives will be selected for the hydrotesting and will be used in concentrations that are ALARP without compromising the integrity of the testing.

Table 8.5 Summary of management measures for water quality.

predicted to disperse across the seabed over distances of 10 to 20 km, rather than to accumulate in particular areas. The model indicated that these particles would tend to migrate towards Mermaid Sound during the March to April period and then migrate southward along the coastal margin to Cape Preston and beyond during the May to June period.

More specific predictions for each HDD case are given below.

Planned Case:

- **Figure 8.18** shows a sequence of the predicted sedimentation patterns for the planned case over a 6-week period with 2 weeks of discharge and 4 weeks post-discharge. Localised sedimentation was predicted for particles larger than clay and silt. The main sedimentation footprint (deposition greater than 1 mg/cm^2) around the discharge point was predicted to grow slowly but then undergo expansion of the lighter margin at a number of points in time. These periods corresponded to periods of increased wave action and to the peaks in suspended sediment concentrations, indicating that the levels of wave action predicted for the location would periodically cause resuspension of the deposits around the exit point but that this heavier material would tend to only shift locally during each event.
- The maximum bottom deposition within 50 m of the discharge point along the southeast tidal axis was predicted to be in the order of 400 mg/cm^2 (approximately 11 mm thickness, area averaged over 25 x 25 m grid cell) (**Figure 8.19**). At 400 m along this axis, the bottom deposition was less than 10 mg/cm^2 (less than 1 mm thickness), indicating that only a minor part of the discharged sediments would reach that far from the discharge point.

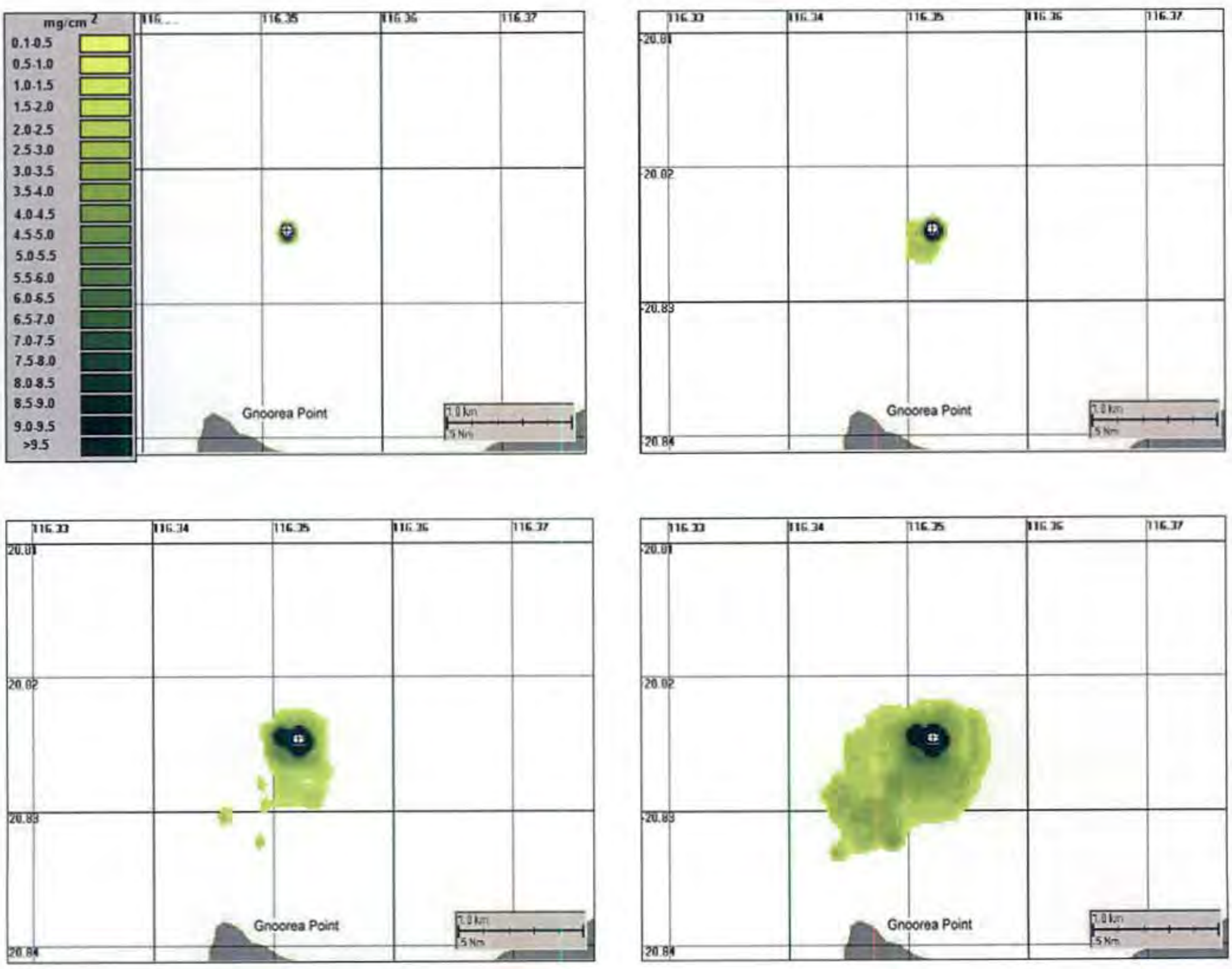

Figure 8.18 Time sequence of predictions of the cumulative deposition of cuttings (mg/cm^2) around the discharge from the HDD Planned Case covering 2 weeks of discharge and 4 weeks post-discharge. White circle with cross hairs indicates HDD exit point.

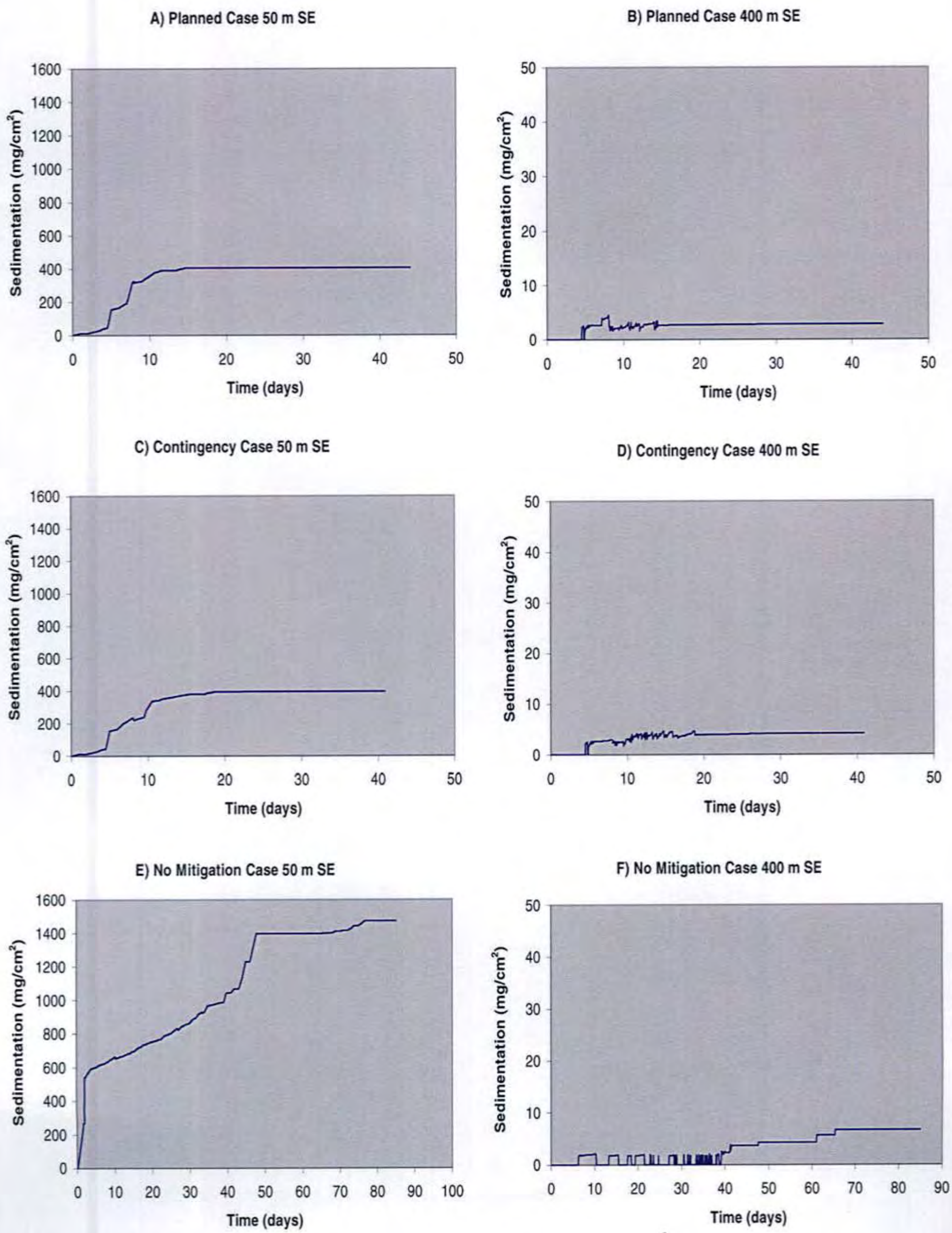

Figure 8.19 Sedimentation concentrations (mg/cm²) through time at 50 m and 400 m to the south east of the HDD discharge location for 3 cases for HDD program.

Contingency Case:

- **Figure 8.20** shows a sequence of the predicted sedimentation patterns for the contingency case over a 6-week period with 3 weeks of discharge and 3 weeks post-discharge. Localised sedimentation near the source of discharge was predicted for particles larger than clay and silt. As for the planned case, the main sedimentation footprint around the discharge point was predicted to grow and undergo expansion of the lighter margin at a number of points in time. These periods corresponded to periods of increased wave action; hence, resuspension of some of the previously deposited sediment was most likely the cause.
- Deposition loads near the centre of the sedimentation pile were predicted to reach levels up to 400 mg/cm^2 (approximately 11 mm thickness) (**Figure 8.19**). Maximum levels of bottom deposition within 400 m from the discharge point were less than 10 mg/cm^2 (**Figure 8.19**), indicating that only a minor part of the discharged sediments would reach that far from the discharge point.

No Mitigation Case:

- **Figure 8.21** shows a sequence of the predicted sedimentation patterns for the no mitigation case over a 14-week period with 12 weeks of discharge and 2 weeks post-discharge.
- Deposition loads near the centre of the sedimentation pile were predicted to reach levels of up to 1,400 to 1,600 mg/cm^2 (approximately 20 mm thickness) (**Figure 8.19**). Concentrations at 400 m were predicted to remain near zero until the passage of one of the larger resuspension events, at which time concentrations peaked at around 7 mg/cm^2.

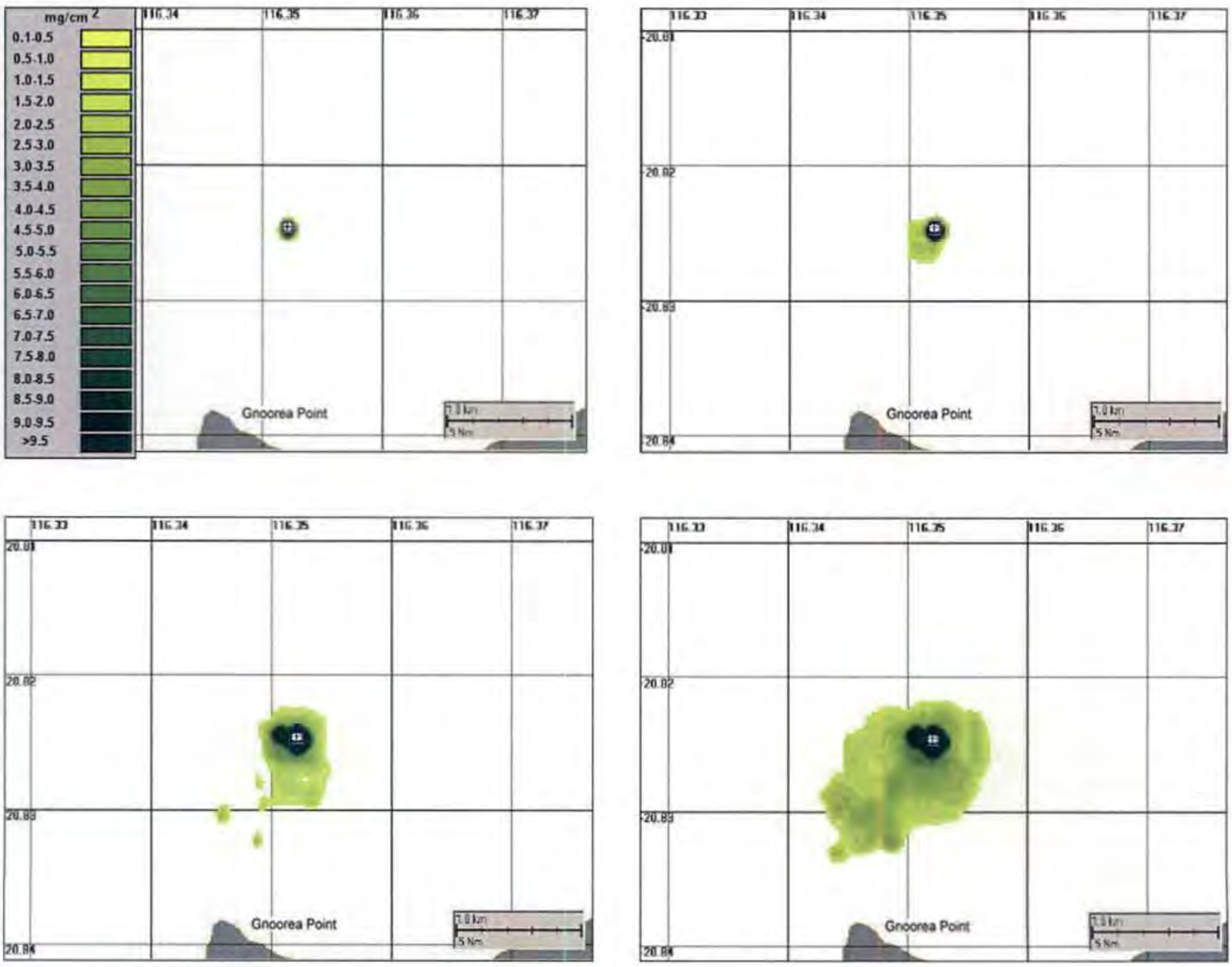

Figure 8.20 Time sequence of predictions of the cumulative deposition of cuttings (mg/cm^2) around the discharge from the HDD Contingency Case covering 3 weeks of discharge and 3 weeks post-discharge. White circle with cross hairs indicates HDD exit point.

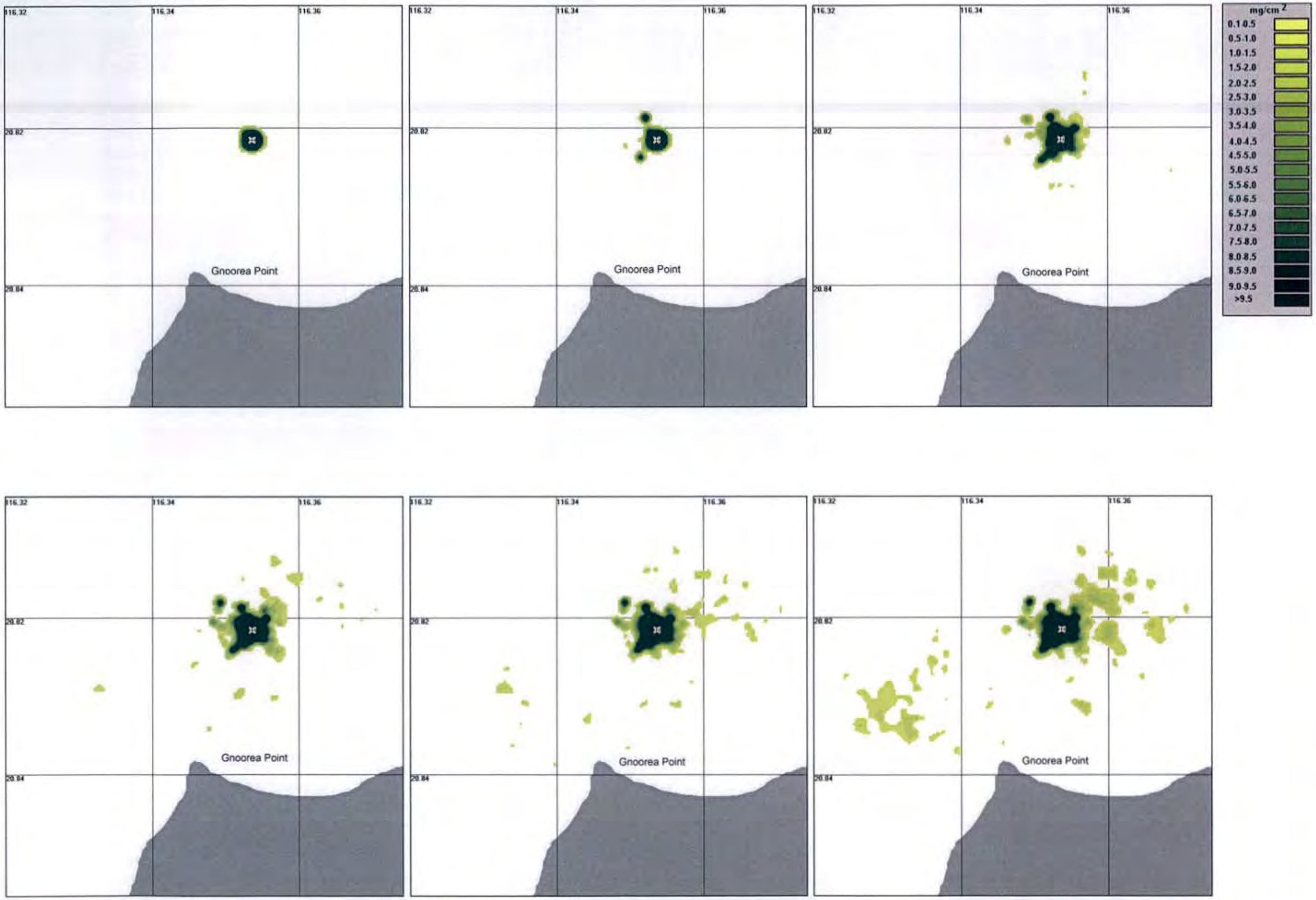

Figure 8.21 Time sequence of predictions of the cumulative deposition of cuttings (mg/cm^2) around the discharge from the HDD No Mitigation Case covering 12 weeks of discharge and 2 weeks post-discharge. White circle with cross hairs indicates HDD exit point.

8.2.2.1 Impacts

The potential impacts of the hazards to geology and geomorphology include:

- Disturbance to key seabed features.
- Localised alteration of seabed morphology through sediment deposition or physical damage.

8.2.2.2 Management

The CEMP will include a number of measures to manage the impacts to geology and geomorphology so that the management objectives and long-term target of the Regnard Marine Management Area will be met. These measures are summarised in **Table 8.6**.

8.2.2.3 Residual Risks

Based upon the implementation of the above management measures, the residual risks to geology and geomorphology for all of the identified hazards is ranked from "B" to "negligible", with the higher residual risks associated with drilling activity of the HDD program.

For all three HDD cases, numerical modelling indicated that bentonite and finer cuttings particles would be effectively dispersed by the ambient currents and wave action over distances of tens of kilometres and hence would not remain settled locally. Simulations indicated that sand and larger particles would settle around the discharge point and accumulate; however, there would be reworking of these particles occasionally by more energetic combinations of wave and current energy. The effect of these relatively short-lived events would be a progressive spread of the fringe of the accumulations onto adjacent areas. These fringe deposits tended to be of low concentration and thickness and also tended to be slowly eroded by ongoing resuspension.

The results of the numerical modelling for the fate and trajectory of HDD discharges indicate that, under the planned case, in which the volume of cuttings and fluids is reduced to as low as reasonably practicable, the residual risk to geology and geomorphology was considered to be acceptable due to the localised and transient elevations in sedimentation concentrations.

8.3 MARINE ECOLOGICAL IMPACTS

The construction, operation and physical presence of the DCDP may potentially result in environmental impacts to:

- Benthic primary producers and their habitats:
  - Seagrasses and macroalgae.
  - Corals.
  - Mangroves.
  - Soft sediments.
- Marine fauna:
  - Sea turtles.
  - Marine mammals.
  - Shorebirds and seabirds.
  - Invertebrates and fish.

8.3.1 Benthic Primary Producers

Benthic primary producers are predominantly marine plants (seagrasses, mangroves, macroalgae and turf algae) but also include corals, while benthic primary producer habitats can be considered as both the benthic primary producer communities and the substratum that supports these communities (EPA, 2004a). These have been described previously in **Section 5.3.1**.

Key hazards that have the potential to impact benthic primary producers in the vicinity of the DCDP include:

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Geology and geomorphology	Seabed disturbance	*Modification to seabed at HDD exit point (see Table 8.2).* *Support vessel anchoring.*	Disturbance to seabed features. Localised alteration of seabed morphology through sediment deposition.	• Required for span correction of pipeline at HDD exit point. • Modifications to the seabed will only occur after the HDD exit hole is made, thereby restricting the disturbed area to that which is necessary given the specific conditions at the exit location. • The HDD exit point and anchoring positions have been sited to avoid significant seabed features. • The location coordinates of significant seabed features are entered into the survey systems for barge and anchor-handling support vessels. • Installation and support vessels will use Apache's shallow-water anchoring procedure.
	HDD discharges	*Cuttings and drilling fluids discharged during drilling.*	Localised alteration of seabed morphology through sediment deposition.	• Planned case for HDD with delay in punch out selected on the basis of reducing volume of discharge to ALARP. • Bentonite, a low-toxicity drilling fluid, will be used. • Solids separation equipment will be functioning to maximise the volume of drilling fluid removed from cuttings.

Table 8.6 Summary of management measures for geology and geomorphology.

- Modifications to the seabed around the HDD exit point either through jetting away loose sediments and exposing hard substrate or by placement of grout bags under the pipeline for support. These modifications may be temporary (jetting away sediments) or more permanent (placement of grout bags) (see **Table 8.2**).
- Discharges associated with the HDD program in the form of suspended sediment and sedimentation concentrations above background levels.
- Support vessel discharges, including accidental release of diesel.
- Disposal of hydrotest water.

The management objective stated in the Draft Management Plan for the Dampier Archipelago Marine Park and Regnard Marine Management Area for benthic primary producers (identified as coral reef communities, mangrove communities, macroalgal and seagrass communities, subtidal soft-bottom communities, intertidal sand and mudflat communities and rocky shore communities) is to ensure diversity, biomass and abundance of species is not significantly impacted by human activities (physical disturbance, fishing, trampling). The long-term target for unzoned areas within the Marine Management Area is "maintained in a natural state, except for areas where some level of acceptable change is approved by the appropriate government regulatory authority".

Effects of Turbidity and Sedimentation. Background information is provided here on the effects of turbidity (suspended sediments) and sedimentation on benthic primary producers to provide sufficient context for the assessment of the potential impacts of the discharges associated with the HDD program. The key components of the assessment are consistent with the guidance provided by the EPA (2004a) for the protection of benthic primary producer habitat in Western Australia and consist of:

- Identification and mapping of marine benthic primary producer habitat (**Section 5.3.1**).
- Definition of threshold values for suspended sediment concentrations and sedimentation rates for benthic primary producers (this section).
- Definition of marine management units for benthic primary producers (this section).
- Identification of zones of potential impact, effect and influence for benthic primary producers (this section).
- Quantification of potential loss of benthic primary producers using cumulative loss thresholds (this section).

RPS Environment Pty Ltd carried out the assessment of the impacts from the DCDP HDD program to marine benthic primary producers (RPS 2008b), the results of which are summarised here.

Effects of Turbidity and Sedimentation on Seagrass. Seagrass is dependent upon sufficient available light for its survival. The minimum light requirements of seagrasses are much higher than those of other plants: 10% to 20% of incident light at the sea surface (Duarte, 1991), compared with 0.5% to 2% for terrestrial plants (Dennison et al., 1993). Therefore, light availability is often the major limiting factor for seagrasses, with a small reduction in light penetration through the water column reducing the depth range, and hence area, of seagrass (Longstaff & Dennison, 1999; Preen & Marsh, 1995).

Major seagrass losses have been known to occur after cyclones due to a combination of reduced light penetration due to high suspended sediment loads, burying of plants and seeds, and scouring of the seafloor (Preen & Marsh, 1995). Pulsed turbidity events, such as occur after cyclones, can be highly destructive to seagrass meadows, with recovery rates depending on the species effected. However, seagrasses are also able to tolerate periods of naturally high turbidity and can withstand some increase in the frequency of turbid events (EPA, 2001b). Cyclone Vance in March 1999 reduced the average seagrass cover in Exmouth Gulf in Western Australia to 0.15% of pre-cyclone standing biomass, with 70% of surveyed sites being completely denuded. By November 2000, seagrass cover had increased to 10.3%, and recovery was attributed to the early colonising species *Halodule uninervis* and *Halophila ovalis*. By December 2001, the seagrass meadows had shown a remarkable recovery to 41.9% cover, together with a shift toward dominance by *Halophila spinulosa*, *Cymodocea serrulata* and *Syringodium isoetifolium* (Kenyon et al., 2002).

Seagrasses vary widely in their tolerance to light deprivation, with some species showing a low tolerance while other species can survive for many months in conditions below their minimum light requirements (Duarte, 1991; Longstaff & Dennison, 1999). A light deprivation experiment found that *Halophila ovalis*, a common species at Gnoorea Point, was able to survive for 1 month deprived of light compared to 5 months in other genera (Longstaff & Dennison, 1999). Other studies report *Halophila* species to be comparatively low-light tolerant (Duarte, 1991; Vermaat et al., 1996). Some seagrass species, including *Halophila*, are able to adapt to low-light conditions by increasing their leaf length and effective surface area to receive light (McLennan & Sumpton, 2005).

The ability of seagrass species to tolerate sedimentation is also variable. This may be partly due to growth form, with lineolate species, such as *Cymodocea*, *Halodule* and *Thalassia*, able to respond to burial by vertical elongation of the leaves. In contrast, species with ellipsoid leaves, such as *Halophila*, may not be able to respond to the same degree, with only minor elongation possible (Vermaat et al., 1996). Horizontal rhizome growth can also be used to keep the leaves above the sediment, with faster growth in smaller, short-lived species (for review, see Vermaat et al., 1996). The distribution, abundance and composition of seagrass in an area may therefore be in part a function of the long-term trends in light availability and the ability of individual species to survive pulsed turbidity events (changes in light and sediment loads) (Longstaff & Dennison, 1999), in addition to such other factors as depth, exposure and epiphyte loads.

Increases in suspended sediment in marine waters from runoff during rain events, from wave action or from anthropogenic causes (such as drilling or dredging activities) reduce light penetration through the water column. The quantity of suspended sediment or drill cuttings and the duration of suspension (pulsed or long-term effect) will determine the effect on the seagrass meadows. The seagrass meadows at Gnoorea Point are exposed to conditions typical of this region, including turbid waters associated with the tide and wind-driven currents and seasonal cyclone events. Consequently, the seagrass in this region is expected to be naturally highly ephemeral in response to seasonal changes in turbidity, with distribution and abundance influenced by adequate light penetration.

The majority of seagrass meadows at Gnoorea Point are in water less than 5 m deep (RPS, 2008), a distribution that suggests restricted light penetration due to turbid water. The dominant seagrass in this area was *Halophila ovalis*, which, in addition to tolerating light deprivation (Longstaff & Dennison, 1999), is known to recover rapidly after large-scale disturbances (Kenyon et al., 2002). The long-term survival strategy of this species appears to be very successful natural recovery after disturbances via rapid regrowth from seed or vegetative fragments (McLennan & Sumpton, 2005; Kenworthy, 1992, cited in Longstaff & Dennison, 1999; Vermaat et al., 1996).

In general, sedimentation rates of 2 to 13 cm per year can be tolerated by species with vertical stem elongation, while species with fast growth rates, such as *Halophila*, may be able to tolerate less than 5 cm of sedimentation over a period less than 2 months (Vermaat et al., 1996). To ensure seagrass survival, an increase in turbidity by a factor of five above background levels in waters over seagrass was used as a trigger value by the EPA in Victoria during dredging operations in Geelong (EPA, 2001b).

Effects of Turbidity and Sedimentation on Macroalgae. Macroalgal community structure and productivity is determined by a complex of biotic and abiotic factors, including wave energy, substrate type, topography, nutrient availability, temperature, light attenuation, depth, competition for space and herbivory (Hurd, 2000). In addition to natural factors, anthropogenic influences (including dredging, construction of marinas and port facilities, spoil dumping, sewage disposal, stormwater discharge and land reclamation) are likely to impact on coastal systems and thereby impact on algal communities (Cheshire & Westphalen, 2000).

Differences in reproduction, growth and morphology, as well as the timing of disturbance events in relation to algal reproduction and recruitment, influence the way in which algal species respond to environmental changes (Benedetti-Cecchi et al., 2001; Cheshire & Westphalen, 2000). Phaeophyte communities appear to be similar to seagrass in terms of their response to sediment and turbidity loadings, with losses under severe conditions (Cheshire et al., 1998) and branch elongation and increased branching as an adaptation to low-light conditions (Monro & Poore, 2005).

Several studies have considered the effect of sedimentation on macroalgal communities and have concluded that the main impact is on algal recruitment, particularly of the larger brown macroalgae (for review, see Cheshire & Westphalen, 2000). In a study of recruitment of the brown macroalgae on reefs off the Adelaide coast, Cheshire et al. (1999) concluded that the low rates of recruitment at reefs that were in close proximity to recent dredging operations were due to heavy sediment loads. The macroalgae at Gnoorea Point are well adapted to turbid waters, and the scale of the sediment loads from the HDD program. is expected to be much smaller than that of dredging, resulting in very little effect on macroalgal recruitment.

Sedimentation is also thought to reduce macroalgal productivity either by smothering algal fronds or through increased turbidity in the water column (Cheshire et al., 1999). Lower productivity may reduce levels of stored carbohydrate and result in a decline in reproductive output. High levels of sedimentation also adversely affect the sessile marine invertebrates associated with algal communities and may lead to changes in community structure (Cheshire & Westphalen, 2000).

Turfing algae are thought to both tolerate and promote sedimentation (Kendrick, 1991), and high turf cover may be indicative of heavy sediment loads. Apart from trapping sediment, turf algae may also restrict the recruitment of large, canopy-forming macroalgae. An absence of larger algae and dominance by turf algae may indicate a disturbed ecosystem (Benedetti-Cecchi et al., 2001; Oigman-Pszczol et al., 2004) or one adapted to high sedimentation.

Smothering of turfing algae by large sediment loads may result in a subsequent reduction of herbivorous fish species, which prefer the turf-forming algae over large fleshy brown algae (McClanahan et al., 1999). Conversely, a loss of larger macroalgae will result in a reduction in available habitat for invertebrates, which shelter under the canopy, and a loss of fish species that feed extensively on invertebrates (McClanahan et al., 1999). Loss of large macroalgae may also result in an increase in macroalgal diversity, with a shift to turf-dominated communities (Toohey et al., 2007). Changes in the composition of the associated faunal communities are also likely to result in a change in the trophic structure of these systems. Such changes are likely to effect the recovery of these systems.

Effects of Turbidity and Sedimentation on Corals. Sedimentation and turbidity are major causes of degradation of scleractinian corals (Rogers, 1983; Cortés & Risk, 1985; Pastorok & Bilyard, 1985; Hodgson, 1990). However, the extent and severity of the impact is highly variable and depends on a range of factors, including the coral species affected, suspended sediment concentration, sediment grain size, water depth, water temperature and the length of time the disturbance occurs (Rogers, 1990). Coral assemblages persist in areas subject to periods of high natural turbidity and sedimentation, for example, pulsed events that occur during cyclones and river floods in the Dampier Archipelago. These events expose corals to high concentrations of total suspended solids (TSS) and high sedimentation rates for short periods of time. Coastal coral reefs can flourish in relatively turbid water with high levels of particulate matter; however, they tend to be restricted to less than 10 m water depth (Fabricius, 2005).

Generally, the species composition of coral communities in turbid areas is different to the composition of clear water communities. Turbid water communities may be more species-rich than clear water communities (Blakeway & Radford, 2005), but the colonies are generally less well developed. Taxa resilient to turbidity and sedimentation dominate in these areas, and the coral assemblage can survive the short-term impacts. However, in certain cases, such events can also cause mass mortality of corals, and some coral reefs do not recover but shift to macroalgae-dominated reefs, particularly if recruitment of corals is affected.

Corals in turbid areas with large tidal range, such as the Dampier Archipelago, are generally only exposed to high turbidity for part of the tidal cycle. Flood tides carrying clean, offshore water into coral areas flush out the particulate material resuspended near the coast, thus reducing turbidity. The periods between short episodes of high turbidity (acute disturbance) allow the corals to recover sufficiently to maintain positive energy budgets. During large perturbations, such as cyclones or large-scale dredging programs, the corals are exposed to extended periods of consistently high turbidity and sedimentation (chronic disturbance). It is during these periods of persistent low light and sedimentation load that corals are more likely to die. Coral assemblages on Heron Island in Queensland and other Indo-Pacific reefs usually recovered from acute disturbances but did not recover from chronic disturbances (Connell et al., 1997).

Many corals can adjust to low-light conditions within a period of 5 to 10 days by increasing the size and amount of chloroplasts in zooxanthellae, a process known as photoacclimation (Fabricius, 2005). The ability of coral to photoacclimatise depends on the variability of the existing environment, with high variability of light due to wave action and tides in very shallow environments reducing the effectiveness of this process. The depth range in which photoacclimation will occur is 4 to 40 m (Fabricius, 2005).

Excessive sedimentation and turbidity adversely affect coral communities by altering both biological and physical processes. Sediments deposited on coral tissues can cause necrosis through smothering or bacterial infection, and suspended sediments can abrade polyps (Rogers, 1983; Brown et al., 1990; Hodgson, 1990; Wesseling et al., 1999). Active sediment removal by corals, through ciliary movements and mucus secretion, together with reduced light availability due to smothering, places increased energy stress on corals (Dallmeyer et al., 1982; Stafford-Smith & Ormond, 1992; Reigl & Branch, 1995). Physiological stresses may reduce growth and calcification rates and, if persistent, will cause coral bleaching and death (Dodge & Vaisnys, 1977; Bak, 1978; Rogers, 1983; Wesseling et al., 1999; Torres & Morelock, 2002). Increased levels of sedimentation and turbidity can also inhibit the fertilisation, survival, recruitment and settlement of juvenile corals (Babcock & Davies, 1991; Te, 1992; Gilmour, 1999).

The coral assemblages on the shallow, subtidal limestone pavements at Gnoorea Point comprised mostly turbid water species. Coral abundance was very low (generally less than 5% cover) and restricted to isolated coral bombora and patch reef with small coral colonies. The coral species at this site are well represented elsewhere in the area between the Dampier Archipelago and Cape Preston.

Effects of Turbidity and Sedimentation on Mangroves. Mangroves grow in the intertidal zone of the tropics, with the most extensive areas of mangrove swamp occurring on sedimentary shorelines where rivers discharge onto low-gradient coasts (Ellison, 1998). However, excess input of sediment to mangroves can cause the death of mangrove forests by burial of aerial roots. The impact from additional loads depends on each species' tolerance and root morphology, i.e., tall prop roots in *Rhizophora* compared with lower pneumatophores in *Avicennia* (Ellison, 1998). Mangroves are known to tolerate sedimentation rates of up to 10 mm per year, with most species tolerating less than 5 mm per year (for review, see Ellison, 1998).

Definition of Threshold Values and Impact Zones. Limited information is currently available on the TSS concentrations or sedimentation levels that can be tolerated by macroalgae and seagrass. In the absence of adequate information, existing criteria for predicting adverse impacts on corals (Chevron, 2005) were taken as a conservative indicator of the response of all benthic primary producers. This approach is considered conservative because the available research suggests that macroalgae and seagrass are less susceptible than corals to long-term impacts from sedimentation and turbidity due to their ephemeral nature and ability to recover from disturbances.

Three zones representing different levels of potential impacts were established for the purposes of this impact assessment:

- Zone of impact – loss of all benthic primary producers.
- Zone of effect – sublethal effects and some loss of sensitive species.
- Zone of influence – reduced water quality with no measurable effect on benthic primary producers.

The threshold criteria, given in **Table 8.7**, are deliberately conservative to account for a lack of information on benthic primary producer responses to various stressors, marked differences in the responses of benthic primary producer communities, and other factors that may increase rates of mortality. These factors include high water temperatures or light/depth limitations already operating at the community level. The criteria also account for the possible additive effects of increased TSS and sedimentation.

The threshold criteria for each of the three zones were defined on the basis of sediment load and exposure time to turbidity and sedimentation above background levels, taking into account published values for acute (short-term), medium-term and chronic (long-term) responses to both sedimentation and elevated TSS. The greatest effects of sedimentation and elevated TSS on corals are

Variable	Timeframe	Concentration	Time (cumulative days)
Zone of impact ***(loss of benthic primary producers)***			
TSS	Short	25 mg/L or more	5 in 15
	Medium	10 mg/L or more	20 in 60
	Long	5 mg/L or more	80 in 240
Sedimentation	Daily	100 mg/cm²/d or more	1
	Short	25 mg/cm²/d or more	5 in 15
	Medium	10 mg/cm²/d or more	20 in 60
	Long	5 mg/cm²/d or more	40 in 120
Zone of effect ***(sublethal effects and some partial loss of benthic primary producers)***			
TSS	Short	25 mg/L or more	2 in 6
	Medium	10 mg/L or more	7 in 21
	Long	5 mg/L or more	20 in 60
Sedimentation	Daily	50 mg/cm²/d or more	1
	Short	25 mg/cm²/d or more	2 in 6
	Medium	10 mg/cm²/d or more	7 in 21
	Long	5 mg/cm²/d or more	20 in 60
Zone of influence ***(no loss of biota)***			
TSS		2 mg/L or more	In any daylight period (~12 hours)
Sedimentation		1 mg/cm²/d or more	During any 24-hour period

Table 8.7 Threshold criteria for corals to identify zones of impact, effect and influence predicted from trajectory and fate modelling of HDD discharges.

likely to be from a continuous reduction in light and/or continuous sediment deposition; however, if there is no recovery time for corals in between pulse turbidity or sedimentation events, the effects may be cumulative. The coral health threshold criteria are designed to take into account these repeated stress events.

Within each zone, there is potential for a range of impacts. For example, in the zone of impact, effects may range from total mortality of all corals to mortality of specific coral taxa, mortality of individual colonies, or partial death of colonies. The spatial extent of the three zones (impact, effect and influence) was derived using the outputs from the numerical modelling of the trajectory and fate of drilling discharges from HDD described in **Section 8.1** and **Appendix 5**.

Except for well-developed coral communities, such as *Porites* bombora, the majority of benthic primary producers and benthic primary producer habitat within the zones of impact and effect are expected to recover within 5 years of the HDD operations. This includes all seagrass and macroalgal communities, which are well adapted to cycles of disturbance and recovery.

Porites bombora take a long time to establish and are not likely to recover within 30 years if lost during HDD operations. It is predicted that *Porites* bombora would be permanently lost within the zone of impact but suffer only partial mortality (less than 30%) within the zone of effect. If the benthic primary producers or benthic primary producer habitats are predicted to take in excess of 30 years to recover, they are considered to be permanently lost.

Coral within the zone of impact, other than *Porites* bombora, were presumed to suffer total mortality due to changes in substrate structure from the discharge of HDD drill cuttings. It is predicted that, within 5 years, cuttings would migrate away from the immediate impact zone, allowing these corals to recolonise limestone pavement. A summary of the predicted impacts to benthic primary producers within the zones of impact and effect is in given in **Table 8.8**.

Definition of Benthic Primary Producer Habitat Management Unit. A single management unit encompassing the nearshore zone of Gnoorea Point within Regnard Bay was assigned to assess the impacts to benthic primary producer habitat as recommended by the EPA (2004). This area is referred to as the Gnoorea Point management unit and encompasses 5,045 ha (**Figure 8.22**). The benthic primary producer habitats within the Gnoorea Point management unit are continuous and connected hydrographically as suggested by plume modelling. The Gnoorea Point management unit does not represent an ecologically discrete unit; rather it is part of a larger area of relatively homogeneous benthic primary producer habitat extending out from the DCDP area.

Definition of this management unit took into account the proposed Regnard Marine Management Area (formerly known as the proposed Cape Preston Marine Management Area) conservation zones. The unit lies within an unzoned portion of the Regnard Marine Management Area (CALM, 2003) and is a Category C management unit with a cumulative loss threshold of 2% (EPA, 2004).

Benthic habitat type	Key receptor	Reason for selection	Zone of Impact		Zone of Effect	
			Predicted effects	Recovery time frame	Predicted effects	Recovery time frame
Coral communities • More resilient species • Large bombora	*Porites* spp.	Large bombora, species widespread in region, resilient but slow-growing, ecologically important	High mortality (up to 100%)	Permanent loss, recovery more than 30-years	Some mortality (up to 30%)	Partial loss, recovery 2 to 5 years
Coral communities • More sensitive species	*Turbinaria* spp. *Favites* spp.	Small colonies, sensitive but fast-growing	High mortality (up to 100%)	Temporary loss, recovery 2 to 5 years	High mortality (up to 100%)	Temporary loss, recovery 2 to 5 years
Macroalgae-dominated (limestone reef)	*Dictyopteris* spp.	Widespread and abundant	High mortality (up to 100%)	Temporary loss, recovery 2 to 5 years	High mortality (up to 100%)	Temporary loss, recovery 2 to 5 years
Seagrass-dominated	*Halophila* spp.	Widespread and abundant, ephemeral	High mortality (up to 100%)	Temporary loss, recovery 2 to 5 years	High mortality (up to 100%)	Temporary loss, recovery 2 to 5 years

Table 8.8 Predicted impacts to benthic primary producers within the zones of impact and effect.

Within the Gnoorea Point management unit, approximately 860 ha of the area are comprised of intertidal and subtidal macroalgae-dominated benthic primary producer habitat. Seagrass meadows are also extensive, covering an additional 1,100 ha, both inside the protective rock platform barrier surrounding Gnoorea Point and on the seaward side of the rock platform. Coral cover was generally low, limited to scattered small corals on the submerged limestone pavement, with occasional isolated *Porites* bombora within the macroalgae- or seagrass-dominated habitats outside of the seaward rock barrier. Total coral cover within the management unit was estimated at 44 ha.

Cumulative Loss Calculations. EPA Guidance Statement No. 29 is aimed at protecting benthic primary producer habitat (EPA, 2004). The statement specifically applies to development proposals that cause destruction of or damage to benthic primary producer habitat. The guidelines provide for the protection and maintenance of ecosystem integrity by applying a risk-based environmental framework, which includes cumulative loss thresholds (EPA 2004).

Cumulative impacts are defined as the sum of all damage/loss of benthic primary producer habitat caused by human activities since European habitation of Western Australia (~ 200years) and do not include changes to benthic primary producer habitat caused by natural events, such as severe storms (EPA, 2004).

Gnoorea Point was used for the Stag pipelay operation in 1997, and a small area of damage to the limestone rock barrier can be seen in aerial photography. However, this area has been recolonised by benthic primary producers since this disturbance and now supports macroalgal communities similar to the surrounding rock barrier areas. No damage to seagrass meadows was seen in aerial photography or during the field survey. Other human impacts include trampling of intertidal rock platforms and mud flat areas by tourists. Neither of these activities has resulted in a measurable loss of benthic primary producer habitat.

The area surrounding Gnoorea Point and the proposed site of HDD operations is classified as Category C: "other designated areas", under Guidance Statement No. 29 (EPA, 2004). According to the guidance statement, limited damage/loss of benthic primary producer habitat and associated benthic primary producer communities may be acceptable, where no alternatives exist, with a cumulative loss is less than 2% of the area of benthic primary producer habitat within a defined management unit, or where there is no perceived threat to ecosystem integrity (EPA, 2004).

Consistent with EPA guidance (EPA, 2004), unavoidable impacts to benthic primary producer habitat have been assessed as either "permanent loss" or "temporary change". A 30-year recovery period was selected as the basis for distinguishing between permanent loss and temporary change to benthic primary producer habitat.

A permanent loss of benthic primary producer habitat indicates that the functionality of the habitat has changed so that it can no longer support the same benthic primary producer community or that damage to that community will persist for more than 30 years, e.g., *Porites* bombora in the zone of impact.

A temporary change to benthic primary producer habitat indicates impacts that may be sublethal or lethal but that have a short recovery time. The benthic primary producer habitat retains its ecological function and is predicted to show a full recovery, including the complete suite of marine species associated with the original benthic primary producer community, in less than 5 years. Macroalgae-dominated limestone reefs with scattered corals and seagrass meadows within the zones of impact and effect are considered to be temporarily affected.

Quantified Impacts of Sedimentation and Sediment Suspension Concentrations on Benthic Primary Producers. The results of the impact assessment of benthic primary producers are discussed below in terms of the three cases for HDD:

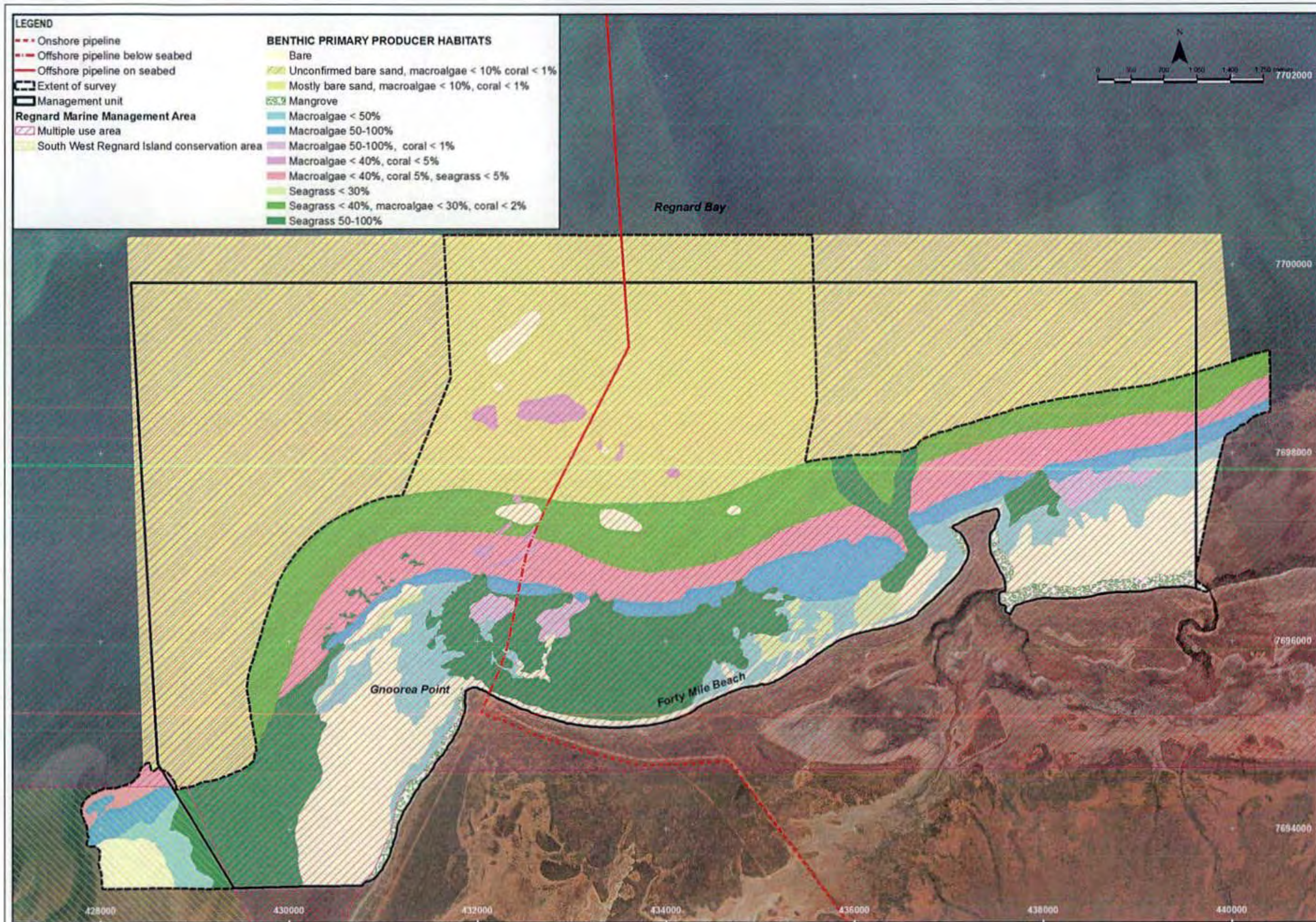

Figure 8.22 Map showing Gnoorea Point management unit superimposed over benthic primary producer habitats.

Planned Case:

- The zone of impact, which is centred around the HDD exit point 1.8 km from the shoreline, is localised, covers an area of 3.74 ha and is 220 m wide at its widest point (**Figure 8.23**). The zone extends over three benthic primary producer habitat types: macroalgae less than 40%, coral 5%, seagrass less 5%; seagrass less than 40%, macroalgae less than 30%, coral less than 2%; and macroalgae less than 40%, coral less than 5%. The size of the zone of impact for each benthic primary producer habitat is presented in **Table 8.9**.
- The zone of effect is only slightly larger than the zone of impact; it covers an additional 1.2 ha and is 250 m wide (**Figure 8.23**). This zone covers the same three benthic primary producer habitats as the zone of impact, and the sizes of these habitats within the zone of effect are also presented in **Table 8.9**.
- The zone of influence, which represents the maximum extent of visible plume from the HDD operations, extends 2.5 km in an east–west direction from the HDD exit point and 1.6 km in a north–south direction. It covers a total area of 168.72 ha (**Table 8.9**).
- The main benthic primary producer communities that will be affected within the zones of impact and effect are mostly seagrass- or macroalgae-dominated habitats with occasional corals (less than 5%). The habitat dominated by seagrass also comprises less than 30% macroalgae and less than 2% coral. Both macroalgae and seagrass are predicted to recover rapidly from disturbance (in less than 5 years). The corals growing in these habitats are well represented elsewhere in the area and are predicted to recover within 5 years.
- No regionally significant coral assemblages or assemblages of sensitive coral species, such as *Acropora*, were found within the zones of impact, effect or influence for the planned case. No *Porites* bombora have been identified within the zone of impact.
- Suspended sediment concentrations rarely exceeded 25 mg/L, and no visible plume was predicted to persist after 15 days (see **Figure 8.2**). The cumulative coral health threshold criteria were triggered by high pulses of suspended sediment concentrations for short periods, rather than by long-term, low suspended sediment concentrations. Within 50 m southeast of the HDD exit point, the habitat is comprised of seagrass (less than 40%), macroalgae (less than 30%) and coral (less than 2%). Elevated suspended sediment concentrations over the short term are expected to result in some light reduction; however, suspended material is likely to disperse rapidly with tidal flushing.
- The sedimentation concentrations predicted within 50 m southeast of the HDD exit point are in excess of the concentrations required to trigger the threshold for the zone of impact and are predicted to persist in excess of 40 days (see **Figure 8.19**). The threshold criteria for the zone of effect were triggered by long-term rather than daily exceedences in sedimentation concentration.

Contingency Case:

- The HDD exit point for the contingency case is in the same location as the planned case; however, the period of HDD discharge is extended by one week to 3 weeks because of an additional reaming pass. The zone of impact is localised to the area surrounding the HDD exit

Benthic Primary Producer Habitat	Zone of impact (ha)	Zone of effect (ha)	Zone of influence (ha)
Mangrove			
Bare			15.60
Macroalgae less than 50%			14.62
Macroalgae 50% to 100%			18.08
Macroalgae less than 40%, coral 5%, seagrass less than 5%	0.60	0.75	50.17
Seagrass less than 40%, macroalgae less than 30%, coral less than 2%	1.82	0.31	30.34
Seagrass 50% to 100%			20.68
Macroalgae less than 40%, coral less than 5%	1.32	0.14	6.75
Mostly bare sand, macroalgae less than 10%, coral less than 1%			0.52
Seagrass less than 30%			2.58
Macroalgae 50% to 100%, coral less than 1%			9.38
Unconfirmed bare sand, macroalgae less than 10%, coral less than 1%			
TOTAL	**3.74**	**1.20**	**168.72**

Table 8.9 Predicted areas of benthic primary producer habitats impacted by HDD discharges associated with the Planned Case.

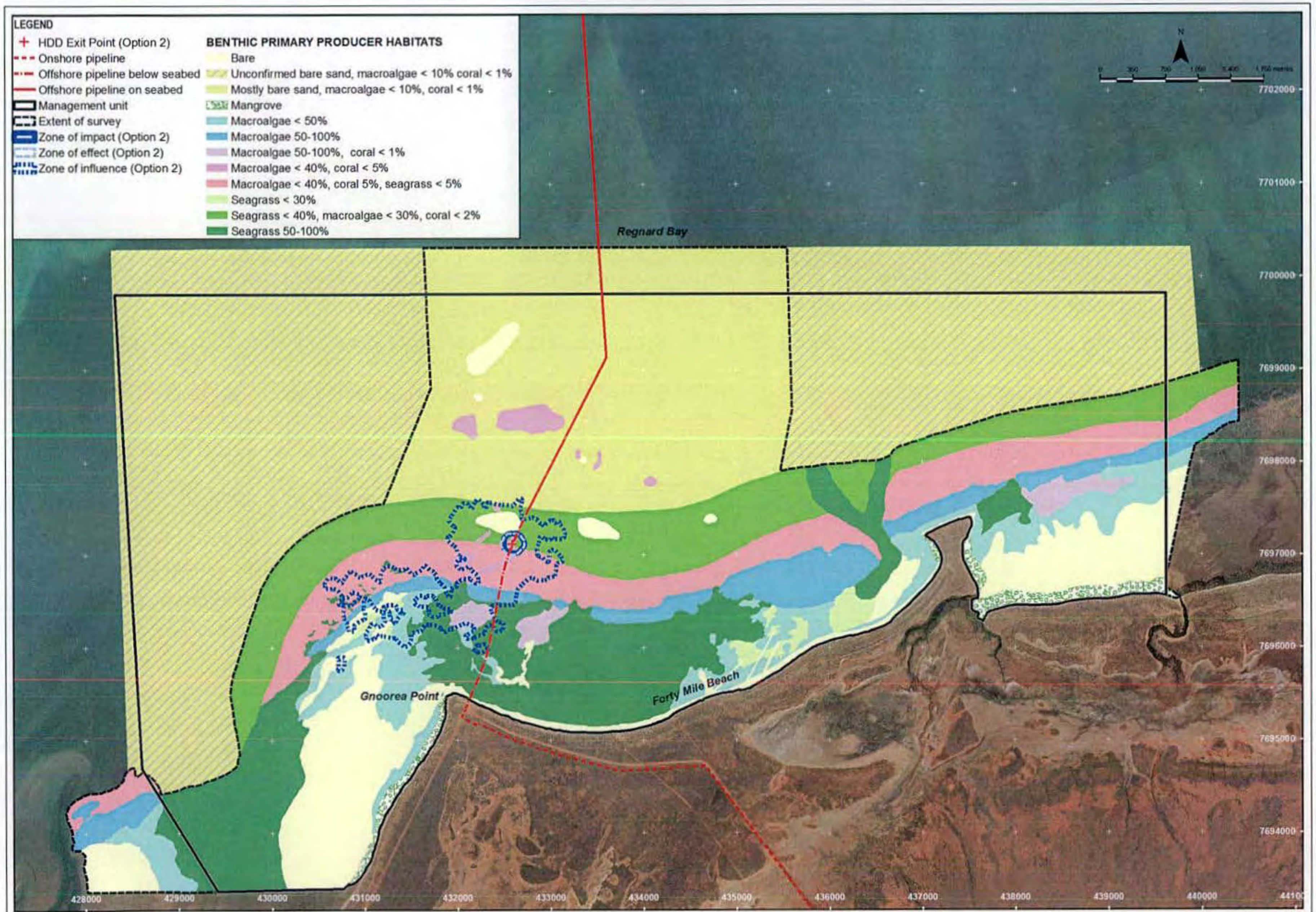

Figure 8.23 Map showing zones of impact, effect and influence for HDD Planned Case superimposed over benthic primary producer habitats.

point, covers an area of 3.66 ha and is 220 m wide (**Figure 8.24**). The zone of impact is 0.08 ha smaller than the zone of impact for the planned case and extends over three benthic primary producer habitat types: macroalgae less than 40%, coral 5%, seagrass less than 5%; seagrass less than 40%, macroalgae less than 30%, coral less than 2%; and macroalgae less than 40%, coral less than 5%. The size of the zone of impact for each benthic primary producer habitat is presented in **Table 8.10**.

- The zone of effect is only slightly larger than the zone of impact; it covers an additional 1.23 ha and is 260 m wide (**Figure 8.24**). This zone covers the same three types of benthic primary producer habitat as the zone of effect plus a small area of bare habitat, and the size of these habitats within the zone of effect is also presented in **Table 8.10**.
- The zone of influence extends 3.4 km in an east–west direction from the HDD exit point and 2.5 km in a north–south direction. It covers a total area of 452.41 ha (**Table 8.10**) and is more than 2.5 times larger than the zone of influence for the planned case.
- The main benthic primary producer communities that will be affected within the zone of impact and effect are the same as for the planned case and are expected to recover rapidly after disturbance.
- Suspended sediment concentrations 50 m southeast of the HDD exit point for the contingency case were very similar to those for the planned case; however, they persisted for an additional 5 days due to the extra reaming operation under this case (see **Figure 8.2**). Suspended sediment concentrations were slightly higher 400 m southeast of the HDD exit point compared to the planned case; and slightly elevated concentrations persisted for 20 days, although this was at a level not predicted to have measurable impacts on the benthic primary producers.
- Sedimentation concentrations 50 m southeast of the HDD exit point for the contingency case were very similar to those at the same distance for the planned case (see **Figure 8.19**). Concentrations were slightly higher 400 m southeast of the HDD exit point for the contingency case when compared to the planned case, as expected with the additional reaming pass and extra discharges. Elevated sedimentation concentrations at both sites were predicted to persist for more than 40 days.

No Mitigation Case:

- HDD discharges would continue for 12 weeks under the no mitigation case, and thus the impacts are likely to be chronic rather than acute due to the extended period of cuttings and fluids discharge into the marine environment. The zone of impact, which lies 2.26 km from the shoreline, is localised to the area surrounding the HDD exit point and covers an area of 9.37 ha. At its widest point, the zone of impact is 320 m wide (**Figure 8.25**). The zone extends over two benthic primary producer habitat types (seagrass less than 40%, macroalgae less than 30%, coral less than 2% and mostly bare sand, macroalgae less than 10%, coral less than 1%) plus a small area of bare habitat. The size of the zone of impact for each benthic primary producer habitat under this case is presented in **Table 8.11**.
- The benthic primary producer habitats that will predominantly be affected within the zone of impact are bare sand with minimal macroalgae cover or are seagrass-dominated. The habitat dominated by bare sand

Benthic Primary Producer Habitat	Zone of impact (ha)	Zone of effect (ha)	Zone of influence (ha)
Mangrove			
Bare		0.03	34.94
Macroalgae less than 50%			29.03
Macroalgae 50% to 100%			29.7
Macroalgae less than 40%, coral 5%, seagrass less than 5%	0.58	0.17	92.75
Seagrass less than 40%, macroalgae less than 30%, coral less than 2%	1.77	0.75	81.35
Seagrass 50% to 100%			105.91
Macroalgae less than 40%, coral less than 5%	1.31	0.28	6.92
Mostly bare sand, macroalgae less than 10%, coral less than 1%			42.06
Seagrass less than 30%			7.12
Macroalgae 50% to 100%, coral less than 1%			22.63
Unconfirmed bare sand, macroalgae less than 10%, coral less than 1%			
TOTAL	**3.74**	**1.20**	**168.72**

Table 8.10 Predicted areas of benthic primary producer habitats impacted by HDD discharges associated with the Contingency Case.

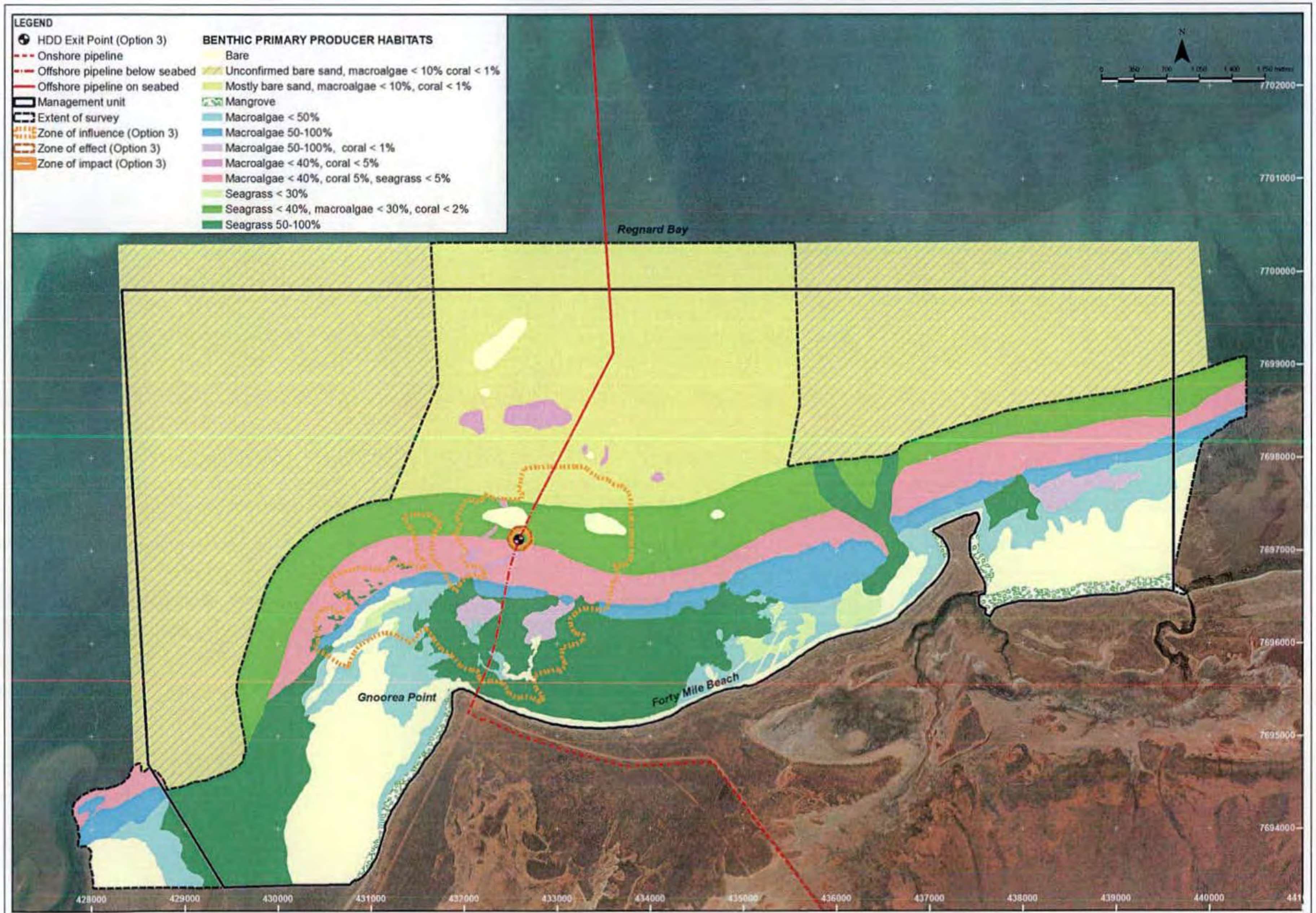

Figure 8.24 Map showing zones of impact, effect and influence for HDD Contingency Case superimposed over benthic primary producer habitats.

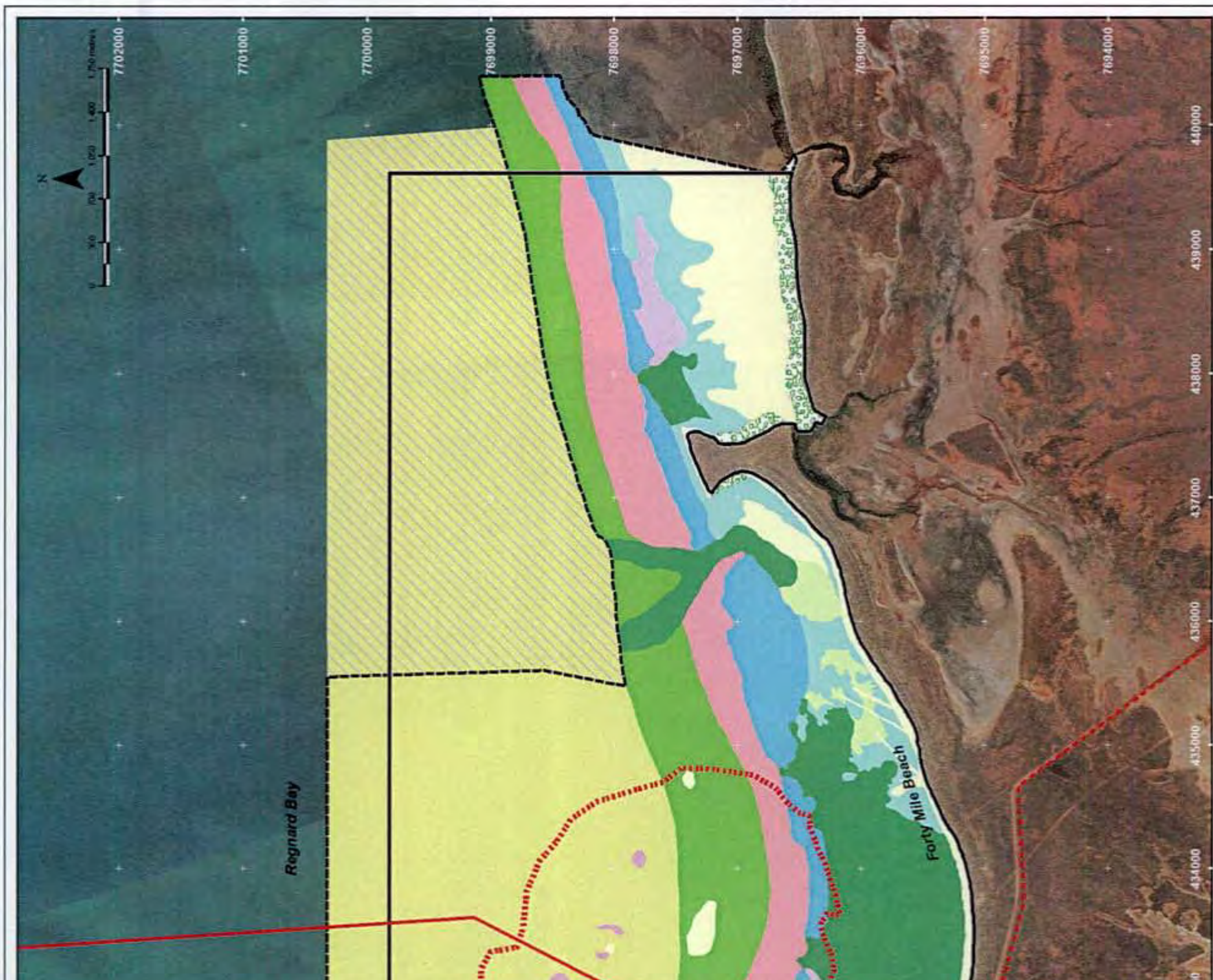

Figure 8.25 Map showing zones of impact, effect and influence for HDD No Mitigation Case superimposed over benthic primary producer habitats.

has occasional emergent rock pavement supporting the growth of macroalgae and occasional small corals. The loss of benthic primary producers from this habitat is unlikely to be significant considering the low overall cover within the habitat and widespread regional distribution.

- The seagrass communities are dominated by *Halophila* spp., which are ephemeral and known to recover well from disturbance. Within the seagrass-dominated habitat are patches of exposed rock platform with macroalgae, mostly *Dictyopteris*, and a small proportion of coral. Both macroalgae and seagrass are predicted to recover from disturbance in the short term (less than 5 years).
- The zone of effect is only slightly larger than the zone of impact and covers an additional 0.13 ha (**Figure 8.25**). This zone covers the same three benthic primary producer habitats as the zone of impact, and the size of each habitat within the zone of effect is also presented in **Table 8.11**.
- The zone of influence extends 6 km in an east–west direction from the HDD exit point and 3 km in a north–south direction; it covers an area of 1,516.29 ha. The zone of influence will be affected by both the predicted suspended sediment and sedimentation concentrations; however, it is the migration of sediment at very low levels away from the HDD exit point that is responsible for the extent of this zone. The zone of influence for the suspended sediment concentrations is localised near the HDD exit point.
- No regionally significant coral assemblages or assemblages of sensitive coral species, such as *Acropora*, were found within the zones of impact, effect or influence. No *Porites* bombora have been identified within the zone of impact or effect. The scattered coral communities on limestone pavement within the zones of impact and effect comprise species of *Turbinaria, Favites, Goniastrea, Favia, Porites, Leptastrea, Platygyra, Cyphastrea* and *Symphyllia*. It is expected that total mortality of these corals will occur within the zones of impact and effect. However, tidal flushing is expected to reduce the impacts from sedimentation on these corals, and recovery is predicted within 5 years.
- Suspended sediment concentration for the no mitigation case rarely exceeded 25 mg/L, and no visible plume is predicted to persist after 48 days (see **Figure 8.2**). The cumulative coral health threshold criteria were triggered by pulses of high suspended sediment concentrations for short periods, rather than by long-term, slightly elevated suspended sediment concentrations. Within 50 m of the HDD exit point, the habitat is comprised of seagrass (less than 40%), macroalgae (less than 30%) and coral (less than 2%). Elevated suspended sediment concentrations over the short term are expected to result in some light reduction; however, suspended material is likely to disperse rapidly with tidal flushing. The benthic primary producers in this area are known to cope well with short-term reductions in light.
- Suspended sediment concentration 400 m south east from the HDD breakout point is below the threshold criteria for the zones of impact and zone of effect confirming the localised nature of the predicted impacts from HDD (see **Figure 8.2**).
- Sedimentation concentrations are cumulative and include resuspension over time. The predicted sedimentation was well in excess of the concentrations required to trigger the

Benthic Primary Producer Habitat	Zone of impact (ha)	Zone of effect (ha)	Zone of influence (ha)
Mangrove			
Bare	0.74	0.01	61.44
Macroalgae less than 50%			53.8
Macroalgae 50% to 100%			45.6
Macroalgae less than 40%, coral 5%, seagrass less than 5%			189.24
Seagrass less than 40%, macroalgae less than 30%, coral less than 2%	4.73	0.12	272.91
Seagrass 50% to 100%			92.92
Macroalgae less than 40%, coral less than 5%			34.32
Mostly bare sand, macroalgae less than 10%, coral less than 1%	3.9	0	375.93
Seagrass less than 30%			7.25
Macroalgae 50% to 100%, coral less than 1%			21.71
Unconfirmed bare sand, macroalgae less than 10%, coral less than 1%			361.17
TOTAL	**9.37**	**0.13**	**1,516.29**

Table 8.11 Predicted areas of benthic primary producer habitats impacted by HDD discharges associated with the No Mitigation Case.

zone of impact 50 m from the breakout point (see **Figure 8.19**). Within 400 m of the breakout point there was a dramatic decrease in the sedimentation concentration.

Cumulative Loss Estimates. The areas of benthic primary producer habitat predicted to be permanently lost under the three cases described above are compared in **Table 8.12**. The exact coverage of scattered corals and coral bombora for each habitat is not known; therefore, the total coral cover (percentage) for each habitat, together with the disturbance footprint at the HDD exit point (given in **Table 8.2**), has been used to calculate permanent loss. This incorporates a level of conservatism into the calculations.

The areas of benthic primary producer habitat predicted to be permanently lost under the planned case are all below the 2% cumulative loss threshold value. The HDD discharge in the planned case will result in a permanent loss of 0.12 ha of coral from within the macroalgae- and seagrass-dominated habitats with scattered corals. The benthic primary producers predicted to undergo a temporary change are macroalgae and seagrass covering a total area of 4.32 ha in varying densities.

The areas of benthic primary producer habitat predicted to be permanently lost under the contingency case are similar to losses under the planned case, as expected, and are all below the 2% cumulative loss threshold value. The HDD discharge in the contingency case will result in a permanent loss of 0.12 ha of coral from within the macroalgae- and seagrass-dominated habitats with scattered corals. The benthic primary producers predicted to undergo a temporary change are macroalgae and seagrass covering a total area of 4.75 ha in varying densities.

The areas of benthic primary producer habitat predicted to be permanently lost under the no mitigation case are also all below the 2% cumulative loss threshold value. The HDD discharge in the no mitigation case is predicted to result in a permanent loss of 0.1 ha of coral from within the macroalgae- and seagrass-dominated habitats with scattered corals. The benthic primary producers predicted to undergo a temporary change are macroalgae and seagrass covering a total area of 9.39 ha in varying densities.

Effects of Diesel on Benthic Primary Producers

Generally, the impact of an oil spill on benthic primary producer habitat is minimal, except in shallower waters where oil may contact the seabed due to tidal movement. Entrained oils can affect flora and fauna in these environments, while heavier oils may persist in sediments for a period of time.

Benthic Primary Producer Habitat (BPPH)	EPA CLT* (%)	Total area of BPPH before disturbance (ha)	Planned Case		Contingency Case		No Mitigation Case	
			Permanent coral loss % (ha)	Temporary macroalgae & seagrass loss % (ha)	Permanent coral loss % (ha)	Temporary macroalgae & seagrass loss % (ha)	Permanent coral loss % (ha)	Temporary macroalgae & seagrass loss % (ha)
Mangrove		57.74						
Bare		468.28						0.001% (0.74 ha)
Macroalgae less than 50%		244.68						
Macroalgae 50% to 100%		177.59						
Macroalgae less than 40%, coral 5%, seagrass less than 5%	2	357.45	0.01% (0.03 ha)	0.2% (0.72 ha)	0.01% (0.03 ha)	0.2% (0.72 ha)		
Seagrass less than 40%, macroalgae less than 30%, coral less than 2%	2	479.47	0.01% (0.03 ha)	0.44% (2.10 ha)	0.01% (0.03 ha)	0.52% (2.5 ha)	0.02% (0.07 ha)	1.0% (4.79 ha)
Seagrass 50% to 100%		591.08						
Macroalgae less than 40%, coral less than 5%	2	34.32	0.17% (0.06 ha)	4.38% (1.5 ha)	0.17% (0.06 ha)	4.45% (1.53 ha)		
Mostly bare sand, macroalgae less than 10%, coral less than 1%		851.56					0.003% (0.03 ha)	0.45% (3.86 ha)
Seagrass less than 30%		39.12						
Macroalgae 50% to 100%, coral less than 1%		45.84						
Unconfirmed bare sand, macroalgae less than 10%, coral less than 1%		1,698.15						
TOTAL		**5,045.28**	**0.12**	**4.32**	**0.12**	**4.75**	**0.10**	**9.39**

*Cumulative loss threshold.

Table 8.12 Cumulative loss thresholds for benthic primary producer habitats for the three HDD cases.

Mangroves. The sensitivity of mangroves to oil spills has been well recorded, with extensive defoliation and sometimes mortality being noted at a number of spills. In general, damage occurs through the smothering of lenticels (mangrove breathing pores) on pneumatophores, or prop roots, or by the loss of leaves due to chemical burning (Duke et al., 1999).

Mangrove communities typically occur in sheltered areas of low wave energy, making retention of oil within the sediments a potentially long-term problem. Retention of oil in the substrate may result in chronic exposure to oil due to the flushing of retained oil out of the sediment over each tidal cycle. The burrows of organisms and the roots of trees also act as a conduit for light oils, allowing the penetration of oil deep into the sediment.

Oil spill predictive modelling indicates that there is the potential for the spill to reach the mangrove area west of Gnoorea Point. As is typical for mangrove communities, this area is has low wave energy, and thus the potential impact on the mangroves would be significant in the event of a large oil spill. Mangroves beyond the immediate area are less likely to be impacted due to the low amounts of oil expected to come ashore.

Algae and Seagrass. Algae are considered to be relatively resilient to oil, primarily due to their morphological features, such as the presence of a mucilage layer or the presence of fine "hairs", which reduce the amount of hydrocarbon that will adhere to the algae. Intertidal seagrass beds, however, are more prone to damage. Tolerance to oil varies among species, with depressed growth rate, leaves turning brown, and a covering by algae being the reported responses. The susceptibility of seagrass to hydrocarbon spills will depend largely on the seagrass distribution. Deeper communities will be protected from oiling under all but the most extreme weather conditions. Shallow seagrasses are more likely to be affected by dispersed oil droplets or, in the case of seagrasses that emerge above the sea surface, direct oiling. Intertidal seagrass communities would theoretically be the most susceptible because the leaves and rhizomes may both be affected.

Algae and seagrass beds occur throughout the DCDP nearshore marine environment. These are benthic primary producers that provide an important source of food and shelter for marine fauna, as well as stabilise the shoreline and seabed. The potential impact on algae and seagrass would be significant in the event of a large oil spill event.

Corals. Studies and field observations have found all species of corals to be sensitive to the effects of oil, although there are considerable differences in the degree of tolerance between species (Jackson et. al., 1989). The effects of oil on corals range from short- or long-term sublethal effects to irreversible tissue necrosis and death. The timing of an oil spill event in relation to other potential sources of stress, such as ambient temperature or reproductive stage, could also have significance in that corals are likely to be more sensitive to oil spill events at times of physiological stress.

The corals in the Gnoorea Point region are located in sufficiently deep waters to not be exposed to direct oiling and consequently are considered unlikely to suffer any significant impacts. The larvae of corals, however, are sensitive to entrained oils; and in the event of a significant oil spill, there may be potential for impacts on the reproductivity of corals.

8.3.1.1 Impacts

The potential impacts of the hazards to benthic primary producers include:

- Direct loss of benthic primary producer habitat.
- Indirect impacts to benthic primary producers from elevated suspended sediment and sedimentation concentrations.
- Physical impacts of hydrocarbons to marine habitat and organisms, toxicity to marine biota and nutrient enrichment from support vessel or hydrotest water discharges.

8.3.1.2 Management

The CEMP will include a number of measures to manage the impacts to benthic primary producers from the hazards described so that the management objectives and long-term target of the Regnard Marine Management Area will be met. These measures are summarised in **Table 8.13**.

8.3.1.3 Residual Risks

Impacts to benthic primary producer habitat from the DCDP are expected to comprise direct loss of habitat via removal by air jetting at the HDD exit point and burial by placement of grout bags at the HDD exit point and via settlement of cuttings at the HDD exit point. There will also be physical damage due to support vessel anchor placement and scour. The HDD program in the planned case will result in a permanent loss of 0.12 ha of coral from within the macroalgae- and seagrass-dominated habitats with scattered corals. The benthic primary producers predicted to undergo a temporary change are macroalgae and seagrass covering a total area of 4.32 ha in varying densities. It is predicted that recolonisation in the short term will occur by macroalgae and/or seagrass once the substrate has stabilised. The areas of benthic primary producer habitat predicted to be permanently lost under the planned case are all below the 2% cumulative loss threshold set by EPA (2004). The residual risks from the HDD program are considered acceptable ("B").

The potential risks from the accidental release of diesel from HDD support vessels into the marine environment was considered as having a moderate consequence for all three scenarios modelled; however, the likelihood of such events occurring was considered as highly unlikely given the proposed management measures; therefore, the residual risk of impacts to benthic primary producers is considered acceptable ("B").

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Benthic Primary Producers	Seabed disturbance	*Modification to seabed at HDD exit point (see Table 8.2).* *Support vessel anchoring.*	Direct loss of benthic primary producer habitat. Indirect impacts to benthic primary producers from elevated suspended sediment and sedimentation concentrations.	• Required for span correction of pipeline at HDD exit point. • Modifications to the seabed will only occur after the HDD exit hole is made, thereby restricting the disturbed area to that which is necessary given the specific conditions at the exit point. • The HDD exit point and anchoring locations sited to avoid significant seabed features. • The location coordinates of significant seabed features are entered into the survey systems for barge and anchor-handling support vessels. • Installation and support vessels use Apache's shallow-water anchoring procedure. • Post-HDD marine habitat survey of benthic primary producer habitat to enable detection of change and comparison with model predictions of cumulative loss estimates from HDD drilling discharges.
	HDD discharges	*Cuttings and drilling fluids discharged during drilling.*	Indirect impacts to benthic primary producers from elevated suspended solids and sedimentation concentrations.	• Planned case for HDD with delay in punch out has been selected on the basis of reducing volume of discharge to ALARP. • Bentonite, a low-toxicity drilling fluid, will be used. • Solids separation equipment will be functioning to maximise the volume of drilling fluid removed from cuttings. • Detailed records kept of the daily drilling operations including the volume of bentonite used, recycled/reconditioned and/or discharged to the marine environment.
	Support vessel discharge – domestic waste	*Support vessel use during HDD operations.*	Toxicity to marine biota. Nutrient enrichment in receiving waters.	• No domestic wastes will be disposed of in the nearshore marine environment in which the HDD activities are to take place. • Vessel wastes will be either brought to shore or disposed of in deeper waters in accordance with the legislative requirements and MARPOL and AMSA regulations. • CEMP documents waste management practices that will be implemented during all phases of the proposed works, including on support vessels during the HDD operations, by Apache and its appointed contractors. • All domestic waste will be stored in clearly marked skips, and waste containers will be provided on all vessels.
	Support vessel discharge – deck drainage	*Support vessel use during HDD operations.*	Physical impacts of hydrocarbons to marine habitat and organisms. Toxicity to marine biota.	• Areas on vessels where hazardous materials will be stored, including fuels, oils and lubricants, will be bunded, and drainage from these areas will be directed to a sump (or similar) that is connected to an oily water separator or containment tank for disposal onshore. • Scupper plugs will be fitted at drainage points to prevent discharge of deck wash into the marine environment. These will only be removed before or during heavy rain storms to prevent the deck flooding. • No contaminated waste will be intentionally discharged via deck washdown. • Contaminated drainage will be contained and diverted to the slops tank or sump or will be mopped up to prevent overboard discharge. • Vessels will have absorbent booms and clean-up materials readily available so that any spill on deck can be rapidly contained. • Drip trays will be used to capture oily material. • Routine maintenance and monitoring of vessels and equipment will allow for early detection of leaks, minimising the potential for discharge of hydraulic oils and other hydrocarbons, and ensuring a quick response to repair leaks and clean up spills.
	Support vessel discharge – diesel spills.	*Support vessel use during HDD operations.*	Physical impacts of hydrocarbons to marine habitat and organisms. Toxicity to marine biota.	• Apache's bunkering management procedures will be followed. • No vessel-to-vessel refuelling will occur in shallow waters. • Compliance with the legislative requirements and MARPOL and AMSA regulations. • OSCP and vessel SOPEP developed and implemented. These plans: – Ensure effective and timely management of spills of hydrocarbons. – Describe the procedures to deal with an oil spill. – Define the roles and responsibilities of response personnel. – Describe the external resources available for use in combating oil spills and how these resources will be coordinated. – Be integrated with State and Commonwealth government and industry response plans.
	Hydrotest water	*Hydrotesting of onshore and offshore pipeline.*	Toxicity to marine biota	• No planned discharge will be made to the nearshore marine environment. • Low-toxicity chemical additives will be selected for the hydrotesting and will be used in concentrations that are ALARP without compromising the integrity of the testing.

Table 8.13 Summary of management measures for benthic primary producers.

8.3.2 Sea Turtles

Key hazards that have the potential to impact sea turtles in the DCDP area include:

- Light generated from vessel operation and HDD activities (onshore and offshore).
- Noise generated from vessel operation and HDD activities.
- Vessel operations.
- Unplanned discharge from vessels.

Indirectly, there are hazards associated with the DCDP that may result in the loss of benthic primary producers, including corals, seagrasses, macroalgae and mangroves, that provide habitat and food sources for sea turtles. These are discussed in **Section 8.3.1**.

The management objective stated in the Draft Management Plan for the Dampier Archipelago Marine Park and Regnard Marine Management Area for sea turtles is to ensure no loss of species diversity and that abundance of turtles is not significantly impacted by visitor disturbance. The long-term target is "no loss of turtle diversity and abundance as a result of human activity".

Light

The shallow nearshore waters and mangroves in the vicinity of the DCDP area are used as developmental and foraging habitat by juvenile and adult green turtles, flatbacks and possibly hawksbill turtles (**Section 5.3.2.3**) while the shorelines at the eastern end of Forty Mile Beach are used for nesting in low numbers compared to elsewhere on the mainland coast of the Pilbara and offshore islands.

Lighting used to carry out 24-hour operations associated with the HDD drilling program will cause light emissions, which have the potential to disrupt the behaviour of sea turtles, particularly nesting of adult female turtles and the emergence of hatchling turtles. Given that turtles are only known to nest at the eastern end of Forty Mile Beach, it is highly unlikely that lighting from onshore HDD operations will disrupt female nesting and hatchling emergence. The lighting from support vessels associated with the HDD program may potentially cause some short-term disruption to nearshore foraging and migrating turtles.

Noise

Noise emissions generated by vessel activity and HDD operations in the DCDP area can potentially have non-physiological effects on marine fauna, including sea turtles, such as:

- Attraction to the source of noise.
- Increased stress levels.
- Localised avoidance.
- Behavioural changes.

There is little information available about the sensitivity of sea turtles to subsea noises (WEL, 2006a); however, it is expected that sea turtles would avoid an area before sound reached a level at which it could cause physical harm. In terms of the non-physiological effects, the noise generated during the construction phase may disrupt nearshore foraging and migrating turtles and cause some short-term displacement of sea turtles in and adjacent to the DCDP area as they would tend to move away from the disturbance. However, they are likely to return to the area once the disturbance has ceased.

Vessel Operations

There is the potential for collisions between sea turtles and the vessels used for the HDD program. The impact is considered to be minor as these animals tend to exhibit behavioural and avoidance responses and the vessels will be moving at restricted speeds within the construction area. Vessels operating in the nearshore area are not permitted to dispose of any wastes into the marine environment.

Effects of Diesel on Sea Turtles

Sandy beaches are found in the vicinity of Gnoorea Point, along Forty Mile Beach and beyond the immediate areas within the predicted path of any oil slick. Sandy beaches are significant ecologically, particularly for the nesting of sea turtles, but also have high aesthetic and recreational value to the region. Accumulation of oil on sandy beaches may affect nesting turtles or hatchlings on their way to the ocean, although it is unlikely that there will be impacts on eggs from penetration of oil into the sand given that turtle nests are generally beyond the high tide mark (which is where stranded oil is most likely to accumulate). Heavier oils are easier to remove from sandy beaches through mechanical processes; however, when oils penetrate into the sand, they can persist for some time and have ongoing impacts to fauna, aesthetics and recreational uses of the beach.

Sea turtles that utilise the Regnard Bay area for development and foraging may be susceptible to oil slicks as they breathe and swim close to the water surface. Contact with an oil slick may cause skin or eye irritations or injuries to the lungs if fumes are inhaled. There is also a potential for ingestion of oil and subsequent toxic effects if contaminated foods (e.g., macroalgae and seagrasses) are consumed.

Sea turtles, being highly mobile, can avoid oil slicks in the water. They are more at risk when females are nesting on sandy beaches or hatchlings are emerging and making their way to the water.

8.3.2.1 Impacts

The potential impacts of the hazards to sea turtles include:

- Disorientation of turtles during nesting and hatching activity from artificial light sources.
- Disturbance due to noise associated with the HDD activities and vessel operation.
- Direct impact from collision with vessels.
- Ingestion of solids wastes from vessels.
- Impact of diesel spill in marine environment.

Indirectly, there are hazards associated with the DCDP that may result in the loss of benthic primary producers, including corals, seagrasses, macroalgae and mangroves, that provide habitat and food sources for sea turtles. These are discussed in **Section 8.3.1**.

8.3.2.2 Management

Pendoley Environmental Consultants was commissioned to provide a review of the light mitigation measures that can be applied effectively to this specific phase of the project. The following measures are likely to be assessed to manage light spill:

- Reducing the number of lights.
- Reducing the wattage of lights.
- Altering the direction of lights.
- Shielding lights.
- Using motion detectors and timers on lights.
- Altering the colour of the light.
- On-site environmental representative to ensure compliance with CEMP.

Actual light mitigation measures will be selected and implemented based upon this assessment and finalised when the contractor responsible for the works has been appointed and details of the proposed HDD spread are known. The overriding aim will be to minimise the potential for lighting to disrupt sea turtle behaviour without compromising safe working practices.

Apache will support a regional survey (proposed by Pendoley Environmental) of turtle nesting activity in the Dampier Archipelago, including Forty Mile Beach and Regnard Islands, during the 2008/09 nesting season. If the regional survey does not proceed, then Apache will undertake a more localised survey focusing on Forty Mile Beach and Regnard Islands.

No noise reduction or mitigation measures specific to sea turtles are proposed as it is considered that noise levels from DCDP activities are highly unlikely to impact sea turtle populations. At most, transient and slight behavioural modifications may occur for a few individuals transiting the area during the construction phase.

The CEMP will include a number of measures to manage the impacts to sea turtles from the hazards described so that the management objectives and long-term target of the Regnard Marine Management Area will be met. These measures are summarised in **Table 8.14**.

8.3.2.3 Residual Risks

Given the limited nesting activity in the region and the implementation of the proposed mitigation measures, the residual risks to sea turtle populations from the hazards associated with the HDD program in the nearshore marine environment and onshore can be considered to be "negligible".

8.3.3 Marine Mammals

A number of species of whales and dolphins are known to occur in the Dampier Archipelago/Cape Preston region and Regnard Bay. The area further offshore from the DCDP area is within the annual migration paths for the humpback whale (**Section 5.3.2.5**). During the southern migration in particular, which takes place closer inshore in early spring, there may be mothers and calves resting in the shallow waters of Regnard Bay. Dugongs have been sighted in the Regnard Bay Marine Management Area where the seagrass meadows of the bay provide foraging habitat.

Key hazards that have the potential to impact marine mammals in the DCDP area include:

- Noise generated from vessel operation and HDD activities.
- Unplanned discharge from vessels.
- Vessel operations.

Indirectly there are hazards associated with the DCDP that may result in the loss of benthic primary producers, including seagrasses that provide habitat and food source for dugongs.

The management objective stated in the Draft Management Plan for the Dampier Archipelago Marine Park and Regnard Marine Management Area for marine mammals is to ensure the species diversity and abundance of dugong and resident cetaceans is not significantly impacted by visitor disturbance and traditional hunting and to ensure no loss of species diversity of marine mammals and that abundance of migratory cetaceans is not significantly impacted by physical disturbance and human interaction. The long-term target is "no loss of marine mammal diversity and abundance as a result of human activity".

Noise

Marine mammals, and in particular cetaceans, employ an extremely acute acoustic sense to monitor the environment and thus are sensitive to subsea noise and to a lesser extent noises above the water surface. Baleen whales (including humpback whales) are generally considered to be more sensitive to low-frequency noises, such as those generated by vessels.

Noise generated during the HDD program may interfere with the acoustic perception of any marine animals in the vicinity and may cause some marine mammal species to avoid the immediate area. Underwater noise impacts to humpback whales in Regnard Bay during the HDD program will be largely avoided as the activity is scheduled for completion prior to the peak of the southern migration period in early spring.

Vessel Operations

The potential for collision between marine mammals, such as whales, dolphins and dugongs, and HDD support vessels is considered to be low given that these species are likely to exhibit behavioural and avoidance responses and vessels will be operating under restricted speeds within the immediate area. The potential for vessel collisions with humpback whales during the southern migration period has been minimised as HDD program will take place outside of this period.

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Sea Turtles	Seabed disturbance	*Modification to seabed at HDD exit point (see Table 8.2).* *Support vessel anchoring.*	Indirect impact through loss of food source and habitat.	• Measures will be put in place to minimise the impacts to benthic primary producers (see Table 8.13)
	HDD discharges	*Cuttings and drilling fluids discharged during drilling.*	Indirect impact through loss of food source and habitat.	• Planned case for HDD with delay in punch out has been selected on the basis of reducing volume of discharge to ALARP.
	Light	*Onshore HDD operations.* *Support vessel operations.*	Disorientation of turtles during nesting and hatching activities.	• Lighting is required for navigation and safety; however, it will be minimised to that necessary for safe working conditions. • HDD operations have been scheduled to occur between January and August 2009, with initial site preparation works involving 12-hour daylight operations only. • Location of HDD activities is distant from shorelines with turtle nesting activity. • Shielding and redirection of lights will be done as feasible without compromising safe working operations and will vary among vessels. • A dedicated marine fauna observer will be employed between 1 November to 31 March (EPBC Act Referral Decision particular manner condition). • Formalised reporting requirements for fauna sightings and observations will be put in place. • Apache will support a regional survey of turtle nesting activity in 2008/09 nesting season. If regional survey does not proceed, then Apache will undertake a more localised survey focusing on Forty Mile Beach and Regnard Islands.
	Noise	*Onshore HDD operations.* *Support vessel operations.*	Disturbance to sea turtles.	• Location of HDD activities is distant from shorelines with turtle nesting activity. • Noise mitigation measures for HDD operations are detailed in Table 7.23.
	Support vessel movements	*Support vessel operations.*	Collision with sea turtles.	• Vessels will be restricted in speed of travel due to the nature of the work and shallowness of the work location.
	Support vessel discharge – domestic wastes	*Support vessel operations.*	Ingestion of solid wastes.	• Vessel wastes will be either brought to shore or disposed of in deeper waters in accordance with the legislative requirements and MARPOL and AMSA regulations. • CEMP documents waste management practices that will be implemented during all phases of the proposed works, including on support vessels during the HDD operations, by Apache and its appointed contractors. • All domestic waste will be stored in clearly marked skips, and waste containers will be provided on all vessels.
	Support vessel discharge – diesel spills	*Support vessel operations.*	Toxicity to sea turtles.	• Apache's bunkering management procedures will be followed. • No vessel-to-vessel refuelling will occur in shallow waters. • Compliance with the legislative requirements and MARPOL and AMSA regulations. • OSCP and vessel SOPEP developed and implemented. These plans will: – Ensure effective and timely management of spills of hydrocarbons. – Describe the procedures to deal with an oil spill. – Define the roles and responsibilities of response personnel. – Describe the external resources available for use in combating oil spills and how these resources will be coordinated. – Be integrated with State and Commonwealth government and industry response plans.

Table 8.14 Summary of management measures for sea turtles.

Effects of Diesel on Marine Mammals

Marine mammals are potentially impacted by hydrocarbon spills due to the fact that they breathe at the surface, at which point they may inhale hydrocarbon fumes, which can result in damage to lungs and the respiratory tract. Hydrocarbons, including diesel, are not likely to adhere to their skin, as these animals are generally smooth skinned and hairless.

Entrained hydrocarbons are unlikely to cause harmful effects to marine mammals due to their relatively low toxicity, the limited period of exposure and the low dosages of hydrocarbons received.

8.3.3.1 Impacts

The potential impacts of the hazards to marine mammals include:

- Disturbance due to noise associated with the HDD program and vessel activity.
- Direct impact from collision with vessels.
- Ingestion of solids wastes from vessels.
- Indirect impact through loss of food source and habitat.

8.3.3.2 Management

The CEMP will include a number of measures to manage the impacts to marine mammals from the hazards described so that the management objectives and long-term target of the Regnard Marine Management Area will be met. These measures are summarised in **Table 8.15**.

8.3.3.3 Residual Risks

Given the low level of impacts to marine mammals from the HDD program and the implementation of the proposed mitigation measures, the residual risks of the hazards identified are considered "negligible".

8.3.4 Shorebirds and Seabirds

Key hazards that have the potential to impact shorebirds and seabirds in the DCDP area include:

- Light generated from vessel operation and HDD activities (onshore and offshore).

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Marine Mammals	Seabed disturbance	*Indirect impact through loss of food source.*	Indirect impact through loss of food source	• Measures will be put in place to minimise the impacts to benthic primary producers (see Table 8.13)
	Noise	*Support vessel operations.*	Disturbance to marine mammals.	• Equipment will be designed to normal petroleum practice, which includes specifications for noise levels. • HDD activities will take place outside of critical whale migration periods.
	Support vessel movements	*Support vessel operations.*	Collision with marine mammals.	• The interaction of construction and operation vessels with cetaceans will be consistent with Part 8 of the Environmental Protection and Biodiversity Conservation Regulations 2000. • Vessels will be restricted in speed of travel due to the nature of the work and shallowness of the work location.
	Support vessel discharge – domestic wastes	*Support vessel operations.*	Ingestion of solid wastes.	• No domestic wastes will be disposed of in the nearshore marine environment in which the HDD activities are to take place. • Vessel wastes will be either brought to shore or disposed of in deeper waters in accordance with the legislative requirements and MARPOL and AMSA regulations. • CEMP documents waste management practices that will be implemented during all phases of the proposed works, including on support vessels during the HDD operations, by Apache and their appointed contractors. • All domestic waste will be stored in clearly marked skips, and waste containers will be provided on all vessels.
	Support vessel discharge – diesel spills	*Support vessel operations.*	Toxicity to marine mammals.	• Apache's bunkering management procedures will be followed. • No vessel-to-vessel refuelling will occur in shallow waters. • Compliance with the legislative requirements and MARPOL and AMSA regulations. • OSCP and vessel SOPEP developed and implemented. These plans will: – Ensure effective and timely management of spills of hydrocarbons. – Describe the procedures to deal with an oil spill. – Define the roles and responsibilities of response personnel. – Describe the external resources available for use in combating oil spills and how these resources will be coordinated. – Be integrated with State and Commonwealth government and industry response plans.

Table 8.15 Summary of management measures for marine mammals.

- Noise generated from vessel operation and HDD activities.
- Unplanned discharge from vessels.

Indirectly, there are hazards associated with the DCDP that may result in the loss of benthic primary producers and associated higher-order species that provide a food source or habitat for shorebirds and seabirds, for example, the intertidal macroalgae- and seagrass-dominated habitat with associated infaunal and subfaunal invertebrates.

The management objective stated in the Draft Management Plan for the Dampier Archipelago Marine Park and Regnard Marine Management Area for seabirds is to ensure no loss of species diversity and that abundance of seabirds is not significantly impacted by physical disturbance or loss of habitat. The long-term target is "no loss of seabird and shorebird diversity and abundance as a result of human activity".

Light

Lighting has been linked to attraction and possible disorientation of seabirds and shorebirds (Weise et. al., 2001). However, the footprint of lighting associated with the HDD program is very small compared to the habitat and range of seabirds and shorebirds. This area is also used by campers using generator-driven lights at night, and it is likely that seabirds and shorebirds are accustomed to lighting in this area.

Noise

There is the potential for short-term displacement if birds are disturbed by the noise and activity of the HDD program; however, they are likely to return to the area once the noisy activities cease.

Vessel Operations

The discharge of food scraps from vessels can attract seabirds and shorebirds. No wastes will be disposed of by the HDD support vessels in the nearshore marine environmental in accordance with legislative and regulatory requirements.

Effects of Diesel on Seabirds and Shorebirds

There are several habitats around Gnoorea Point that are used by seabirds and shorebirds (**Figure 5.2**). Rocky intertidal shores occur east of Gnoorea Point in the DCDP nearshore marine area. Rocky intertidal shores and the ecological communities they support are at risk from the smothering and toxic effects of diesel. Filter feeders, such as molluscs, are especially liable to ingesting hydrocarbons with lethal and sublethal effects. The predictive modelling shows these rocky areas to be susceptible in the event of a significant oil spill incident.

Mud and sand tidal flats support mangrove communities and are known to be areas of high productivity, as well as feeding grounds for wading birds. In the DCDP area, these are found to the west of Gnoorea Point and support a mangrove community and provide habitat for a range of migratory birds as outlined in **Section 5.3.2.5**. In the event of a diesel spill, if oil makes contact with these areas, the oil is unlikely to penetrate very deeply due to the fine sediment. Burrows of animals may, however, act as pathways for the oil, assisting penetration into the substrate, which would make clean up and recovery more difficult and add to the time required for the area to recover. The most significant impact of diesel in this area is the impact to the mangroves themselves, as well as the potential to contaminate and reduce the food supply for migratory birds that utilise this area.

Seabirds are highly susceptible to hydrocarbon spills, given that they spend large amounts of time on the sea surface, dive when disturbed and have relatively low reproductive rates. Birds that come into contact with hydrocarbons may lose the ability to waterproof feathers, which affects the ability to regulate body temperature and to remain buoyant on the water. There is also the potential for ingestion of oil as they attempt to clean feathers or ingest contaminated foods.

The type of oil affects the level of impacts, with the heavier, more persistent oils having a greater impact to birds. Diesel is less likely to persist in the marine environment to reach sensitive receptors and result in high numbers of sea bird mortality. Thus, the potential for impacts to seabird population is lessened.

8.3.4.1 Impacts

The potential impacts of the hazards to shorebirds and seabirds include:

- Attraction and possible disorientation from artificial light sources.
- Underwater noise associated with the HDD activities and vessel operation causing a reduction in prey availability.
- Ingestion of solids wastes from vessels.
- Attraction to food scraps from vessels.
- Toxicity to shorebirds and seabirds from a diesel spill.

In addition, there may be indirect impacts through the loss of food source and habitat for shorebirds and seabirds.

8.3.4.2 Management

The CEMP will include a number of measures to manage the impacts to shorebirds and seabirds from the hazards described so that the management objectives and long-term target of the Regnard Marine Management Area will be met. These measures are summarised in **Table 8.16**.

8.3.4.3 Residual Risks

The impacts identified for seabirds and shorebirds are minor; and when mitigation measures are applied, the residual risks to populations from the hazards associated with the HDD program in the nearshore marine environment can be considered to be "negligible".

8.3.5 Invertebrates and Fish

Key hazards that have the potential to impact invertebrates and fish in the DCDP area include:

- Seabed disturbance.
- Light generated from vessel operation and HDD activities.

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Shorebirds and Seabirds	Seabed disturbance	*Modification to seabed at HDD exit point (see Table 8.2).* *Support vessel anchoring.*	Indirect impact through loss of food source and habitat.	• Measures will be put in place to minimise the impacts to benthic primary producers (see Table 8.13).
	Light	*Onshore HDD operations.* *Support vessel operations.*	Attraction and possible disorientation from artificial light sources.	• Lighting is required for navigation and safety; however, it will be minimised to that necessary for safe working conditions. • HDD operations have been scheduled to occur between January and August 2009, with initial site preparation works involving 12-hour daylight operations only. • Shielding and redirection of lights will be done as feasible without compromising safe working operations and will vary among vessels. • Formalised reporting requirements for fauna sightings and observations will be put in place.
	Noise	*Support vessel operations.*	Underwater noise can cause reductions in prey availability.	• Equipment will be designed to normal petroleum practice, which includes specifications for noise levels.
	Support vessel discharge – domestic wastes	*Support vessel operations.*	Ingestion of solid wastes. Attraction to food scraps from vessels.	• Compliance with the legislative requirements and MARPOL and AMSA regulations. • CEMP documents waste management practices that will be implemented during all phases of the proposed works including on support vessels during the HDD operations by Apache and their appointed contractors. • All domestic waste will be stored in clearly marked skips and waste containers will be provided on all vessels.
	Support vessel discharge – diesel spills	*Support vessel operations.*	Toxicity to shorebirds and seabirds.	• Apache's bunkering management procedures will be followed. • No vessel-to-vessel refuelling will occur in shallow waters. • Compliance with the legislative requirements and MARPOL and AMSA regulations. • OSCP and vessel SOPEP developed and implemented. These plans will: – Ensure effective and timely management of spills of hydrocarbons. – Describe the procedures to deal with an oil spill. – Define the roles and responsibilities of response personnel. – Describe the external resources available for use in combating oil spills and how these resources will be coordinated. – Be integrated with State and Commonwealth government and industry response plans.

Table 8.16 Summary of management measures for shorebirds and seabirds.

- Underwater noise generated from vessel operation and HDD activities.
- Unplanned discharge from vessels.

The management objective stated in the Draft Management Plan for the Dampier Archipelago Marine Park and Regnard Marine Management Area for finfishes and invertebrates is to ensure no loss of species diversity, ensure abundance of non-target finfishes and invertebrates is not impacted by fishing and activities that degrade critical habitats and to manage target finfish and invertebrate species for ecological sustainability. The long-term target is "no loss of finfish and invertebrate diversity and abundance as a result of human activity".

Lights

Fish and mobile invertebrates may be attracted to the lights of support vessels and may congregate around the vessels, increasing the risk of predation.

Noise

Fauna, including mobile invertebrates and fish, may be disturbed by noise associated with vessel activity. Short-term displacement of fish and mobile invertebrates may occur if animals move away from the noise; however, animals are likely to return to the area once the noise has ceased.

Vessel Operations

The discharge of food scraps from vessels can be a source of nutrient enrichment or contamination of the receiving waters that could impact invertebrates and fish. No wastes will be disposed of by the HDD support vessels in the nearshore marine environmental in accordance with legislative and regulatory requirements.

Effects of Diesel on Fish and Invertebrates

Plankton are primary producers and are likely to be an important part of the food chain in the nearshore marine environment for the

DCDP area. In the event of an oil spill, the key impact to plankton will be on the surface of the water where the oil is located. Plankton in the water column may, however, also be affected by entrained oils. Spatial movement and effective reproductive strategies will result in rapid recovery for plankton.

Fish may be exposed to spilled hydrocarbons either through direct contact with the oil spill, which will contaminate their gills, or through the water column, which may contain toxic hydrocarbon components, such as benzene, that may be absorbed by their eggs, larvae and juvenile stages. The impacts to fish are greatest in areas where there is limited dispersion potential of the oil spill.

8.3.5.1 Impacts

The potential impacts of the hazards to invertebrates and fish include:

- Loss of benthic habitat.
- Behavioural changes due to light and noise associated with the HDD and vessel activity.
- Nutrient enrichment from disposal of domestic wastes in receiving waters.
- Toxic effects from discharges.

8.3.5.2 Management

The CEMP will include a number of measures to manage the impacts to invertebrates and fish from the hazards described so that the management objectives and long-term target of the Regnard Marine Management Area will be met. These measures are summarised in **Table 8.17**.

8.3.5.3 Residual Risks

The HDD construction program poses minimal risks to fish and invertebrate populations in the nearshore marine environment. When mitigation measures are applied, the residual risks to populations from the hazards associated with the HDD activities in the nearshore marine environment can be considered to be "negligible".

Aspect	Hazards	Sources	Impacts	Mitigation/Controls
Invertebrates and fish	Seabed disturbance	*Modification to seabed at HDD exit point (see Table 8.2).* *Support vessel anchoring.*	Loss of benthic habitat.	• Measures will be put in place to minimise the impacts to benthic primary producers (see Table 8.13).
	Light	*Onshore HDD operations.* *Support vessel operations.*	Behavioural changes.	• Lighting required for navigation and safety, however, minimised to that necessary for safe working conditions. • HDD operations planned from January to August 2009, with initial site preparation works involving 12 hour daylight operations only. • Shielding and redirection of lights feasible without compromising safe working operations, and will vary among vessels. • Formalised reporting requirements for fauna sightings and observations.
	Noise	*Support vessel operations.*	Behavioural changes.	• Equipment will be designed to normal petroleum practice, which includes specifications for noise levels.
	Support vessel discharge – domestic wastes	*Support vessel operations.*	Nutrient enrichment in receiving waters.	• Compliance with the legislative requirements of MARPOL and AMSA regulations. • CEMP documents waste management practices that will be implemented during all phases of the proposed works including on support vessels during the HDD operations by Apache and their appointed contractors. • All domestic waste will be stored in clearly marked skips and waste containers will be provided on all vessels.
	Support vessel discharge – deck drainage	*Support vessel use during HDD operations.*	Physical impacts of hydrocarbons to marine habitat and organisms. Toxicity to marine biota.	• Areas on vessels where hazardous materials will be stored, including fuels, oils and lubricants, will be bunded, and drainage from these areas will be directed to a sump (or similar) that is connected to an oily water separator or containment tank for disposal onshore. • Scupper plugs will be fitted at drainage points to prevent discharge of deck wash into the marine environment. These will only be removed before or during heavy rain storms to prevent the deck flooding. • No contaminated waste will be intentionally discharged via deck washdown. • Contaminated drainage will be contained and diverted to the slops tank or sump or will be mopped up to prevent overboard discharge. • Vessels will have absorbent booms and clean-up materials readily available so that any spill on deck can be rapidly contained. • Drip trays will be used to capture oily material. • Routine maintenance and monitoring of vessels and equipment will allow for early detection of leaks, minimising the potential for discharge of hydraulic oils and other hydrocarbons, and ensuring a quick response to repair leaks and clean up spills.
	Support vessel discharge – diesel spills	*Support vessel use during HDD operations.* *Support vessel operations.*	Toxicity to fish and invertebrates.	• Apache's bunkering management procedures will be followed. • No vessel-to-vessel refuelling will occur in shallow waters. • Compliance with the legislative requirements and MARPOL and AMSA regulations. • OSCP and vessel SOPEP developed and implemented. These plans will: – Ensure effective and timely management of spills of hydrocarbons. – Describe the procedures to deal with an oil spill. – Define the roles and responsibilities of response personnel. – Describe the external resources available for use in combating oil spills and how these resources will be coordinated. – Be integrated with State and Commonwealth government and industry response plans.
	Hydrotest water	*Hydrotesting of onshore and offshore pipeline.*	Toxicity to marine biota.	• No planned discharge will be made to the nearshore marine environment. • Low-toxicity chemical additives will be selected for the hydrotesting and will be used in concentrations that are ALARP without compromising the integrity of the testing.

Table 8.17 Summary of management measures for invertebrates and fish.

9.1 OVERVIEW

Oil and gas production activities may have impacts on the human populations involved in or located near a proposed development. The nature and extent of these impacts are shaped by such factors as the existing economic, demographic and cultural characteristics of the community or communities, as well as the type and scale of activity proposed or already occurring. These social impacts (positive or negative, direct or indirect, independent or cumulative) can influence the way in which communities or individuals live, relate to one another and cope as members of society (World Bank, 2001).

This chapter of the Draft PER identifies the potential social impacts from the proposed DCDP and the associated preventive and management strategies that will be implemented to reduce impacts to an acceptable level. Activities associated with the DCDP have been assessed through a comprehensive environmental impact assessment process as described in Chapter 7 (**Section 7.2**).

Social impacts may occur as soon as a project is announced. From this point, interest groups can become active in presenting their arguments, and tensions can mount even before economic investment begins. For this very reason, Apache commenced a stakeholder consultation program soon after the possibility of a project was announced in August 2007, in order to inform the community about the proposed development, elicit feedback, incorporate environmental and social concerns into the project design wherever practicable, and ultimately operate the gas development with the support (or "social licence") of the local community.

Stakeholders may be affected groups or individuals that:

- Live near the resource.
- Are forced to relocate.
- Have an interest in the proposed action or change.
- Use or value the resource.
- Are interested in its use.

The manner in which Apache has approached community consultation for the DCDP is detailed in Chapter 2. Discussions and observations by Apache staff involved in the consultation process have assisted in the preparation of the social impact assessment. The social aspects associated with the DCDP development are broadly outlined as:

- Economy and social profile.
- Public health.
- Regional infrastructure and services.
- Land uses and protected areas.
- Fisheries.
- Recreation and tourism.
- Indigenous and non-indigenous heritage.

These aspects are discussed in detail in the following sections.

9.2 ECONOMY AND SOCIAL PROFILE

The capital expenditure required for the development is estimated to be A$900 million. The predicted annual operating expenditure for the development is approximately A$25 million.

Based on the volume of recoverable gas predicted from the Reindeer Field and assuming a market average gas price of A$6/GJ (note that actual contract information is confidential), it is expected that, over the life of the Reindeer Field, approximately A$3.0 billion will be generated from gas and condensate sales. Petroleum resource rent tax and company tax to be paid over that period is estimated to be in the order of A$1.2 billion

The proposed development will also lead to an increase in employment for both site- and office-based positions. It is estimated that, during the peak construction period, up to 200 people will be employed, with between 20 and 30 permanent positions during operations.

9.2.1 Impacts

The DCDP will impact positively on the economy by:

- Contributing directly to Australia's gross domestic product.
- Providing employment and training opportunities, potentially for local and indigenous people.
- Improving business opportunities for associated and local industries.

9.2.2 Management

No management measures are required.

9.2.3 Residual Risks

The risks to the economy and social profile are positive.

9.3 PUBLIC HEALTH

There are no existing, permanent settlements in the areas proposed to be used by the DCDP. The only sensitive receptors in the vicinity of the DCDP will be the accommodation facility for the permanent workforce at the gas plant, which will be located approximately 1 km south of the plant boundary, and the recreation area at Gnoorea Point located approximately 10 km northwest of the plant boundary.

The camping and recreation area at Gnoorea Point is used by a small number of locals and tourists for day trips, as well as for overnight stays and extended stays in the winter peak season.

9.3.1 Impacts

The potential project elements that could be hazardous to the health of the employees based in the accommodation facility or users of the recreational area at Gnoorea Point include:

- Emissions to the atmosphere, such as nitrogen oxides and particulate matter (PM_{10}) from routine and non-routine plant operations.
- Dust from vegetation clearing, earthworks, vehicle and machinery movements (for site levelling and trenching) and weld grinding operations during the construction of the gas plant and pipeline infrastructure and associated facilities.
- Noise from vehicle and machinery movements, material off-loading, weld grinding, and other such construction activities.
- A potential increase in the risk of exposure of the public to nuisance insects and insect-transmitted diseases.
- Exposure to domestic effluent and sewage.
- Contamination of drinking water supply (groundwater) from accidental hydrocarbon or chemical spills or seepage from the produced water evaporation ponds.

The potential impacts to public health from emissions and discharges are discussed in detail in **Section 7.3.4** (Air Quality), **Section 7.3.5** (Noise Emissions), **Section 7.5** (Routine Liquid Wastes) and **Section 7.6** (Non-routine Liquid Wastes).

There is a potential for emissions during construction resulting from the combustion of fuel for machinery and vehicle operation. These emissions will be transient in nature and are considered minor, posing a negligible risk to human health. During the routine operations of the gas plant, there will be atmospheric emissions resulting from generators, compressors and flares. During non-routine events, such as commissioning, de-commissioning, start up and shut down, there is the potential for increased emissions for short periods of time.

The ground-level concentrations of air emissions relevant to human health were predicted for both routine and non-routine operations (**Section 7.3.4**). Concentrations of nitrogen dioxide, oxides of nitrogen and ozone were shown to remain below the assessment criteria during routine and non-routine operations with little change over the existing conditions. Ozone concentrations are predicted to increase marginally over the existing conditions but still remain well below assessment criteria. The concentration of particulate matter (PM_{10}) predicted for non-routine operations at Gnoorea Point were also considered negligible. Based on the predictions, the risks to public health from air emissions during construction and operation can be considered negligible.

The generation of dust and noise is anticipated during the construction phase of the project and to a lesser extent the operations phase. This is unlikely to result in impacts to human health but has the potential to impact public amenity of the recreational area. The impacts of dust and noise on the recreational uses of the area are discussed in **Section 9.8**.

The project has a slight potential to increase exposure of the public to nuisance insects, insect-transmitted diseases and animal reservoirs of pathogens that may cause human disease. Ponded water during construction and operations may provide habitat for the breeding of nuisance insects, such as mosquitoes. The project-related ponded water bodies will include temporary water storage areas established for construction (**Sections 3.5.6** and **3.6.1**), bunded storage areas and stormwater ponds following rainfall, and permanent areas, such the evaporation ponds for the disposal of produced water during operations (as described in **Section 3.5.5**).

The DCDP is expected to generate domestic liquid waste in the form of greywater and sewage, primarily from the accommodation facility (**Section 3.6.5.3**). Sewage and wastewater contain bacteria, fungi, parasites, and viruses that can cause intestinal, lung, and other infections. Domestic effluent will be managed via a wastewater treatment plant to a Class A level of treatment, including subsequent filtration and disinfection (**Section 3.5.8.5**).

There is a risk to groundwater resources of contamination from spills and seeps during construction and operation of the DCDP. Drinking water for the DCDP will be sourced from groundwater within the project area. Anecdotal evidence also suggests that campers using the Forty Mile Beach area source their drinking water from pastoral wells in the area. Groundwater contamination may therefore have a subsequent impact on public health. The potential impacts to and management measures for groundwater are discussed in **Section 7.3.2**. In addition, the DCDP Drinking Water Quality Management Plan includes a risk-based approach in line with the Australian Drinking Water Guidelines 2004 for the protection of the project's drinking water supply.

9.3.2 Management

Management measures to minimise the impacts to public health are summarised in the **Table 9.1**.

Other management measures to minimise impacts on human health are outlined in the following tables:

Table 7.20 Summary of Air Emission Management Measures.
Table 7.23 Summary of Noise Management Activities.
Table 7.27 Summary of Liquid Waste Management Measures.
Table 7.28 Summary of Non-routine Liquid Waste Management Measures.

9.3.3 Residual Risks

Residual risks to public health from the construction and operation of the DCDP are considered to be "negligible".

9.4 REGIONAL INFRASTRUCTURE AND SERVICES

The Shire of Roebourne is well serviced with infrastructure and social services; however, there is considerable pressure on these services in response to the current population growth within the region, housing and accommodation shortages and higher than average costs of living.

Aspect	Hazards	Sources	Impacts	Mitigation/controls
Public health	Increase in risk of exposure to nuisance insects. Exposure to greywater and sewage. Contamination of drinking water supply.	*Construction and operational activities.*	Increase in risk of exposure to nuisance insects. Infectious disease.	Apache will consult and cooperate with the Shire of Roebourne on mosquito control issues. Apache will implement a DCDP Mosquito Management Plan including strategies aimed at reducing unnecessary ponded water within its area of influence through good housekeeping and cyclone preparation practices. Apache will introduce appropriate measures to eradicate mosquito breeding in storm water and evaporation ponds. Additionally, Apache will assess the use of adulticides (insecticides to kill adult mosquitoes) around the perimeter of the accommodation facility. Other features of the DCDP Mosquito Management Plan include: • Base line mosquito / midge survey to identify breeding locations. • On-going monitoring and education to develop an effective anti-mosquito campaign. • Intervention measures such as use of traps, larvacides and the use of adult knock-down products. • Pre-cyclone preparedness to reduce the potential for water traps. • Post-cyclone preparedness to monitor previously identified breeding locations and apply control agents as necessary. The wastewater treatment plant will be specified to produce effluent quality consistent with the DoH Class A recycled water quality criteria. The DCDP Health Management Plan will ensure personnel exposure will be limited to only those involved in maintenance of the system. All maintenance work will be carried out by designated licensed contractors in line with the DCDP Health Management Plan. The DCDP Drinking Water Quality Management Plan includes drinking water protection strategies in line with the Australian Drinking Water Guidelines 2004, including: • Raw water sampling and analysis. • Catchment monitoring and maintenance. • Water abstraction source and method. • Well exclusion zone. • Water treatment, storage and reticulation. • Operational monitoring and maintenance. • Competency of personnel. • Water quality monitoring and reporting. • Incident response.

Table 9.1 Summary of management measures for public health.

The DCDP will be accessed during the construction and operations phases via the North West Coastal Highway and the Forty Mile Beach Road. Traffic frequencies on the North West Coastal Highway are relatively light, with historical movements of approximately 20 events per hour averaged over a 24-hour period. Traffic movements on the Forty Mile Beach Road (unsealed) are limited to recreational users visiting Forty Mile Beach. **Section 3.5.8.1** describes the proposed road upgrades required to safely manage traffic access to the DCDP. The key available services in the Karratha/Dampier region are detailed in **Table 6.1**.

9.4.1 Impacts

The DCDP accommodation facility will provide its own on-site services, including power, potable water treatment, communications, sewage treatment and effluent disposal. Hence, no additional pressure will be placed on the region's existing accommodation, energy, water or wastewater treatment facilities. Solid and hazardous waste will be disposed of in a licensed facility or landfill site in accordance with local guidelines and regulatory requirements.

The project will impact upon the North West Coastal Highway via increased traffic volumes when moving construction and building materials by truck to the site. During operations, the project will also result in one to two road tankers a day travelling between the gas plant and Kwinana, transporting condensate to a refinery.

Construction activities may also result in the deterioration of the Forty Mile Beach Road through the action of heavy vehicle transport. Vehicles will be used to transport pipe joints and equipment to support the construction of the onshore and HDD sections of the supply gas pipeline. In addition, a 0.75-km section of the Forty Mile Beach Road, between the gas plant and the North West Coastal Highway, will be used for heavy vehicle transport of materials to support the construction of the gas plant and gas plant ancillary area. Movements of tandem or triple trailers to transport infill materials to the plant site will require transit along the North West Coastal Highway, which will impact on the use of the highway by the public.

9.4.2 Management

Management measures to minimise the impacts to regional infrastructure and services are summarised in the **Table 9.2**.

9.4.3 Residual Risks

Considering the relatively small scale of the development and the mitigation controls detailed in the **Table 9.2**, the residual impact to regional infrastructure and services is predicted to be "negligible".

9.5 LAND USE AND TENURE

The land tenure and current land use for the proposed site of the DCDP includes areas under pastoral lease, road reserves, pipeline infrastructure corridor (DBNGP), existing shore-based marine facility used to support the oil and gas industry, and Crown reserves used for camping and recreational uses. The project area is defined and land tenure is described in **Section 6.7**.

9.5.1 Impacts

Earthworks and preparation of construction sites, such as the gas plant, HDD setup and laydown area and the onshore pipeline construction right of way, will result in relatively large volumes of materials, such as vegetation, topsoil, rock and soil overburden, being suitably stockpiled for use during reinstatement. The construction of the proposed DCDP will thus cause some temporary disruptions to the existing land uses in order to protect public safety and the security of the project site and equipment.

The most significant impact of these access restrictions will be during the construction of the shoreline crossing using HDD. The HDD operations are proposed to take place over 6 to 8 months from January to August 2009. The HDD construction area (Reserve 46694) is close to the existing boat ramp and camp sites (**Figure 3.12**) and will cause temporary disruptions to seasonal campers and users of the boat ramp. Indirectly, this could lead to further impacts by the increase or movement of the footprint of the existing camp sites.

Additionally, there will be a temporary restriction on campers using the existing unauthorised septic tank, which could indirectly result in uncontrolled toilet waste discharge.

The operational DCDP will result in some changes to the current surface and landscape within the onshore site footprints but essentially will not affect the tenure and land use of the area.

9.5.2 Management

To minimise impacts to the existing recreational land uses of the area, the HDD construction area footprint has been designed to allow continued public access to the boat ramp at Gnoorea Point (**Figure 3.12**). The layout of the construction site shows the re-routing of the access road to allow access to the boat ramp and to the camp sites adjacent to the west of Reserve 44694. The community will be advised of any temporary disruptions, in line with the project's community consultation plan (**Section 2.2.6**), and adequate signage will be in place to inform recreational users of the area of the proposed project prior to construction.

To minimise the indirect impact of uncontrolled toilet waste discharged as a result of access to the existing facility being restricted, the provision of alternative sewage disposal arrangements for seasonal campers will be discussed with the Shire of Roebourne.

The management measures are summarised in **Table 9.3**.

9.5.3 Residual Risks

The residual risk to land uses and tenure based on the temporary disruption to recreational users due to construction activities is considered to be "B" (acceptable) in light of the management measures outlined in **Section 9.5.2**.

Aspect	Hazards	Sources	Impacts	Mitigation/controls
Regional infrastructure and services	Use of: Water supply; Power supply; Waste disposal; Traffic networks; Emergency services; Communication services	*Construction and operational activities.*	Increased pressure on existing infrastructure and utilities. Increased traffic volumes on the North West Coastal Highway. Deterioration of the unsealed Forty Mile Beach Road.	The DCDP will be self-sufficient in the provision of accommodation, potable water and power supply, wastewater treatment and communications onsite. Apache proposes to upgrade the North West Coastal Highway and the Forty Mile Beach Road intersection, allowing for the efficient and safe movement of over-sized trucks and machinery to the proposed project areas. Construction and Operations Traffic Management Plans will be developed for the project to address road safety issues associated with the transport of personnel and materials including: • Interaction between plant and equipment and personnel / vehicles. • Signage and traffic control personnel. • Access and egress and parking areas. • Prevention of damage to off-site and sensitive areas. • Speed limits. • Minimise disruption to road users. • Minimise potential impacts to the environment. The proponent will liaise with the Shire of Roebourne such that pre- and post-inspections of the Forty Mile Beach Road may be conducted and agreement reached as to the remedial work to be undertaken by the proponent following works completion to reinstate the road to its previous condition.

Table 9.2 Summary of management measures for regional infrastructure and services.

Aspect	Hazards	Sources	Impacts	Mitigation/controls
Land use and tenure	Interaction with public. Use of public areas.	*Construction and operational activities.*	Intersection of lease areas (pipeline) with land leases. Temporary disruptions during construction. Disruptions to seasonal campers. Disruption to boat ramp users. Potential increase or movement of footprint of existing camp sites. Camper access to existing septic tank facility will be restricted.	Community liaison with Forty Mile Beach users prior to construction in line with the DCDP Community Consultation Plan. Signage to alert public of construction activities. HDD construction area footprint to allow continued public access to boat ramp at Gnoorea Point. Alternative access road to be provided to allow access to camp sites adjacent to the west of Reserve 44694. Provision of alternative sewage disposal arrangements for seasonal campers to be discussed with the Shire of Roebourne.

Table 9.3 Summary of management measures for land use and tenure.

9.6 PROTECTED AREAS

The DCDP will be located within the unzoned area of the proposed Regnard Marine Management Area and will be 25 km southwest of the proposed Maitland conservation zone and approximately 5 km northeast of the proposed South West Regnard Island conservation zone (**Figure 6.2**).

Regnard Islands Reserve and Eaglehawk Island Nature Reserve (Reserves 33831 and 36913 respectively) are in the vicinity of the DCDP (approximately 10 km northwest and 20 km northeast respectively).

By 2015, some portions of Mardie Station and the adjoining Karratha Station will be handed over to the Department of Environment and Conservation so as to provide a terrestrial conservation reserve adjacent to the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area and to include a representative example of the Roebourne Plains grasslands/cracking clays (a Priority Ecological Community) in the conservation reserve system. The future tenure of the exclusion has not yet been confirmed, however, it is likely to allow for protection of both conservation and recreational values. The area of overlap with this future DEC managed land and the DCDP is a portion of the DCDP gas plant site currently located on Mardie Station, to the north of the De Grey-Mullewa Stock Route, representing 31.17 ha. This area of overlap represents 0.2% of the pastoral lease land (Karratha and Mardie Stations) to be managed by DEC from 2015 onwards.

The closest national park to DCDP is the Millstream-Chichester National Park located approximately 100 km to the southeast.

9.6.1 Impacts

The proposed development occurs within the unzoned area of the Regnard Marine Management Area. Potential adverse impacts to protected areas, including the three proposed conservation areas within the marine management area (**Section 6.9.1**), have been minimised during the planning phase through careful project area selection.

Indirect impacts to adjacent marine protected areas from accidental hydrocarbon or chemical spills or routine wastewater discharges are considered to be minor. This is discussed further in **Section 8.2.2**.

The area of overlap of the DCDP gas plant site and the future DEC managed land represents 0.2% of the current pastoral lease land of Karratha and Mardie Stations to be managed by DEC in the handover in 2015. Given the small extent of aerial overlap and the location of the overlap at the edge of the proposed DEC managed land, the functioning DCDP gas plant will not impact on the protection of the conservation values proposed for this area.

9.6.2 Management

No impacts are expected to protected areas; therefore, no specific management measures, beyond those already described in other sections of this document, are proposed.

A decommissioning plan for DCDP will be developed in advance of decommissioning and will include measures for the rehabilitation of lands used for the DCDP in accordance with the prevailing legislation, land tenure and guidelines at the time of decommissioning and closure of DCDP.

9.6.3 Residual Risks

Given the location of the DCDP in relation to protected areas, the residual risks to protected areas are considered to be "negligible".

9.7 FISHERIES

The Pilbara Region supports a range of commercial fisheries and is a popular recreational fishing destination. Commercial fishing operations occurring in the vicinity of the DCDP include the Commonwealth-managed Western Skipjack Fisheries, Western Tuna and Billfish Fisheries, and Southern Blue fin Tuna Fisheries. State-managed fisheries include the Onslow Prawn Fisheries, Pilbara Fish Trawl Managed Fisheries and Pilbara Trap Managed Fisheries. In addition, there are pearling aquaculture licences in the vicinity of the DCDP and reports of licensed Marine Aquarium Fisheries operating in the area.

Recreational fishing is also popular in the vicinity of Gnoorea Point and the proposed DCDP. Given the high tidal range, much of the recreational fishing is boat based, with line fishing, netting and spear fishing used by fishers to target a variety of species.

Proposed activities associated with the construction and operations phases of the DCDP that have the potential to impact the commercial and recreational fishing operations include:

- Seabed disturbance – a result of pipeline installation and support vessel mooring.
- HDD discharge – from HDD pipeline installation activities.
- Vessel discharge – from support vessels associated with the HDD operations.
- Hydrotesting activities.
- Spills and leaks (unplanned discharge) – from vessel collisions, deck wash etc.

9.7.1 Impacts

Potential impacts to commercial and recreational fisheries with permits or licences within the proposed DCDP area include:

- Temporary loss of access to fishing grounds.
- Temporary disturbance to fish habitat, feeding and spawning areas and migration routes from HDD and seabed disturbance activities.
- Loss of income from fishing activities from accidental hydrocarbon or chemical spills in the vicinity of the project.
- Snagging of fishing nets on subsea equipment.

Loss of short-term access to commercial and recreational fishing grounds may occur during the horizontal directional drilling activities when safety exclusion zones are required to be established 500 m around the construction vessels and HDD exit point.

Given that most commercial fisheries do not operate within the shallow intertidal waters of the project area, there is a negligible risk to these industries. The impact to recreational fishers can also be considered low, based on the temporary nature of the project activities, the nearshore location and the lower level of fishing activities in the shallow waters.

Activities associated with the HDD will result in localised, short-term increases in suspended solids, which may potentially impact on recreational fishers and commercial operations including Marine Aquarium Fisheries (who rely on good visibility for diving) operating in the area. The extent of the area affected by the elevated suspended solid was predicted and discussed in **Section 8.1**. Given the localised and temporary nature of the suspended solids impacts from the HDD, the level of impacts to recreational fisheries and the Marine Aquarium Fisheries is considered to be low.

The potential for spills and leaks that result in contamination of the marine environment and subsequent toxicity to marine life are considered to be low. These are discussed in **Section 8.2.1**.

The subsea infrastructure in the nearshore development area poses a low level of risk to commercial fisheries, which tend not to operate in these shallow waters. Risks of snagging for recreational fisheries are considered to be no greater than snagging risks from natural subsurface rock features.

9.7.2 Management

The management measures for fisheries are summarised in **Table 9.4**.

9.7.3 Residual Risks

Given that the exclusions zones and areas impacted by increased suspended solids will be very small in relation to the fishing grounds and the temporary nature of the works, the residual risks to the commercial and recreational fisheries are predicted to be "negligible".

9.8 RECREATION AND TOURISM

Forty Mile Beach and Gnoorea Point are popular recreational areas for locals and tourists. The Forty Mile Beach Road provides access to the beach, the shallow waters of Regnard Bay, camping areas and the boat ramp (**Section 6.11**). Activities associated with the construction of the DCDP and the eventual presence and operation of the gas plant have the potential to impact recreation and tourism in the area.

Key hazards are the construction activities, in particular the HDD (which is planned to take place close to recreational facilities and in the nearshore marine environment), and the presence of the plant and related infrastructure.

Aspect	Hazards	Sources	Impacts	Mitigation/controls
Fisheries	Construction activities, HDD	*Accidental hydrocarbon or chemical spills.* *Sediment displacement and dispersion.* *Exposed components of subsea infrastructure.*	Temporary loss of access to fishing grounds. Loss of income. Temporary disturbance to fish and fish habitat from HDD. Damage to fishing equipment. Toxicity to marine life from unplanned spills and discharges.	Exclusion zones around offshore facilities will be gazetted and marked on admiralty charts. Strict hydrocarbon and chemical handling procedures will be adhered to on all construction vessels. An approved oil spill contingency plan and spill kits will be readily available onboard vessels. Information relating to the location of permanent subsea project components will be provided to the relevant authorities for representation on admiralty charts. Consulting with the fisheries governing agencies and local Marine Aquarium Fisheries prior to commencing marine construction to keep them informed of timing and duration of activities.

Table 9.4 Summary of management measures for fisheries.

9.8.1 Impacts

Key impacts to recreation and tourism include:

- Noise.
- Dust.
- Visual impact.
- Access restrictions on land and in the marine environment.
- Elevated suspended solid concentrations in the marine environment.

The generation of noise and dust is expected during the construction phase of the DCDP and to a lesser extent during the operations phase. Although noise and dust are unlikely to impact human health, they do have the potential to impact on public amenity and subsequently the values of the area for recreation and tourism. Recreational users of Forty Mile Beach were identified as potential receptors of the noise and dust associated with the construction and operation of the DCDP, particularly during HDD construction for the shore crossing.

The predicted L_{A10}noise levels for the HDD drilling operations at the shore crossing for varying metrological conditions ranged from 40 dB(A) to 65 dB(A) in the surrounding recreational camp sites to higher levels of 65 dB(A) to 70 dB(A), potentially experienced directly adjacent to the construction site boundaries. Noise levels reduce to 35 dB(A) at approximately 1 km from the construction site under calm conditions and 1.5 km from the construction site under worst-case weather conditions. **Section 7.3.5** discusses the impacts of noise in detail. Noise modelling of the HDD activities at the shore crossing demonstrates that visitors to the beach (including campers) will be impacted by noise levels from these operations during the 3- to 4-month drilling period.

Operational noise from the gas plant is not expected to impact upon the recreational users of the Forty Mile Beach area due to the distance (approximately 10 km) between the two locations. Operational noise emissions from the shore crossing and onshore sections of the supply gas pipeline are expected to be non-existent.

Dust emissions from the DCDP are expected to be mostly generated during the construction phase of the project. Dust may have a temporary impact on local air quality during construction by reducing visibility (potentially affecting safety and amenity) and thus impacting on the recreational and tourist value of the area.

The construction activities and general presence of the gas plant and related infrastructure can impact the visual amenity of the area and subsequently the recreational and tourism values. A visual impact assessment was conducted for the proposed DCDP (**Section 7.3.7**); it concluded that there would be a low level of impact to visual amenity based on:

- The distance to the proposed project from key view points.
- Screening of the proposed project by existing relief and vegetation.
- The overall low height of the proposed project and the minimal change in elevation within the viewsheds.
- The overall medium landscape value of the area.

There is the potential for impacts to the recreational and tourism values of the area through access restrictions that will occur on land in the vicinity of the HDD construction site and also in the marine environment immediately around the construction vessels and HDD exit point. These are discussed in **Section 9.5** and **9.7** respectively.

The marine HDD activities have the potential to cause a temporary increase in suspended solids around the HDD exit point, which can potentially disrupt such recreational activities as fishing and diving in the shallow Regnard Bay, as well as impacting on the visual amenity of the seascape. The impacts will be of a temporary nature and localised as described in detail in **Section 8.1**.

9.8.2 Management

Management measures that will help to mitigate the visual impact of the DCDP include perimeter landscaping. Other management measures to minimise impacts on recreation and tourism are covered in the following tables:

Table 7.20 Summary of Air Emission Management Measures.
Table 7.23 Summary of Noise Management Measures.
Table 8.2 Summary of Water Quality Management Measures.
Table 9.2 Summary of Management Measures for Land Use and Tenure.

9.8.3 Residual Risks

With the implementation of the proposed dust management controls, the residual environmental risks of dust emissions are predicted to range from "B", indicating an acceptable level of risk, to "negligible". The higher level of risk rating applies to the potential dust generation at the HDD construction site, taking into account the higher sensitivity of the receptors in this area (the Forty Mile Beach recreational area).

Taking into account the management measures described above, the residual risks from noise emissions during construction have been ranked from "B", indicating an acceptable level of risk, to "negligible", with the higher residual risks connected to the HDD program. Residual noise risks associated with the operation of the gas plant have been ranked as "negligible".

The impacts to land uses and tenure based on the temporary disruption to recreational users due to construction activities is considered to be "B" (acceptable) in light of the management measures outlined in **Section 9.5.2**.

The impacts from elevated suspended solids in the marine environment as a result of the HDD program will be temporary and localised as described in detail in **Section 8.1**.

The overall visual impact from the proposed project was considered low to slight based on the visual impact assessment, with an overall risk to amenity as it relates to recreation and tourism considered to be "negligible".

9.9 INDIGENOUS HERITAGE

The proposed project area lies within two registered and overlapping Native Title claims as lodged by the Yaburara and Coastal Mardudhunera people and the Wong-Goo-Tt-Oo people (jointly referred to as the Aboriginal Groups). A total of five Aboriginal heritage sites lie partially within or in close proximity to DCDP areas as recorded within the DIA heritage site database. Field survey work conducted by the proponent in 2006 and 2007 in consultation with representatives from the Aboriginal Groups verified the location of some of the sites listed on the DIA database and also identified other previously unrecorded Aboriginal heritage sites within the project area (**Tables 6.3** and **6.5**).

Under section 18 of the *Aboriginal Heritage Act 1972*, Apache submitted an application for consent to certain uses based upon the proponent's intent to develop and operate the DCDP in areas that may overlap the location of some of these Aboriginal heritage sites. The application was submitted in accordance with the act in order to use the land comprising the project area and also to seek approval to disturb some of the Aboriginal heritage sites. It is anticipated that the Minister for Indigenous Affairs will provide consent to use the land and to disturb some of the sites subject to the implementation of an approved Aboriginal Heritage Management Plan which will be approved prior to any ground disturbance works commencing on site.

9.9.1 Impacts

The key hazard to Aboriginal heritage sites is from clearing and earthwork activities associated with site preparation. Impacts from these activities include disturbance to known sites as detailed below, as well as unplanned disturbance resulting from unauthorised clearing of or access to areas outside the DCDP areas.

Disturbance to Known Heritage Sites

Proposed disturbance to known Aboriginal sites requires consent from the Minister for Indigenous Affairs in accordance with the requirements of the *Aboriginal Heritage Act 1972*. In its section 18 application for consent to use the land within the project area (**Figure 3.2**), Apache has proposed that six of the sites will be protected during works, seven of the sites will be disturbed and the subject of future Aboriginal Heritage Act section 16 permits to undertake approved heritage site salvage work, and 23 sites will be disturbed to the extent that they may be destroyed. There is also the potential for some disturbance to three previously recorded and registered Aboriginal heritage sites located within the project area; however, this disturbance will be partial and only to the extent that the site areas overlap with the works as proposed within the project area. Required protection, together with the level of disturbance to other heritage sites, is summarised in the **Table 9.5**.

Accidental Disturbance to Heritage Sites

Accidental disturbance to Aboriginal heritage sites could result from access to and/or unauthorised land clearance outside the clearing footprint or in the event that a site has not been previously identified and the location recorded. The clearing footprint for the DCDP has been designed to minimise impact to sites of heritage significance; however, accidental disturbance outside the planned disturbance footprint could occur through vehicle and personnel movements outside of the designated areas. The extent of the impact would depend on the significance of any disturbed sites. Measures will be in place to minimise the risk of accidental disturbance to areas outside the clearing footprint.

Although the DCDP areas have been thoroughly surveyed, there is the potential that a new Aboriginal heritage site may be discovered during the site works and unknowingly be disturbed without consent under the Aboriginal Heritage Act. Measures will be in place to ensure that all ground disturbance works is undertaken in a manner to minimise the unintentional disturbance to heritage sites that have not been previously identified during field survey work.

9.9.2 Management

In respect of the individual land elements of the proposed DCDP (as shown on **Figure 3.2**), the proposed impact to sites of Aboriginal heritage significance, together with Apache's proposed management responses, are listed in **Table 9.6**.

For heritage sites indicated to be protected during earthworks and operations, the following management strategies are proposed:

- Sites WG-16 and WG-17 external to and to the east of Project Area 4. These two sites will be protected from future interference by the installation of the gas plant perimeter fence, which will prevent intrusion into the site area by gas plant personnel. Signage will be affixed to the perimeter fence with the wording "Warning Keep Out - Areas to the east of this sign contain sites of significance to Aboriginal people and are not to be interfered with".
- Site DIA 11816 to the north of Project Area 7 and Sites AISC5 and AISC6 to the south of Project Area 8. These sites will be protected from future interference by the installation of the accommodation facility perimeter fence, which will prevent intrusion into the site areas by personnel using the accommodation facility. Signage will be affixed to the perimeter fences with the wording "Warning Keep Out - Areas to the north/south of this sign contain sites of significance to Aboriginal people and are not to be interfered with".
- Site DIA 8417, artefacts scatter to the west of Project Area 2. This site is to remain undisturbed and will be indicated within the Aboriginal Heritage Management Plan and DCDP plans and drawings to ensure avoidance.

In addition, the proponent is committed to the following management practices that will be implemented prior to the commencement of ground disturbance works:

- The project Aboriginal Heritage Management Plan will be updated to Revision 0 (Approved for Use) and submitted to the DIA for review and comment following the Minister's decision in respect of Apache's section 18 application. Each Ministerial condition that may apply with respect to consent to use the land will be addressed within the Aboriginal Heritage Management Plan to the satisfaction

Proposed Protection or Disturbance	Applicable Sites
Sites to be protected during works	WG-16, WG-17, DIA 11816, AISC5, AISC6 and DIA 8417
Sites to be disturbed and the subject of future section 16 permits to undertake salvage work	WG-06/AIGP1, WG-08, WG-20 (grinding slab only), AIGP3, AISC3, WG-05/AISC1, and AISC4
Sites to be disturbed to the extent that they may be partially or totally destroyed	WG-07, WG-09, WG-20 (artefact scatter only), WG-21, WG-22, WG-19, WG-01, WG-02, WG-03, WG-04, WG-15, WG-18, WG-36, WG-37, WG-38, WG-39, WG-40, WG-41, WG-42, WG-24, WG-25, WG-26, and WG-23.
Sites to be partially disturbed or destroyed but only to the extent that these sites are overlapped by works within the project area	DIA 15018, DIA 10526 and DIA 18091

Table 9.5 Summary of Aboriginal heritage sites proposed for protection or disturbance.

Site ID	Description	Potential Impacts and Management Response
Shore-based Marine Facility (exisiting) - Project Area 2		
DIA 8417	Artefact scatter to the west of Project Area 2.	Site to remain undisturbed and to be indicated within the Aboriginal Heritage Management Plan and DCDP plans and drawings to ensure avoidance.
Onshore Section of Supply Gas Pipeline Route - Project Area 3(a)		
WG-06 AIGP1	Grinding stones and artefact scatter.	Site will be disturbed and artefact salvage will be undertaken as the basis of a future section 16 permit application.
WG-07	Artefact scatter.	Sites will be unavoidably and totally disturbed to the extent that the artefacts will be destroyed. No artefact salvage to be undertaken.
WG-08	Grinding stone slab and artefact flake.	Site will be disturbed and artefact salvage will be undertaken as the basis of a future section 16 permit application.
WG-09	Artefact scatter.	Sites will be unavoidably and totally disturbed to the extent that the artefacts will be destroyed. No artefact salvage to be undertaken.
WG-20	Grinding stone slab and artefact scatter.	Site will be disturbed and artefact salvage of the grinding stone will be undertaken as the basis of a future section 16 permit application. The associated artefact scatter will be unavoidably disturbed and destroyed; no artefact salvage to be undertaken.
WG-21 WG-22	Artefact scatters.	Sites will be unavoidably and totally disturbed to the extent that the artefacts will be destroyed. No artefact salvage to be undertaken.
AIGP3 AISC3	Grinding patch. Artefact scatter.	Sites will be disturbed and artefact salvage of the grinding patch and the artefact scatter will be undertaken as the basis of a future section 16 permit application.
DIA 15018	Artefact scatter, engraving, grinding patches/ grooves possibly lying within Project Area 3(a).	Site will be unavoidably disturbed and artefact salvage will be undertaken as a condition of a future section 16 permit application.
Onshore Pipeline Route - Project Area 3(b)		
WG-19	Artefact scatter.	Sites will be unavoidably and totally disturbed to the extent that the artefacts will be destroyed. No artefact salvage to be undertaken.
Plant Site Area - Project Area 4		
WG-01 WG-02 WG-03 WG-04 WG-15 WG-18 WG-36 WG-37 WG-38 WG-39 WG-40 WG-41 WG-42	Artefact scatters.	Sites will be unavoidably and totally disturbed to the extent that the artefacts will be destroyed. No artefact salvage to be undertaken.

Table 9.6 Impacts and management of Aboriginal heritage sites.

Site ID	Description	Potential Impacts and Management Response
Plant Site Area - Project Area 4		
WG-05 AISC1	Artefact scatter.	The site WG-05 is common with AISC1. Site will be disturbed and artefact salvage of the artefact scatter will be undertaken as the basis of a future section 16 permit application.
WG-16 WG-17	Artefact scatters.	Sites to remain undisturbed and to be indicated within the Aboriginal Heritage Management Plan and DCDP plans and drawings to ensure avoidance.
DIA 10526	Artefact scatter possibly at the southeast margin of Project Area 4 and predominantly further southeast of Project Area 4.	Site has been disturbed previously by DBNGP construction. Further disturbance of the general area the artefact is recorded within is expected during DCDP construction work as an unavoidable impact, however there is no certainty that the site exists within the actual footprint to be disturbed by the DCDP. No artefact salvage intended in respect of this site since there is no firm evidence of site existence within DCDP Project Area. Should the site be confirmed to be within the DCDP disturbance area, artefact salvage will be undertaken.
DIA 18091	Artefact scatter, historical with likely location lying outside and to the east of Project Area 4.	There is no firm evidence that this site lies within the DCDP project area.
Gas Plant Ancillary Area - Project Area 5		
WG-24 WG-25 WG-26	Artefact scatters.	Sites will be unavoidably and totally disturbed to the extent that the artefacts will be destroyed. No artefact salvage to be undertaken.
AISC4	Artefact scatter.	Site will be disturbed and artefact salvage of the artefact scatter will be undertaken as the basis of a future section 16 permit application.
Temporary Water Storage Area - Project Area 6		
WG-23	Artefact scatter	Sites will be unavoidably and totally disturbed to the extent that the artefacts will be destroyed. No artefact salvage to be undertaken.
Accommodation Facility Area – Project Area 7 and 8		
AISC5	Artefact scatter	Sites will be avoided during the construction and operational phases of the project.
AISC6	Artefact scatter	Sites will be avoided during the construction and operational phases of the project.
DIA 11816	Engraving, grinding patches/grooves with likely location to the north of Project Area 7.	There is no evidence that this site lies within the DCDP project area and its possible location will be indicated within the Aboriginal Heritage Management Plan and DCDP plans and drawings to ensure avoidance.

Table 9.6 Impacts and management of Aboriginal heritage sites. *(continued)*

of the DIA. The Aboriginal Heritage Management Plan will only be implemented for use within the project area following endorsement of the the plan by the DIA.

- All personnel that are to work within the project area will be made aware of their obligations under the Aboriginal Heritage Act.
- The location of the Aboriginal heritage sites as per **Section 6.12** will be referred to within the DCDP site heritage induction that will occur and be required:
  - For all personnel that are to commence work on site.
  - Until such time as the sites are dealt with in accordance with the management responses outlined in **Table 9.6** and to be more fully addressed within the Aboriginal Heritage Management Plan, as approved for use.
- In the event that ground disturbance works are required within the project area prior to the issue of section 16 permits to disturb sites, then the sites are to either:
  - Be avoided.
  - Preserved *in situ*.
  - The subject of a future section 16 permit to undertake approved heritage site salvage work.

These sites shall be clearly delineated by the installation of temporary fencing and/or appropriate warning signage so as to avoid the possibility of unintentional disturbance.

- The proponent will engage Aboriginal heritage monitors from both Aboriginal Groups for the purposes of monitoring ground disturbance work, as agreed to by the proponent and the Groups, those being:
  - During the trench excavation for construction of the onshore section of the supply gas pipeline over previously undisturbed ground within Project Areas 2, 3(a) and 3(b).

Aspect	Hazards	Sources	Impacts	Mitigation/controls
Aboriginal heritage sites	Clearing and earthworks.	*Site preparation, access tracks.*	Planned disturbance, damage or loss to sites or artefacts of Aboriginal heritage. Unplanned disturbance, damage or loss to sites or artefacts of Aboriginal heritage.	Disturbance to recognised sites of low to moderate significance within the project area will be minimised where possible. Any proposed disturbance to recognised heritage sites within the project area will require approval under section 18 of the Aboriginal Heritage Act and will be the subject of section 16 permit applications. The proponent will engage Aboriginal heritage monitors from both Aboriginal Groups for the purposes of monitoring ground disturbance work, as agreed to by the proponent and the Groups, those being; • During the trench excavation for construction of the onshore gas pipeline over previously undisturbed ground within Project Areas 2, 3(a) and 3(b). • Prior to infill of soil over previously undisturbed ground within the project area where the requirement for monitoring shall cease after the natural ground has been covered by infill material. In the event that ground disturbance works are required within the project area prior to the issue of section 16 permits to disturb sites, then the sites that are to either: • Be avoided. • Preserved *in situ*. • The subject of a future section 16 permit to undertake approved heritage site salvage work These sites shall be clearly delineated by the installation of temporary fencing and/or appropriate warning signage so as to avoid the possibility of unintentional disturbance. The project Aboriginal Heritage Management Plan will be updated to Revision 0 (Approved for Use) and submitted to the DIA for review and comment following the Minister's decision in respect of Apache's section 18 application. Each Ministerial condition that may apply with respect to consent to use the land will be addressed within the Aboriginal Heritage Management Plan to the satisfaction of the DIA. The Aboriginal Heritage Management Plan will only be implemented for use within the project area following endorsement of the plan by the DIA. All personnel that are to work within the project area will be made aware of their obligations under the Aboriginal Heritage Act. The location of the Aboriginal heritage sites as per Section 6.12 will be referred to within the DCDP site heritage and environment induction that will occur and be required: • For all personnel that are to commence work on site. • Until such time as the sites are dealt with in accordance with the management responses outlined in Table 10.2 and to be more fully addressed within the Aboriginal Heritage Management Plan, as approved for use.

Table 9.7 Summary of management measures for Aboriginal heritage sites.

- Prior to infill of soil over previously undisturbed ground within the project area where the requirement for monitoring shall cease after the natural ground has been covered by infill material.

The management measures for indigenous heritage are summarised in **Table 9.7**.

9.9.3 Residual Risks

The Pilbara Region contains many Aboriginal heritage sites of both archaeological and ethnographic significance. The types of heritage sites occurring in the region include shell middens, standing stones, grinding patches, stone features (for example, hunting hides and pits), quarries and rock art.

Such heritage sites date Aboriginal occupation in the region to many thousands of years ago.

The works associated with the proposed DCDP will result in disturbance to a number of identified Aboriginal heritage sites. However, reports commissioned by the proponent in close consultation with senior Aboriginal persons representing both the Wong-Goo-Tt-Oo people and the Yaburara and Coastal Mardudhunera people indicate that the sites are of low to moderate significance to both Aboriginal Groups. Their significance arises from the fact that they are associated with the Groups' ancestors and have historical and cultural significance to the Groups for that reason. They do not appear to have ritual or ceremonial significance to either Group and are similar to sites that are replicated in great numbers elsewhere throughout the region. Thus, the potential for impact on Aboriginal heritage for these Groups on a regional basis is considered to be negligible.

9.10 NON-INDIGENOUS HERITAGE

As discussed in **Section 6.13**, no places of non-indigenous historical significance were found within or adjacent to the proposed DCDP area during the database searches of the Register of the National Estate and the Register of the Heritage Council of WA.

9.10.1 Impacts on Non-indigenous Heritage

There will be no impacts resulting from activities of the DCDP on non-indigenous heritage, as there are no heritage sites within the project area.

9.10.2 Management

No specific management measures are required.

9.10.3 Residual Risks

Residual risks are considered to be "negligible".

This chapter describes the environmental management framework that will be applied to the DCDP to manage environmental risks to ALARP. The framework described in this chapter follows that of the Australian/New Zealand Standard (AS/NZS) International Organisation for Standardisation (ISO) 14001:1996, Environmental Management Systems – Specification with Guidance for Use.

Apache recognises the environmental sensitivities of the project area and will carry out the commitments made throughout this Draft PER to ensure minimal environmental impact. Apache is well placed to undertake this task, given its background of successfully managing oil and gas exploration and production in sensitive environments on the North West Shelf.

Apache is responsible for the environmental impact assessment process in support of the preparation of an environmental impact assessment document to satisfy the requirements of the *Environmental Protection Act 1986*, Part IV (as described in **Section 1.2.1**). Apache will undertake all consultation and actions required to progress the environmental impact assessment of the DCDP. Apache will also be responsible for obtaining "Works Approvals" as required for prescribed premises under the Environmental Protection Act, Part V, and all other approvals as required and outlined in **Section 1.2.2**.

10.1 ENVIRONMENTAL POLICY

Apache is committed to protecting the environment in all its oil and gas exploration and production activities. This commitment is described in the Apache Environmental Management Policy, provided in **Section 1.4.3**, as endorsed by the Managing Director. The policy sets out the company's environmental management objectives and provides the overarching guidance for all environmental management activities. Continuous improvement in environmental performance is an essential component of this policy.

The environmental management and measures described in this Draft PER are consistent with Apache's Environment Policy.

10.2 ENVIRONMENTAL MANAGEMENT PLANS

Apache will fulfil the commitments and the avoidance, mitigation and management measures made throughout this Draft PER through the implementation of a construction environmental management plan (CEMP) for the construction phase of the DCDP.

The CEMP documents Apache's requirements during the construction of the elements of the DCDP covered by this Draft PER, including the HDD program. These include regulatory requirements, company standards and project commitments, including any DCDP-specific environmental approval conditions. A preliminary CEMP covering the scope of this draft PER, has been provided in **Appendix 8**.

An operations environmental management plan (OEMP) for the operations phase will be developed during the construction phase of the DCDP once final engineering and equipment selection is completed.

The broad objectives of the DCDP environmental management plans are to:

- Achieve and demonstrate best-practice environmental management of any aspect of the development that may have an impact on the environment.
- Minimise and manage the consequences where an impact is unavoidable to a level considered to be ALARP.

The DCDP environmental management plans also describe the procedures and equipment proposed to prevent, mitigate, monitor and manage potential impacts.

10.2.1 Oil Spill Contingency Plan

The probability of a large hydrocarbon spill to the marine environment during the marine support works associated with the horizontal directional drilling program for DCDP was assessed as unlikely. The main preventative measure to reduce the risk of potential environmental impacts, should such an event occur, will be the implementation of Apache's Oil Spill Contingency Plan (OSCP) for the North West Shelf.

Apache have an OSCP that covers its current operations on the North West Shelf, approved by the DoIR, under the requirements of the *Petroleum (Submerged Lands) Act 1982 (P(SL)A)*. This OSCP will be updated with site specific information to cover the construction phase of the DCDP and submitted to DoIR for approval. The plan will be updated for the operational phase of the DCDP, as required by P(SL)A.

Apache's updated Oil Spill Contingency Plan (OSCP) for the DCDP will:

- Ensure effective and timely management of spills of hydrocarbons.
- Describe the procedures to deal with an oil spill.
- Define the roles and responsibilities of response personnel.
- Describe the external resources available for use in combating oil spills and how these resources will be coordinated.
- Be integrated with State and Commonwealth government and industry response plans.

In the unlikely event of a hydrocarbon spill that is beyond the response capability of Apache, a request will be made for the activation of the State Plan or the National Plan to 'Combat Pollution of the Sea by Oil and other Noxious and Hazardous Substances'.

10.2.2 Other Management Plans

This draft PER also references other management plans that will be used in conjunction with the Construction Environmental Management Plan to manage the environmental risks associated with the DCDP.

The DCDP Health Management Plan is the controlling document for the management of public health issues. Based upon advice from the Department of Health (DoH) on the draft DCDP Health Management Plan, it was recommended that mosquito and drinking water management issues be excised into standalone management plans.

Therefore, Apache has developed and will implement the following plans to cover public health issues, pending review and final approval by the DoH:

- DCDP Health Management Plan covering wastewater treatment and disposal from the accommodation facility, air quality and noise during construction and operations phases of the DCDP and the storage and handling of hazardous substances. Management measures and actions are provided in **Section 9.3.2**, **Table 9.1**, of this PER.
- DCDP Mosquito Management Plan will be prepared in accordance with the DoH publication Mosquito Management Manual 2006 and the Australian Mosquito Control Manual 2002. Management measures and actions are provided in **Section 9.3.2**, **Table 9.1**, of this PER.
- DCDP Drinking Water Quality Management Plan will be prepared within the the framework for the management of drinking water quality based on a preventive, risk management approach, as provided in the Australian Drinking Water Guidelines. The potential risks to water quality associated with DCDP activities include pathogen contamination, turbidity, pesticides and nutrient contamination. Management measures and actions are provided in **Section 9.3.2**, **Table 9.1**, of this PER.

A Traffic Management Plan will also be developed for use during construction and operations phase of the DCDP. The Traffic Management Plan will contain control measures for site based vehicles to minimise hazards to the environment, personnel and the public, including:

- Interaction between heavy plant/equipment and light vehicles.
- Interaction between personnel and vehicles.
- Signage and traffic control personnel.
- Access and egress.
- Parking areas.
- Sensitive areas such as recorded Aboriginal heritage sites.
- Speed limits and access of vehicles into congested and restricted work areas.
- Location and proximity of public roadways and pedestrian walkways.
- Access for emergency vehicles.
- Transportation of buildings, equipment and goods to site.

10.3 IMPLEMENTATION OF ENVIRONMENTAL MANAGEMENT PLANS

The appointed construction contractors will be responsible for ensuring that environmental requirements, detailed by Apache within their contracts, are incorporated into their designs, equipment, material selection and construction activities. The environmental management structure for Apache's interface with the construction contractors for the DCDP is summarised in **Figure 10.1**.

Each construction contractor will be responsible for producing an environmental management plan (EMP) for its scope of work for review and approval by Apache. The contractor's EMP will document the processes through which it will meet Apache's contractual environmental requirements, including compliance with regulatory requirements, DCDP environmental approval conditions and management of subcontractors. Contractors will undertake environmental risk assessments for their scope of work, to be used in the development of job-specific work instructions.

It is important that the roles and responsibilities of Apache personnel and contractors are understood and followed during all phases of the development. The key roles and responsibilities for ensuring that environmental performance objectives, standards and criteria are met are outlined in **Table 10.1**. These roles and responsibilities will evolve further in consultation with the relevant contractors as the project progresses.

An integral part of the implementation of the CEMP, OEMP and contractor's EMP's is the provision of environmental awareness information to all personnel involved in the project. As a minimum the environmental induction package will ensure workers are made aware of the environmental sensitivities of the project area and surrounds, and the DCDP environmental requirements, commitments, guidelines and procedures. Induction materials will be tailored to be appropriate for a number of different groups of workers.

10.4 ENVIRONMENTAL PERFORMANCE

The environmental performance of the proposed DCDP will be measured, benchmarked and reported against environmental performance objectives (goals), standards (equipment, personnel or procedure for managing risk) and criteria (a way of determining whether the objectives and standards have been met). These criteria are objective and verifiable and will be measured, calculated or estimated, providing Apache with the means of:

- Demonstrating compliance with regulatory requirements, conditions and standards, as well as Apache's commitments and Environmental Management Policy.
- Assessing performance against the criteria.
- Achieving and demonstrating best practice and continual improvement to the regulators and the public.

Role	Responsibilities
Construction and Operations Phases	
Apache Managing Director	• Ensures compliance with Apache's Environmental Management Policy. • Provides adequate resources for environmental management. • Implements the emergency response strategy in the case of an environmental incident. • Maintains communication with company personnel, government agencies and the media.
Apache Environment Manager	• Liaises with and provides advice and guidance to the relevant Apache and contractor managers to ensure compliance with all aspects of the environmental management plans. • Carries out environmental education and inductions. • Develops and participates in the oil and chemical spill response plan and emergency response strategy. • Develops and implements a relevant environmental monitoring program and reports this to the Managing Director. • Provides resources for conducting environmental audits to ensure compliance with the relevant environmental management plan. • Reviews environmental incident reports and prepares or assists the relevant personnel (DCDP Construction Manager during construction and Devil Creek Gas Plant Person in Charge during operations) to prepare corrective action reports. • Reports all incidents to the DEC or DoIR, as required.
Construction Phase Only	
Apache DCDP Manager	• Ensures compliance with Apache's Environmental Management Policy. • Ensures overall compliance with the CEMP with advice and guidance from the Environment Manager. • Reports environmental incidents to the Environment Manager. • Assists the Managing Director in the implementation of the emergency response strategy in the event of an environmental incident.
Contractors' Construction Managers	• Implement and ensure adherence to all relevant environmental legislative requirements, commitments, conditions and procedures at the DCDP construction site. • Ensure that all plans, commitments and procedures are available to personnel. • Maintain clear communication with the workforce (including subcontractors). • Communicate hazards and risks to the workforce and the importance of following good work practices. • Ensure emergency response equipment is in place and ready for use. • Report environmental incidents to the Apache DCDP Manager and ensure follow-up actions are carried out. • Apply appropriate enforcement mechanisms to prevent breaches of the Apache CEMP and contractor EMP. • Ensure environmental information is included in regular reports to Apache during the construction phase.
Contractors' Supervisors including Vessel Masters during HDD program	• Implement and ensure adherence to all relevant environmental legislative requirements, commitments, conditions and procedures including onboard vessels. • Ensure that all plans, commitments and procedures are available to personnel. • Maintain clear communication with the construction and vessel crews. • Communicate hazards and risks to the workforce and the importance of following good work practices. • Maintain construction sites and vessels in a state of preparedness for emergency response. • Report environmental incidents to the DCDP Manager and ensure follow-up actions are carried out. • Apply appropriate enforcement mechanisms to prevent breaches of the Apache CEMP and contractor EMP.
Contractors' personnel, subcontractors and visitors	• Adhere to the Apache CEMP and contractor EMP in letter and in spirit. • Follow good housekeeping procedures and work practices. • Suggest and encourage improvement wherever possible. • Report environmental incidents to the Supervisor.
Operations Phase Only	
Apache Operations Superintendent	• Ensures compliance with Apache's Environmental Management Policy. • Ensures overall compliance with the OEMP with advice and guidance from the Environment Manager. • Reports environmental incidents to the Environment Manager. • Assists the Managing Director in the implementation of the emergency response strategy in the event of an environmental incident.

Table 10.1 Environmental roles and responsibilities for the DCDP.

Role	Responsibilities
Operations Phase Only	
Apache Person in Charge (Devil Creek Gas Plant)	• Ensures compliance with all relevant environmental legislative requirements, commitments, conditions and procedures as provided in the OEMP. • Maintains clear communication with the Operations Superintendent. • Reports environmental incidents to the Operations Superintendent and ensures that corrective action reports are prepared and provided to the Environment Manager and that follow-up actions are carried out. • Supervises the on-scene operations in the event of an environmental incident. • Ensures corrective actions arising from environmental audits are undertaken.
Devil Creek Gas Plant workforce and visitors	• Adhere to the OEMP in letter and in spirit. • Follow good housekeeping procedures and work practices. • Suggest and encourage improvement wherever possible. • Report environmental incidents to the Person in Charge.

Table 10.1 Environmental roles and responsibilities for the DCDP. *(continued)*

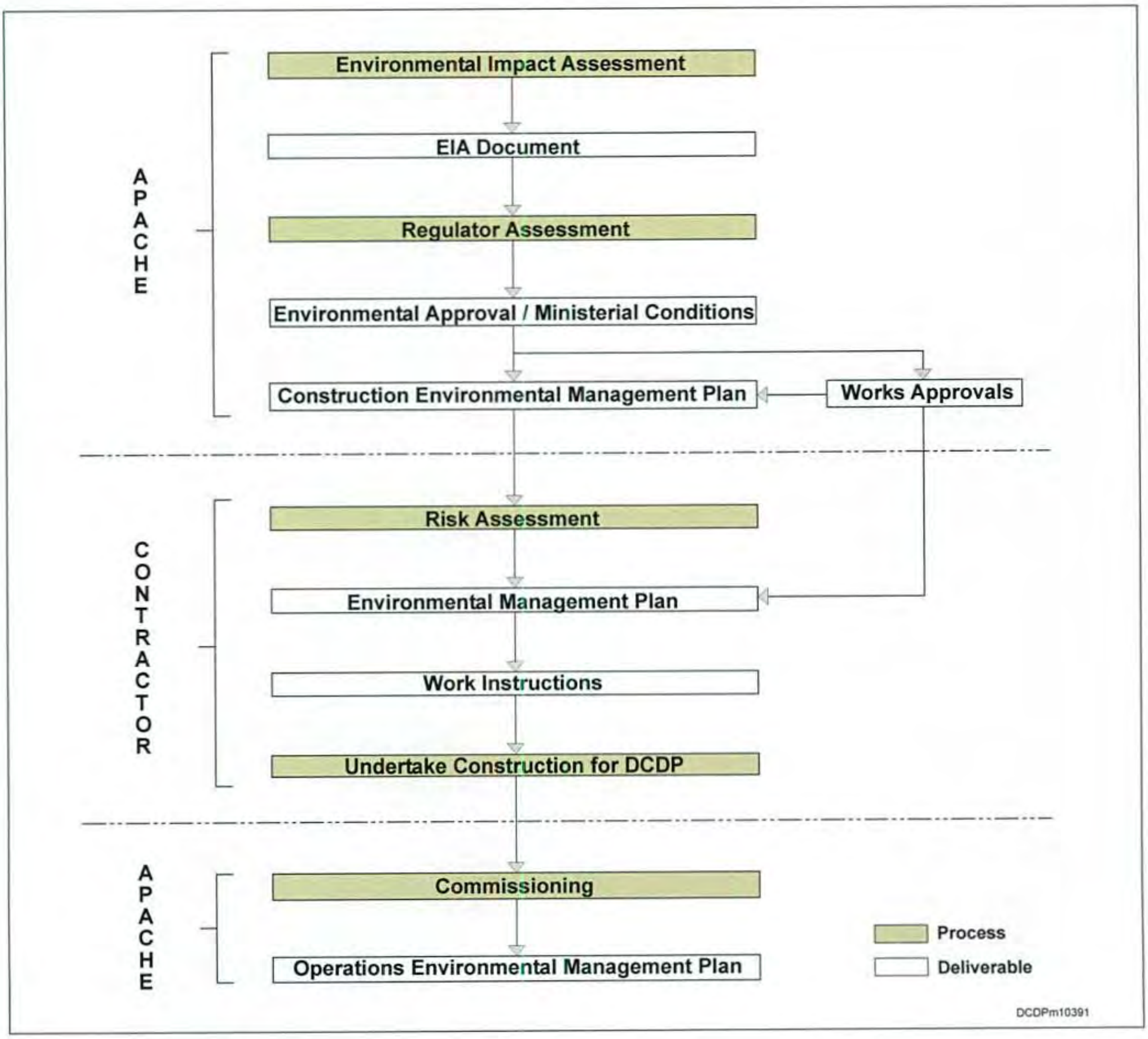

Figure 10.1 Environmental Management Policy

The environmental performance objectives, standards and criteria developed for the DCDP are summarised in the preliminary CEMP provided in **Appendix 8**. Audits of the project during the construction and operations phases will be undertaken against the performance criteria described in **Appendix 8** and the key commitments given in **Table 10.2**.

To determine whether the environmental management measures outlined in the CEMP and other procedural documents are being adhered to, various measures will be put in place. These measures will provide indications of environmental performance.

10.4.1 Monitoring

Environmental management monitoring can occur at three separate but interrelated levels, these being:

- Systems and procedures.
- Activities.
- Physical, chemical and/or biological aspects of the receiving environment.

The environmental monitoring program that will be in place for the DCDP will encompass all three levels of monitoring as described below.

10.4.1.1 Systems and Procedures Monitoring

Performance standards for the implementation of systems and procedures will be developed for each phase of the DCDP and built into the contracts of the major contractors. Apache will quantitatively monitor how these performance standards are being met, through supervision, inspections and audits.

10.4.1.2 Activities Monitoring

The contractors will be responsible for the internal reporting of various aspects of monitoring and reporting, including but not limited to waste disposal inventories (type, amount, reuse or disposal destination), water use, and fuel use. Monitoring and reporting records will also be used to support regulatory compliance reports as required.

10.4.1.3 Receiving Environment Monitoring

The objective of monitoring the receiving environment is to measure the effect of the DCDP on the environment. The results of this monitoring can then be compared to baseline information gained from the surveys conducted as part of the environmental impact assessment process, e.g., groundwater quality. It is envisaged that a post-construction survey of the nearshore marine environment will be required to assess the impacts of the HDD program on the nearshore marine habitat. The details of this survey have yet to be determined and will be developed in consultation with DEC.

10.4.2 Compliance Evaluation

Compliance evaluations are best undertaken as audits. Apache environmental staff undertake audits of Apache's facilities and of the vessels contracted to Apache at the commencement of each contract and yearly thereafter, unless more frequent audits are required (e.g., working in particularly sensitive locations). The audits are conducted against the relevant environmental document (e.g., environmental management plan, management plan, procedure) that can be modified as appropriate. Feedback from the audit is provided to Apache management at the end of the audit to enable immediate actioning of identified non-conformances or non-compliances. A formal audit report is later distributed to the relevant personnel.

Audits determine whether the daily and weekly environmental inspections that must be undertaken are being appropriately carried out, through direct interviews and reviewing records.

It is proposed that audits of the contractors' EMPs will be undertaken by Apache during construction of the DCDP to ensure that the requirements of the CEMP are being implemented. It is proposed that a formal audit of the contractors' EMPs will be undertaken at the commencement of construction and annually thereafter. A series of informal inspections and feedback to the contractors will also be taken on an opportunistic basis throughout the construction period.

10.4.3 Incident Reporting and Investigation

An environmental incident is an incident that results in or has the potential to result in an adverse effect on the environment. Such incidents include, for example, spills of chemicals, fuels or product outside bunded areas; unauthorised disturbance of flora or fauna; unauthorised venting of gas or discharge to the environment; and breach of environmental licensing conditions or statutory regulations.

All environmental incidents will be reported in the first instance to the relevant supervisor, who will then report to the Apache Environment Manager. A delegate of the Environment Manager will enter all incidents into Apache's Incidents Database as per Apache's Hazard Reporting, Incident Notification and Investigation Procedure (Document AE-91-IF-002).

Internal incident reports will be electronically documented and stored on Apache's server.

Additionally, any environmental incidents that meet the criteria below will be reported to the Department of Industry and Resources and the Department of Environment and Conservation verbally and followed up by a written report from the Environment Manager, as soon as practicable, not later than 3 days following the incident.

- A hydrocarbon or hazardous chemical spill larger than 80 L.
- An unplanned gaseous release larger than 500 m^3.
- Injury or death of fauna.
- A breach of legislation or a regulatory or license condition.

As a minimum, the written incident reports will include:

- Description of the incident.
- Action taken to avoid or mitigate any adverse environmental impact.
- Details of performance standard or objectives breached.
- Corrective action to prevent similar incidents.

All environmental incidents in Apache's incident database are provided to APPEA to allow an assessment on the type and number of incidents occurring within the oil and gas industry.

Any incident investigations will be undertaken in accordance with Apache's Hazard Reporting, Incident Notification and Investigation Procedure (Document AE-91-IF-002). As a minimum, the Apache DCDP Project Manager, Contractors' Construction Manager and Apache Environmental Manager will participate in any incident investigations during the construction phase. Operations phase incidents investigations will involve the Apache Person in Charge of the Devil Creek Gas Plant and the Apache Environmental Manager.

The purpose of the incident investigation is to identify the actions required to prevent a recurrence of the incident. At Apache, the following principles apply:

- All incidents are assessed and an investigation may take place depending on the circumstances.
- Incident investigations are aimed at collecting facts.
- All investigations take place as soon as practicable after the incident.
- Witness statements are taken as soon as practicable after the incident to ensure the statements are as accurate as possible.

The sequence of systematic investigation involves:

- Confirmation of the incident outcomes.
- Identification of the incident.
- Identification of the causal factors.
- Identification of the root causes.
- Assessment of the factors of control.
- Recommendations for remedial action.

Analysis of incident reports will be conducted periodically to assist in the identification of any trends or common factors.

In some instances, the lessons learned from an incident have value for other areas within Apache and to the wider industry. This information can be conveyed via an Alert. Anyone who believes the lessons learned from an incident would be of value to a wider audience may initiate this process.

10.4.4 Management Review

Periodic reviews of the overall effectiveness of the CEMP will be undertaken by senior management to ensure continual improvement, sustainability and effectiveness.

10.5 KEY COMMITMENTS

The Draft PER identifies the environmental aspects of the DCDP, the potential impacts and the management measures to avoid, mitigate and manage those impacts (see Chapters 7, 8 and 9 and **Appendix 8**). It forms the basis of comprehensive management actions to ensure a high level of environmental management and performance consistent with national and international standards and statutory obligations.

The EPA requires that the environmental impact assessment process carried out by proponents lists key commitments that will become legally enforceable. These key commitments for the DCDP are given in **Table 10.2**.

Action No.	Topic	Actions	Objectives	Timing	Advice from
Environmental Management					
1	Inductions	Provide environmental inductions to all personnel accessing DCDP work areas.	To ensure workforce compliance with environmental requirements, commitments, guidelines and procedures.	Prior to access to DCDP work areas during construction and operations phases.	DEC DoIR DoCEP
2	Audits	Carry out environmental audits during construction and operations phases.	To ensure workforce compliance with environmental requirements, commitments, guidelines and procedures.	During construction and operations phases.	DEC DoIR DoCEP
3	Incidents	Provide environmental incident reporting procedure that includes: • Documenting and reporting incidents to Apache Environment Manager. • Notifying the appropriate regulatory authority if required. • Recording incidents in Apache's Incidents database. • Incident investigation protocols. • Generating corrective actions to minimise likelihood of recurrence.	To ensure compliance with environmental commitments made in this PER and with Ministerial commitments.	During construction and operations phases.	DEC DoIR DoCEP
4	Emergency Preparedness and Response	Provide emergency preparedness and response procedures that include: • Response plan for cyclones. • Emergency response management and structure. • Oil and chemical spill response plan.	To ensure the ability to deal with emergency and other non-routine situations.	During construction and operations phases.	DEC DoIR DoCEP
5	Construction Environmental Management Plan	Implement a CEMP for the construction phase, including revisions as required throughout the construction phase.	To ensure compliance with environmental commitments made in this PER and with Ministerial commitments.	Prior to and during construction phase.	DEC DoIR DoCEP
6	Contractors' Construction Environmental Management Plan	Ensure contractors' EMPs are consistent and compliant with Apache's.	To ensure compliance with environmental commitments made in this PER and with Ministerial commitments.	Prior to and during construction phase.	DEC DoIR DoCEP
7	Operations Environmental Management Plan	Finalise, implement and review an OEMP for the operations phase.	To ensure compliance with environmental commitments made in this PER and with Ministerial commitments.	Prior to and during operations phase.	DEC DoIR DoCEP
8	Performance	Ensure a high standard of environmental performance by: • Enforcing compliance with EMPs. • Carrying out inductions. • Carrying out audits. • Having dedicated on-site environmental personnel during construction.	To ensure compliance with environmental commitments made in this PER, Ministerial commitments and Apache's Environmental Management Policy.	During construction and operations phases.	DEC DoIR DoCEP

Table 10.2 Key environmental commitments for the DCDP.

Action No.	Topic	Actions	Objectives	Timing	Advice from
Terrestrial Impacts					
9	Landforms and soils	Implement a CEMP that includes: • Installation of erosion and sediment control structures where deemed necessary. • Controls for movement of vehicles and personnel on-site. • Inspection for erosion and sedimentation on-site following significant rainfall events. • Post-construction rehabilitation.	To minimise impacts to natural drainage patterns and of soil compaction during construction.	Prior to and during construction phase.	DEC DoIR DoCEP
10	Landforms and soils	Implement a CEMP that includes: • Inspection for erosion and sedimentation on-site following significant rainfall events. • Measures to remedy erosion and sedimentation impacts should they occur. • Restrict vehicle movements to designated access tracks and working areas.	To minimise impacts to natural drainage patterns and of soil compaction during operations.	Prior to and during operations phase.	DEC
11	Groundwater and Surface Water	Implement a CEMP that includes: • DoW licence conditions on quantity and rate of groundwater abstraction. • Groundwater monitoring program. • Provision of designated washdown areas with effluent management controls. • Minimum requirements for fuel, oil and chemical storage, including provision of secondary containment and access control. • Procedures for refuelling operations. • Oil and chemical spill response plan.	To minimise impacts to groundwater and groundwater-dependent ecosystems.	Prior to and during construction phase.	DEC DoIR DoCEP DoW
12	Groundwater and Surface Water	Implement a CEMP that includes: • Maintenance of on-site drainage water management system designed to segregate clean water and treat potentially contaminated water. • Groundwater monitoring program. • Provision of designated washdown areas with effluent management controls. • Bunded and contained storage of hazardous materials. • Procedures for refuelling operations. • Oil and chemical spill response plan.	To minimise impacts to groundwater and groundwater-dependent ecosystems.	Prior to and during operations phase.	DEC

Table 10.2 Key environmental commitments for the DCDP. *(continued)*

Action No.	Topic	Actions	Objectives	Timing	Advice from
13	Air Emissions	Prepare and implement CEMP that includes: • Measures to minimise the generation and spread of dust. • Measures to reduce the emissions from engines and equipment during construction. • Enclosing or shielding grinding operations where practicable at the HDD construction site at Gnoorea Point.	To minimise impacts on fauna, flora and recreational amenity of Gnoorea Point and Forty Mile Beach.	Prior to and during construction phase.	DEC DoIR DoCEP
14	Air Emissions	Prepare and implement OEMP that includes: • Flare metering for greenhouse gas emission reporting. • Maintenance regimes to ensure equipment is correctly and regularly maintained.	To reduce venting, flaring and combustion of hydrocarbons to ALARP.	Prior to and during operations phase.	DEC
15	Noise	Prepare and implement CEMP that includes: • Details of measures to control noise (including vibration) emissions, such as mufflers, noise-absorbing walls and enclosures, and strategic positioning of equipment. • Procedures to be adopted for monitoring noise (including vibration) emissions during construction.	To minimise impacts on fauna and on the recreational amenity of Gnoorea Point and Forty Mile Beach.	Prior to and during construction phase.	DEC DoIR
16	Noise	Undertake a reassessment of the noise impacts from the gas plant during detailed design to ensure that noise from the gas plant received at the DCDP accommodation facility complies with the assigned noise limits for noise-sensitive premises detailed in the Environmental Protection (Noise) Regulations 1997.	To minimise impacts on fauna in the vicinity of the gas plant and gas plant workforce.	Prior to and during operations phase.	DEC
17	Lighting	Implement a CEMP that includes: • Details of measures to reduce lighting to ALARP without compromising safe working conditions.	To minimise impacts on terrestrial fauna and on the recreational amenity of Gnoorea Point and Forty Mile Beach.	Prior to and during construction phase.	DEC DoIR
18	Lighting	Implement a CEMP that includes: • Details of measures to reduce lighting to ALARP without compromising safe working conditions.	To minimise impacts on terrestrial fauna in the vicinity of the gas plant and accommodation facility.	Prior to and during operations phase.	DEC
19	Visual Impact	Perimeter landscaping of the gas plant will be undertaken.	To minimise the visual impacts of the gas plant.	During last-construction and operations phases.	DEC SoR
20	Waste (Solid and Liquid)	Implement a CEMP that includes: • Secure measures for containment of wastes on-site. • Storage of liquid wastes within bunded areas. • Procedures for disposal of hydrotesting water. • Efforts to minimise waste generation and to reuse or recycle materials. • Procedures for waste disposal to an appropriately licensed landfill or waste disposal facility with all hazardous waste measured, documented and tracked. • Recording and reporting volume of waste material on a monthly basis.	To minimise the impacts from the generation, handling, storage and disposal of waste.	During construction and operations phases.	DEC

Table 10.2 Key environmental commitments for the DCDP. *(continued)*

Action No.	Topic	Actions	Objectives	Timing	Advice from
21	Vegetation and Flora	Implement a CEMP that includes: • Details of measures for the protection of vegetation and flora, such as controlling site vehicle and personnel movements, and surveying and marking the footprint for vegetation clearance during site preparation works. • Fire response equipment stationed nearby during hot-work. • Rehabilitation management actions.	To minimise impacts to vegetation and flora by: • Minimising the amount of vegetation that is permanently cleared. • Preventing disturbance to adjacent areas.	Prior to and during construction phase.	DEC DoIR
22	Vegetation and Flora	Implement a CEMP that includes: • An exclusion zone over the *Eremophila forestii subsp. forestii* vegetation association adjacent to the accommodation facility. • Fire response equipment on-site. • Rehabilitation management actions.	To minimise impacts to vegetation and flora by preventing disturbance to adjacent areas.	Prior to and during operations phase.	DEC
23	Terrestrial Fauna and Subterranean Fauna	Implement a CEMP that includes: • Details of measures for the protection of fauna, including managing the specific risks posed by pipeline trench excavation, controlling site vehicle and personnel movements, and surveying and marking the footprint for vegetation clearance during site preparation works. • Fire response equipment on-site. • DoW licence conditions on quantity and rate of groundwater abstraction. • Groundwater monitoring program.	To minimise impacts to terrestrial fauna and subterranean fauna.	Prior to and during construction phase.	DEC DoIR DoW
24	Terrestrial Fauna and Subterranean Fauna	Implement a OEMP that includes: • Details of measures for the protection of fauna, such as controlling site vehicle and personnel movements. • DoW licence conditions on quantity and rate of groundwater abstraction. • Groundwater monitoring program. • Fire response equipment on-site.	To minimise impacts to terrestrial fauna and subterranean fauna.	Prior to and during operations phase.	DEC
25	Weeds	Implement a CEMP that includes: • Details of measures to identify, mark out and assess controllability of existing weed infestations and to establish and maintain vehicle and equipment hygiene through quarantine procedure. • Monitoring throughout construction to identify introductions or the spread of weeds and to manage any new infestations, where they can be effectively controlled.	To minimise the introduction and spread of weed species.	Prior to and during construction phase.	DEC

Table 10.2 Key environmental commitments for the DCDP. *(continued)*

Action No.	Topic	Actions	Objectives	Timing	Advice from
26	Rehabilitation	Implement a CEMP that includes: • Details of measures for the removal and stockpiling of vegetation and topsoil. • Details the actions required for active rehabilitation of suitable areas.	To maximise rehabilitation success by minimising the effects of vegetation clearance. To ensure that the area is suitably rehabilitated with regard to the control of erosion and sedimentation.	During construction and operations phases.	DEC
Marine Impacts					
27	Sea turtles and other marine megafauna	Implement a CEMP that includes: • Details of measures to reduce lighting associated with the HDD program to a minimum. • Provision for marine fauna observer during the period 1 November to 31 March within 1.5 km of Forty Mile Beach to record, if any, turtle nesting behaviour. • Details of measures to manage vessel operations with regard to speed, movement, anchoring, discharges, and waste management.	To minimise impacts to marine fauna. Minimise the risks of vessel collision with marine fauna, other vessels or grounding.	During construction phase.	DEC
28	Nearshore Marine Habitat	Implement an HDD program that minimises the volume of drilling discharges to the marine environment as outlined in Planned Case. Implement a CEMP that includes: • Details of measures to limit the disturbance to the seabed. • Measures to minimise the impacts from the generation, handling, storage and disposal of waste. • Measures to prevent contaminated deck drainage from entering the marine environment. • Measures to minimise the risk of accidental spills to the marine environment. • Measures to control vessel movements within shallow, nearshore waters. • Commitment to post-construction survey to assess impacts of HDD program.	Minimise impacts to water quality, benthic primary producers, marine fauna and the recreational amenity of Gnoorea Point and Forty Mile Beach. Minimise physical disturbance to seabed and avoid physical damage to significant features from vessel anchors. Store fuel and oils according to best practice.	During construction phase.	DEC
Social Impacts					
29	Stakeholder Consultation	Undertake ongoing consultation with stakeholders prior to and during the construction phase of DCDP.	Apache will implement a Community Consultation Plan to continue communication between Apache and stakeholders so that environmental and social impacts arising from the DCDP are minimised.	Prior to and during construction phase.	
30	Public Health	Apache will implement a DCDP Health Management Plan, Mosquito Management Plan and Drinking Water Quality Management Plan to ensure the health and safety of the workforce and public are protected, these will include: • Health management strategies including: – Waste water treatment and disposal controls.	To reduce the risks of exposure to nuisance insects, exposure to greywater and sewage, and contamination of drinking water supply.	During construction and operations phases.	SoR

Table 10.2 Key environmental commitments for the DCDP. *(continued)*

Action No.	Topic	Actions	Objectives	Timing	Advice from
		- Protection of workers who may be involved in exposure to the waste water treatment plant. - Dust suppression as required. - Noise control strategies. - Hazardous substances storage and use controls. • Mosquito management strategies including: - Base line mosquito / midge survey. - On-going monitoring and education. - Use of traps, larvicides and adult knock-down products. - Pre-cyclone preparedness to reduce the potential for water traps. - Post-cyclone preparedness to monitor previously identified breeding locations and apply control agents as necessary. • Drinking water protection strategies in line with the Australian Drinking Water Guidelines 2004 covering: - Raw water sampling and analysis. - Catchment monitoring and maintenance. - Water abstraction source and method. - Well exclusion zone. - Water treatment, storage and reticulation. - Operational monitoring and maintenance. - Competency of personnel. - Water quality monitoring and reporting. - Incident response. Construction and Operations Traffic Management Plans will be implemented for the project to address road safety issues associated with the transport of personnel and materials including: - Interaction between plant and equipment and personnel / vehicles. - Signage and traffic control personnel. - Access and egress and parking areas. - Prevention of damage to off-site and sensitive areas. - Speed limits. - Minimise disruption to road users. - Minimise potential impacts to the environment.			

Table 10.2 Key environmental commitments for the DCDP. *(continued)*

Action No.	Topic	Actions	Objectives	Timing	Advice from
31	Regional infrastructure and services	Construction and Operations Traffic Management Plans implemented for the project.	To minimise road safety risks associated with the transport of personnel and materials.	During construction and operations phases.	SoR MRWA
32	Regional infrastructure and services	The proponent will liaise with the Shire of Roebourne such that pre- and post-inspections of the Forty Mile Beach Road may be conducted and agreement reached as to the remedial work to be undertaken by the proponent following works completion to reinstate the road to its previous condition.	To ensure that any DCDP construction related deterioration of the public Forty Mile Beach Road (unsealed) is remediated.	Prior to and during construction.	SoR
33	Fisheries	Implement a CEMP that includes: • Strict hydrocarbon and chemical handling procedures on all construction vessels. • An approved oil spill contingency plan and spill kits will be readily available onboard vessels. • Consulting with recreational fishing groups and local Marine Aquarium Fisheries prior to commencing marine construction to keep them informed of timing and duration of activities.	To minimise the risks to the marine environment and fisheries.	Prior to and during construction phase.	DEC DoF
34	Fisheries	Information relating to the location of permanent subsea project components will be provided to the relevant authorities for representation on admiralty charts.	To minimise the risks to fisheries.	During operations phases	DoF
35	Aboriginal Heritage	The Aboriginal Heritage Management Plan will be implemented for use within the project area following endorsement by the DIA.	To ensure continued liaison with Aboriginal Groups and compliance with Aboriginal Heritage Act requirements.	Prior to and during construction.	DIA
36	Recreational Use of Gnoorea Point	Apache will implement the following measures: • Signage to alert public of construction activities. • Alternative access road to be provided to allow access to camp sites adjacent to the west of Reserve 44694. • Provision of alternative sewage disposal arrangements for seasonal campers to be discussed with the Shire of Roebourne. • Access to boat launching facility to be maintained throughout construction period. • Public consultation and supply of construction schedule information prior to construction. • Noise management measures to be implemented. • Light management measures to be implemented. • Complaints reporting procedure.	To minimise the disturbance to recreational users of Gnoorea Point throughout DCDP construction.	Prior to and during construction.	SoR

Table 10.2 Key environmental commitments for the DCDP. *(continued)*

11.1 DCDP TEAM

This Draft PER was prepared by Apache's internal Environment Department and contractors, comprising:

Libby Howitt – Senior Environmental Scientist, Lead Author, EIA Coordinator and Editor

Michael Cobb – Environmental Scientist, Contributing Author and EIA Coordinator

Petrina Raitt – Senior Environmental Consultant (RPS Ecos), Contributing Author

Damian Williams – Senior Environmental Consultant (RPS Ecos), Contributing Author

Ian Ross – Supervising Draftsperson, GIS Management

Graham Murray – Draftsperson

Bristal Davies – Draftsperson

Marnie Graham – Administrative assistance

Several Apache personnel and contractors working on the DCDP provided technical input and reviews of the Draft PER, including:

Harry Wyeth – Project Engineer

Paul Burren – Process Engineer

HK Chiam – Offshore Installation Manager

Vijay Kumar – Senior Project Engineer

Marc Van der Smissen – Construction Manager

11.2 SPECIALIST CONSULTANTS

The following specialist consultants were contracted to Apache to assist in the EIA for the DCDP, and their contribution and expertise is gratefully acknowledged.

Organisation	Role
APASA	HDD plume modelling
Astron Environmental Services	Flora survey and impact assessment
Atteris	HDD design and engineering advice
Bamford Consulting Ecologists	Fauna impact assessment
Bennelongia Environmental Consultants	Sub-fauna impact assessment
Coffey Environments	Acid sulfate soils assessment, Groundwater quality impact assessment, Health Assessment
Coffey Geotechnics	Hydrogeological investigation, Geotechnical investigations
IRC	Environmental HAZID Facilitation
JDA Consultant Hydrologists	Flood study
Liz Jacobsen	Technical editing
Pendoley Environmental	Sea turtle nesting site survey
RPS	Marine habitat description and impact assessment
SKM	Air quality impact assessment
SVT Engineering Consultants	Noise impact assessment
TriSurv	Geophysical seabed surveys.
WorleyParsons Komex	Visual impact assessment

11.3 TECHNICAL REVIEWS

External reports produced for Apache by consultants have been reviewed for completeness, accuracy and content by the responsible consultant and by the relevant personnel at Apache through a review and document control process.

The HDD plume modelling study prepared by Asia Pacific Applied Science Associates was technically reviewed by Dr Peter Ridd, Reader in the School of Mathematics, Physics and IT at James Cook University, Townsville 4811, Australia.

Specialist advice was sought from Dr Kellie Pendoley from Pendoley Environmental Consultants with regard to impacts on sea turtles.

The draft PER has been reviewed by the relevant technical personnel designing the DCDP and by the EPA against the approved Environmental Scoping Document for the DCDP.

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A$	Australian dollars.
ASS	Acid Sulphate Soils
ACMC	Aboriginal Cultural Materials Committee
ADCPs	Acoustic-Doppler Current Profilers
AEL	Apache Energy Ltd
AHMP	Aboriginal Heritage Management Plan
AHA	*Aboriginal Heritage Act 1972*
AHD	Australian Height Datum
ALARP	As low as reasonably practicable
ANPL	Apache Northwest Pty Ltd
ANZECC and ARMCANZ	Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand
APPEA	Australian Petroleum Production and Exploration Association
AQIS	Australian Quarantine Inspection Service
AWDG	Australian Drinking Water Guidelines (2004)
Bbls/day	Barrels per day
Bbls/TJ	Barrels per Terra Joule
Bombie	Massive, spherical boulders of coral, whose shape ensures a maximum surface area for their coral polyps to filter food from the water.
Bonn	Bonn Convention on the Conservation of Migratory Species of Wild Animals. An intergovernmental treaty aimed at conserving terrestrial, marine and avian migratory species throughout their range.
BPPH	Benthic primary producer habitat
BTEX	BTEX refers to a group of compounds (benzene, toluene, ethylbenzene and total xylenes) which are naturally occurring components of petroleum. BTEX are the most toxic constituents of petroleum and solvents.
Calcrete	A layer where cemented carbonate accumulation has occurred. The material must be hard in a pan or in the substrate.
CALM	Department of Conservation and Land Management (WA) – now known as the Department of Environment and Conservation
CAMBA	China-Australia Migratory Birds Agreement
CEMP	Construction Environmental Management Plan
CLT	Cumulative loss threshold
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2-e (carbon dioxide equivalent)	Carbon dioxide equivalent is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential. For example, the global warming potential for methane over 100 years is 21. This means that emissions of one million metric tons of methane is equivalent to emissions of 21 million metric tons of carbon dioxide.

Commissioning	The process by which a facility is confirmed to operate as expected. Involves the testing of equipment that is being operated in the particular configuration for the first time.
Condensate	A low-density mixture of hydrocarbon liquids that are present as gaseous components in the raw natural gas produced from many natural gas fields. It condenses out of the raw gas if the temperature is reduced to below the hydrocarbon dew point temperature of the raw gas.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Cumulative	Increasing or enlarging by successive addition.
CTD	Current, temperature, depth
Cuttings	Cuttings are pieces of rock, gravel and sand removed from a hole during the drilling process.
dB	Decibel. A logarithmic scale used to denote the intensity, or pressure level, of a sound relative to the threshold of human hearing. A step of 10 dB is a ten-fold increase in intensity or sound energy and actually sounds a little more than twice as loud.
dB(A)	Decibels with the sound pressure scale adjusted to conform with the frequency response of the human ear.
DBNG	Dampier to Bunbury natural gas
DBNGP	Dampier to Bunbury natural gas pipeline
DCDP	Devil Creek Development Project
DEC	Department of Environment and Conservation (WA), formerly the Department of Conservation and Land Management and the Department of Environmental Protection.
DEWHA	Department of Environment, Water, Heritage and the Arts (Cwlth), formerly DEWR (Department of Environment and Water Resources)
DIA	Department of Indigenous Affairs (WA)
DoCEP	Department of Consumer and Employment Protection (WA)
DoIR	Department of Industry and Resources (WA)
DoW	Department of Water (WA)
DPI	Department of Planning and Infrastructure (WA)
DRF	Declared Rare Flora
Dry-break coupling	A hose connection which allows disconnection without spilling any fluid, similar to those used by fuel tankers delivering fuel to service stations.
EIA	Environmental Impact Assessment
ENSO	El Nino Southern Oscillation
EMP	Environmental Management Plan
EPA	Environmental Protection Authority
EPBC	*Environmental Protection and Biodiversity Conservation Act 1999*
FEED	Front end engineering and design. A process that provides costs and technical data on a proposed project to enable a decision on final commitment to construction.

FESA	Fire and Emergency Safety Authority
FIFO	Fly In Fly Out
Flaring	A process in which gas is burnt in a safe and controlled manner.
FRM Act	*Fisheries Resource Management Act 1994*
FSA	Formal Safety Assessment
GDAS	Global Data Assimilation System
Geotechnical	Relating to engineering study of subsurface soils, involving specialised drilling or sampling for soil analysis and testing.
GFS	Global Forecast System
Gilgai	Used to describe land surface characterised by irregular, alternating mounds and depressions and is commonly referred to as 'crab hole' country. This microrelief is formed due to clay horizons shrinking and swelling with alternate drying and wetting cycles which forces 'blocks' of subsoil material gradually upwards to form mounds.
GIS	Geographic Information System. A computer-based system used to integrate, manage and analyse data spatially
Gm^3	Billion cubic metres
GOTM	General Ocean Turbulence Model
GPS	Global Positioning System. A system of satellites, computers and receivers that is able to determine the latitude and longitude of a receiver on Earth by calculating the time difference for signals from different satellites to reach the receiver.
Greenhouse Gas	A wide variety of gases that trap heat near the Earth's surface, preventing its escape into space. Greenhouse gasses such as carbon dioxide, methane, nitrous oxide and water vapour occur naturally or result from human activities such as the burning of fossil fuels.
H_2S	Hydrogen sulphide.
ha	Hectare
Habitat	The area or environment where an organism or ecological community normally lives or occurs.
HAZID	Hazard Identification. A formal hazard identification process to identify situations that could represent a hazard and the events that may lead to these hazards being realised.
HAZOP	Hazard and Operability
HDD	Horizontal Directional Drilling
HDPE	High Density Polyethylene
hr/day	hours per day
HWM	High Water Mark
H_2S	Hydrogen Sulphide
HYDROMAP	A three-dimensional hydrodynamic model.
IBRA	Interim Biogeographic Regionalisation for Australia
IMCRA	Interim Marine and Coastal Regionalisation for Australia

IPAS	Integrated Project Approval System
IPCC	Intergovernmental Panel on Climate Change.
IUCN	The International Union for the Conservation of Nature and Natural Resources.
JAMBA	Japan-Australia Migratory Bird Agreement.
ISO14001	An international standard that specifies a process (called an Environmental Management System or EMS) for controlling and improving a company's environmental performance.
Joule-Thompson Valve	A valve with a small orifice used to cool gases. High pressure gas on one side of the valve drops very suddenly, to a much lower pressure and temperature, as it passes through the orifice exploiting the Joule-Thompson effect (cooling a pressurized gas by rapidly expanding its volume, or, equivalently, creating a sudden drop in pressure.
km	kilometre
kl	kilolitre
kl/day	kilolitres per day
kl/hr	kilolitres per hour
kl/yr	kilolitres per year
KP	kilometre point
kW/m^2	kilowatts per square metre
LAA	*Land Administration Act 1997*
LAT	Lowest astronomical tide
LIMO	Low Impact Mining Operation
LWM	Low Water Mark
m	metre
Macroalgae	Macroscopic (visible to the naked eye) and multicellular algae (e.g., seaweed, kelp), in contrast with microscopic algae.
m AHD	Metres above the Australian Height Datum - the datum used for the determination of elevations in Australia. The determination used a national network of bench marks and tide gauges, and set mean sea level as zero elevation.
Marine Management Area	Under the CALM Act (Section 13C(1((2)), a MMA is established *for the purpose of managing and protecting the marine environment so that it may be used for conservation, recreational, scientific and commercial purposes.* Under the CALM Act (Section 6), includes: (a) the airspace above such wasters or land; (b) in the case of waters, the seabed or other land beneath such waters and the subsoil below the seabed or other land to a depth of 200 m; and (c) in the case of land other than waters, the subsoil below such land to a depth of 200 m.
Marine Park	Under the CALM Act (Section 13C(1((2)), a marine park is established *for the purpose of allowing only that level of recreational and commercial activity which is consistent with the proper conservation and restoration of the natural environment, the protection of indigenous flora and fauna and the preservation of any feature*

	of archaeological, historic or scientific interest. Under the CALM Act (Section 6), includes: (a) the airspace above such wasters or land; (b) in the case of waters, the seabed or other land beneath such waters and the subsoil below the seabed or other land to a depth of 200 m; and (c) in the case of land other than waters, the subsoil below such land to a depth of 200 m.
mbgl	Metres below ground level
mE	metres east
ME	mean error
mN	metres north
m^3	Cubic Metres
ML	Megalitres (1 million litres)
MMboe	Million barrels of oil equivalent
MMSCF	Million standard cubic feet
MMSCFD	Million standard cubic feet per day
MHF	Major Hazard Facility
MRWA	Main Roads Western Australia
N_2O	Nitrous oxide. Potent greenhouse gas that has a large number of natural sources and is a secondary product of the burning of organic material and fossil fuels.
Natural Gas	A highly compressible, highly expandable mixture of hydrocarbons having a low specific gravity and occurring naturally in gaseous form. Besides hydrocarbon gases, natural gas has may contain appreciable quantities of nitrogen, helium, carbon dioxide, hydrogen sulphide and water vapour. Although gaseous at normal temperatures and pressures, the gases comprising the mixture that is natural gas are variable in form and may be found either as gases or as liquids under suitable conditions of temperature and pressure.
NB	Nominal Bore
NCEP	US National Centre for Environmental Prediction
NDT	Non Destructive Testing
NEPM	National Environmental Protection Measure
NES	National Environmental Significance
NGO	Non-governmental organisation.
NOAA	US National Oceanographic and Atmospheric Administration
NOHSC	National Occupational Health and Safety Commission
NOPSA	National Offshore Petroleum Safety Authority
NORM	Naturally Occurring Radioactive Material
North West Shelf	A geographic province rather than a physiographic feature. The North West Shelf extends about 2,400 km along the northwest margin of the continent, and includes the continental shelf proper and the marginal platforms and plateaus, out to about the 2,000 m isobath. The entire region lies within the tropics.

NPI	National Pollution Inventory.
NTA	*Native Title Act (Cwlth) 1993*
NTU	Nephelometric Turbidity Units
NO_x	Nitrous Oxides. A range of compounds which contain nitrogen and oxygen, such as NO, NO_2, etc. which result from combustion of fuels. NO_x is often associated with photochemical smog when mixed with hydrocarbons in the atmosphere.
NWCH	North West Coastal Highway
NWW3	WWIII predictions using GFS wind input are termed NWW3 (as an acronym for NOAA WAVEWATCH III).
OC	Organochlorine
ODAC	Office of Development Approvals Coordination
OEMP	Operations Environmental Management Plan
Oolite	A spherical to subspherical silt-, sand- or gravel-sized concretion of limestone.
OP	Organophosphorous
PAH	Polycyclic Aromatic Hydrocarbons
PAR	Photosynthetically active radiation
PASS	Potential Acid Sulphate Soils
PDD	Project Definition Document
PER	Public Environmental Review.
PF	Priority Flora
pH_F	Field pH. Field determination of pH in a soil:water mixture. A field test used to measure existing acidity used to identify the presence of acid sulphate soils.
pH_{FOX}	Field peroxide pH. Field determination of pH in a soil:water mixture following reaction with hydrogen peroxide. A field test used to give an indication of the presence of potential acidity, used for identifying potential acid sulphate soils.
PIN	Pilbara Nearshore marine bioregion
PPA	*Petroleum Pipelines Act 1969*
PDWSA	Public Drinking Water Supply Area
PER	Public Environmental Review
PFW	Produced Formation Water. Water component separated from reservoir fluids brought to surface during the production process.
PL 75	WA Onshore Pipeline Licence 75
ppmv	Parts per million on a volume basis
Purge gas	Purge gas (Natural gas, fuel gas, inert gas, or nitrogen) serves to keep air out of storage tanks, flare stacks and process vessels, to prevent the formation of explosive mixtures of air and flammable gases.
Reef	Sedimentary features, built by the interaction of organisms and their environment, that have synoptic relief and whose biotic composition differs from that found on and beneath the surrounding sea floor. A reef lies beneath the surface of the water. Reefs are held up by a macroscopic skeletal framework. Coral reefs are an excellent example of this kind. Corals and calcareous algae grow on top of one another and form a three-dimensional framework that is modified in various ways by other organisms and inorganic processes.

Reid vapour pressure	The Reid vapour pressure is an absolute pressure at 37.8°C (100°F) in kilopascals (pounds-force per square inch). This test method is used to determine the vapour pressure at 37.8°C (100°F) of petroleum products and crude oils with initial boiling point above 0°C (32°F).
RMSE	Root mean square error
ROMS	Regional Ocean Modelling Systems
RSD	Resources Safety Division (DoCEP)
SBMF	Shore Based Marine Facility
SSC	Suspended sediment concentration
Seagrass	A flowering plant from one of four plant families (*Posidoniaceae, Zosteraceae, Hydrocharitaceae,* and *Cymodoceaceae*) that grow in the marine saline environment. Most species superficially resemble terrestrial grasses of the Family Poaceae. Because these plants must photosynthesise, they are limited to growing submerged in the photic zone of water, and most occur in shallow and sheltered coastal waters anchored in sand or mud bottoms. They undergo pollination while submerged and complete their entire life cycle underwater. Seagrass beds (or meadows) are highly diverse and productive ecosystems.
SI	Scatter index
SO_2	Sulphur Dioxide
SSFATE	A sediment fates model.
Stabilised Condensate	Condensate that has been through a treatment process whereby impurities such as formation water and gas are removed which releases the pressure caused by the gas and water, leaving a flat (stabilised) liquid.
Stygofauna	Subterranean fauna found in air-filled water-filled voids.
Subtidal	Areas in shallow coastal areas that are below the low tide mark.
Supratidal	Above the normal influence of the tide (e.g. rocks that are usually not submerged).
SWAN	Simulating WAves Nearshore (SWAN) phase averaging wind wave model
TAPM	The Air Pollution Model (TAPM) is a software package developed by CSIRO to estimate the spread and impact of air pollution.
TBC	To Be Confirmed
TDS	Total Dissolved Solids. An expression for the combined content of all inorganic and organic substances contained in a liquid that are present in a molecular, ionised or micro-granular suspended form. Generally the operational definition is that the solids must be small enough to survive filtration through a sieve size of 2 micrometres (µm). Total dissolved solids are normally only discussed for freshwater systems, since salinity comprises some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is generally considered not as a primary pollutant (it is not deemed to be associated with health effects), but it is rather used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants.
TEC	Threatened Ecological Community
TJ/day	Terra Joules per day
Troglofauna	Subterranean fauna found in air-filled voids.

TOC	Total organic carbon
TPH	Total Petroleum Hydrocarbons
TSS	Total suspended solids
VCP	Vegetation Clearing Permit
VOC	Volatile Organic Compounds. Organic substances with low molecular weight that will evaporate at normal atmospheric temperatures and pressures.
UCL	Uncommitted Crown Land
USACE	US Army Corps of Engineers
UWA	University of Western Australia
WA	Western Australia
WC Act	*Wildlife Conservation Act 1950*
WWIII	Wave model WAVEWATCH III

12.1 UNITS OF MEASUREMENT

ºC	degrees Celsius
B	billion
bbl/d	barrels per day
bbl	barrel
cm	centimetre (10 mm)
cm yr^{-1}	centimetres per year
dB	decibels
Gl	gigalitre
ha	hectare
kL	kilolitre (1,000 litres)
kL/d	kilolitre per day
km	kilometre (1,000 m)
km^2	square kilometre
kPa	kilopascals
kW	kilowatt
L	litre (1,000 mL)
m	metre (100 cm)
m^2	square metre
m^3	cubic metre
mcf	million cubic feet
mg L^{-1}	milligrams per litre
mg/L	milligrams per litre
mg cm^{-2} d^{-1}	Milligrams per square centimetre per day
mg/cm^2	Milligrams per square centimetre
mL	millilitre
ML	Megalitre
mm	millimetre
M	Thousand
MM	million
MMboe	million barrels of oil equivalent
MPa	megapascals
Mt	megatonnes (1,000 tonnes)
nm	nautical mile
pH	Measure of acidity or alkalinity
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
scf	Standard cubic feet
T	tonne (1,000 kg)
TJ	terrajoules
TDS	total dissolved solids
TSS	total suspended solids
µg	micrograms
µm	micrometre, or micron
V	volt
%	per cent

12.2 MULTIPLICATION FACTORS

10^{2}	hecto (h) = 100
10^{3}	kilo (k) = 1,000
10^{6}	mega (M) = 1,000,000
10^{9}	giga (G) = 1,000,000,000
10^{-2}	centi (c) = 0.01
10^{-3}	milli (m) = 0.001
10^{-6}	micro (μ) = 0.000001
10^{-6}	nano (n) = 0.000000001

12.3 CONVERSION FACTORS

1 kilolitre	6.29 barrels
	264.17 US gallons
	1 tonne
1 cubic metre	1 kilolitre (1,000 litres)
	1 tonne
	35.315 cubic feet
	6.29 bbl
1 barrel	158.987 litres
	42.0 US gallons
	0.159 cubic metres
	0.158 tonnes
1 cubic foot	0.0283 cubic metres
1 US gallon	0.02381 bbl
	3.785 litres
1 megajoule	947.8 British thermal units (BTU)
	0.2778 kilowatt hours (kWh)
1 nautical mile	1.852 km
1 kilometre	0.53961 nm