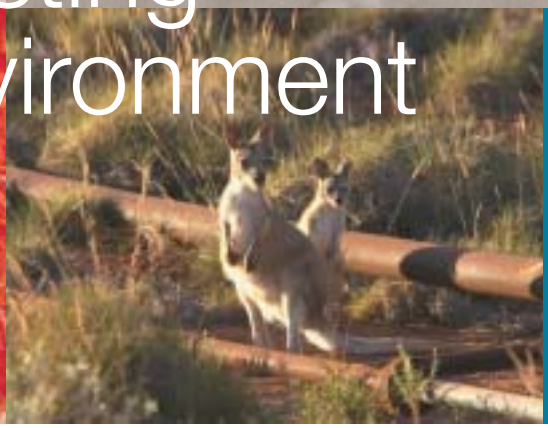
08: Existing Environment



The area of the proposed Gorgon Development lies in the tropical waters of Australia's north-west shelf approximately 1200 km north of Perth and 120 km west of Dampier and the Burrup Peninsula. This coastal environment is scattered with numerous small islands, the largest of which is Barrow Island. Barrow Island supports an operating oilfield and is a Class A nature reserve for the purpose of conservation of flora and fauna.

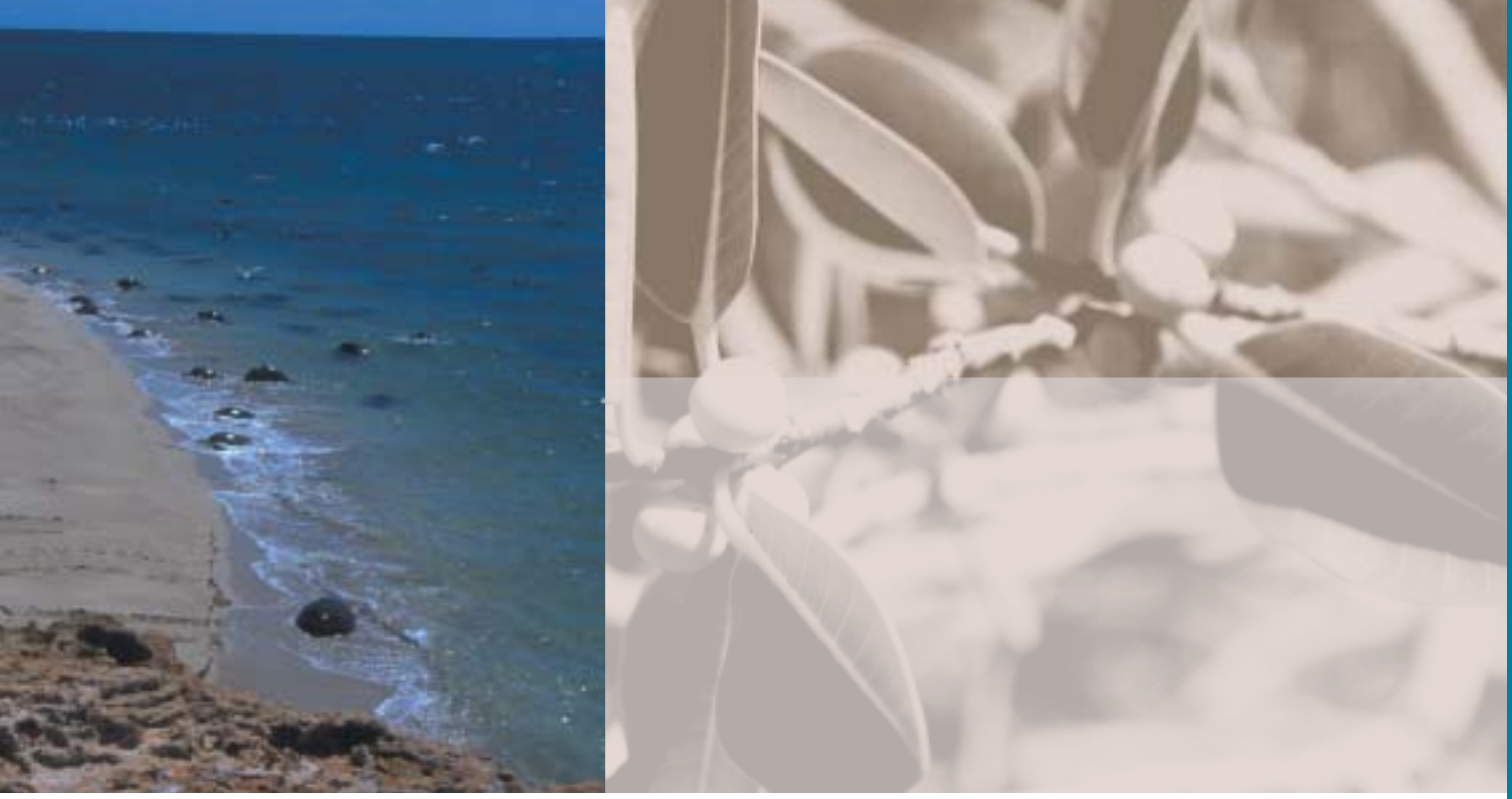
The Gorgon gas field lies in approximately 200 m water depth on the edge of the continental shelf. The proposed feed gas pipeline corridor from the gas field to the west coast of Barrow Island will include areas of deep water sediments, high profile limestone reefs, low profile limestone reefs and shallow water sediments. Each of these benthic habitats is widespread throughout the Montebello/Lowendal/Barrow Island region.

High wave energy strongly influences the physical structure of intertidal habitats on the west coast of Barrow Island. The nearshore section of the feed gas pipeline will be constructed beneath high-profile reef, a rocky platform and the sandy beach at North White's Beach.

Landforms on Barrow Island are predominantly developed by coastal processes that are dominated by the effects of wind and water. The terrain along the onshore feed gas pipeline route on the island ranges from undulating sand dunes and plains on the western side to gently undulating rocky terrain on the eastern side. The terrain in the proposed Development area is flat to undulating and gradually slopes upward from the coastline.

The proposed causeway and materials offloading facility will extend from Town Point across the intertidal and subtidal limestone pavement reef that fringes the east coast of Barrow Island. The shipping channel area is mainly limestone pavement reef with macroalgae, especially *Sargassum*, scattered hard and soft corals and thin sand veneers. The proposed jetty will dissect two areas of coral reef with variable cover of live coral and patches of coral bombora.

The proposed domestic gas pipeline and optical fibre cable routes between the east coast of Barrow Island and the mainland generally lie in water depths of approximately 16 m. Benthic habitats along this route are characterised by sparse filter-feeding assemblages on pavement reef and scattered



seagrass meadows on soft sediments. All of the faunal assemblages that occur along the domestic gas pipeline route and optical fibre cable route are expected to be widespread throughout the Pilbara nearshore bioregion.

On the mainland coast, sand and mud flats interspersed with areas of rocky pavement reef are backed by an extensive mangrove and samphire system. The mangrove community adjacent to the proposed domestic gas pipeline shore crossing on the mainland represents the most significant marine plant assemblage in any of the proposed Development areas.

A total of 406 vascular plant taxa have been recorded on Barrow Island which constitutes approximately 23% of the flora records documented for the Pilbara region. Fourteen vascular plant taxa have been introduced to Barrow Island, the majority of which occur in, or near, previously disturbed sites.

No Declared Rare Flora species, as listed under subsection (2) of Section 23F of the *Western Australian Wildlife Conservation Act 1950* and as listed by the Department of Conservation and Land Management occur on Barrow Island. Two Priority species grow on Barrow Island: *Helichrysum oligochaetum* (Priority 1); and *Corchorus interstans* (ms) (Priority 3).

No vegetation communities listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* have been recorded or are known to occur on Barrow Island. Further, no Threatened Ecological Communities as listed on the Department of Conservation and Land Management Threatened Ecological Database have been recorded or are known to occur on Barrow Island.

Barrow Island supports 13 species of resident terrestrial mammal, with a further two species of bat recorded as vagrants to the island. Six of these species are listed by the state as rare or likely to become extinct. Many of the mammals are widespread and abundant on Barrow Island including the burrowing bettong, spectacled hare wallaby, golden bandicoot, Barrow Island euro and northern brushtail possum. All mammal species recorded within the Development area are widespread on the island, with the exception of the the water-rat which is restricted to coastal habitats around the island.

The black-flanked rock-wallaby does not occur within any of the proposed Development areas. There are no distinctive habitat features within the proposed Development area that are likely to support unusually high population densities of any mammal species.

Important bird species on Barrow Island include migratory shorebirds and visiting seabirds. Barrow Island is known as a staging site for many migratory birds. Waterbird abundances are highest on the coast in the south-east and south of Barrow Island. The intertidal habitats in the vicinity of Town Point, and other infrastructure associated with the Development, are of relatively low importance for coastal waterbirds. The proposed Development area is not of higher ecological significance than surrounding areas for any landbird species. The endemic white-winged fairy wren has been recorded within the Development area and is widespread on Barrow Island.

Green sea turtles nest on all sandy beaches along the west coast of Barrow Island. Before and during the summer nesting season mating aggregations are present off the west coast and females are frequently found resting on sandy beaches and intertidal platforms along the coast. Resident (non-nesting animals) forage on the algae covered rocky platforms throughout the year. The area of the proposed feed gas pipeline shore crossing at North White's Beach is not a locally important green turtle nesting site.

Nesting flatback turtles favour mid-east coast beaches on Barrow Island. The beaches either side of the proposed Development area at Town Point (Terminal Beach and Bivalve Beach) are important components of this regionally significant rookery.

Many species of terrestrial reptiles live on Barrow Island; one species of blind snake is restricted to the island and one skink species has a disjunct distribution that includes only Barrow Island in Western Australia. The invertebrates, including short range endemics on Barrow Island, are generally known from several locations on the island. The only exceptions are a new species of scorpion and a new species of pseudoscorpion that were recently recorded within the proposed Development area. The wider distribution of these species on Barrow Island is not yet known; however, they are expected to occur in similar habitats at other parts of the island.

Subterranean fauna from Barrow Island are important from a biodiversity perspective due to their endemicity at high taxonomic levels and uncertain distributions at the species level. Surveys have indicated that stygofauna occur in groundwater habitats across the island. In addition to stygofauna, areas of karst within the Development site also provide habitat for troglobitic fauna (terrestrial subterranean fauna). However, these assemblages may not be as diverse as those recorded from caves and more developed karstic areas in other parts of Barrow Island.

There are 13 registered archaeological sites on Barrow Island although none are close to the proposed Development site, and there are no listed ethnographic sites. There are two ethnographic sites located close to the proposed domestic gas pipeline route on the mainland and nine identified cultural heritage sites within the vicinity of the pipeline route.

The Pilbara resident population is approximately 40 000 people, with most people living in close proximity to the coast. The Pilbara region is one of the most important wealth producing regions in Western Australia. The region is responsible for the production of goods and services worth more than $16 billion per annum. The mining and petroleum industries are the predominant earners for the region.

The Western Australian economy is dominated by the resources sector which also contributes largely to the Australian economy. Western Australia is now the major oil and gas producer in Australia, and has more than three-quarters of Australia's identified natural gas resource within its jurisdiction.

8.1 Introduction

This chapter describes the key physical, ecological, social and economic values of the proposed Gorgon Development area (Figure 8-1, Figure 1-4). This information supports the assessment of impacts and risks presented in Chapters 10, 11, 14 and 15.

Locations of various Barrow Island features that are discussed throughout this chapter are shown in Figure 8-2.

8.2 Physical Environment

8.2.1 Introduction

This section of Chapter 8 describes the existing physical environment in the proposed Development area. It includes discussion on the regional setting, climate, bathymetry and sea floor topography, oceanography, topography and landforms, geology and soils, seismic activity, surface hydrology and groundwater.

Figure 8-1:
Overview of Chapter Structure

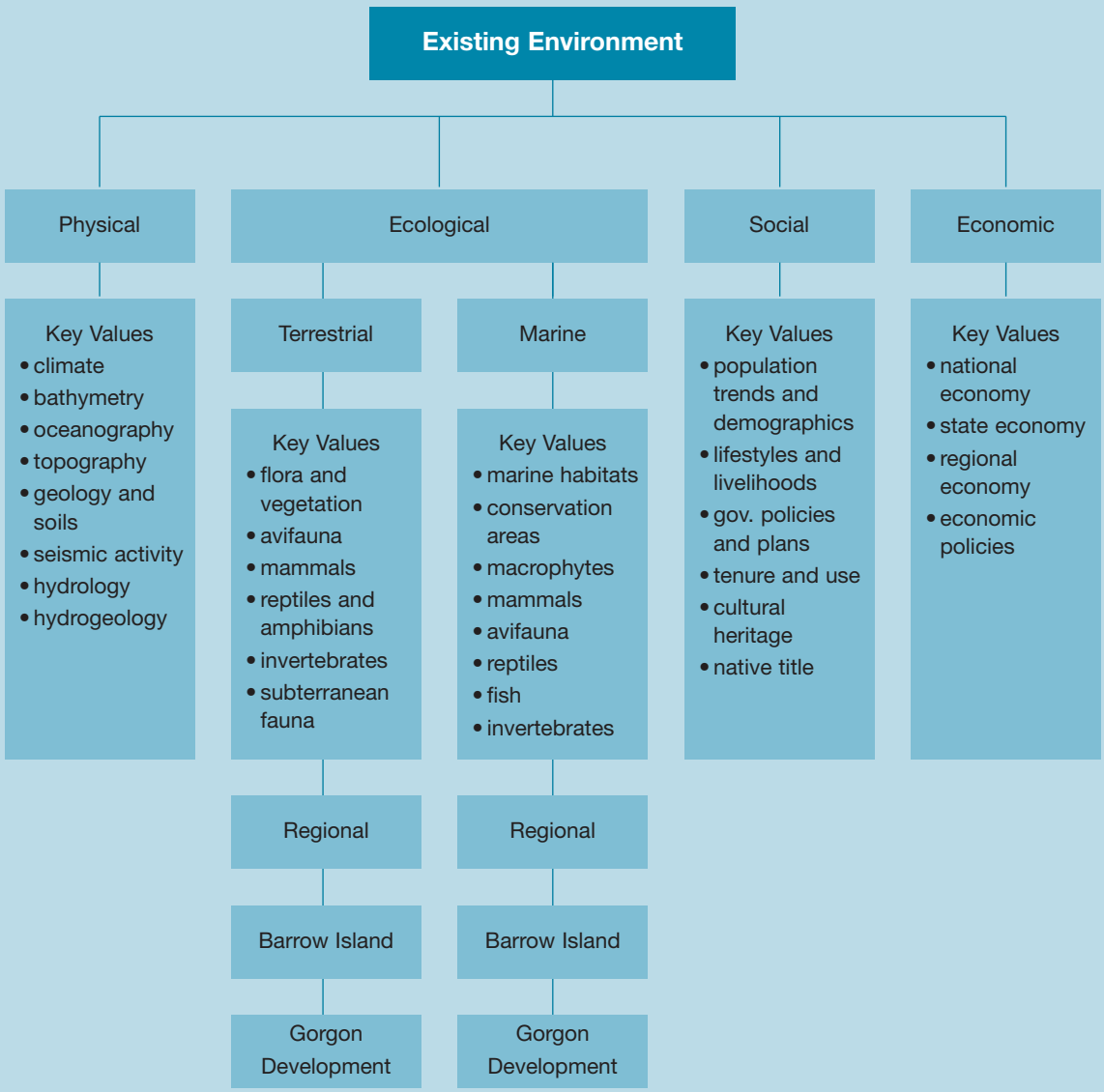
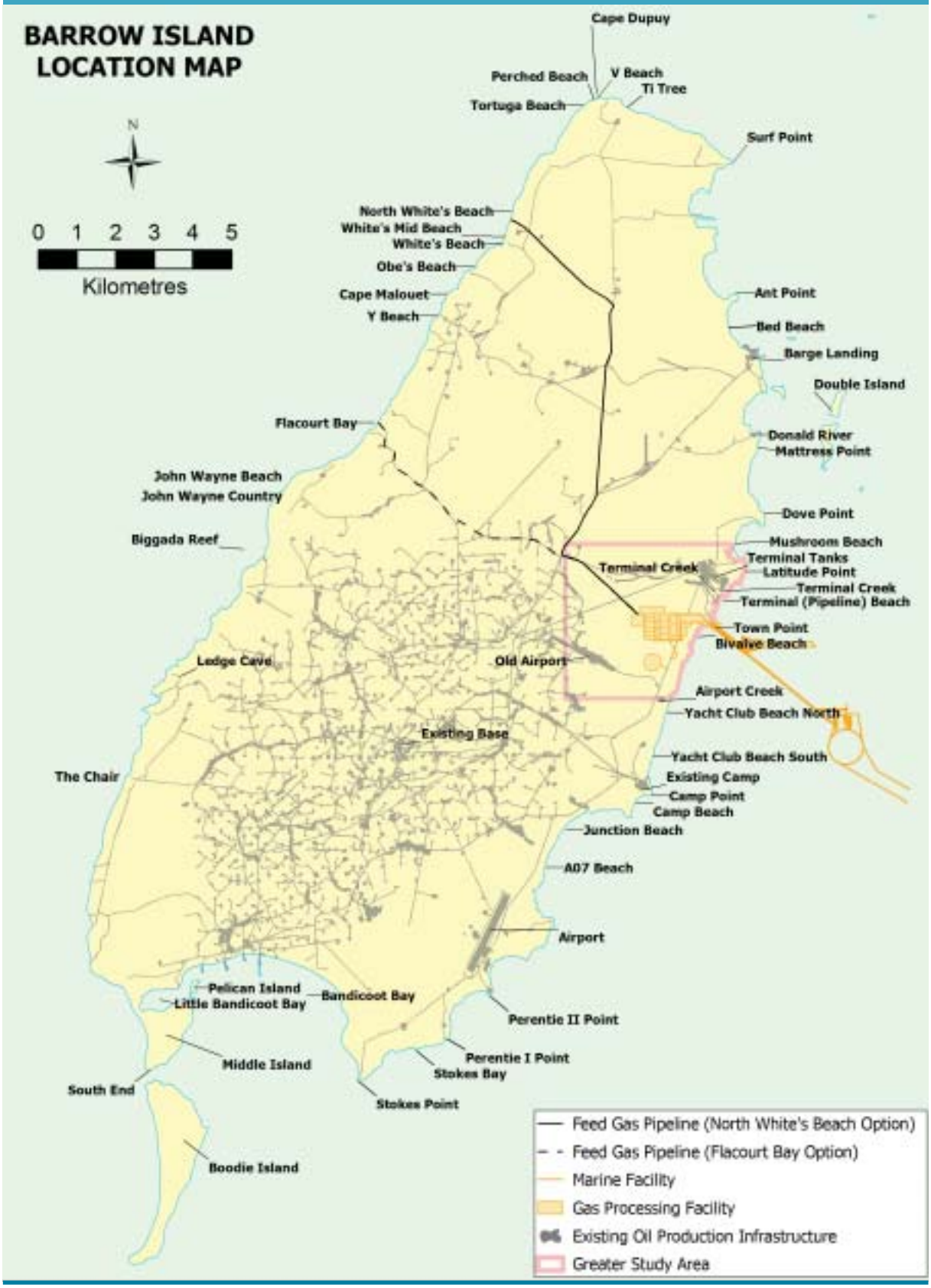


Figure 8-2:
Barrow Island Location Map



8.2.2 Regional Setting

The proposed Gorgon Development is located on Australia's north-west shelf approximately 1200 km north of Perth and 120 km south-west of Dampier. This region is scattered with islands, the largest of which is Barrow Island at 25 km in length, 10 km in width, and approximately 234 km^2 in area.

The Gorgon gas field is located in Commonwealth waters approximately 70 km west of Barrow Island. Barrow Island is the nearest landfall to the Gorgon gas field; lying directly between the field and the mainland (refer to Figure 1-1, Chapter 1).

8.2.3 Climate

The southern portion of the north-west shelf, including Barrow Island, is characterised by an arid, sub-tropical climate.

The summer season occurs from October to March and is characterised by high temperatures, high humidity and predominantly south-west winds (Worley 2003). In contrast, the winter season, June to August, is characterised by clear skies, fine weather and predominantly strong east to south-east winds. The months of April, May and September are considered a transition season during which either the summer or winter weather regime may predominate or conditions may vary between the two. The characteristics of the climate in the Gorgon Development area are summarised in Table 8-1.

Table 8-1:
Climate of the Gorgon Development Area

Temperature	In summer, mean daily maximum temperatures reach 34°C with mean daily minimum temperatures averaging 20°C. During winter, mean daily maximum temperatures reach 26°C with mean daily minimum temperatures of 17°C.
Relative Humidity	Barrow Island experiences regionally high relative humidity that remains fairly constant throughout the year. Early periods of the day experience an annual average of about 65% relative humidity with afternoon periods experiencing between 47% and 59%.
Rainfall	Rainfall on Barrow Island varies significantly from year-to-year and is dependent on rain-bearing low pressure systems, thunderstorm activity and passage of tropical cyclones. The historic annual average rainfall for the area is 320 mm. During the early winter months rainfall is received from frontal systems passing to the south. These events can result in up to 50 mm of rain and account for approximately 35% of annual rainfall (Bureau of Meteorology 2004). In summer, cyclonic events range from storms of 300 mm to milder 30 mm events. Wet years typically receive a large portion of rainfall from tropical cyclones.
Evaporation	The annual evaporation rate is approximately 3500 mm for the region (based on records from the Dampier Salt Weather Station). Daily evaporation rates range from about 11 mm/day during the summer months to 7 mm/day during winter months.
Winds	Wind patterns on the north-west shelf are dictated by seasonal movement of atmospheric pressure systems. During the summer months, high pressure cells produce south to south-westerly winds which vary between 10-13 ms^{-1}. During the winter months, high pressure cells over central Australia produce north-easterly to south-easterly winds with average speeds of between 6-8 ms^{-1}. Seasonal and annual wind roses measured on Barrow Island between 1980 and 1996 are shown in Figure 8-3.
Cyclones	Tropical cyclone activity occurs in the north-west region of Western Australia from November to April. On average, two cyclones pass through the Barrow Island area per year, generating localised wind gusts of over 150 km/hr.

Figure 8-3:
Annual Wind Roses Measured on Barrow Island

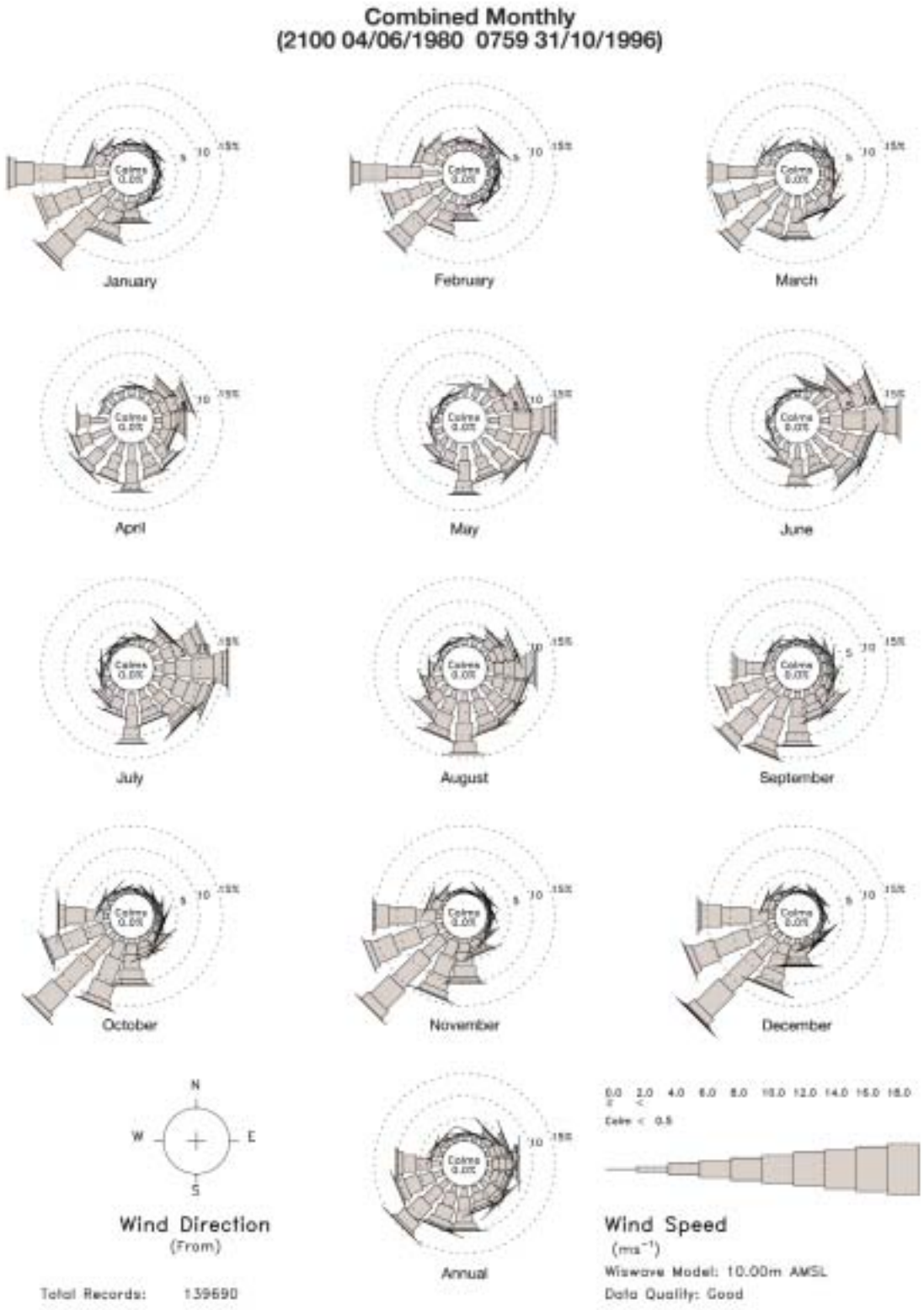
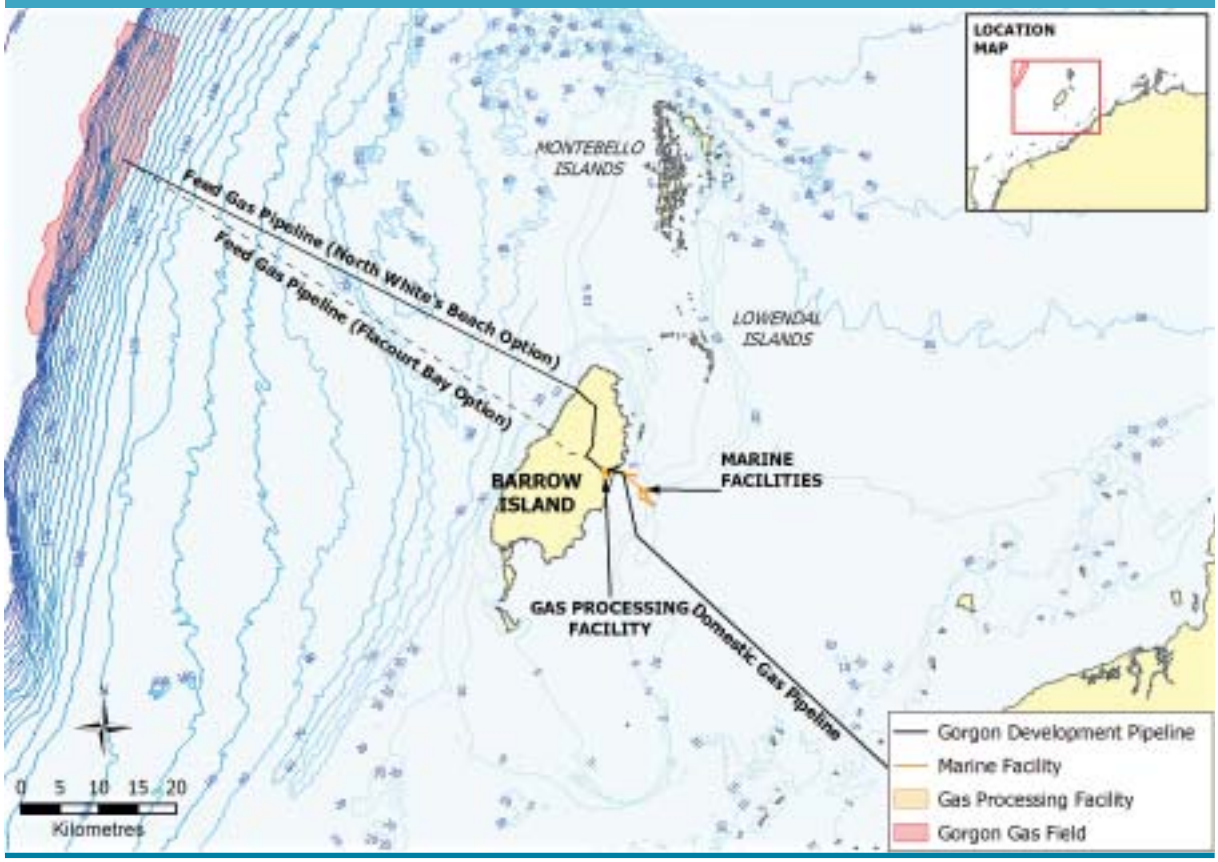


Figure 8-4:
Bathymetry of the Gorgon Gas Field Area



8.2.4 Bathymetry and Sea Floor Topography

The Gorgon gas field lies on the continental slope at a water depth of approximately 200 m. The northern-most portion of the gas field is gently sloping and dissected by a north-west to south-east aligned ridge (Figure 8-4). The southern extent of the gas field is characterised by deeply undulating valley terrain.

The seabed along the majority of the proposed feed gas pipeline route is level with areas of moderate relief comprising rock and reef outcrops.

Water depths adjacent to the east coast of the island vary due to seabed outcrops and the presence of numerous pinnacles. Further offshore, the seabed is generally more level. The proposed domestic gas pipeline route is located in water depths of about 16 m that occur between the island and the mainland.

Substrate and Sediment Characteristics

The sediments in the Barrow Island area are generally undisturbed with the exception of some areas of localised impact from previous and existing activities (e.g. petroleum exploration and production) in the region.

Within the immediate vicinity of the proposed well heads the seabed is characterised by coarse sandy sediments with shell fragments. Three sediment types have been identified for the gas field:

- sandy sediments/carbonate sandy silt (from seabed to ~3 m)
- homogenous carbonate silts/muds (~3 m to ~110 m)
- variably cemented carbonate silts, sandy silts and calcisiltites (~110 m to > 250 m deep).

The shallow geology along most of the proposed feed gas pipeline route consists of unconsolidated sediments overlying a cemented calcarenite substrate. The sediments are generally calcareous and range in grain size from graded silts (4-60 µm) through to coarse sand (<2000 µm) with shells and shell fragments. The thickness of sediment layers varies, ranging from more than 5 m in the proximity of the gas field to a very thin patchy veneer, or absence, over large areas of seabed.

On the east coast of the island, intertidal reef flats and shallow pavements progress to deeper sands offshore. Nearshore limestone or calcarenite pavements are variably covered by sand, gravel and coral. Bare sands overlay limestone pavements in many parts of the area with increased quantities of rubble on exposed pavement where strong water currents are present. The thickness of uncemented sediments overlying limestone pavements are expected to vary between 0.5 m and 3 m (URS 2002).

Along the length of the domestic gas pipeline route, the seabed comprises areas of unconsolidated sediments overlying variably cemented calcarenite substrate, bare sand with occasional rocky outcrops and limestone pavement reef with a veneer of sand. The sediments are calcareous and range from fine sands through to coarse sands with shells and shell fragments. The ocean depth between Barrow Island and mainland Australia is very shallow nearshore, and relatively flat, with a range of 0-20 m. Detailed bathymetry has recently been collected for the Marine Offloading Facility (MOF), the LNG shipping channel and jetty areas (Figure 8-5).

8.2.5 Oceanography

General oceanographic characteristics in the vicinity of the proposed Gorgon Development are summarised in Table 8-2.

Figure 8-5:
Sea Floor Bathymetry, East Coast of Barrow Island

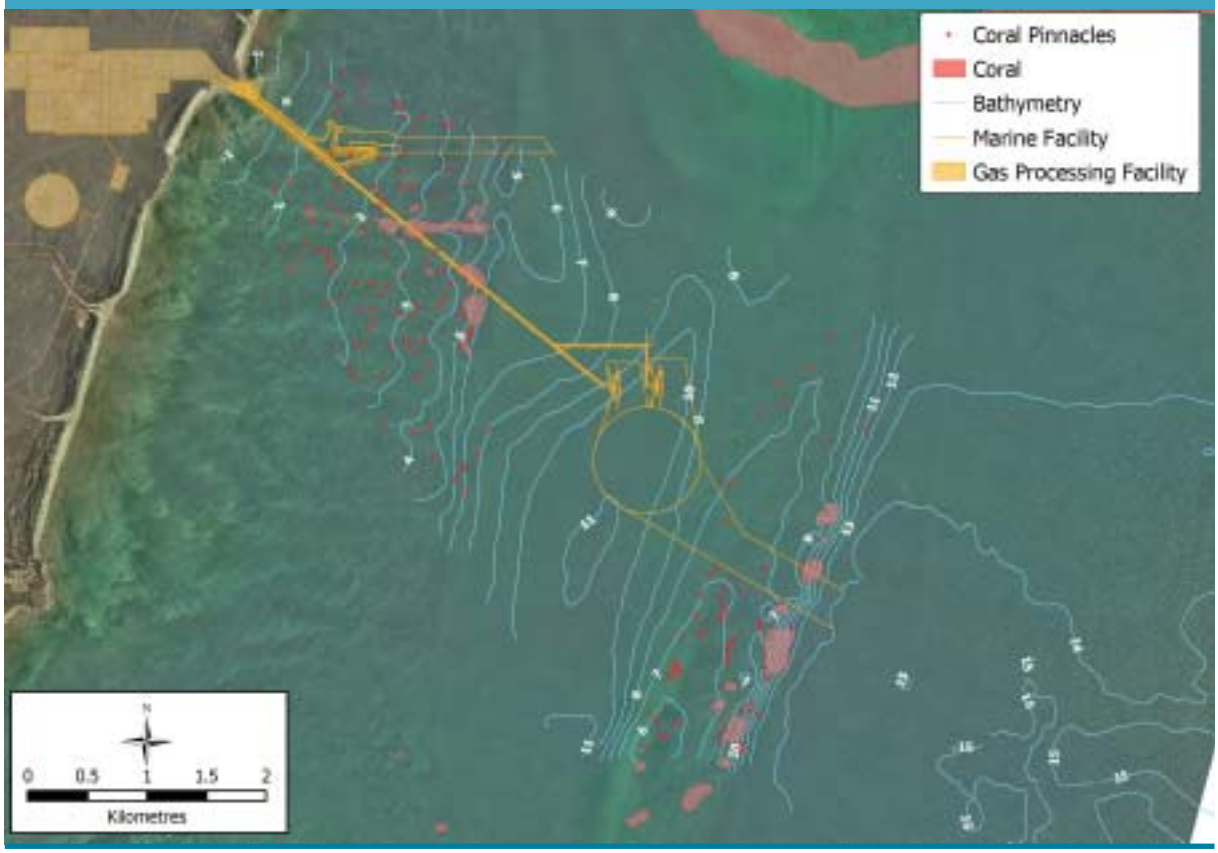


Table 8-2:
Oceanographic Characteristics of the Gorgon Development Area

Waves	The prevailing oceanic conditions in the Gorgon Development area are governed by a combination of sea and swell waves. Sea waves are shorter period waves generated by local winds whereas swell waves are generated by distant storms. The west coast of Barrow Island is affected by the southern ocean swell which refracts around the northern and southern ends of the island. On the east coast, periods of greatest wave activity correspond to periods of strong easterly winds (ChevronTexaco Australia 2003a). Figure 8-6 illustrates the directionality, seasonality and magnitude of the combined wave field at the existing tanker loading facility 9 km off the east coast of Barrow Island.
Tides	Tides in the Barrow Island region are semi-diurnal, comprising two high tides and two low tides per day. The tidal gradients are strong and aligned in a north-south direction. The combination of moderate tidal ranges, and shallow bathymetry, results in large areas of exposed seabed at low tide (West Australian Petroleum 1989).
Currents	Currents are principally driven by semi-diurnal tidal forcing. Near Barrow Island, tidal currents run strongly parallel to the eastern shore and funnel through the offshore channel north of the Town Point site. Current measurements at the tanker mooring confirm the tidal nature of these currents, reflecting a distinct spring-neap (14-day) tidal cycle and a semi-diurnal pattern. The maximum current measured at this point was 0.62 m/s. The direction of the tidal currents (for both spring and neap) was a flood flow towards the south-west and an ebb flow towards the north-east (Chevron Texaco Australia 2003a) (Figure 8-7 and Figure 8-8).
Water Temperature	Surface water temperatures in the vicinity of the Gorgon gas field and the offshore portions of the proposed feed gas pipeline vary between 22°C and 31°C. From the surface to a depth of 100 m, the water column is generally well-mixed. The mean for depths between 200 and 250 m is around 10°C (ChevronTexaco Australia 2003a). Water temperatures at the proposed tanker terminal range from a late summer peak of about 30°C to a winter low of about 21°C during July and August (ChevronTexaco Australia 2003a). The seawater in the region of the proposed domestic gas pipeline is generally well-mixed with uniform temperatures throughout the water column.

Figure 8-6:
Wave Data – East Coast of Barrow Island

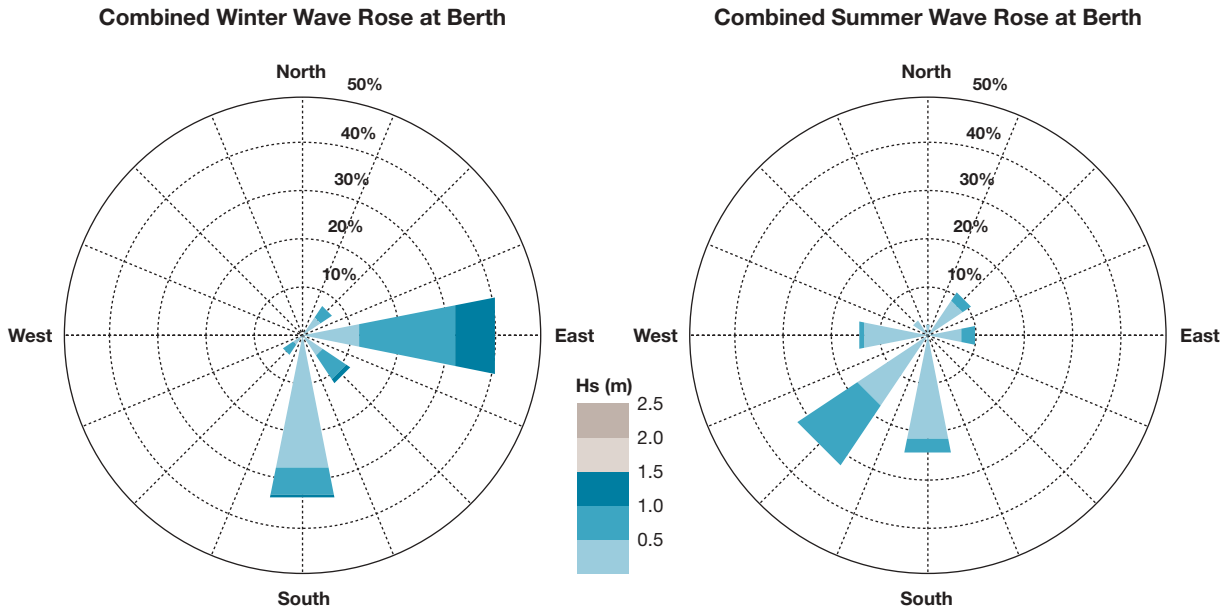


Figure 8-7:
Near Surface Current – Barrow Island

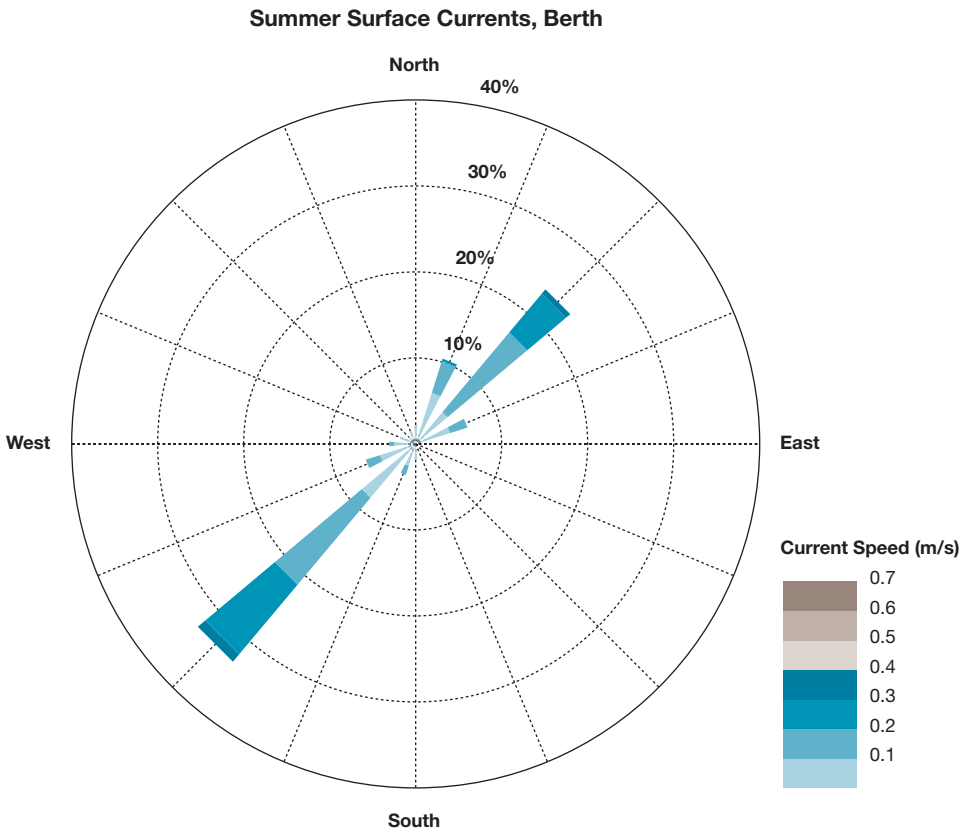


Figure 8-8:
Near Bottom Current – Barrow Island

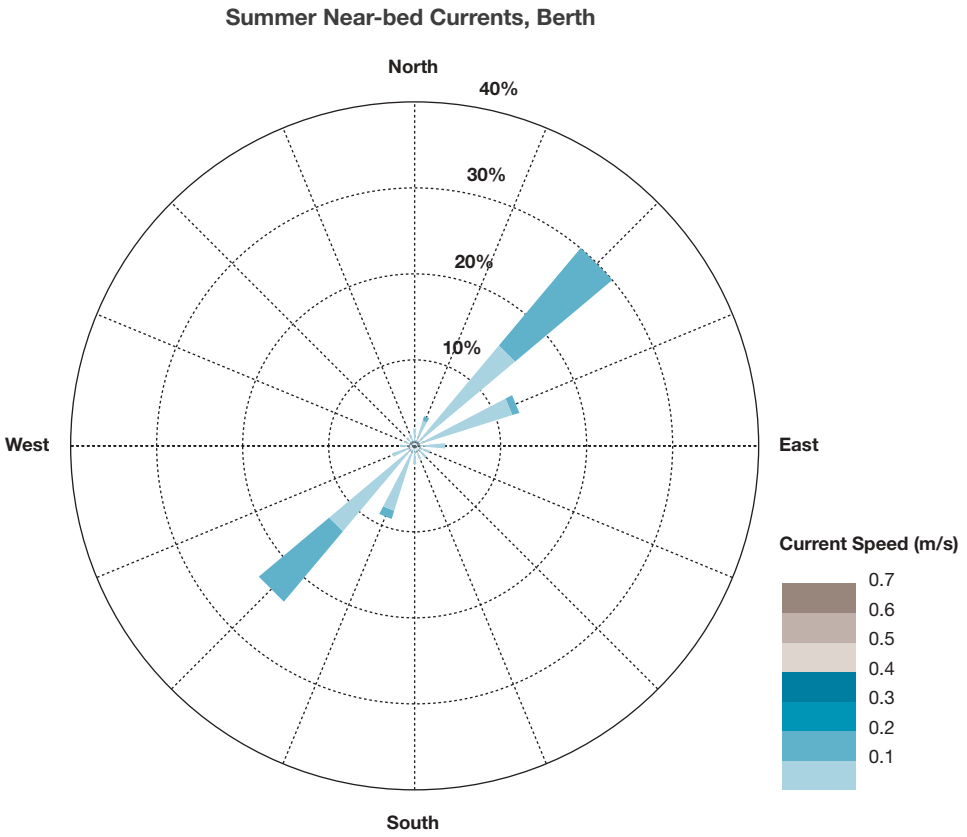


Table 8-3:
Landscape Units of Barrow Island

Landscape Unit	Description
West Coastal Complex	The west coast of Barrow Island is exposed to direct wind and wave action from the Indian Ocean. The coastline topography varies from rocky weathered sheer cliffs to less steep, traversable inclines. Typically narrow sandy beaches occur between weathered rocky headlands. This coastline is a significant feature of Barrow Island.
East Coastal Complex	The eastern coastline is protected with a slight land gradient to the ocean. This coastline is characterised by vegetated sand dunes and expansive tidal flats. Vegetation types along the east coast are dominated by *Triodia angusta*.
Valley Slopes and Escarpments	The western half of Barrow Island is characterised by steep formed valleys, escarpments and exposed limestone ridges. Typical vegetation on valley slopes and escarpments is described as open, low shrubland dominated by *Triodia wiseana*. Mixed emergent lower growing shrub species such as *Acacia bivenosa, Petalostylis labicheoides* and *Pentalepis trichodesmoides* occur on the southern escarpments.
Limestone Ridges	This landscape unit occurs generally throughout the central upland plateaus of the island. The terrain ranges from steeper slopes in the west to flatter more gentle undulations as the ridges continue east. Typical vegetation on the limestone ridges includes hummock grassland of *Triodia wiseana* with low mixed shrubs including *Acacia gregorii* and *Melaleuca cardiophylla.*
Creek or Seasonal Drainage lines	This landscape unit occurs generally in the broad valleys and flats of limestone ridges and is located adjacent to the coastal fringes. This landscape has deeper alluvial soil structure and denser and taller vegetation. The vegetation in this unit type is described as mixed hummock grassland of *Triodia angusta* with pockets of dense shrubs along major creek lines.

8.2.6 Topography and Landforms

Five landscape units have been identified on Barrow Island. These units are described briefly in Table 8-3.

The topography of Barrow Island in relation to proposed infrastructure and facilities is illustrated in Figure 8-9. The gas processing facility area is undulating and facilities will be terraced to suit the terrain.

The mainland section of the domestic gas pipeline crosses the Onslow Coastal Plain. The plain extends south of Robe Point, to Mary Anne Point and north to Cape Preston. Terrain along the 30 km length of this section of the pipeline is generally flat and only reaches approximately +50 m AHD.

The Onslow Coastal Plain comprises saline flats that fringe the coastline and extensive sandy plains with longitudinal dunes trending north-west or north. Broad clay plains are also present with numerous base clay pans and circular grassy depressions (Payne et al.1988). Near the coastline, the clay plains become increasingly masked by aeolian sand.

8.2.7 Geology and Soils

Barrow Island is a geological extension of the Cape Range Peninsula, which became separated from mainland Australia between 8000 and 6000 years ago as a result of rising sea levels.

The island is composed of coastal deposits overlying tectonically folded limestone. Three broad geomorphic units have been identified:

- limestone uplands
- near coastal lowlands
- coastal fringe.

The geology of the proposed incoming pipeline landfall location at North White's Beach and the alternative Flacourt Bay site consists of minor coastal sands overlying shoreline sandstone platforms. North White's Beach has a headland to the south, while Flacourt Bay is bounded by headlands to the north and south. These headlands are comprised of cliffs consisting of cemented calcirudite overlain by cemented siliceous calcarenite (coastal Tamala limestone). Exposure to

Figure 8-9:
Topography of Gas Processing Facility Area

the open ocean, storm events and general climatic conditions has resulted in the erosion of areas of weaker limestone to form cavities and caves in the rock face.

On the feed gas pipeline route between the landfall and the gas processing facility site, the surface geology consists of outcrops of variably weathered Trealla limestone, interspaced with alluvial and colluvial deposits. These deposits are associated with the intermittent dendritic drainage system present on the island and primarily consist of calcarenitic sands and gravels.

The surface geology at the proposed gas processing facility consists of limestone (Tamala limestone), floodplain deposits, dune sands and gravels. Investigations conducted near the gas processing facility site encountered up to 10 m of sands and clays overlying limestone. Solution holes in limestone up to 450 mm in diameter and 1.2 m deep have been observed at several locations at the proposed gas processing facility site. Drilling logs for investigations conducted at the existing terminal tanks nearby suggests the possible presence of solution cavities. Based on historic borehole information, it is likely that cavernous zones are present in the vicinity of the water table throughout the limestone substrata across the proposed gas processing facility site.

The geology of the proposed domestic gas pipeline shore crossing at Town Point consists of a calcrete ridge, cliffs and beach sands. Tidal lagoons are present in the shoreline rock platforms present to the north and the south of Town Point.

The geology along the domestic gas pipeline route on mainland Australia is dominated by alluvium deposits influenced by the Robe and Fortescue Rivers that are located some distance on either side of the proposed pipeline route. The two major geological units recorded are:

- Pleistocene alluvium and eluvium consisting of loosely consolidated red to brown clay, silt, sand, sandy clay, gravel, gravel veneer in places and gilgais that is common. This is the main Quaternary unit overlying basement rocks in low lying areas.
- Recent alluvium consisting of mainly clay silt and sand, some gravels in an unconsolidated matrix. These are flood deposits in the form of silt sheets, levees and clay pans related to present day drainage patterns.

Soils of the coastal plains are mainly neutral and alkaline earths with areas of acid and alkaline red earths, often with a cover of surface gravel (Dames and Moore 1990). These soils are generally well-drained particularly nearer to the coast where sands and sandy loams are present (Payne et al. 1988). In low lying plains, the soils are dominated by hard alkaline red soils with the occasional presence of dispersive clay soils. The clay content impedes drainage resulting in water-logging during heavy periods of rainfall and gilgai formations (i.e. shallow depressions in the land surface). The soils are low in nutrients (nitrogen and phosphorus).

8.2.8 Seismic Activity

Barrow Island is located within a linear zone of seismicity known as the North West Shelf Zone. The Barrow Fault, located at the southern end of the island, is represented topographically by a low, east-west trending scarp. The surface expression of the fault is marked by occasional clay pans and rare deposits of sulphur. Barrow Island occurs in an area of relatively low seismic activity.

Few tsunamis have been observed along the Western Australian coast. Tsunamis are water gravity waves associated with submarine seismic disturbances. The Sunda Arc, south of the Indonesian islands is the most likely source of earthquake generated tsunamis affecting the north-west coast of Western Australia (Worley 2004). Records show that of the eight or so major earthquakes expected to occur in the Sunda Arc region every hundred years, two or three could be felt in Western Australia. For large tsunami wave heights to develop, the transition from deep sea floor to coastline must be sudden. Western Australia has a wide, shallow continental shelf, therefore it is unlikely that severe tsunami effects will ever be experienced in Western Australia, either from a close offshore earthquake as in the case of Geraldton in 1885, or from more distant earthquakes (Worley 2004).

8.2.9 Surface Hydrology

The surface hydrology on Barrow Island is characterised by:

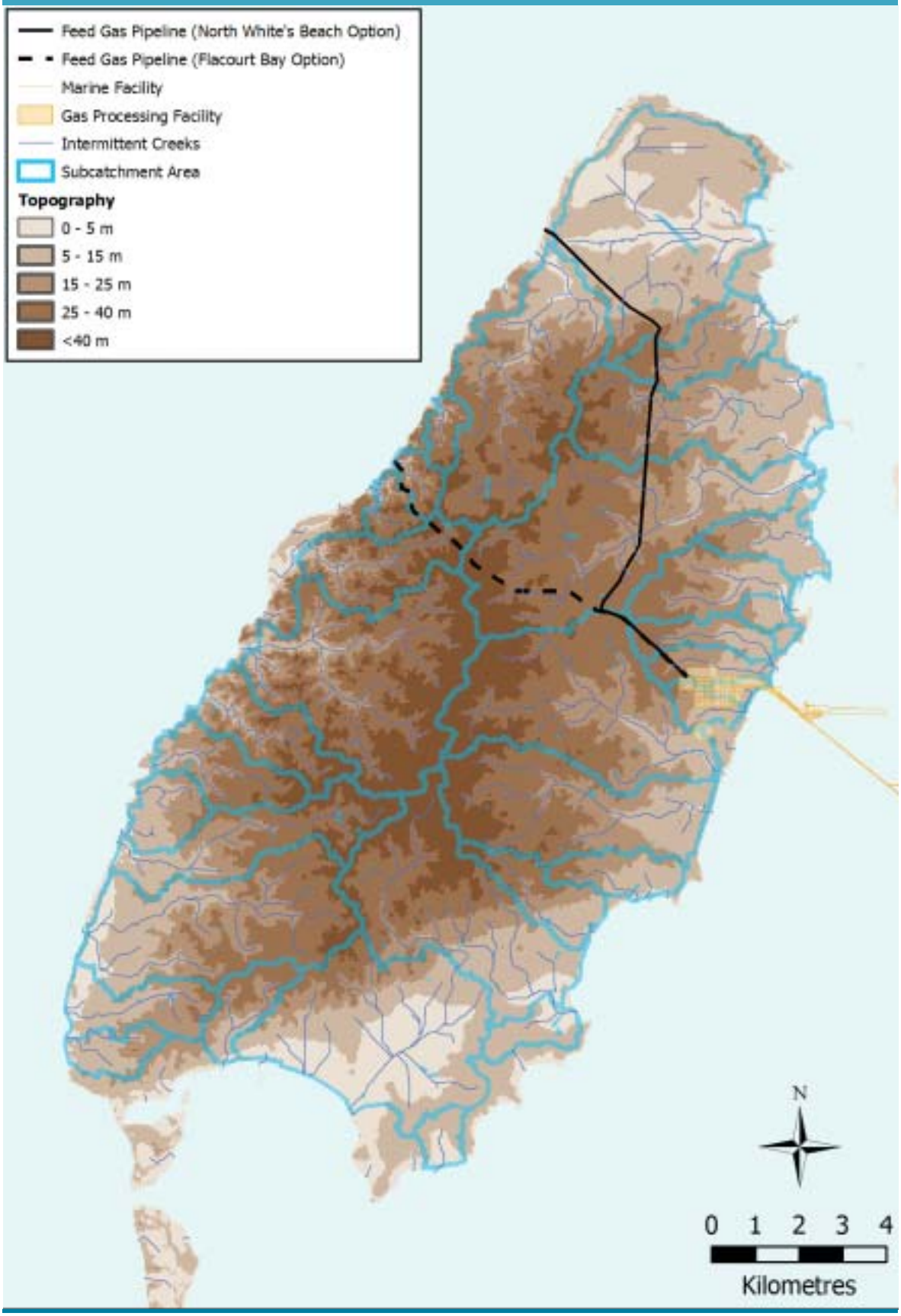
- unpredictable, but sometimes very intense, rainfall resulting in significant runoff and short-term ponding
- consistently high rates of evaporation resulting in extremely low soil moisture content
- high infiltration capacities of the surface sands and limestones which is conducive to recharge of relatively deep groundwater aquifer(s).

The hydrological regime of the island is split by a water divide running north to south along a central, elevated ridge. Creeks flow along a largely east-west orientation on either side of this divide but are highly ephemeral and usually dry. Figure 8-10 shows the drainage basins Barrow Island including those crossed by the various pipeline routes and within the gas processing facility site.

Permanent surface water sources occur in freshwater seeps. The largest of these occurs near the mouth of Biggada Creek on the west of the island and a smaller one at The Ledge, both on the west coast of Barrow Island. Both these seeps are outside of the Gorgon Development area (greater than 5 km from the nearest pipeline alignment). Other seeps are ephemeral and generally only appear after rain events. The nearest ephemeral freshwater seep is located approximately 500 m south of the North White's Beach pipeline shore approach option. Freshwater seeps provide an important water source for the island's fauna.

The mainland section of the proposed domestic gas pipeline route is located between the two major drainage lines of the Fortescue River and Robe River. These rivers are ephemeral and only flow following heavy rainfall. The rivers comprise permanent water holes which are maintained by sub-surface drainage (Bowman, Bishaw and Gorham 1991). Minor creek lines occur between these two major drainage lines; however the majority of creek lines are undefined and flow as sheet flow across the coastal saline flats. Sholl Creek, Trevarton Creek and Gerald Creek are located approximately 5 km to

Figure 8-10:
Surface Hydrology – Drainage Basins



the north of the proposed domestic gas pipeline route. Drainage lines to the south include Peter Creek, Myanore Creek and the Robe River.

There are approximately 13 locations along the length of the mainland section of the domestic gas pipeline route that will intersect ephemeral drainage lines. None of these support significant stream flows.

8.2.10 Hydrogeology

Two aquifers are located below Barrow Island: a confined, saline aquifer known as the Flacourt Sands Aquifer which is situated at depths of between 900 m and 1200 m; and a shallow unconfined aquifer (watertable) located predominantly within Tertiary limestone. The two aquifers are hydraulically separated from one another by a thick sequence of low permeability material (lower Gearle siltstone). These two aquifers are currently used to supply the Chevron Australia oilfield operations on the island.

The shallow unconfined aquifer forms a lens of fresher groundwater floating upon denser, more saline seawater. The boundary between the fresh and saline water is not a sharp boundary line, but a transition zone of brackish water caused by seasonal fluctuations in rainfall, tidal action, and amount of water extraction and discharge.

Recharge to the aquifer is principally from rainfall. Groundwater discharge is predominantly to the ocean, although given the high evaporation rates, some loss of groundwater is expected to occur from evaporation in areas where the watertable is shallower than about 2 m below ground surface.

On mainland Australia, the hydrogeological properties of the two major geological units within the development area are described in Table 8-4 from information detailed in the hydrogeological investigations undertaken north of Fortescue River (HGM 2000).

Aquifer Hydraulics

Available monitoring data shows that the watertable elevation is highest toward the centre of the island, resulting in a north-south oriented watertable mound along the length of the island.

Observed hydraulic gradients are low, ranging from 0.001 to about 0.01 (or a drop in water level of between 3.0 and 30.5 cm over a 30.5 m distance). This is consistent with observed groundwater monitoring data, which shows watertable elevations of not more than a few metres above sea level towards the central part of the island. In areas where karst features occur, preferential recharge would result in highly variable watertable geometry, which could explain some of the local variability in watertable elevations observed on the island.

Groundwater Dynamics

A relationship between tidal fluctuations and groundwater levels has been observed on some parts of Barrow Island. Although a dynamic relationship between groundwater and the ocean would normally be expected, the influence of tidal fluctuations generally decreases with increasing distance from the coast. This has not been consistently observed at Barrow Island, most likely because of the low hydraulic gradient of the watertable and the significant effects of karstic limestone that enables strong hydraulic connection with the ocean.

Table 8-4:
Hydrogeological Properties of Major Mainland Geological Units

Unit	Characteristics
Fortescue River Alluvium	• gravels from major aquifer with high permeability • aquifer covers extensive area beneath floodplain • groundwater is fresh in most floodplain area • groundwater is marginal to brackish on edge of floodplain • groundwater is brackish to saline at depth near coast
Eluvium-Residual Soils	• mostly above the water table • forms local aquifer where saturated, connected to alluvium

Source: HGM, 2000. Iron Ore Mine and Downstream Processing, Cape Preston, Western Australia. Public Environmental Review. Prepared for Austeel Pty Ltd.

Groundwater Use

Groundwater is utilised on the island for both processing and domestic uses. Process water is pumped from the confined Flacourt Sands Aquifer, while the shallower unconfined aquifer is used for domestic purposes.

Salinity

Groundwater salinity rates from the upper aquifer vary considerably across the island, ranging from about 250 milligrams per litre (mg/L) total dissolved solids (TDS) to about 25 000 mg/L TDS (ChevronTexaco Australia 2000). The large variations in salinity reflect variable recharge rates and the sensitive balance of the fresh water/seawater interface.

Lower salinities occur in areas where recharge is rapid. Rapid recharge generally occurs in areas of highly permeable soils overlying porous karst limestone. Higher salinities occur where recharge is slower, represented by clays and silts overlying massive limestone, and in areas where the fresh/seawater interface is close to the surface of the watertable. The salinity of seawater is about 35 000 mg/L TDS, therefore the higher ranges of groundwater salinities (i.e. 25 000 mg/L TDS) represent areas of significant seawater intrusion.

Groundwater Contamination

There are no indications of groundwater contamination from current operations at any of the sites associated with the proposed Development (ChevronTexaco Australia 2000). Groundwater has, however, been impacted by hydrocarbons at the tank farm about 1 km north of the proposed gas processing facility site. It is unlikely that this impacted groundwater could extend far enough southwards to affect the proposed site. Moreover, during periods in which the creek immediately south of the tank farm is flowing, it would act as a temporary hydraulic barrier to south-flowing groundwater.

8.3 Ecology

8.3.1 Introduction

This section of Chapter 8 describes the existing biological environment in the Development area. It includes discussion of terrestrial and marine habitats and associated flora and fauna (including subterranean fauna) within the context of the Pilbara region, Barrow Island and the Gorgon Development areas.

The information presented on the terrestrial and marine environments of Barrow Island are based on numerous field surveys which commenced in early 2002 as part of the ESE Review process. Work has been ongoing since that time with additional surveys planned through to 2006.

8.3.2 Terrestrial Ecology

Flora and Vegetation Communities

Floristic diversity is an important component of terrestrial biodiversity on Barrow Island. Taxonomic surveys were conducted to identify possible rare and endangered plant species within the proposed Development areas and to assess whether these species are represented in areas outside the Development areas.

Vegetation communities and vegetated habitats are critical to the integrity of the Barrow Island ecosystem. The vegetation communities in the proposed Development areas and adjacent areas were mapped to identify potentially restricted communities and assess their representation outside proposed Development areas.

Botanical survey methods are summarised in Box 8-1. A full technical report is included in Technical Appendix C1.

Box 8-1:
Vegetation and Flora Survey Methodology

Vegetation was mapped within a greater study area of approximately 1683 ha surrounding the proposed gas processing facility, administration building, construction village and optical fibre cable route on Barrow Island (Figure 8-2). Seventy-two vegetation plots, each containing 25, 10 m x 10 m quadrats where possible, were established within the greater study area. Six of these plots were within the proposed gas processing facility footprint. Flora lists were compiled within each plot.

Vegetation plots on Barrow Island were established and surveyed in September and October 2003 and January 2004. The proposed gas processing facility area was re-surveyed in April and May 2004, following cyclonic rains, to collect annual species. Pipeline routes were surveyed in April and May 2004 and additional surveys to determine the extent of possibly restricted communities were conducted in May and July 2004.

Box 8-1: (continued)
Vegetation and Flora Survey Methodology

Vegetation maps for the proposed pipeline routes on Barrow Island were developed from detailed site observations, aerial photograph interpretation and plant specimen collections.

The areas to the north and south of the existing runway at the Barrow Island airport and alongside all of the roads between the airport and the barge landing were surveyed in July 2004 to identify major vegetation sensitivities in these areas. A preliminary survey of the proposed CO_2 seismic monitoring area was conducted in April 2005 to identify major constraints on disturbance in this area and to identify requirements for further survey work.

Surveys of the proposed domestic gas pipeline route on the mainland were undertaken on foot and by helicopter in May 2004. Major vegetation boundaries were identified from the air or from aerial photographs and the dominant vegetation within these areas described from site observations and plant collections.

Surveys were undertaken in accordance with EPA Guidance No. 51 (Environmental Protection Authority 2004b). Survey methodology and limitations are detailed in Technical Appendix C1.

Regional

Barrow Island lies in the Fortescue Botanical District, a subdivision of the Eremaean Botanical Province as defined by Beard (1980). The Eremaean province occupies approximately 70% of the state and is described by Beard (1980) as part of the arid zone which is dry and contains significant areas of 'barren, rocky and sandy country' but receives sufficient rainfall to maintain vegetated cover.

The Fortescue botanical district, or Pilbara region, covers approximately 178 000 km^2 and extends from north of Onslow, south and east to Paraburdoo and Newman, bounds the east side of the Oakover River and extends north and west to Goldsworthy.

The Fortescue Botanical District consists of 'tree and shrub steppe communities with *Eucalyptus* trees, *Acacia* shrubs, *Triodia pungens* and *Triodia wiseana'* (Beard 1990). [Note: *T. pungens* is a synonym of *T. epactia*]. Beard (1990) also notes the presence of mulga in valleys and 'short-grass' plains in alluvial areas. Mineral exploration since the 1960s has increased the knowledge of the area.

Barrow Island

Flora – The Eremaean nature of the flora on Barrow Island is demonstrated by the dominance of *Triodia* and *Acacia* and families such as Poaceae (grasses), Chenopodiaceae (chenopods), Papilionaceae (legumes), Malvaceae and Asteraceae (daisies) (Mattiske Consulting 1997).

The flora of Barrow Island is typical of the arid Pilbara region but has floral affinities with the Cape Range area on the mainland (Trudgen 1989; Mattiske Consulting 1997). Trudgen (1989) suggested that similarities between the vegetation on the Cape Range, which lies within the Carnarvon Botanical District, and the vegetation on Barrow Island, reflect past linkages to the mainland.

A total of 68 families, 180 genera and 406 vascular plant taxa have been recorded on Barrow Island. It is estimated that at least 90% of the vascular flora of Barrow Island has been documented. Approximately 20 to 30% of species are expected to occur only after cyclonic events or fires. Fourteen introduced vascular plant taxa have been recorded on Barrow Island, the majority of which have been recorded in or near previously disturbed sites. Table 8-5 summarises the regional affinities of the Barrow Island flora.

Two Priority species, protected under the *Wildlife Conservation Act 1950*, have been collected on Barrow Island: *Helichrysum oligochaetum* (Priority One) and *Corchorus interstans* (ms) (Priority Three).

Taxa that tend to be restricted to creek beds and gullies on Barrow Island are of conservation significance due to the relative rarity of this habitat on the island. The taxa associated with these habitats include *Abutilon otocarpum*, *Dysphania kalpari*, *Euphorbia* sp. 'A', *Gossypium australe* and *Hibiscus*

Table 8-5:
Summary of Geographical Spread of Species and Taxa Recorded on Barrow Island

Geographical Range	Number of Species/Taxa
Potentially restricted distribution on Barrow Island	17
Extensions from Kimberley	122
Extensions from Pilbara	193
Extensions from Cape Range and southern districts	50
Widespread (multiple botanical districts)	115

sturtii var. *platychlamys*. Most of these species occur only after favourable seasonal rains and were not recorded in 2003 and 2004 surveys, with the exception of *Abutilon otocarpum* which previously had only been recorded in Terminal Creek on the upper east part of Barrow Island (Mattiske and Associates 1993a, b).

Taxa that are restricted in distribution in the region or are only known from a few locations on Barrow Island are of conservation significance. Vegetation communities that are defined by the occurrence of these taxa are described in the following section.

Seventeen plant taxa require further attention in order to confirm their classification, distribution and conservation status on the island including variants of:

- *Acacia bivenosa*
- *Abutilon* sp.
- *Calandrinia* aff. *remota*
- *Ficus brachypoda* (hairy variant – ex *Ficus platypoda* var. *lachnocaula*)
- *Heliotropium* sp.
- *Lechenaultia* sp.
- *Sida* sp.

These seventeen species are considered to be locally significant pending confirmation of their conservation status (Technical Appendix C1).

Vegetation Communities – The vegetation of Barrow Island is unique amongst the islands of the north-west shelf (Astron Environmental 2002). The Barrow Island vegetation, and the soils, geology and topography show stronger affinities with Cape Range than with other Pilbara sites.

Barrow Island was originally classified into eight major vegetation units by Buckley (1983). These units were subsequently refined by Mattiske and Associates (1993b) who mapped 34 vegetation types based on major landforms, soil type and species composition over the whole island.

No vegetation communities listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) or Threatened Ecological Communities as listed in the Department of Conservation and Land Management (CALM) Threatened Ecological Communities Database (www.naturebase.net/plants_animals/watscu/tec.html) have been recorded on Barrow Island.

Vegetation communities which either have restricted distribution on the island, or contain threatened or restricted species, represent evolutionary significant units and are considered to be of conservation significance. Communities of conservation significance on Barrow Island include:

- Communities containing *Grevillea pyramidalis* ?subsp. *leucadendron* which are restricted on the island (Plate 8-1).
- Communities at the western end of the alternative feed gas pipeline at Flacourt Bay (C1d, C2e, C5b, C5c and C4e) which are restricted to the near-coastal areas (Plate 8-2).
- The limestone community (L3c) near the proposed pipeline shore crossing at North White's Beach which appears to be restricted on the island (Plate 8-3).
- Limestone communities containing, or expected to contain, *Tephrosia clementii* (F5d and F5e) which appear to be restricted on the island.

Plate 8-1:
Grevillea pyramidalis ?subsp. *leucadendron* Community (L6b) on Proposed North White's Beach Pipeline Route

Plate 8-2:
Coastal Community (C5c) on Limestone at Flacourt Bay

Plate 8-3:
Limestone community (L3c) on the Proposed North White's Beach Pipeline Route

Gorgon Development Area

Flora – The number of vascular plant taxa and families recorded within the proposed gas processing facility footprint and along the proposed pipeline routes from Flacourt Bay and North White's Beach are shown in Table 8-6. The flora of the proposed optical fibre cable route will be surveyed in winter 2005 to facilitate selection of the final alignment.

No introduced species were recorded in any of the proposed Development areas during the 2003 and 2004 surveys (Technical Appendix C1). One introduced species, *Setaria verticillata*, was recorded near the proposed North White's Beach pipeline corridor during post cyclonic rain surveys. This individual plant was a new record for the Island.

Table 8-6:
Tally of Plant Taxa and Families Recorded Within Proposed Development Areas on Barrow Island

Proposed Development Area	No. Taxa	No. Families	Dominant Families
Proposed gas processing facility footprint	48	26	Euphorbiaceae (7 taxa), Papilionaceae (4 taxa), Poaceae (3 taxa), Asteraceae (3 taxa)
Proposed North White's Beach pipeline route	67	27	Chenopodiaceae (9 taxa), Poaceae (9 taxa) and Asteraceae (7 taxa)
Proposed alternative Flacourt Bay pipeline route	60	27	Poaceae (12 taxa), Asteraceae (5 taxa) and Papilionaceae (4 taxa)

No Declared Rare Flora as listed under Section 179 of the EPBC Act, or listed by CALM were found within proposed Development areas.

Helichrysum oligochaetum (Priority One) was not recorded within any of the proposed Development areas. *Corchorus interstans* (Priority Three) was recorded in nine of the twelve communities within the proposed gas processing facility area and within the proposed North White's Beach pipeline corridor (Technical Appendix C1). *Corchorus interstans* is widely distributed on Barrow Island and occurs on the Pilbara mainland. *Corchorus interstans* recovers well from disturbance and is not considered under threat on Barrow Island.

Plant species which are of conservation significance, due to restricted or unknown distribution on Barrow Island, or high ecological significance, are discussed in full in Technical Appendix C1. Those that occur within or adjacent to the proposed Development areas are listed in Table 8-7 with notes on their local, island and wider distribution.

The conservation status of taxa of unresolved identity, including morphological variants of known species, is uncertain and their wider distribution on the island is unconfirmed. Their identities cannot be resolved until the taxonomy of their groups is revised. They represent genetic diversity in the Barrow Island flora and are treated as evolutionary significant units until their taxonomy can be resolved. Unresolved taxa that occur in Development areas are part of communities that are well represented outside impact areas.

Table 8-7:
Restricted or Poorly Known Species

Species	Distribution	Distribution in Development Area
Grevillea pyramidalis ?subsp. *leucadendron*	Scattered populations on slopes with limestone outcropping on Barrow Island.	South of the proposed gas processing facility and along the proposed North White's Beach pipeline route.
Hakea lorea subsp. *lorea*	Widespread within several vegetation communities on Barrow Island.	In communities associated with valleys, drainage systems, limestone slopes and ridges along proposed pipeline routes and within the proposed gas processing facility area.
Melaleuca cardiophylla	Widespread on Barrow Island. Significant for unknown regrowth abilities and as habitat for the endemic white-winged fairy wren.	Occurs within the proposed gas processing facility area and pipeline routes in vegetation communities associated with drainage systems, flats, limestone ridges and slopes, and valley slopes and escarpments. Just over 3% of this community is likely to be affected by the proposed gas processing facility footprint and pipelines (51.48 ha of 1583 ha across the island as a whole).
Hybanthus aurantiacus	Extends from Barrow Island to the Kimberley and Pilbara regions.	Occurs within the proposed gas processing facility area.
Whiteochloa airoides	Extends from Barrow Island to the Kimberley and Pilbara regions. Has been recorded on the west coast and in inland areas of Barrow Island.	Occurs in one area towards the western end of the proposed feed gas pipeline route from Flacourt Bay.
Acacia synchronicia	Is very restricted on Barrow Island but appears to be widespread in mainland areas.	This species occurs to the north and north-east of the existing airstrip.

Vegetation Communities – Eighty-three vegetation communities were mapped within the area encompassing the proposed gas processing facility, associated infrastructure near Town Point and along the proposed pipeline corridors (Figure 8-11 to Figure 8-15). The mapping units for the vegetation communities were based on data from the current surveys and previous studies by Mattiske and Associates (1993b) and Astron Environmental (2002).

Vegetation communities within the proposed Development areas are described in Table 8-8.

Table 8-8:
Summary of Vegetation Communities Recorded within Proposed Development Areas on Barrow Island

Development Area	Vegetation Communities
Proposed Gas Processing Facility	Twelve vegetation communities were mapped within the proposed gas processing facility footprint. The proposed footprint also includes areas of disturbance and unvegetated rocky ground. The dominant communities within the proposed footprint are V1m, F8a and L3i. Community V1m consists of *Melaleuca* and *Acacia* heath over mixed *Triodia* hummock grassland on limestone slopes and ridges. Community F8a consists of *Acacia bivenosa* shrubland over mixed *Triodia* hummock grassland on flats and valley floors. Community L3i consists of *Acacia bivenosa* shrubland over mixed *Triodia* hummock grassland on limestone slopes, small rises and flats. 0.092 ha of major drainage line vegetation community which is restricted in distribution on the island is likely to be affected by the proposed gas processing facility area. There are two small *Grevillea* communities to the south of the proposed gas processing facility outside the proposed Development area.
Proposed Optical Fibre Cable Route	The proposed optical fibre cable route runs through coastal vegetation communities between the proposed gas processing facility and the coast. The communities affected by the cable route will be determined when the final route has been selected. Impacts to restricted communities will be avoided in selecting the cable route.
North White's Beach Feed Gas Pipeline	The pipeline corridor contains 44 vegetation communities over an area of approximately 36 ha. The corridor contains three communities dominated by the restricted species *Grevillea pyramidalis* subsp.?*leucadendron*, with a total area of 3 ha which would be impacted by the proposed pipeline. Limestone community L3c on this proposed pipeline route is very restricted and up to 0.1 ha of this community may be impacted by the proposed pipeline.
Alternative Flacourt Bay Proposed Feed Gas Pipeline	The alternative pipeline corridor from Flacourt Bay to the gas processing facility contains 23 vegetation communities over an area of about 22 ha. The proposed pipeline route includes five communities: C1d, C2e, C5b, C5c and C4e which are restricted to low beach dunes and coastal limestone flats. Approximately 0.5 ha of major drainage communities, which are restricted on the island would be impacted by the alternative pipeline.
Proposed CO_2 Injection Well Sites and CO_2 seismic monitoring area	The locations for the proposed CO_2 injection wells and seismic source/receiver lines have not been finalised, pending further geophysical modelling. The wells and the seismic monitoring grid will be overlain on the 1994 seismic grid, as much as possible, to maximise re-use of previously disturbed vegetation communities. Previously undisturbed, restricted vegetation communities will be avoided. Preliminary survey of the general area indicates that the vegetation communities that will need to be avoided include major drainage communities, coastal dune communities and clay pan communities to the north. The area will be mapped and the final sites chosen to avoid areas of high conservation value.
Airport Extension and Road Widening	Vegetation communities containing *Acacia synchronicia* to the north of the existing airstrip are restricted on the island. These communities have not been fully described or mapped and will be surveyed to assist in selecting the final alignment of the extended runway if it is required. Roadside communities are well represented in the areas adjacent to the roads. The areas immediately abutting the roads are frequently disturbed due to the accumulation of grader spoil and are dominated by *Triodia angusta*.

Mainland – Domestic Gas Pipeline Corridor

The proposed domestic gas pipeline corridor on the mainland is 50 m south of, and parallel to, the existing Apache Energy Sales Gas Pipeline corridor which extends through coastal mangrove and samphire associations, salt pans and inland terrestrial vegetation associations to Compressor Station 1 on the Dampier to Bunbury Natural Gas Pipeline. The terrestrial section of the corridor is on a pastoral lease and the area has been heavily affected by introduction of weed species and disturbance by domestic stock.

The terrestrial vegetation communities along the proposed domestic gas pipeline route are dominated by three major and two minor vegetation units with isolated occurrences of the introduced species *Prosopis* sp. and *Cenchrus ciliaris* (Dames and Moore 1998). In general, these vegetation units recovered successfully along the Apache Energy Sales Gas Pipeline easement in the 5–6 years subsequent to the initial pipeline installation.

Terrestrial Avifauna

Terrestrial avifauna (landbirds) populations were surveyed to assess the importance of the proposed Development areas in relation to other parts of Barrow Island and the Pilbara region. Surveys focussed on the only listed landbird species, the 'Vulnerable' and endemic white-winged fairy wren (*Malurus leucopterus edouardi*). The methodology used in the surveys is described in Box 8-2 and a full technical report is provided in Technical Appendix C3. Seabirds and shorebirds are discussed in Section 8.3.3 and are also included in Technical Appendix C3.

Box 8-2:
Avifauna Survey Methodology

Landbirds were surveyed twice a month along 1 km transects within the proposed Development area from September 2003 to October 2004. Surveys involved walking along fixed transects and recording landbirds within 25 m and beyond 25 m of each transect. Landbird locations were related to major vegetated habitat types within the Gorgon Development area.

A more intensive survey was conducted in October 2004 to examine habitat preferences of the white-winged fairy wren. Further surveys of the nesting habitat preferences of white-winged fairy wrens are planned for winter 2005.

Surveys were conducted in accordance with EPA Guidance No. 56 (Environmental Protection Authority 2004a). Survey methodology and limitations are described in Technical Appendix C3.

Regional

The landbirds of the Pilbara region include transient species that move throughout the region and resident or regular visitors that are more loyal to particular sites. Landbirds regularly travel between the Pilbara mainland and the offshore islands within the Montebello/Lowendal/Barrow Island groups. Consequently, many of the landbirds on the offshore islands are vagrants from the mainland. The white-winged fairy wren is widely distributed through the region, but does not travel between the islands and the mainland. It no longer occurs on the Montebello Islands (Burbidge 2004) and isolated populations have diverged genetically.

Figure 8-11:
Vegetation Legend (Page 1)

Barrow Island 2003/2004 Vegetation Community Legend

C1a	Open Grassland of *Spinifex longifolius* with low scattered *Atriplex isatidea, Myoporum montanum, Euphorbia myrtoides* and *Salsola tragus* shrubs and herbs on seaward face of white sandy fore dunes.
C1d	Low Open Shrubland of *Scaevola cunninghamii, Corchorus* sp. and *Heliotropium glanduliferum* over Very Open Grassland of *Spinifex longifolius* over scattered *Cynanchum floribundum* creeper on lower slopes at the base of primary sand dunes.
C1e	Grassland of *Spinifex longifolius* over Low Open Shrubland of *Threlkeldia diffusa* with scattered *Rhagodia preissii* subsp. *obovata* and *Frankenia pauciflora* var. *pauciflora* on ridges and back slopes of white sandy foredunes.
C2a	Shrubland to Tall Shrubland of *Acacia coriacea* over Low Open Shrubland to Open Shrubland of *Acacia bivenosa* with low scattered *Olearia dampieri* subsp. *dampieri* shrubs over Open Hummock Grassland to Grassland of *Triodia angusta* on dune swales, slopes and ridges.
C2b	Open Shrubland of *Acacia coriacea* over Low Open Shrubland of *Acacia bivenosa* and *Pentalepis trichodesmoides* with scattered *Acanthocarpus verticillatus* over Hummock Grassland of *Triodia angusta* and *Triodia wiseana* on red/brown sandy flats.
C2c	Shrubland to Tall Shrubland of *Acacia coriacea* over Low Open Shrubland to Open Shrubland of *Acacia bivenosa* with low scattered *Olearia dampieri* subsp. *dampieri* shrubs over Open Hummock Grassland to Grassland of *Triodia angusta* on dune slopes and ridges.
C2d	Low Open Shrubland of *Acacia coriacea* and *Myoporum montanum* over Grassland to Hummock Grassland of *Spinifex longifolius* with patches of *Triodia epactia* in swales between dunes.
C2e	Low Open Shrubland of *Myoporum montanum* with *Corchorus* sp. over Grassland to Hummock Grassland of *Spinifex longifolius* with *Triodia angusta* over scattered *Cynanchum floribundum* creeper on crest of primary dunes.
C2f	Open Shrubland of *Acacia coriacea* over Low Open Shrubland of *Olearia dampieri* subsp. *dampieri* and *Acacia bivenosa* with occasional *Stylobasium spathulatum* over Hummock Grassland of *Triodia epactia* on sandy dune ridges (over scattered *Heliotropium glanduliferum* and *Diplopeltis eriocarpa* on back of red/brown sandy flats and dunes).
C2g	Shrubland of *Acacia coriacea* over Low Shrubland to Shrubland of *Olearia dampieri* subsp. *dampieri, Stylobasium spathulatum* and *Acacia bivenosa* over Hummock Grassland of *Triodia epactia* over low scattered *Threlkeldia diffusa* herbs in swales between dunes.
C2h	Low Shrubland of *Acacia coriacea* with *Rhagodia preissii* subsp. *obovata* over Very Open Herbland of *Threlkeldia diffusa* over Grassland to Hummock Grassland of *Triodia epactia* and *Spinifex longifolius* on secondary dune slopes and ridges.
C3a	Open Heath of *Acacia bivenosa* over Low Open Shrubland of *Olearia dampieri* subsp. *dampieri* with low scattered *Myoporum montanum* and *Enchylaena tomentosa* var. *tomentosa* shrubs over Open Hummock Grassland of *Triodia epactia* on red/brown sandy flats behind dunes.
C4e	Open Shrubland of *Trichodesma zeylanicum* over Low Open Shrubland of *Corchorus* sp., *Olearia dampieri* subsp. *dampieri, Scaevola cunninghamii* and *Whiteochloa airoides* over Open Hummock Grassland of *Triodia angusta* over *Cynanchum floribundum* scattered creepers on upper slope to mid slopes of sandy dunes.
C5a	Low scattered *Frankenia pauciflora* var. *pauciflora* shrubs with scattered *Oldenlandia crouchiana* herbs and *Cyperus cunninghamii* subsp. *cunninghamii sedges* on coastal limestone cliffs and in major drainage lines in coastal areas.
C5b	Low scattered *Pentalepis trichodesmoides, Olearia dampieri* subsp. *dampieri, Corchorus* sp. and *Tephrosia rosea* shrubs over Hummock Grassland of *Triodia angusta* over scattered *Cynanchum floribundum* creepers on limestone ridges and flats (plateaus).
C5c	Very Open Hummock Grassland of *Triodia angusta* over low scattered *Scaevola cunninghamii, Corchorus* sp., *Frankenia pauciflora* var. *pauciflora* and *Heliotropium glanduliferum* scattered herbs and shrubs on lower slopes on limestone.
C5d	Low Open Shrubland of *Myoporum montanum* over Very Open Grassland of *Spinifex longifolius* with scattered Hummocks of *Triodia epactia* over Low Open Shrubland of *Frankenia pauciflora* var. *pauciflora* with scattered *Heliotropium glanduliferum* on flat sandy swales with occasional limestone outcropping behind primary dunes.
D1a	Scattered tall *Acacia coriacea* shrubs over Low Shrubland to Shrubland of *Stylobasium spathulatum* and *Acacia bivenosa* over Very Open Herbland of *Acanthocarpus verticillatus* over Closed Hummock Grassland of *Triodia angusta* with scattered *Triodia wiseana* on valley floors and deep gullies. This unit contains occasional *Hakea lorea* subsp. *lorea.* Unit also contains areas of scoured drainage channel in areas of heavy seasonal flow.
D1c	Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia angusta* with *Triodia epactia* at edges in major drainage lines.
D1d	Low Open Shrubland of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia epactia* with patchy *Triodia angusta* and *Triodia wiseana* on lower slopes and broad drainage flats.

Figure 8-11:
Vegetation Legend (Page 2)

D1e	Open Shrubland of *Stylobasium spathulatum, Pentalepis trichodesmoides* with *Trichodesma zeylanicum* over Closed Hummock Grassland of *Triodia angusta* and *Triodia wiseana* over Low Open Shrubland of *Acacia bivenosa* and *Acacia gregorii* in some locations on lower slopes, drainage flats and wide drainage lines.
D1f	Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Stylobasium spathulatum* with patchy *Petalostylis labicheoides* over Hummock Grassland to Closed Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana* in major drainage lines. This unit contains occasional *Hakea lorea* subsp. *lorea.*
D1g	Closed Hummock Grassland of *Triodia angusta* and *Triodia wiseana* over low scattered *Tephrosia rosea* and *Indigofera monophylla* shrubs in wide drainage lines.
D2c	Scattered tall *Trichodesma zeylanicum* shrubs over Hummock Grassland of *Triodia angusta* with *Triodia wiseana* over Low Open Shrubland of *Tephrosia rosea* in disturbed drainage lines.
D2d	Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia epactia* and *Triodia wiseana* over Low Shrubland of *Acacia gregorii* in minor creek and drainage lines.
D2f	Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Stylobasium spathulatum* with patchy *Petalostylis labicheoides, Acacia gregorii* and *Acacia bivenosa* over Hummock Grassland to Closed Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana* in minor drainage lines. This unit contains occasional *Hakea lorea* subsp. *lorea.*
F4a	Low Open Woodland of *Erythrina vespertilio* over Low Open Shrubland of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia wiseana* and *Triodia angusta* with occasionally emergent *Ficus brachypoda* on flats with shallow red/brown sands and emergent limestone.
F5a	Low Open Shrubland of *Stylobasium spathulatum* with scattered *Pentalepis trichodesmoides* and *Senna glutinosa* over Hummock Grassland of *Triodia angusta* with *Triodia epactia* over Low Open Shrubland of *Diplopeltis eriocarpa* on gentle low slopes and flats.
F5b	Scattered low *Ficus brachypoda* trees over scattered low *Pentalepis trichodesmoides, Acacia bivenosa, Corchorus* sp. , *Tephrosia rosea* and *Streptoglossa decurrens* shrubs over Closed Hummock Grassland of *Triodia epactia* with *Triodia angusta* on flats.
F5c	Low Open Shrubland of *Pentalepis trichodesmoides* over mixed Hummock Grassland of *Triodia epactia* with occasional *Triodia angusta* over Low Open Shrubland of *Diplopeltis eriocarpa* and *Acacia gregorii* on limestone ridges, slopes and flats.
F5d	Scattered low *Ficus brachypoda* trees over Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia angusta* over scattered low *Corchorus* sp., *Scaevola cunninghamii* and *Heliotropium glanduliferum* herbs and shrubs on upper slopes and mid slopes of small limestone rises.
F5e	Scattered low *Ficus brachypoda* trees over low scattered *Pentalepis trichodesmoides* shrubs over Open Hummock Grassland of *Triodia angusta* with *Triodia epactia* over low scattered *Scaevola cunninghamii, Diplopeltis eriocarpa* and *Acacia bivenosa* shrubs on limestone flats and rises with shallow pale pink sands.
F6a	Low Open Shrubland of *Acacia bivenosa* and *Stylobasium spathulatum* over Hummock Grassland of *Triodia epactia* on red/brown sandy flats.
F6b	Scattered low *Ficus brachypoda* trees over Low Open Shrubland of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia epactia* with on sandy slopes and flats with occasional limestone outcropping.
F6c	Tall Open Shrubland of *Acacia coriacea* over low scattered *Stylobasium spathulatum* shrubs over Open Hummock Grassland of *Triodia epactia* on light red/brown sandy flats.
F6d	Open Shrubland of *Trichodesma zeylanicum* over low scattered *Pterocaulon sphacelatum* shrubs over Hummock Grassland of *Triodia epactia* on limestone flats with shallow sands.
F7a	Low scattered *Pentalepis trichodesmoides* and *Trichodesma zeylanicum* shrubs over Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Diplopeltis eriocarpa* and scattered *Acacia gregorii* on limestone slopes.
F7b	Scattered low *Ficus brachypoda* trees over Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia wiseana* with patches of *Triodia angusta* on sandy flats.
F7c	Open Shrubland of *Senna glutinosa* over Low Open Shrubland of *Pentalepis trichodesmoides* and *Tephrosea rosea* over Closed Hummock Grassland of *Triodia angusta* on red/brown sandy flats.
F7d	Scattered *Hakea lorea* subsp. *lorea* shrubs over Low Scattered *Pentalepis trichodesmoides* and *Trichodesma zeylanicum* shrubs over Closed Hummock Grassland of *Triodia epactia* and *Triodia wiseana* on mid slopes and flats.
F7e	Low Open Shrubland of *Pentalepis trichodesmoides* over low scattered *Corchorus* sp. and *Sarcostemma viminale* subsp. *australe* shrubs over Hummock Grassland of *Triodia wiseana* on red/brown sandy flats (with pockets of *Eriachne mucronata* on valley floors).
F8a	Low Open Shrubland to Open Shrubland of *Acacia bivenosa,* with occasional scattered *Pentalepis trichodesmoides, Stylobasium spathulatum* and *Acanthocarpus verticillatus* shrubs over Hummock Grassland to Closed Hummock Grassland of *Triodia wiseana* with occasional *Triodia angusta* on flats and valley floors.

Figure 8-11:
Vegetation Legend (Page 3)

F8b	Scattered tall *Hakea lorea* subsp. *lorea* shrubs over Low Open Shrubland of *Pentalepis trichodesmoides* over low scattered *Tephrosia rosea* shrubs over Hummock Grassland of *Triodia wiseana* on red/brown sandy flats.
L1a	Scattered low *Ficus brachypoda* and *Pittosporum phylliraeoides* trees over low scattered *Stylobasium spathulatum* and *Petalostylis labicheoides* shrubs over Hummock Grassland of *Triodia wiseana* with occasional *Cymbopogon ambiguus, Tephrosia rosea* and *Triodia angusta* on limestone ridges and upper slopes.
L1b	Scattered low *Ficus brachypoda* trees over low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* on limestone slopes and ridges.
L1c	Scattered low *Ficus brachypoda* over Low Open Shrubland of *Acacia bivenosa* over Closed Hummock Grassland of *Triodia angusta* with *Triodia epactia* and occasional *Triodia wiseana* on limestone slopes and ridges.
L1d	Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Diplopeltis eriocarpa* and *Heliotropium glanduliferum* on limestone flats (plateau).
L1e	Scattered low *Ficus brachypoda* and *Pittosporum phylliraeoides* trees (with *Mallotus nesophilus)* over Hummock Grassland of *Triodia wiseana* with patchy *Triodia angusta* over low scattered *Diplotepltis eriocarpa* shrubs on limestone slopes and flats.
L1f	Scattered low *Ficus brachypoda* and *Pittosporum phylliraeoides* trees over Hummock Grassland of *Triodia wiseana* and patchy *Triodia angusta* on limestone slopes and ridges.
L3a	Low Open Shrubland of *Stylobasium spathulatum* with *Petalostylis labicheoides* over Closed Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana* over Low Open Shrubland of *Acacia gregorii* on limestone slopes and ridges.
L3b	Low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* with *Triodia epactia* over low scattered *Acacia gregorii* and *Diplopeltis eriocarpa* shrubs on limestone slopes and ridges.
L3c	Low scattered *Diplopeltis eriocarpa* shrubs with scattered *Cymbopogon ambiguus* and *Cyperus cunninghamii* subsp. *cunninghamii* herbs and grasses on small exposed limestone flats.
L3d	Low scattered *Stylobasium spathulatum* and *Petalostylis labicheoides* shrubs over Low Open Shrubland of *Diplopeltis eriocarpa, Acacia gregorii* and *Hannafordia quadrivalvis* subsp. *recurva* over Hummock Grassland of *Triodia angusta* with *Triodia wiseana* on limestone ridges.
L3e	Scattered low *Ficus brachypoda* and *Pittosporum phylliraeoides* trees over low scattered *Pentalepis trichodesmoides* and *Trichodesma zeylanicum* shrubs over mixed Hummock Grassland of *Triodia wiseana, Triodia angusta* and *Triodia epactia* over low scattered *Diplopeltis eriocarpa* shrubs on slopes and ridges.
L3f	Low scattered *Petalostylis labicheoides* and *Indigofera monophylla* shrubs over Hummock Grassland of *Triodia wiseana* on limestone ridges and upper slopes.
L3g	Low Open Shrubland of *Stylobasium spathulatum* over Hummock Grassland of *Triodia wiseana* with *Triodia angusta* and *Cymbopogon ambiguus* over Low Open Shrubland of *Diplopeltis eriocarpa* on limestone hillslopes.
L3h	Low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* over low scattered *Diplopeltis eriocarpa* shrubs on limestone ridges and flats.
L3i	Low Open Shrubland to Low Shrubland of *Acacia bivenosa* with occasional low scattered *Stylobasium spathulatum* and *Petalostylis labicheoides* shrubs over Hummock grassland of *Triodia angusta* with occasional *Triodia wiseana* on limestone slopes, small rises and flats.
L4a	Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Acacia bivenosa* with scattered *Petalostylis labicheoides* and *Stylobasium spathulatum* over Hummock Grassland of *Triodia wiseana* on limestone ridges and midslopes with patches of *Triodia angusta.* This unit contains occasional *Hakea lorea* subsp. *lorea.*
L5a	Scattered tall *Hakea lorea* subsp. *lorea* shrubs over low scattered *Petalostylis labicheoides* shrubs over Hummock Grassland of *Triodia wiseana* and *Triodia angusta* over low scattered *Acacia gregorii* and *Corchorus interstans* shrubs on limestone ridges.
L5b	Scattered *Hakea lorea* subsp. *lorea* shrubs over low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* on red/brown sandy midslopes.
L6a	Low Open Shrubland of *Grevillea pyramidalis* subsp. *?leucadendron* and *Acacia bivenosa* over Hummock Grassland of *Triodia angusta* low scattered *Acacia gregorii, Scaevola cunninghamii* and *Heliotropium glanduliferum* shrubs and herbs on limestone midslopes.
L6b	Scattered low *Ficus brachypoda* trees over Low Open Shrubland of *Grevillea pyramidalis* ?subsp. *leucadendron* with occasional *Pentalepis trichodesmoides, Trichodesma zeylanicum* with scattered *Acacia gregorii* over Closed Hummock Grassland of *Triodia epactia, Triodia wiseana* and *Eriachne* sp. over Low Open Shrubland of *Acacia gregorii* on upper slopes and midslopes of small rises.
L6c	Low Open Shrubland of *Pentalepis trichodesmoides* with *Grevillea pyramidalis* ?subsp. *leucadendron (Grevillea* only in eastern section of community) over Hummock Grassland of *Triodia wiseana* with patchy *Triodia epactia* over Low Open Shrubland of *Diplopeltis eriocarpa* on mid to upper slopes with red/brown sands and occasional limestone outcropping on rocky rises and slopes.

Figure 8-11:
Vegetation Legend (Page 4)

L6d	Low Open Shrubland of *Pentalepis trichodesmoides* with *Indigofera monophylla* and scattered *Grevillea pyramidalis* ?subsp. *leucadendron* over Hummock Grassland of *Triodia epactia* in minor drainage lines.
L7a	Low Shrubland of *Melaleuca cardiophylla, Stylobasium spathulatum, Pentalepis trichodesmoides, Trichodesma zeylanicum* over Hummock Grassland of *Triodia wiseana* with *Triodia angusta* over Low Open Shrubland of *Acacia gregorii, Acacia bivenosa* shrubs on rocky limestone ridges, slopes and minor gullies, with occasional pockets of *Gossypium robinsonii*.
L7b	Low Shrubland of *Melaleuca cardiophylla* over Hummock Grassland of *Triodia wiseana* with occasional *Triodia angusta* over low scattered shrubs to Low Open Shrubland of *Acacia gregorii* on limestone upper slopes and ridges.
L9a	Low Open Woodland of *Ficus brachypoda* over low scattered *Pentalepis trichodesmoides* and *Sarcostemma viminale* subsp. *australe* shrubs over Closed Hummock Grassland of *Triodia angusta* and *Triodia wiseana* on coastal limestone flats.
S1a	Grassland of *?Eriachne flaccida* over scattered low *Pluchea dunlopii* and *Streptoglossa decurrens* herbs and shrubs on clay pans. (Community contains scattered emergent *Acacia bivenosa* and *Stylobasium spathulatum* shrubs and *Triodia angusta* at edges).
V1a	Low Open Shrubland of *Acacia bivenosa* with *Petalostylis labicheoides* over Hummock Grassland of *Triodia wiseana* with occasional *Triodia angusta* over Low Open Shrubland of *Acacia gregorii* shrubs on limestone midslopes and occasional small rises. This unit contains some areas of disturbance by fauna.
V1b	Low Open Shrubland of *Acacia bivenosa* with *Petalostylis labicheoides* over Hummock Grassland of *Triodia wiseana* and some *Triodia angusta* over Low Open Shrubland of *Diplopeltis eriocarpa* on red/brown sandy flats.
V1c	Scattered low *Ficus brachypoda* and *Pittosporum phylliraeoides* trees over scattered low *Petalostylis labicheoides, Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana, Triodia epactia* and *Cymbopogon ambiguus* on limestone slopes and ridges, with *Stylobasium spathulatum* at edges on red/brown sandy drainage flats.
V1d	Low Open Shrubland of *Acacia bivenosa* with low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia angusta* and *Triodia wiseana* on limestone slopes and low ridges with occasional *Melaleuca cardiophylla.*
V1f	Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Tephrosia rosea* on red/brown sandy flats.
V1g	Scattered tall *Acacia pyrifolia* shrubs over low scattered *Petalostylis labicheoides, Acacia bivenosa* and *Acacia gregorii* shrubs over Hummock Grassland of *Triodia wiseana* with some *Triodia angusta* and *Cymbopogon ambiguus* on red/brown sandy midslopes and in minor drainage lines with occasional outcropping.
V1h	Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Stylobasium spathulatum, Petalostylis labicheoides* and *Acacia bivenosa* over Closed Hummock Grassland of *Triodia wiseana* and *Triodia angusta* over Low Open Shrubland of *Acacia gregorii* on limestone slopes. This unit contains occasional *Hakea lorea* subsp. *lorea.*
V1i	Hummock Grassland of *Triodia epactia* with occasional *Triodia wiseana* over Low Open Shrubland *Acacia gregorii* with *Diplopeltis eriocarpa* on gentle slopes and flats.
V1j	Low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia wiseana* over Low Open Shrubland of *Diplopeltis eriocarpa* and scattered *Acacia gregorii* on limestone slopes.
V1k	Scattered *Acacia pyrifolia* and occasional *Hakea lorea* subsp. *lorea* shrubs over Low Open Shrubland to Low Shrubland of *Melaleuca cardiophylla* over Hummock Grassland of *Triodia wiseana* with patchy *Triodia angusta* over low scattered *Acacia gregorii* shrubs on limestone hillslopes and minor drainage lines.
V1m	Low Open Heath of *Melaleuca cardiophylla* with *Acacia bivenosa, Sarcostemma viminale* subsp. *australe* over Hummock Grassland of *Triodia wiseana* and *Triodia angusta* on limestone ridges and slopes.
V1n	Scattered *Hakea lorea* subsp. *lorea* shrubs over low scattered shrubs to Low Open Shrubland of *Melaleuca cardiophylla* with *Acacia bivenosa, Stylobasium spathulatum* and *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia angusta* on flats and edge of drainage lines.
V3a	Scattered low *Ficus brachypoda* trees over scattered *Acacia pyrifolia* shrubs over Hummock Grassland of *Triodia wiseana* on limestone slopes. This community contains minor drainage lines.
V3b	Scattered *Acacia pyrifolia* shrubs with occasional *Hakea lorea* subsp. *lorea* over low scattered shrubs to Low Open Shrubland of *Petalostylis labicheoides* and *Stylobasium spathulatum,* occasional *Acacia bivenosa* and *Acacia gregorii* over Hummock Grassland of *Triodia wiseana* with patches of *Triodia angusta* on limestone slopes.
R	Rocks
Dist	Disturbed, cleared, roads.
D1a Dist	Disturbed Community D1a drainage areas.

Figure 8-12:
Proposed Northern Pipeline Corridors

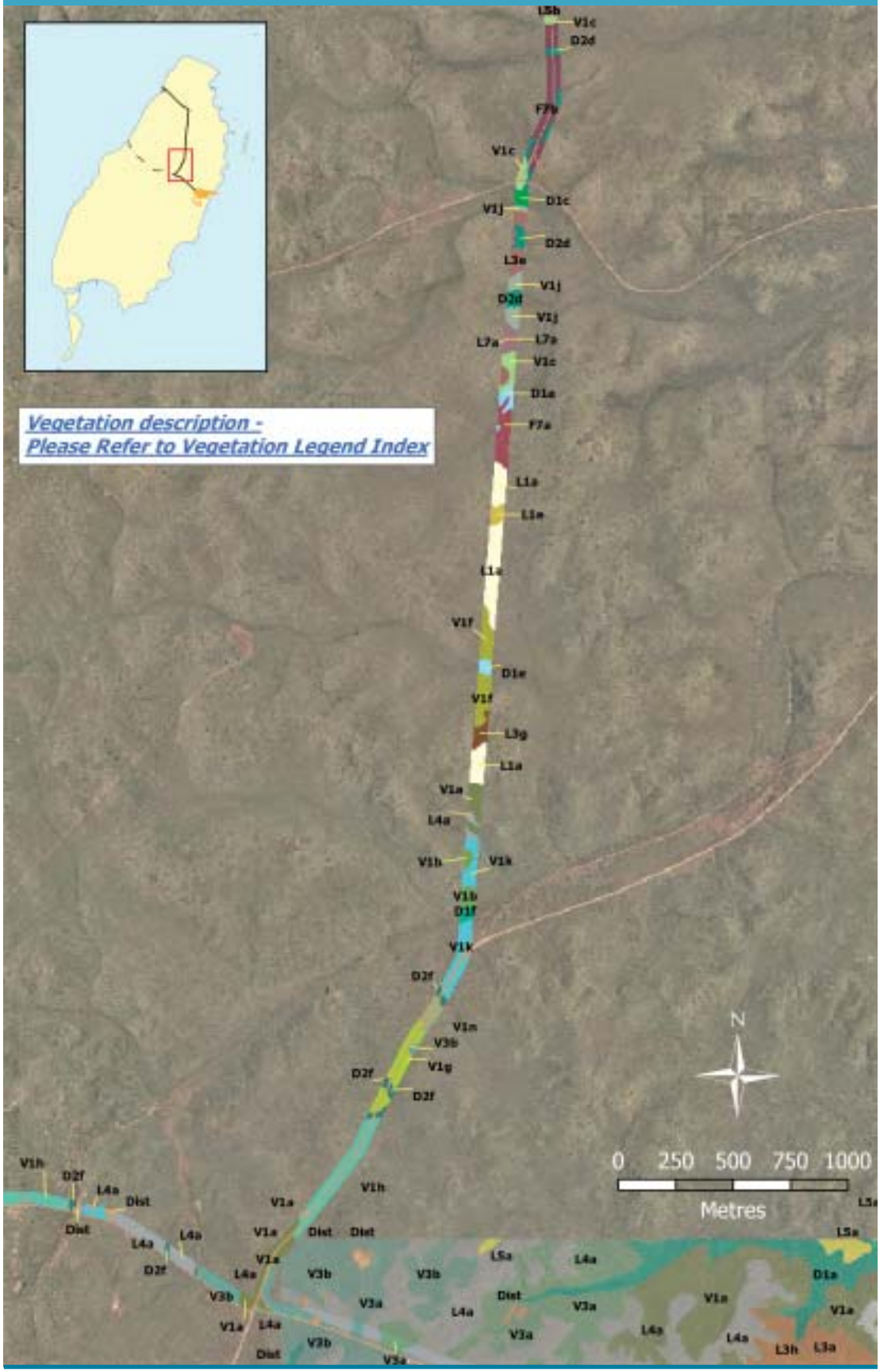


Figure 8-13:
Proposed Northern Pipeline Corridors *(continued)*

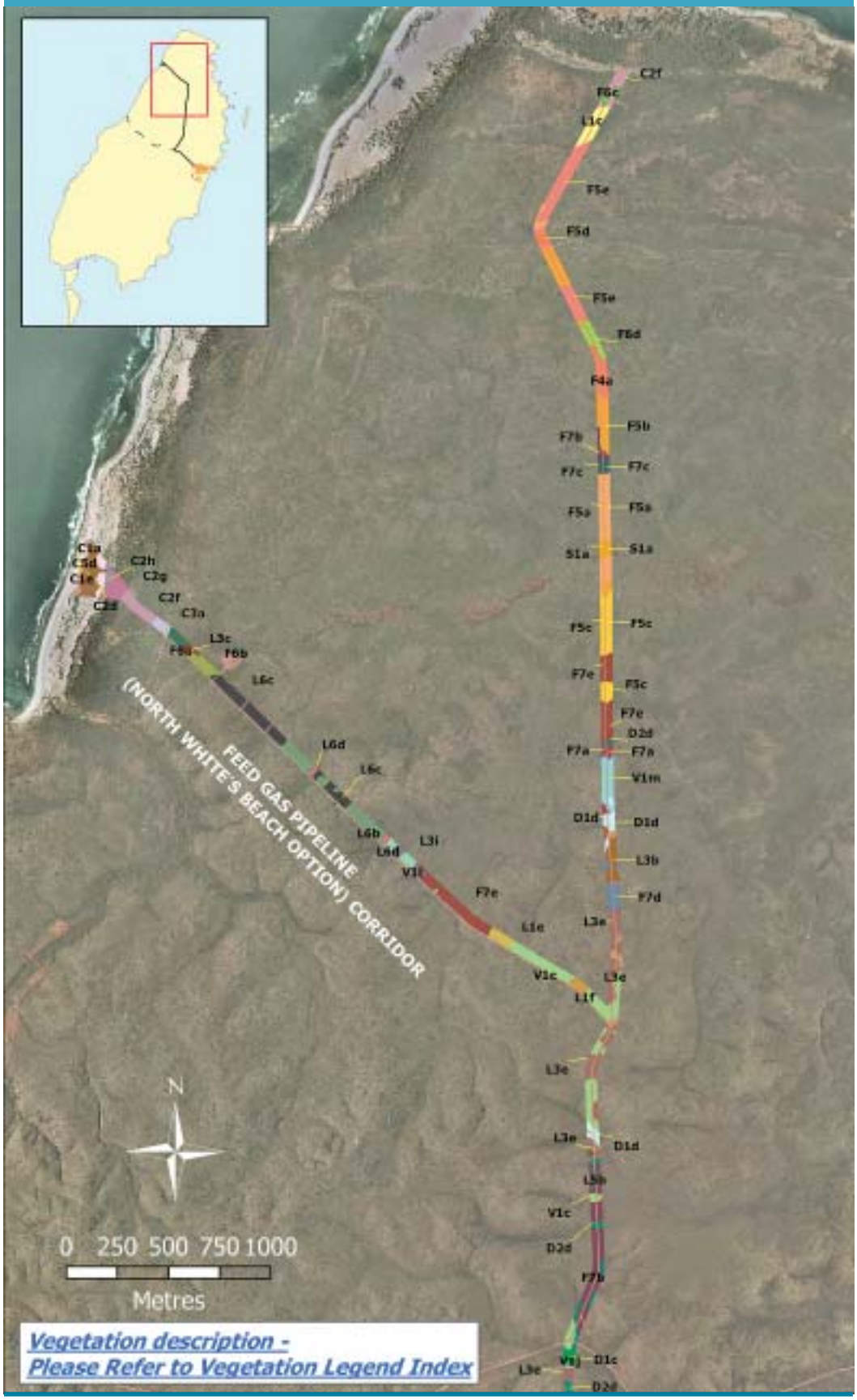
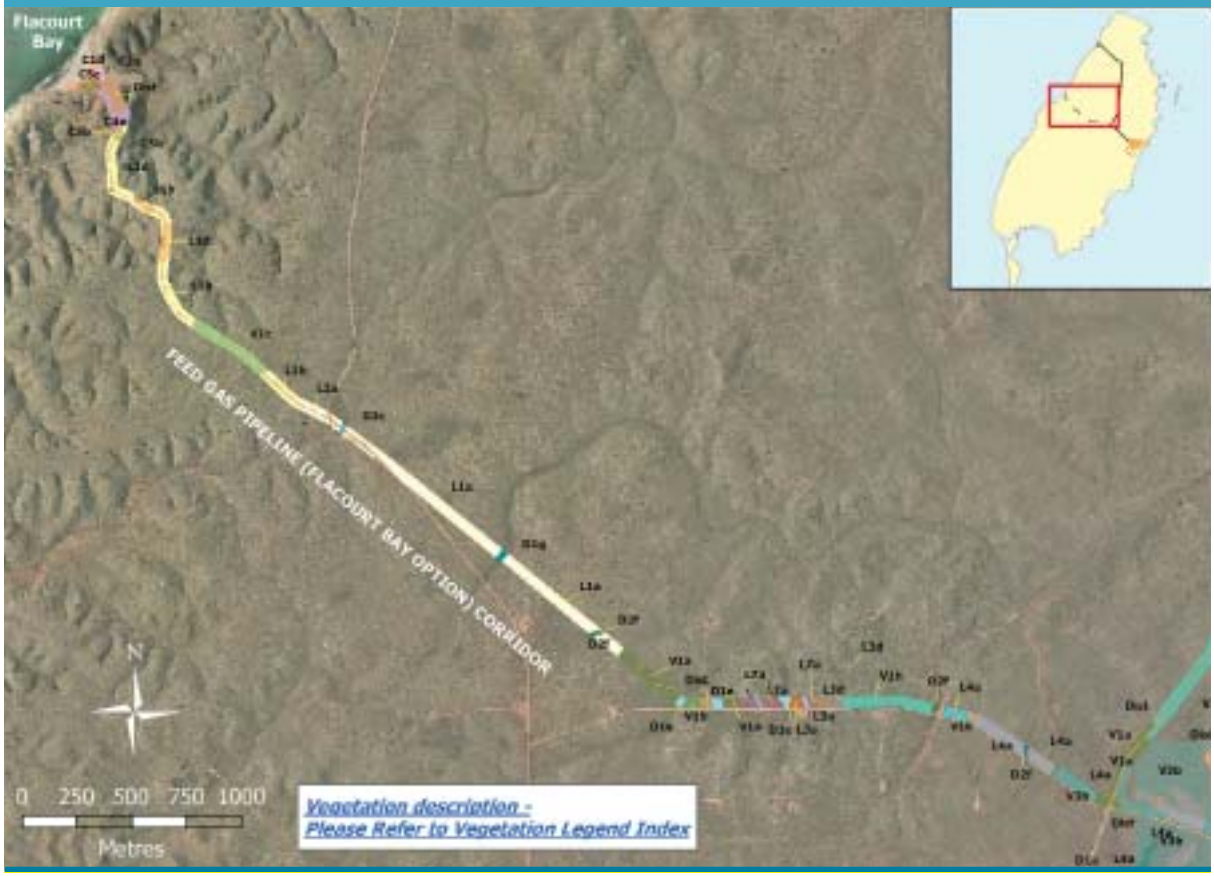


Figure 8-14:
Proposed Feed Gas Pipeline Vegetation



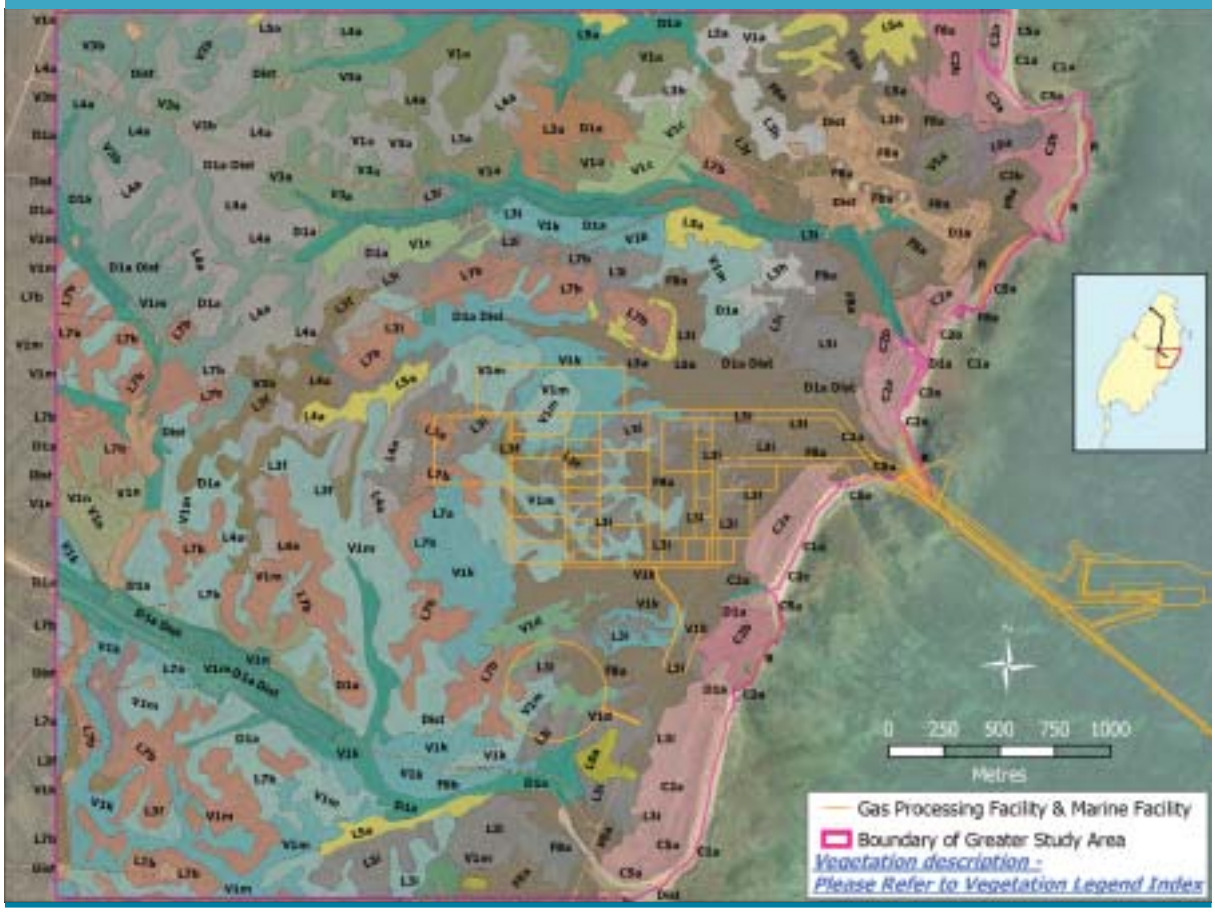
Barrow Island

Fifty-one species of terrestrial avifauna have been recorded on Barrow Island; however only 16 of these species are residents or regular migrants to the island. Most species are considered to be vagrants from the adjacent mainland. The most common landbirds on Barrow Island are the spinifexbird, white-winged fairy wren, singing honeyeater, white-breasted wood swallow and the welcome swallow (Technical Appendix C3).

White-winged Fairy Wrens – The Barrow Island white-winged fairy wren (Plate 8-4) is an endemic subspecies that is abundant, but restricted to Barrow Island. It is listed under Schedule 1 of the Wildlife Conservation Act and as a threatened species (Vulnerable) under the Commonwealth EPBC Act. The white-winged fairy wren is the second most abundant landbird on Barrow Island and is generally associated with complex vegetation structures in the upland areas of Barrow Island (Pruett-Jones and Tarvin 2001) and near-coastal shrublands (Technical Appendix C3). White-winged fairy wrens are part of a stable resident population on Barrow Island that has diverged from other island and mainland subspecies.

Plate 8-4:
Pair of Nesting White-Winged Fairy Wrens on *Melaleuca* Shrub

Figure 8-15:
Gas Processing Facility Footprint



Gorgon Development Area

The abundance of landbirds in the Development area varies across different vegetated habitats. Species richness is highest in coastal *Acacia* shrublands where both the singing honeyeater and the spinifexbird (Plate 8-5) are abundant. White-winged fairy wrens tend to be more abundant in inland *Melaleuca* and *Acacia* shrublands.

Landbirds commonly roost in the scattered emergent shrubs along the side of the roads and may occur at higher densities on roadsides than in adjacent habitats (Pruett-Jones and O'Donnell in prep). There are no critical avifauna habitats in the proposed Development areas that are of higher ecological significance than surrounding areas for any landbird species.

White-winged Fairy Wrens – White-winged fairy wrens are widely distributed across the island and are expected to occur in all of the proposed Development areas. Transect surveys through the area surrounding the proposed gas processing facility indicated that white-winged fairy wrens prefer vegetation communities with emergent shrubs such as *Melaleuca* and *Acacia*. These communities are widespread in the Town Point hinterland and white-winged fairy wrens are abundant within the Development area. The proposed Development areas contain approximately 3–4% of the preferred emergent shrubland communities on Barrow Island and are

Plate 8-5:
Spinifexbird in *Acacia* Shrubland

expected to support a similar proportion of the island's total white-winged fairy wren population.

Mainland – Domestic Gas Pipeline Corridor

Five listed, migratory terrestrial or wetland species (EPBC Act) or their habitats may occur within the vicinity of the mainland domestic gas pipeline corridor. These species include: the white-bellied sea-eagle *Haliaeetus leucogaster*, the barn swallow *Hirundo rustica*, the oriental plover *Charadrius veredus*, the oriental pranticole *Glareola maldivarum* and the little curlew *Numenius minutus*. Four other listed bird species or their habitats may occur within the vicinity of the domestic gas pipeline corridor including: the fork-tailed swift *Apus pacificus*, the great egret *Ardea alba*, the cattle egret *Ardea ibis* and the rainbow bee-eater *Merops ornatus*.

Due to the degraded state of the vegetation communities in this area and the narrow width of the proposed easement, it is unlikely that the domestic gas pipeline corridor contains critical habitat for any listed avifauna. The mangroves in this area are likely to support a more diverse avifauna, of which many species would be restricted to the mangrove zone. Further surveys of avifauna along the proposed pipeline route will be conducted during 2005.

Mammals

Barrow Island is recognised as an important refuge for native mammal species that have either declined in numbers or become extinct on the mainland. Department of Conservation and Land Management (CALM) monitoring has found that most mammal populations are abundant and secure on the island (Burbidge et al. 2003). The mammal fauna of the proposed gas processing facility were surveyed using methods consistent with CALM's monitoring program (Box 8-3).

Regional

The mammal fauna of the Pilbara region has significantly declined due to competition with, and predation from, introduced species. Some offshore islands have been less impacted by introduced species and are important refugia for many species that are under threat on the mainland. Barrow Island is the largest island in the Pilbara region and the second largest island off the Western Australian coast, and having remained largely free of introduced competitors and predators, supports an intact mammal assemblage. The importance of the Barrow Island Nature Reserve is apparent from the following description of the restricted regional distribution of the listed mammals that occur on the Island.

Box 8-3:
Mammal Survey Methodology

Mammals in the vicinity of the proposed gas processing facility area were surveyed in November – December 2003 and October 2004. Six trapping grids, consistent in trap design and layout with CALM's long-term monitoring program on Barrow Island, were established in the main vegetated habitat types within the proposed Development area. Twenty-five cage traps, Elliot traps and pit traps, were set at each grid.

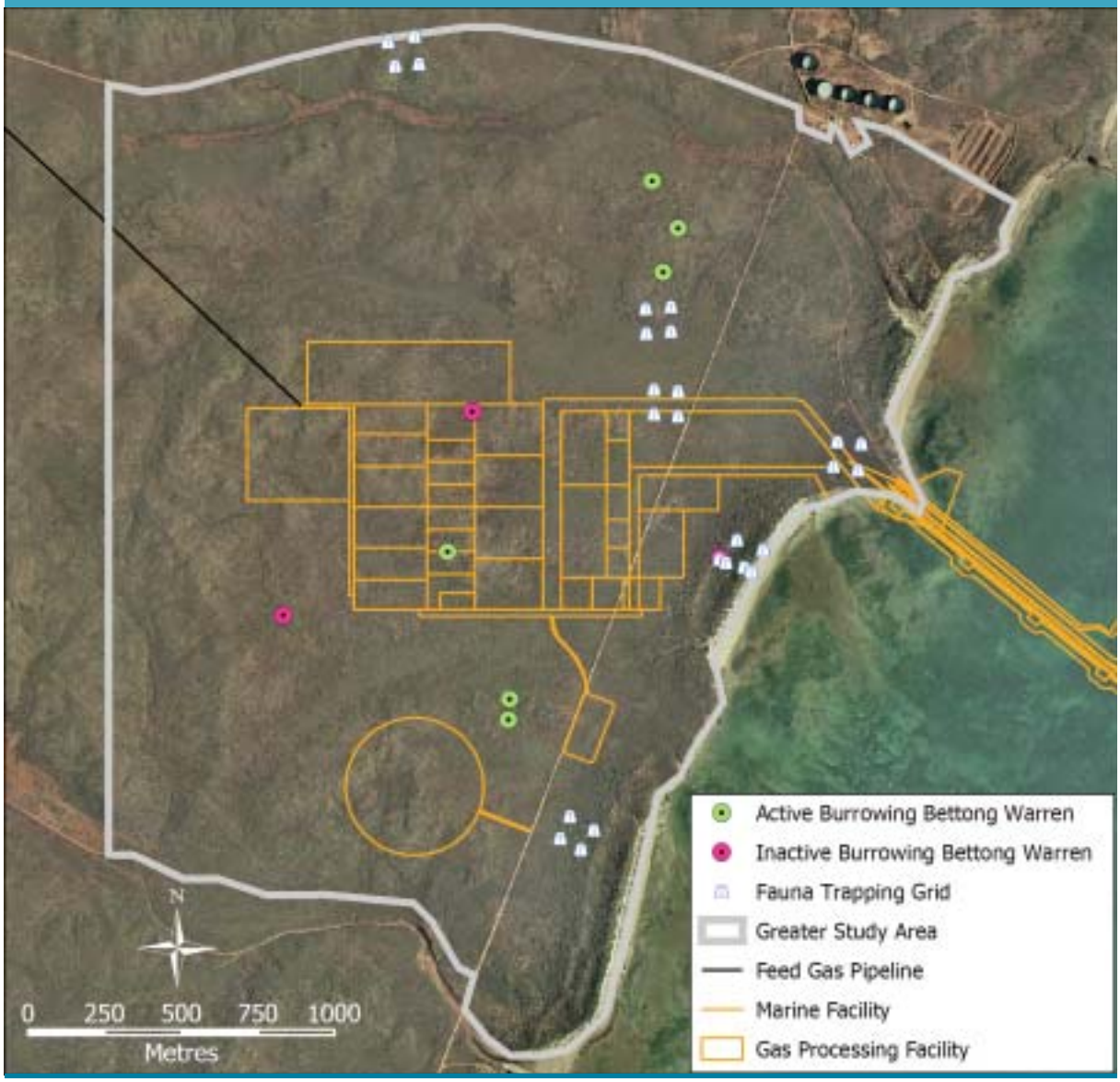
Captured mammals were measured, weighed and marked. Measurements included crown, pes and external gonad dimensions, while notes were made on reproductive condition and the presence of pouch young. Recaptures were accounted for in density estimates.

Burrowing bettong warrens and larger mammals such as spectacled hare wallabies were located using a systematic transect approach which involved walking the entire greater survey area (Figure 8-16) in transects 50 m apart. Observers investigated features such as rocky outcrops or dense vegetation between adjacent transects. Transects were progressively surveyed from October to December 2003. When burrowing bettong warrens were located, the position, number of entrances and signs of recent faunal activity were recorded.

The surveys were undertaken consistent with EPA Guidance No. 56 (EPA 2004a). Survey methodology and limitations are detailed in Technical Appendix C2.

Proposed pipeline routes were surveyed in 2004 for signs of mammal activity, especially burrowing bettong warrens. Bettong warrens in the vicinity of the proposed airport extension and road widening areas were surveyed in July 2004. Fauna in the vicinity of the proposed CO_2 injection sites and seismic monitoring grid will be assessed as part of final site selection. A preliminary survey of mammal habitats in the CO_2 seismic monitoring area was conducted by helicopter and by foot in April 2005.

Figure 8-16:
Fauna Trapping Grids, Burrowing Bettong Warrens and Transect Survey Area



Burrowing Bettong – Burrowing bettongs (*Bettongia lesueur*) (Plate 8-6) were originally widespread across the Pilbara and in other parts of the Australian mainland. They are now confined to a few populations such as those on Barrow Island and Boodie Island in the Pilbara. In the Gascoyne region, the Shark Bay burrowing bettong subspecies (*Bettongia lesueur lesueur*) exists on Bernier Island and Dorre Island. Burrowing bettong populations have been successfully translocated to the mainland and persist at Faure Island and Heirrison Prong in Shark Bay (Burbidge 2004). The continued survival of the mainland population depends on the success of predator control programs such as CALM's Western Shield Fauna Recovery Program.

Barrow Island Golden Bandicoot – The Barrow Island golden bandicoot (*Isoodon auratus barrowensis*) is abundant on Barrow Island and nearby Middle Island. Genetic studies suggest that Barrow Island animals may not be a separate subspecies to mainland golden bandicoots (Burbidge 2004) which are not abundant, but widespread on the mainland.

Spectacled Hare Wallaby – The island subspecies of spectacled hare wallaby (*Lagorchestes conspicillatus conspicillatus*) now exists only on Barrow Island. Populations on Hermite Island and Trimouille Island in the Montebello group were driven to extinction by feral cat and possibly black rat predation (Burbidge 2004).

Barrow Island Euro – The Barrow Island euro subspecies (*Macropus robustus isabellinus*) occurs only on Barrow Island (Burbidge 2004). The subspecies is listed as vulnerable due to its restricted distribution; however the Barrow Island population is considered to be secure.

Black-flanked Rock Wallaby – Remnant populations of the black-flanked rock wallaby (*Petrogale lateralis lateralis*) persist in Cape Range, the southern edge of the Pilbara, the Calvert Ranges, Barrow Island and Salisbury Island (Burbidge 2004). Mainland populations are small and have been impacted by fox predation and large wildfires.

Barrow Island Chestnut Mouse – The Barrow Island subspecies (*Pseudomys nanus ferculinus*) is restricted to Barrow Island where it occupies all vegetated habitats (Burbidge 2004).

Water Rat – Water rats (*Hydromys chrysogaster*) are widely distributed on the east coast of Australia, in southern Western Australia and along the Pilbara coast and offshore islands. There are populations on Barrow Island in the Pilbara and on Bernier and Dorre islands in the Gascoyne region.

Pilbara Leaf-nosed Bat – The Pilbara form of the orange leaf-nosed bat (*Rhinonicteris auratus* – Pilbara form) occurs in small populations at a few known roost sites. Many of these sites are in old mine adits that are likely to collapse in the future. They are very sensitive to human interference and may abandon their roost if disturbed (Burbidge 2004).

Mulgara – Formerly widespread in sandy deserts, mulgara (*Dasycercus cristicauda*) are now rare and have a patchy distribution. The mulgara has recently been recorded in the Pilbara area (Burbidge 2004).

Plate 8-6:
Burrowing Bettong

Barrow Island

Barrow Island is one of Australia's most important mammal conservation areas. The island supports 13 species of resident terrestrial mammal, with a further two species of bat recorded as vagrants to the island. Six species of resident mammals are included either as specially protected fauna under Schedule 1 of the Western Australian Wildlife Conservation Act or listed as Vulnerable on the EPBC Act threatened species list.

Burrowing Bettong – Burrowing bettong warrens are widely distributed on Barrow Island (Figure 8-17). Unlike the more mobile mammal fauna, they are dependant upon their warrens for shelter. Their use of surrounding areas for foraging is unknown however they appear to have home ranges of several kilometres (Donaldson, F. 2004 Personal communication). Occupancy of burrowing bettong warrens appears to fluctuate from year-to-year.

Barrow Island Golden Bandicoot – Golden bandicoots are widespread and abundant throughout their range on Barrow Island. They are the most abundant mammal on the island, with an estimated population of 60 000–80 000 (McKenzie et al. 1995).

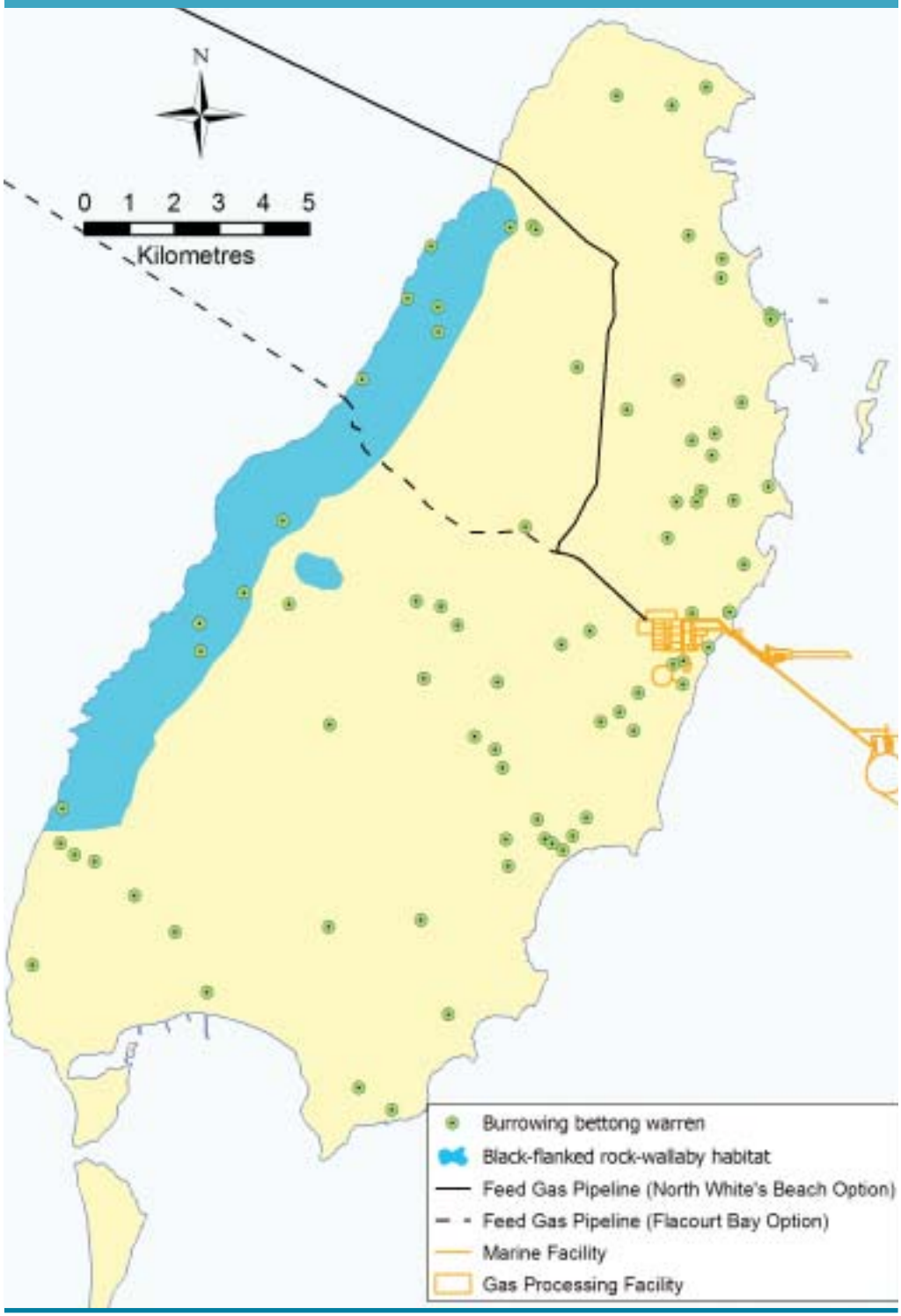
Spectacled Hare Wallaby – Spectacled hare wallabies are widely distributed on Barrow Island (Plate 8-7), generally inhabiting the tall, dense *Triodia angusta* grasslands of drainage systems. However, they forage widely at night in other areas such as *Melaleuca* and *Triodia* on limestone hilltops.

Barrow Island Euro – Population estimates for the Barrow Island euro range from 528–914 (Burbidge et al. 2003) to 1500 (Short et al. 1998). Euros require shade, especially during the hotter months, and often use artificial shelter such as oilfield infrastructure (beam pumps) and buildings.

Black-flanked Rock Wallaby – The distribution of the black-flanked rock wallaby (Plate 8-8) on Barrow Island is limited to rocky outcrops on the west coast (Figure 8-17). Whilst the Barrow Island population is thought to be stable, the population is small and there are concerns that the population may be suffering from genetic depression.

Barrow Island Chestnut Mouse – The Barrow Island chestnut mouse is found in all vegetated habitats on the Island (Burbidge 2004). There are no population estimates for this species.

Figure 8-17:
Distribution of Black-flanked Rock Wallaby Habitat and Burrowing Bettong Warrens (Confirmed and Unconfirmed) on Barrow Island



Water Rat – The water rat has been recorded on the east coast near Town Point where tracks were seen and one specimen was caught in a cage trap (Technical Appendix C2). Tracks on beaches indicate that the water rat occurs all along the coastline on Barrow Island, especially where rocky shores alternate with sandy beaches.

Other Mammals – Other mammal species on Barrow Island, while not listed as threatened or vulnerable at present, are currently under taxonomic review and may be genetically distinct from mainland populations. These island 'races' are considered evolutionary significant units.

Plate 8-7:
Spectacled Hare Wallaby

Plate 8-8:
Black-flanked Rock Wallaby at Flacourt Bay

Gorgon Development Area

All of the terrestrial mammal species of Barrow Island, except bats, were either trapped (8 species) or observed within the proposed Development areas including the feed gas pipeline routes. The same species are also likely to occur in the vicinity of the optical fibre cable route and a subset is likely to occur in the vicinity of the potential airport extension and alongside roads proposed for widening. Bats are likely to forage in the Development areas, but have not been positively identified. All of these species are widespread on the island, with the exception of the black-flanked rock-wallaby and the water-rat. There are no distinctive habitat features within the proposed Development area that are likely to support unusually high population densities of any species. Protected species recorded in the vicinity of the proposed Development area are further discussed in the following sections.

Burrowing Bettong – Burrowing bettongs generally excavate warrens in upland areas of limestone cap rock and appear to feed in adjacent grasslands. There are nine burrowing bettong warrens within the vicinity of the proposed Development area, with a total of approximately 90 warren entrances (Plate 8-9). There is one active warren within the proposed gas processing facility footprint with a total of 20-30 entrances and approximately 10-15 burrowing bettongs (Figure 8-16) (Technical Appendix C2). These burrowing bettongs represent approximately 0.5% of the total Barrow Island population which is estimated to be in the order of 2900 individuals (Burbidge et al. 2003).

There were three active burrowing bettong warrens to the south and south-west of the existing airport runway, each with 10–20 entrances.

No burrowing bettong warrens were found along any of the proposed pipeline routes or along the proposed optical fibre cable route. Two bettong warrens occur in the vicinity of the roads between the airport and the barge landing (near the existing camp and barge landing) and will be avoided during road widening.

Plate 8-9:
Entrance to a Burrowing Bettong Warren

Barrow Island Golden Bandicoot – Densities of golden bandicoots in the proposed Development area are similar to, or less than, those recorded elsewhere on Barrow Island (Technical Appendix C2). If the density of bandicoots is assumed to be consistent over the island, the proposed Development footprint, including areas required for airport extension and road widening, would provide habitat for approximately 1.3% of the island's bandicoot population.

Spectacled Hare Wallaby – The Barrow Island population of spectacled hare wallabies may vary from approximately 5700 to approximately 8600 (Burbidge et al. 2003). Current density estimates of one hare wallaby per four hectares indicate a population of about 75 spectacled hare wallabies in the proposed Development area. This represents approximately 1–2% of the total island population.

Barrow Island Euro – Few euros have been observed in the proposed Development area and most of these have been observed sheltering in coastal and near-coastal limestone areas (Plate 8-10). Approximately ten euros occur in the proposed Development area. This represents approximately 0.7–2% of the island population estimated by Burbidge et al. (2003) and Short et al. (1998). A few euros were observed in the dense *Triodia* to the south of the existing airport.

Plate 8-10:
Euro Sheltering Under Coastal *Ficus*

Black-flanked Rock Wallaby – The population of black-flanked rock wallabies on Barrow Island is estimated at 150 to 200 (Strahan 1995; Burbidge et al. 2003) and is largely confined to limestone outcrops on the west of the island, including Flacourt Bay. The alternative feed gas pipeline from Flacourt Bay would therefore pass through coastal black-flanked rock wallaby habitat. The range of the rock wallabies on the west coast does not extend as far north as North White's Beach.

Black-flanked rock wallabies do not occur in the proposed Development areas at Town Point, along the roads that may be widened or near the existing airport, due to the absence of suitable habitat.

Barrow Island Chestnut Mouse – The Barrow Island chestnut mouse was caught on coastal sandy loams and sands in the vicinity of Town Point. However, the numbers of captures were too low for any conclusions to be drawn as to habitat associations within this area. Data from CALM monitoring in 1998, 2000 and 2003 indicate that the Barrow Island chestnut mouse is more common in other parts of the island, for example Bandicoot Bay. Small mammals were observed around the existing airport at night. Although unconfirmed, the Barrow Island chestnut mouse is likely to inhabit sandy areas in the vicinity of the potential airport extension.

Water Rat – Water rats were observed on beaches at Town Point and an individual was caught amongst rocks at Town Point. They generally inhabit rocky crevices and forage on adjacent sandy beaches and intertidal areas. There are no population estimates for water rats on Barrow Island; however, tracks have been observed on beaches on both the east and west coasts of the island. Water rats are expected to inhabit all of the rocky headlands around Barrow Island.

Mainland

Domestic Gas Pipeline Corridor

The proposed mainland pipeline route runs through the Mardie pastoral lease. This area has been degraded by introduced domestic stock and feral mammals such as cats. The native mammal fauna is therefore expected to be depauperate.

Mulgara – Due to the heavily modified landscape, the mulgara is not expected to occur in the vicinity of the domestic gas pipeline corridor.

Pilbara Leaf-nosed Bat – The Pilbara leaf-nosed bat is not expected to occur in the vicinity of the proposed domestic gas pipeline corridor due to the lack of suitable rocky cave habitat.

Reptiles and Amphibians

The terrestrial herpetofauna (reptile and amphibian fauna) of Barrow Island includes a range of taxa from small sand-dwelling skinks, dragons and snakes up to the large varanid lizards. Some of these species are protected or have been identified as being of conservation significance due their restricted range. The herpetofauna of the Development area was surveyed using the methods described in Box 8-4. The taxonomy of many reptile species on Barrow Island is uncertain and specimens were collected to aid the Western Australian Museum in their taxonomic investigations. A complete technical report is included in Technical Appendix C2. Important marine herpetofauna, such as turtles and sea-snakes, are included in the marine section of this chapter (Section 8.3.3) and in Technical Appendices C6 and C7.

Box 8-4:
Reptile and Amphibian Survey Methodology

Reptiles were surveyed in November–December 2003 and October 2004 using Elliot and pit traps in grids of 25 traps within the six main vegetation types in the proposed Development area. The trapping grid layout was the same as that used in CALM's long-term monitoring program on Barrow Island. The trapping was complemented by hand-collecting of reptiles and foraging and raking during the day and at night in summer 2003/2004 and winter 2004.

All of the trapped reptiles were measured (snout to vent and total length), sexed where possible, weighed and marked prior to release. Subsets of individuals of each sex were collected as voucher specimens and lodged with the Western Australian Museum.

Surveys were conducted in accordance with EPA Guidance No. 56 (EPA 2004a). Specific methodology and limitations of the surveys are presented in Technical Appendix C2.

Regional

The Pilbara region is home to a diverse arid-zone herpetofauna. The geographic separation of island populations from mainland populations is likely to have lead to the evolution of new species, or distinct genetic races, on offshore islands. The taxonomic affinities and conservation status of many species and subspecies is unresolved. CALM is undertaking a regional study of the Pilbara that will help elucidate some of the distributional patterns of various reptiles through range definition and through collection of specimens for taxonomic studies. In the current assessment, it is assumed that the island populations have diverged from the mainland stock and they are treated as distinct island races (or evolutionary significant units).

Ramphotyphlops – The subterranean blind snake, *Ramphotyphlops longissimus*, is not known from the mainland or other Pilbara islands and is currently accepted as highly likely to be endemic and restricted to Barrow Island. This species is listed by CALM as a Priority 2 species.

The blind snake, *Ramphotyphlops grypus,* has been recorded on Barrow Island (one specimen) and is widely distributed across the Pilbara region.

Ctenotus pantherinus acripes – The skink, *Ctenotus pantherinus acripes* (Plate 8-11), appears to be restricted to Barrow Island in Western Australia, but also occurs in the Northern Territory and Queensland. It is likely that this disjunct distribution will be reflected by genetic divergence between the eastern and western populations.

Pilbara Olive Python – The Pilbara olive python (*Lialis olivacea barroni*) occurs only in the Pilbara region and some islands off the coast of Western Australia. Pilbara olive pythons generally inhabit rocky piles during the day and emerge at night to hunt. They are adept swimmers and often hunt in waterholes.

Barrow Island

The reptile and amphibian assemblage on Barrow Island is depauperate in comparison with the herpetofauna of the adjacent mainland. Barrow Island is home to 43 species of reptiles comprising dragons (3 species), legless lizards (5), geckoes (5), skinks (19), blind snakes (3), monitors (3), snakes (5) and one frog species. While some species are known only from single specimens, most of these species, or their habitats, are widely distributed on Barrow Island.

All of the reptile taxa on the island may be distinct genetic races due to separation of the island from the mainland and hence represent evolutionary significant units.

Ctenotus pantherinus acripes – The skink, *Ctenotus pantherinus acripes* (Plate 8-11) appears to be restricted to Barrow Island in Western Australia. This species has been captured from a wide range of habitats on Barrow Island and is widely distributed across the Island (Technical Appendix C2).

Ramphotyphlops grypus – This species of blind snake is known to occur on the island from a single specimen within the Development area. Its distribution across Barrow Island is unknown.

Ramphotyphlops longissimus – The subterranean blind snake, *Ramphotyphlops longissimus*, is currently accepted as highly likely to be endemic and restricted to Barrow Island. This species is listed by CALM as a Priority 2 species.

Other Reptiles and Amphibians – None of the other terrestrial reptile species on Barrow Island are listed as threatened species under the Western Australian Wildlife Conservation Act or the Commonwealth EPBC Act.

The perentie (*Varanus giganteus*) (Plate 8-12) is widespread on Barrow Island and at over 2 m long is an important top order predator of mammals, other reptiles, birds and turtles. The short-tailed varanid, *Varanus brevicauda*, was discovered for the first time in the north of Barrow Island as part of the Gorgon Development environmental studies in 1997. It was found in the north again in the summer 2003/2004 surveys.

The single frog species (*Cyclorana maini*) on Barrow Island is widespread in the adjacent Pilbara region. It breeds in seasonal watercourses and is associated with habitats close to these sites.

Plate 8-11:
Endemic Skink *(Ctenotus pantherinus acripes)*

Plate 8-12:
Perentie *(Varanus giganteus)* and Flatback Turtle Egg

Gorgon Development Area

Twenty-seven species, or more than half of the terrestrial reptiles known to occur on Barrow Island, have been recorded in the vicinity of the Development area encompassing the proposed gas processing facility site. The current study has revealed that some species tend to be associated with particular habitats within the proposed Development area (Table 8-9). These habitats are widespread on the island and these species also occur in other areas outside the gas processing facility site.

Table 8-9:
Patterns of Habitat Association for Common Skinks in the Gorgon Development Area

Species	Habitat Association
Lerista bipes	Very abundant in coastal or near-coastal sandy or sandy-loam soils.
Lerista muelleri	Abundant across all sampled habitats.
Menetia greyii	Absent from coastal sites with sandy soils.
Notoscincus ornatus	Abundant in *Melaleuca* shrubland and *Triodia* grassland on shallow soil with exposed limestone.

Ctenotus pantherinus acripes – This species was caught or observed over a wide area during trapping and opportunistic surveys in the Development area and surrounding habitats (Technical Appendix C2). Seven specimens were caught in five of the six trapping grids over two survey periods in 2003 and 2004, whilst 11 specimens were caught or observed during two opportunistic surveys in 2003 and 2004. This species is expected to be widely distributed across Barrow Island.

Ramphotyphlops longissimus – This species is not known from the proposed Development areas.

Ramphotyphlops grypus – One specimen of this species was observed within the Development area in a *Triodia* grassland habitat that is broadly represented on the island. The distribution and abundance of this species on Barrow Island is unknown as it is the only record from the island.

Other Reptiles and Amphibians – The perentie (*Varanus giganteus*) has been observed on major tracks and beaches within the proposed Development area and in open grassland at Town Point (Technical Appendix C2). This species is widely distributed across the island. Additionally, two snake species (the Mulga snake *Pseudechis australis*, Stimson's python *Antaresia stimsoni*) were observed within or close to the proposed Development area.

The single frog species on Barrow Island is likely to breed in ephemeral water bodies in the Town Point area, in Airport Creek to the south of the proposed Development site, along the proposed pipeline routes and in other areas across the island.

Mainland

Domestic Gas Pipeline Corridor

The reptile assemblage along the proposed domestic gas pipeline route on the mainland is expected to be degraded by feral predators and habitat alteration through livestock grazing.

Pilbara Olive Python – The Pilbara olive python is restricted to rocky habitats in the Pilbara and is not expected to occur in the sandy habitats along the domestic gas pipeline corridor.

Invertebrates

Invertebrates are an important component of the faunal biodiversity of Barrow Island and other arid ecosystems. The term 'short-range endemics' is used to describe invertebrate species such as trapdoor spiders, snails and millipedes, that are restricted in range by poor dispersal and are generally endemic to small areas (<10 000 km^2). They represent a potential biodiversity peak due to genetic divergence of isolated populations. Short-range endemic groups likely to be important on Barrow Island were determined in consultation with the Western Australian Museum and were the focus of surveys for this environmental impact assessment. The methods used for surveying short-range endemics for the current assessment are described in Box 8-5 and a full technical report included in Technical Appendix C4.

Box 8-5:
Short-range Endemics Survey Methodology

The invertebrate groups Araneae, Pseudoscorpionida, Scorpionida, Diplopoda and Pulmonata were targeted by systematic pit trapping surveys in November and December 2003. Pit trapping was complemented by hand foraging methods including head-torching, burrow excavation, lifting rocks, peeling bark, and foraging through leaf litter and under *Triodia* hummocks in late 2003 and in August 2004. This enabled collection of particular spider taxa, camaenid land snails, insects, scorpions, millipedes, centipedes, and pseudoscorpions. Leaf litter and other debris found beneath *Triodia* clumps were collected and later sieved for cryptic invertebrates.

Voucher specimens were collected, preserved and lodged with the Western Australian Museum for ongoing taxonomic studies. Land snails were collected for ongoing genetic and evolutionary studies by the University of Western Australia.

Regional

Many invertebrate taxa have effective dispersal mechanisms, such as flying reproductive stages, and hence are widely distributed in suitable habitats across the Pilbara. These taxa are also likely to be able to disperse on strong offshore winds to offshore islands in the Montebello/Lowendal/Barrow Island group. The introduced American cockroach (*Periplaneta americanus*) is an example of an invasive invertebrate that may reach offshore islands through natural dispersal processes. Invertebrate groups that are adept at dispersal can readily exchange genetic material between populations; hence island populations are unlikely to be evolutionary significant units.

Conversely island populations of short-range endemic invertebrates have limited potential for dispersal and are likely to have diverged genetically from Pilbara mainland populations. The taxonomy of many of these endemic groups is poorly resolved and there may be many species restricted to individual islands or groups of islands in the Pilbara region.

Barrow Island

Over 40 potential short-range endemic invertebrate taxa were collected on Barrow Island during surveys. The collection comprised spiders (19 taxa), pseudoscorpions (4), centipedes (3), millipedes (1), scorpions (2) and land snails (4). A full description of the collection is included in Technical Appendix C4.

The mound building termites (Isoptera) are an important component of the terrestrial ecosystem on Barrow Island. In addition to their role in cycling organic matter, the termite mounds, which are widespread across the island, provide valuable shelter for reptiles, birds and mammals.

The landsnail fauna on Barrow Island is dominated by camaenids (*Rhagada* spp. and *Quistrachia barrowensis*) that may be endemic to the island. Three pupillid species that are widespread on the mainland have also been recorded on Barrow Island. Although morphologically close to the mainland populations, the Barrow Island taxa are assumed to be genetically divergent from the mainland taxa. Genetic analysis of the dominant species of *Rhagada* sp. '2' indicates that this taxon is endemic to Barrow Island and has diverged genetically from the mainland populations. This supports the approach that all of the probable short-range endemic taxa be treated as evolutionary significant units.

Several groups of spiders occur on Barrow Island including trapdoor spiders (Mygalomorph) (Plate 8-13), master weavers, net-casting, sac, white tailed and wolf spiders (Araneomorph spiders). None of these taxa are protected species. Ongoing research will determine whether they constitute significant evolutionary units.

Plate 8-13:
Trapdoor Spider (*Mygalomorph*)

Two species of centipede (*Ethmostigmus curtipes* and *Scolopendra laeta*) have been collected on Barrow Island. Both of these species have widespread distributions over the Pilbara and throughout Australia.

The pin cushion millipede (*Polyxenidae*) is also known to exist on Barrow Island. Due to their small size they can be difficult to collect but are known to occur in large (plague) proportions under certain conditions.

Gorgon Development Area

The taxonomy of most invertebrate groups needs to be advanced in order for taxa from Barrow Island to be confidently identified and their conservation significance assessed. The collections donated to the Western Australian Museum from the current study represent an important resource for the ongoing taxonomic resolution of these groups.

The invertebrate taxa collected from the proposed Development area are expected to be widely distributed on the island because the habitats from which they were collected are widespread on the island. Short-range endemism is expected to operate at an island-scale, rather than within parts of the island. Analysis of genetic divergence in *Rhagada* sp. snails found no evidence to suggest that specimens collected from within the Gorgon Development area were genetically distinct from specimens collected elsewhere on the island (Technical Appendix C4).

Plate 8-14:
Unidentified Scorpion (*Urodacus* sp.)

None of the invertebrate fauna known from the proposed Development area are listed under the Wildlife Conservation Act or as Priority fauna by CALM. However, a pseudoscorpion and a single specimen of a large, dark scorpion (*Urodacus* sp.), recently collected within the proposed Development area, appear to be new and undescribed species of conservation significance (Plate 8-14). The distribution of these species is unknown, but they are expected to inhabit similar habitats over much of the island.

Subterranean Fauna

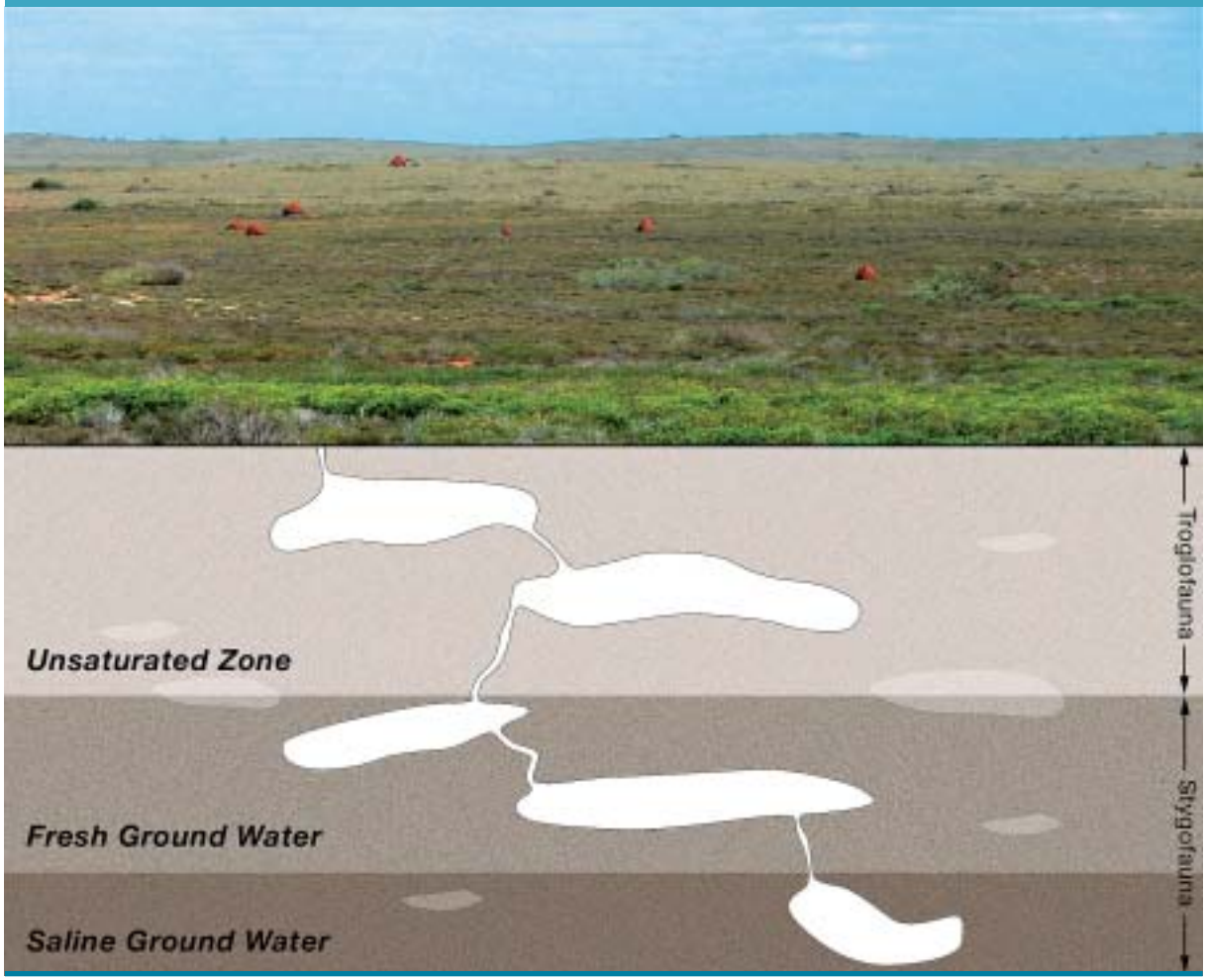
Stygofauna are aquatic subterranean fauna that inhabit cavities and interstices (small or narrow spaces) in groundwater-filled karst or other fractured geological formations. Troglofauna are terrestrial subterranean fauna that inhabit air-filled caves, cavities or interstices in the karst above the watertable (Figure 8-18).

Subterranean fauna are an important component of regional biodiversity for several reasons.
The distribution of subterranean fauna species appears to generally be more restricted than that of similar surface fauna. High levels of endemicity are also characteristic of subterranean taxa, often at high taxonomic levels (e.g. genus, family). Endemic species tend to be concentrated in regions that support relatively diverse communities, rather than being distributed randomly (see review in Strayer 1994, also Humphreys 2000).

Stygofauna in Western Australia and Barrow Island in particular are regarded as geological relicts, descendants from ancient lineages with species characterised by restricted distributions and a low tolerance to disturbance. The stygofauna of Barrow Island represent relict lineages that have arisen from surface fauna ancestors that occurred prior to the break-up of Pangaea (see review in Humphreys 2001).

The Western Australian Museum has studied subterranean fauna from existing bores and caves on Barrow Island since the early 1990s (Humphreys in press). Subterranean fauna sampling methods used in the current study are outlined in Box 8-6. The establishment of permanent subterranean fauna sampling bores provides an important scientific resource for future studies. The full technical report on the preliminary results from subterranean fauna surveys for this proposal is included in Technical Appendix C5.

Figure 8-18:
Troglofauna and Stygofauna Habitat



Box 8-6:
Subterranean Fauna Survey Methodology

Stygofauna were sampled from bores, drill holes and disused wells across Barrow Island by means of modified plankton haul nets. This was carried out as part of a preliminary sampling program for the ESE Review in August 2002 and again during November 2003. Once the net reached the bottom of the hole, it was agitated gently to bring benthos and fauna above the net before hauling it up through the water column. On recovery, the net was flushed thoroughly with water bailed from the same hole. Samples were sorted fresh under a dissecting microscope and preserved in 100% ethanol, or stored in liquid nitrogen for genetic analyses.

Nineteen bores that had previously yielded subterranean fauna (either during sampling for this project or during earlier work by the Western Australian Museum) were sampled during these initial surveys. Each hole was sampled at least three times. Genetic analyses have been initiated to clarify taxonomic affinities of stygofauna from Barrow Island and the mainland. Troglofauna litter traps were installed in three shallow abandoned drill holes in the terminal tanks area. These comprised aviary mesh and PVC tubes baited with locally sourced leaf litter (soaked overnight and microwaved to sterilise and initiate decomposition).

Since this initial work (in 2002 and 2003), a comprehensive drilling program that was designed with the specific objective of sampling subterranean fauna in the gas processing facility area and in surrounding control or reference areas has been completed (Technical Appendix C5 – Attachment 3).

A total of 43 bores have been drilled of which 24 are located within the proposed gas processing facility footprint and 17 outside of the proposed gas processing facility footprint (i.e. reference sites). An additional two bores were drilled along the proposed feed gas pipeline corridor and a further four bores will be established at the North White's Beach and alternative Flacourt Bay shore crossing locations. Depth of bores ranged from approximately 5 m to 50 m with 10 bores (both reference and footprint) drilled to below the halocline. This program makes provision for stygofauna sampling from the freshwater superficial aquifer, saline groundwater below halocline and troglofauna sampling from the karst above the watertable. The subterranean fauna surveys have been conducted in accordance with EPA Guidance Statement 54 (EPA 2003).

Examination of cores from a geotechnical drilling program and ground penetrating radar surveys have also assisted in determining the distribution of karstic substrate in the proposed Development area. This has improved understanding of the subterranean fauna habitat and drill logs allow troglofauna traps to be set at appropriate depths. The bores established as part of this ongoing subterranean fauna sampling program were first sampled for stygofauna in November 2004 with subsequent stygofauna sampling completed in March 2005. Troglofauna traps were also installed in the bores. The sampling and analysis program will continue until construction to establish a baseline for monitoring during construction and operation of the Development.

Regional

The regional distribution and species diversity of subterranean fauna in northern Western Australia has been poorly known historically for most taxonomic groups, although ongoing work is improving this situation. Subterranean fauna have been known from Western Australia since the 1940s, with the blind gudgeon, *Milyeringa veritas* (Plate 8-15), amongst other fauna, being documented from groundwater beneath the coastal plain at Cape Range (Humphreys 2001). However, little work was carried out in relation to subterranean communities until the early 1990s.

Research conducted since this time has suggested a biogeographic link between Barrow Island and Cape Range. One of the true troglofauna species, the schizomid *Draculoides bramstokeri,* reinforces this biogeographical connection between the troglofauna of Barrow Island and the troglofauna of Cape Range on the mainland. *Draculoides bramstokeri* occurs in Ledge Cave and other sites on Barrow Island and has also been recorded from multiple sites on Cape Range. The occurrence of several stygal species in both localities, including the blind gudgeon, *Milyeringa veritas,* the decapod, *Stygiocaris stylifera,* and thermosbaenacean, *Halosbaena tulki,* also supports this model.

Plate 8-15:
Stygofaunal Blind Gudgeon *(Milyeringa veritas)*

Photo: Courtesy of Douglas Elford © Western Australian Museum

Barrow Island

Barrow Island is well recognised as being of high conservation significance for subterranean fauna communities at state, national and international levels. The subterranean fauna of the island demonstrates a high level of endemicity and species diversity, with over 20 species known only from Barrow Island. The fauna of the island includes one of only two stygal vertebrate species occurring in Australia and potentially the only troglobitic reptile known globally.

The stygofaunal assemblage of Barrow Island is known to comprise more than 20 described species with representatives from a diverse range of taxonomic groups. The most diverse group is the Amphipoda with 12 species, including two new species of anchialine hadziid amphipods (*Liagoceradocus* spp.) (Bradbury and Williams 1996 a, b). The other taxa represented in the groundwater fauna are largely also crustacean groups, including the Isopoda, Copepoda, Ostracoda, Thermosbaenacea and aytid decapods. Recent sampling for this study collected the first stygal polychaete worm for the island, highlighting the level of taxonomic richness which may remain to be documented.

The troglofauna of Barrow Island is also significant with most collecting to date having occurred from a few areas where there are caves open to the ground surface, for example Ledge Cave (Cave 6B1). The Western Australian Museum database includes 324 records of terrestrial invertebrates from caves or other subterranean habitats on Barrow Island. However, many of these records are of troglophiles (surface fauna associated with subterranean habitats) rather than true troglofauna.

In the absence of a comprehensive dataset for regional comparison, surveys to date have revealed a troglofauna assemblage with highly endemic elements. For example, *Speleostrophus nesiotes* is the first known troglobitic spiroboloid millipede (Hoffman 1994) and is only known from Ledge Cave on the south-west coast of Barrow Island. The possibly troglobitic reptile *Ramphotyphlops longissimus* is known from a single specimen from Barrow Island (Aplin 1998). These highly endemic taxa are likely to be restricted to sites of high local diversity such as the large caverns on the south-west and west sides of Barrow Island.

Several species of subterranean fauna are protected under the Wildlife Conservation Act and the EPBC Act (Technical Appendix C5). Some of the protected species known from Barrow Island, for example the Vulnerable blind gudgeon *(Milyeringa veritas),* are present in similar habitats at Cape Range on the mainland. It is also likely that other protected species that occur in similar habitats to the blind gudgeon at Cape Range, such as the blind cave eel *(Ophisternon candidum),* are present on Barrow Island.

It is possible that some components of the globally significant remipede community in Bundera sinkhole at Cape Range also occur on Barrow Island. Subterranean habitats on Barrow Island are tidally influenced and are stratified with a freshwater layer overlying deeper saline groundwater. This forms a similar anchialine system to that present in Bundera sinkhole and it is therefore possible that a similar fauna occurs, particularly given the biogeographic affinities between the areas.

Gorgon Development Area – Gas Processing Facility

Subterranean fauna sampling program records to date, confirm that the habitats under both the proposed gas processing facility and the adjacent parts of the island support both stygofauna and troglofauna.

This is consistent with the preliminary review of results from nearby sampling and interpretation of geotechnical data in assessing potential subterranean fauna habitat in the Development area. Caves and highly karstic rock appear to be most common in the west and south-west of Barrow Island. A geotechnical drilling program, comparing potential karst zones at Cape Range and Barrow Island (Dames and Moore 1996), indicated that the large cavities in the Miocene limestones on Cape Range Peninsula at Exmouth were not present in other limestones in the Exmouth area, at Surf Point or at the terminal tanks on Barrow Island.

Boreholes on the east coast of Barrow Island did not intersect significant cavities and the voids observed were <5 cm and did not appear interconnected.

Despite the lower likelihood of major caves in the gas processing facility area, preliminary interpretation of geotechnical drilling results and ground-penetrating radar work to date indicate a karstic environment is present below the site (Biota and Blandford 2004). The drilling logs and other data show a variable stratigraphy, comprising layers of sand and clay interbedded with substantial strata of more competent lithologies such as detrital, conglomeratic and crystalline limestone. The geologic evidence suggests that the area of the gas processing plant footprint contains a range of subterranean habitats in the form of both air and water-filled cavities, ranging in size from 1 mm to less than a metre. Other characteristics include abundant fractures in the more brittle, high strength lithologies; solution cavities in competent lithologies, voids developed in uncompacted sands and detrital sediment. This is supported by the collection of a range of stygal taxa from the terminal tanks area to the immediate north of the planned gas processing facility site.

As noted in Box 8-6, baseline surveys for subterranean fauna will continue on Barrow Island until construction commences. Stygofauna and troglofauna will continue to be sampled both within and outside of the gas processing facility footprint at a total of over 40 locations (Figure 8-19). The results of subsequent sampling, concluded prior to construction, will be published as a separate report. This will provide a species level analysis of subterranean fauna distribution, along with a more complete analysis of the physical nature of the subterranean environment, including stratigraphy, water table depths and groundwater chemistry profiles. The preliminary results of the work conducted up until March 2005 are summarised below.

Preliminary Stygofauna Sampling Results – Stygofauna were collected from 10 of the bores sampled during November 2004. One of the bores where stygofauna were collected was within the proposed gas processing facility area (18), with the remaining nine bores in 'control' areas outside of the development site (Table 8-10). The stygofauna collected during this first sampling phase represented three higher taxonomic groups; Class Malacostraca

Figure 8-19:
Subterranean Fauna Sampling Locations

(Order Amphipoda), Class Copepoda, Class Ostracoda and Class Decapoda (the aytid *Stygiocaris stylifera).* Stygofauna were collected from 12 bores during the March 2005 visit, five of which were located within the Development footprint (Table 8-10). Stygofauna were also recorded from five bores outside of the proposed Development footprint during this second phase. The higher order taxonomic diversity was similar to the initial round of sampling, with five stygofauna taxa represented amongst the collected specimens: Class Malacostraca (Order Amphipoda and Order Bathynellacea), Class Copepoda, Class Ostracoda and Order Decapoda *(Stygiocaris stylifera).*

The sampling to date has collected amphipods, bathynellaceans, isopods and copepods from five locations within the development footprint. All of these higher taxonomic groups are also represented from the control sampling sites and from other collecting localities elsewhere on Barrow Island. Detailed identifications and genetic analyses of the collected specimens are currently ongoing. This will enable the completion of a species level comparison of the stygal taxa collected from within the development site with those from control sites and other localities on the island.

One of the amphipod taxa collected from existing bores near the northern extent of the proposed gas processing facility was the same genetic type as amphipods from other parts of Barrow Island, whilst two of the taxa collected were only recorded from the terminal tanks area. Refer to Technical Appendix C5 for a full description of the preliminary genetic analyses. These findings were based on small sample sizes and the work to be completed as part of the subterranean fauna sampling program will substantially improve the resolution of this work.

Preliminary Troglofauna Sampling Results – Troglofauna specimens have been collected both opportunistically during stygofauna sampling (i.e. hauled dead from the groundwater), and from the dedicated litter traps installed in the first phase of the troglofauna sampling program. The results available to date indicate that troglofauna are widespread both within the development footprint and in the other parts of Barrow Island. Invertebrates collected from the sampling included representatives of four Classes: Arachnida, Collembola, Insecta and Oligochaeta; comprising nine orders: Acarina, Archaeognatha, Haplotaxida, Hemiptera, Hymenoptera, Isoptera,

Table 8-10:
Preliminary Results of First Two Phases of Stygofauna Sampling

Boreholes	November 2004 *	March 2005 *
A4	–	Am (1), Is (remains)
4	–	**Am (5)**
18	**Am (1), Co (1)**	**Am (4)**
21	–	**Ba (4)**
24	–	**Am (1)**
27	–	**Is (1)**
BMW1	Col (1) Sc (2)	Is (1)
BMW4	Co (4)	–
BMW5	Col (1)	Is (1)
BMW7	Am (1), Co (1)	Am (1), Co (1)
S4	Co (2)	–
S5	Am (1) Co (3)	Am (1), St (4)
S6	Am (5) Co (4) St (3)	Co (10), Is (1), St (4)
S9	Os (1) St (9)	Am (1), Col (1), St (7)

** Am = Amphipod, Ba = Bathynellid, Col = Collembola, Co = Copepod, Is = Isopod, Os = Ostracod, St =* Stygiocaris stylifera. *Bores within the gas processing facility area shown in bold; numbers in brackets indicted number of specimens collected.*

Psuedoscorpionida, Thysanura and Schizomida. Preliminary reviews indicate that six of the taxa include potentially troglobitic specimens; the Schizomida (nominally *Draculoides bramstokeri),* Hemiptera, Isopoda, Pseudoscorpionida, Archaeognatha and the Thysanura. Troglobitic specimens were collected from a total of 13 bores, including sites inside and outside of the proposed Development footprint (Table 8-11).

To date, schizomids have been collected from almost all boreholes where troglofauna have been collected (11 of 13 holes; Table 8-11). *Draculoides bramstokeri* (Plate 8-16), is the only schizomid known from Barrow Island and the collected specimens have been nominally assigned this identification. The species is listed as Schedule 1 under the state Wildlife Conservation Act. Confirmation of identification based on morphology by the WA Museum is pending and genetic analysis (DNA comparisons) of the collected schizomid specimens are also currently underway. If the outcomes of these studies confirm a single widespread taxon on Barrow Island, then this may be indicative of a widespread linkage in subterranean karstic habitat and schizomid populations across the sampled area. The findings of this work, combined with the results of additional sampling currently underway, will enable a better assessment of the significance of the troglobitic taxa currently only recorded from the Development footprint (Table 8-11). This will be provided as a stand-alone technical report to be made publicly available.

Plate 8-16:
The Schizomid *Draculoides bramstokeri* Collected from Barrow Island

Photo: Courtesy of Dr Mark Harvey, Western Australian Museum

Table 8-11:
Preliminary Results of First Phase of Troglofauna Sampling

Boreholes	Collected during Stygofauna Sampling *	Collected from Troglofauna Traps *
10	**–**	**Ar (1)**
11	**–**	**Db (1)**
18	**–**	**He (1), Db (4)**
24	**–**	**Th (1)**
21nr	**–**	**I (1), Db (1)**
27	**Db (1)**	**–**
BMW1	Db (3)	–
BMW5	Db (2)	–
BMW6	Db (3)	I (1), Db (1)
BMW7	Db (1)	Ps (1)
S2	–	Db (1)
S4	–	Db (1)
S7	–	I (2), Db (2)

** He = Hemiptera, Is = Isopoda, Ps = Pseudoscorpionida, Ar = Archaeognatha, Th = Thysanura, Db* = Draculoides bramstokeri. *Bores within the gas processing facility area shown in bold; numbers in brackets indicted number of specimens collected.*

In the absence of the final analysis of the taxonomic affinities and the true level of endemism for subterranean fauna in the proposed gas processing facility area, all subterranean taxa found in the proposed impact areas should be treated as having conservation significance.

Gorgon Development Area – Feed Gas Pipeline Corridors

Subterranean fauna habitat is likely to be widespread on the west coast and across the centre of Barrow Island where the proposed feed gas pipeline will run to the proposed gas processing facility on the east coast.

The shore crossing at North White's Beach is not expected to be as significant a site for subterranean fauna as the alternative shore crossing location at Flacourt Bay because the coast and hinterlands are typically sandy with minimal karst development. There is also a high likelihood that any fractures and cavities present at North White's Beach would be sand-filled. However, some geotechnical investigations are planned for this site and the opportunity will be taken to complete and sample two of these drillholes for subterranean fauna.

An additional two dedicated subterranean fauna sampling holes will be drilled at Flacourt Bay as an extension to the existing sampling program. Rock in the vicinity of the alternative pipeline shore crossing at Flacourt Bay is karstic and may contain caves, mesocaverns and fissures that do not open to the ground surface. The subsurface geology from this area is unknown, but surface expressions of the geology indicate that such cavities are likely. Solution tubes and fractures in rock formations near Flacourt Bay suggest that this area is superficially similar to Cape Range and is likely to provide habitat for both troglofauna and stygofauna. Ongoing geotechnical drilling investigations will provide more data on the physical nature of these areas to validate this assessment.

8.3.3 Marine Ecology

Marine Habitats

Marine conservation planning is largely based on protection of marine benthic habitats that support biodiversity and maintain the integrity of the marine ecosystem. The draft Indicative Management Plan for the Proposed Montebello/Barrow Islands Marine Conservation Reserves (CALM 2004) is habitat-based, rather than taxon-based. Subsequently, management and assessment of impacts for the proposed Gorgon Development is generally focussed on biotic habitats, especially areas supporting benthic primary producers (BPPH) such as corals, seagrasses, macroalgae and mangroves.

Marine habitats were assessed by a combination of literature review and field survey. The survey methods are described in Box 8-7 and the full technical reports are included in Technical Appendix C8 (subtidal habitats) and Technical Appendix C9 (intertidal habitats).

Box 8-7:
Marine Habitat Survey Methodology

Intertidal habitats in the vicinity of the proposed causeway at Town Point and the mainland shore crossing of the domestic gas pipeline were surveyed during January and May 2004. The surveys also covered adjacent supratidal habitats.

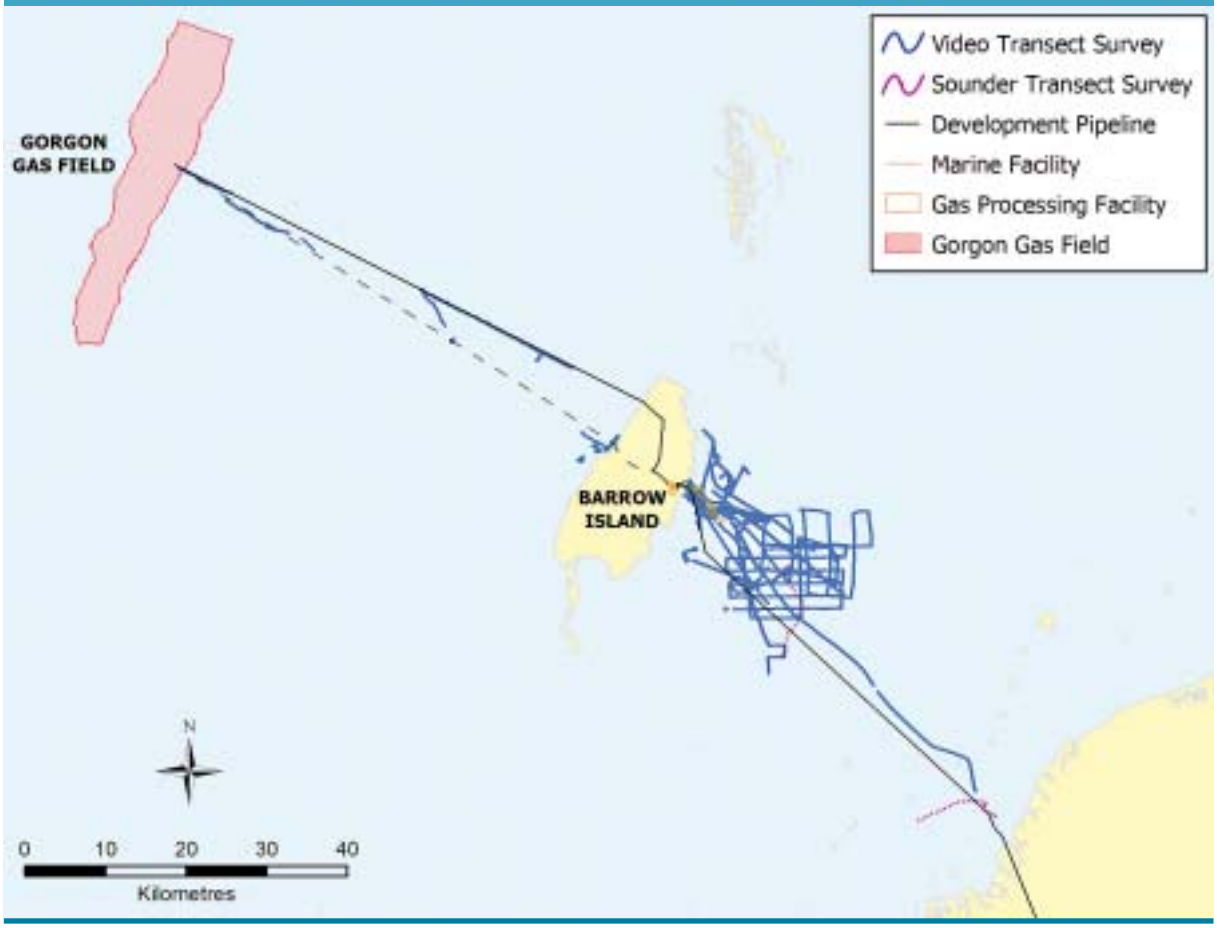
Intertidal areas were surveyed as close as possible to spring low tide to maximise duration of surveys and the area of exposed habitats.

Subtidal areas of high conservation significance within and adjacent to areas of potential impact were identified during surveys in August 2002, January 2003 and January 2004. The survey team examined subtidal benthic habitats near the existing and proposed offshore wells, along the feed gas pipeline route, in the areas associated with the proposed port facilities and along the domestic gas pipeline route to the mainland.

Benthic marine habitats were surveyed using a combination of aerial photography, side-scan sonar data, video transect and snorkel diver surveys. Video transect surveys involved towing an underwater video camera behind the survey vessel (Figure 8-20). Broad-scale habitat maps for the east and west coast Development areas were created from aerial photography and habitat classification was confirmed by ground-truthed data.

Marine habitats at Onslow are described from the literature.

Figure 8-20:
Marine Video Transect Surveys



Regional

The predominant habitats on the exposed west coasts of islands in the Montebello/Lowendal/Barrow Island region are sandy beaches, rocky shores and cliffs. The predominant physical habitats on the sheltered east coasts and the adjacent mainland coast are sand flats, mud flats, rocky pavements, calm sandy beaches and platforms. Mangroves have developed on sheltered coasts of the islands and along the mainland coast. Seagrasses are widespread on soft sediments throughout the region and corals and macroalgae are similarly widespread on hard substrates.

CALM (2004) estimated the linear extent of the four most common coastal habitats in the region as follows:

- beach – 22%
- beach/rocky shore – 11%
- mangal – 4%
- rocky shore – 63%.

Subtidal habitats in the region comprise a range of abiotic habitats such as sand, mud, pavement reef with variable and mobile sheets of sand, and higher profile rocky reefs. In addition to these, there are biotic habitats comprising macroalgal beds, coral habitats and seagrass meadows.

The local distribution of benthic habitats is affected by the frequent passage of tropical cyclones that shape sandy beaches; redistribute boulders and sand sheets over subtidal pavements; and, in extreme cases, cause widespread destruction of biotic habitats.

Barrow Island

Barrow Island is characterised by rocky headlands and low cliffs with sandy or rocky shores stretching between the headlands. It is almost entirely surrounded by limestone pavement reef that extends to the subtidal zone. Broad intertidal reef platforms with scattered mud and sand flats are widespread along the east coast of Barrow Island and in Bandicoot Bay to the south.

On the west and north coasts, the intertidal reef is much narrower, more eroded, supports dense macroalgal turf if exposed, but is often overlain by sand in the upper intertidal zone.

Sandy beaches are widespread around both the east and west coasts of Barrow Island and typically form above the intertidal reef between rocky headlands. CALM (2004) estimated that sandy beaches account for approximately 46% of the shoreline of Barrow Island. Sand cays have developed at Surf Point in the north of Barrow Island and at South End and at Middle and Boodie Islands, but are less common at Barrow Island compared with the rest of the region.

Intertidal mud or sand flats are most developed on the east and south coasts of Barrow Island where lower wave energy allows sediments to accumulate on the broad flat platform reefs.

The main subtidal habitats surrounding Barrow Island are:

- shallow subtidal limestone pavement reef with macroalgae
- deeper subtidal pavement with filter-feeding assemblages
- bare sediments
- coral reefs and bombora
- high profile limestone reefs.

The subtidal limestone platform reef surrounding Barrow Island is usually covered with a veneer of sand or silt of varying thickness and seasonally supports high biomass of brown macroalgae, in particular *Sargassum* (Plate 8-17). *Sargassum* is one of the more

Plate 8-17:
Macroalgae *(Sargassum)* on Shallow Subtidal Pavement Reef

Plate 8-18:
Biggada Reef on the Western Side of Barrow Island

important primary producers in the region. Dense *Sargassum* beds provide shelter, food and substrate for a diverse array of invertebrates and fish.

In deeper areas, beyond the photic zone, macroalgae are replaced by filter-feeding assemblages. The dominant habitat forming fauna are sponges (laminar, cup and branching), soft corals (gorgonians and seawhips), hard corals *(Turbinaria)* and hydroids.

Bare sand sheets are a dynamic feature of the subtidal ecosystem. The sand sheets move in response to tidal and wind-driven currents and storms. In deeper offshore areas with less dynamic water movement, sediments are more stable and fine sediments in particular provide habitat for diverse epifaunal and infaunal assemblages.

Coral reefs and bombora are restricted to the photic zone and vary greatly structurally and ecologically in response to physical disturbance, water clarity and exposure to swell. Corals are abundant around Barrow Island, growing as high profile reefs and on pavement on both the west and east coasts. The most significant coral reefs around Barrow Island are Biggada Reef on the west coast (Plate 8-18), Dugong Reef and Batman Reef off the south-east coast and along the edge of the Lowendal Shelf on the east side of Barrow Island (Plate 8-19).

Gorgon Development Area

Gorgon Gas Field – Subtidal habitats near the Gorgon gas field, which lies in 200 m of water, comprise soft, bioturbated sediments. The benthos in this area is well below the photic zone so there are no marine macrophytes. Fine organic particles settle from the water column to form deep silt and mud.

Plate 8-19:
Porites Coral Bombora Reef on the East Side of Barrow Island

Fine sediments are often resuspended by ground swell and these deeper areas can be turbid near the seabed. The fine sediments also reduce oxygen exchange between the water and the underlying sediments so anoxic layers form generally within centimetres of the seabed surface.

Feed Gas Pipeline Corridor – The feed gas pipeline corridor from the offshore field to the west coast of Barrow Island includes areas of deep water sediments, high profile limestone reefs and shallow water sediments and reefs with macroalgae. The high profile reefs, in approximately 40 m water depth, are too deep to support well-developed benthic primary producer assemblages. The inshore section of the proposed pipelines crosses bare sand habitats and limestone reef covered by macroalgae such as *Sargassum, Dictyopterus* and *Halimeda,* and scattered small corals such as *Turbinaria.* Each of these benthic habitats is widespread throughout the region.

North White's Beach Shore Crossing – The proposed feed gas pipeline crossing at North White's Beach traverses an intertidal and shallow subtidal limestone reef platform and a sandy beach with exposed beach rock bench. The upper surface of the eroded reef platform is bare, presumably due to exposure to the sun at low tide. The holes and fissures in the reef support macroalgae with larger thalli than the turfing algae at Flacourt Bay. The exposed beach rock appears to experience cycles of sand burial and exposure.

The southern end of North White's Beach is sheltered from the sea and swells by the low cliffs of the headland and the intertidal and supratidal areas include boulders and vertical rock faces.

Flacourt Bay Shore Crossing – The alternative shore crossing at Flacourt Bay comprises a broad sandy beach running between two high rocky headlands (Plate 8-20). The beach is exposed to high wave energy and changes seasonally as sand is eroded or deposited. The limestone pavement underlying the beach is exposed at times in both the intertidal and supratidal zones.

The sandy beach slopes into the surf zone and has a narrow (<10 m) intertidal component. The remainder of the intertidal zone is a wave washed rock platform with deep fissures and holes.

Plate 8-20:
Flacourt Bay

Barrow Island Port Facilities – Town Point is a rocky headland with low cliffs descending to a field of boulders and intertidal limestone pavement reef with large pools open to the sea. The area has been modified by the construction and presence of a previous concrete landing/wharf area. Although the landing has been demolished, there is concrete and steel debris within the intertidal and supratidal zones.

The surface of the intertidal pavement is exposed at low tide and supports a low and sparse algal turf with a thin veneer of fine sand. The large rock pools in the intertidal pavement support larger macroalgae around the edge and often sparse seagrass on the sandy bottom.

Part of the proposed causeway and the MOF will be built over nearshore subtidal habitats at Town Point. The causeway will extend from Town Point across the intertidal and subtidal limestone pavement reef that fringes Barrow Island.

The access channel to the MOF will be dredged through limestone pavement reef with macroalgae, especially *Sargassum,* scattered hard and soft corals and thin sand veneers. Towards the offshore edge of the reef, the density and size of the hard corals increases and there are scattered bombora, generally less than 1.5 m high, along the edge of the reef. This habitat is widely distributed along the east coast of Barrow Island and across the Lowendal Shelf.

The proposed LNG export jetty will traverse the broad subtidal limestone pavement reef and extend into deeper water over the sandy seabed off the edge of the reef. The jetty will pass through the *Sargassum* dominated pavement habitats with scattered corals and bombora. The proposed jetty will dissect two areas of coral reef with variable cover of live coral and patches of coral bombora.

The offshore end of the jetty will traverse deeper pavement reef buried under sand of variable thickness. Benthic habitats in the vicinity of the tanker access channel to the offshore end of the jetty are similarly soft sediments over limestone pavement. The sediments support sparse, ephemeral *Halophila* seagrass meadows and seapens. In places where the underlying pavement reef is close to the sediment surface, soft corals such as seawhips, *Rumphella,* and gorgonians exist. These epifauna are not sufficiently dense to constitute a biotic benthic habitat.

The proposed tanker access channel crosses a rocky ridge running southward from the Lowendal Shelf. In the area proposed to be dredged, the ridge rises several metres above the surrounding seabed. The ridge comprises pavement reef with scattered rocky lumps up to 1.5 m high and variable cover of macroalgae, soft corals and hard corals. While the coral bombora fields on the rocky ridge to the south of the dredged area provide complex habitat for a diverse array of marine fauna and are of conservation significance, there are no significant coral patches in the area proposed to be dredged.

The closest ecologically significant coral reef is on the south-western perimeter of the Lowendal Shelf, approximately 2 km from Town Point and 3.5 km north of the proposed LNG offloading facility. The coral reef comprises extensive and well-developed staghorn and tabular *Acropora* colonies in the shallower waters near the southern edge of the shelf. There are large *Porites* dominated coral bomboras in the deeper water along the edge of the shelf. The *Porites* bomboras are up to several metres high and are of conservation significance because they are probably several hundred years old. There are also large *Porites* bombora, scattered bombora and rocky outcrops with macroalgae and small corals on the rocky ridge to the south of the proposed tanker access channel.

Domestic Gas Pipeline Route – The proposed domestic gas pipeline corridor from Town Point on Barrow Island to the mainland coast will traverse a vast and relatively homogeneous expanse of pavement reef with a sand veneer. The underlying pavement supports filter-feeding assemblages where exposed. Closer to the mainland shore, the sandy seabed supports extensive *Halophila* seagrass meadows and crinoids. Scattered small corals and bivalve beds occur on areas of hard substrate. The area is strongly influenced by tidal resuspension of silt and clays that have been deposited from rivers along the mainland coast and is characterised by highly turbid water.

The domestic gas pipeline corridor passes small islands such as Cowle Island near the mainland coast, some of which have fringing coral reefs. These coral reefs are dominated by species resistant to the effects of turbid water and sedimentation. The pipeline route will be selected to avoid the coral dominated platform reefs adjacent the islands.

The mainland shore crossing for the proposed domestic gas pipeline from Barrow Island is adjacent the existing Apache Energy Sales Gas Pipeline easement. The intertidal zone in this area is characterised by sand and mud flats backed by an extensive mangrove and samphire system (refer Figure 8-22).

Optical Fibre Cable Route – The optical fibre cable route from Barrow Island to Onslow will cross the inshore waters of the Rowley Shelf and is expected to traverse very similar habitats to those described for the domestic gas pipeline route above. The proposed optical fibre cable route follows the 7 m bathymetric contour around the southern end of the Barrow Island Shoals, heads south-west across a broad flat area and through the islands and reefs off Onslow (refer to Chapter 6). Most of the proposed route is expected to be limestone pavement reef with variable cover of sediments and scattered seagrasses and filter-feeding assemblages. The nearshore reef platform at Barrow Island supports significant macroalgae beds and scattered corals. The shore crossing at Onslow will cross the nearshore subtidal and intertidal reef near Beadon Point and may pass through nearshore seagrass meadows dominated by *Halophila* and *Halodule.* The final cable route in the shallower nearshore waters off Barrow Island and Onslow will be selected to avoid significant areas of corals and benthic primary producers.

Marine Conservation Areas

The waters surrounding Barrow Island are part of the area covered by the Montebello – Barrow Island marine conservation reserves (CALM 2004). The majority of the conservation area is zoned as a Marine Management Area, recognised for both commercial and conservation values. The Barrow Island Marine Park and Bandicoot Bay conservation area (benthic fauna/seabird protection) will provide additional protection for Biggada Reef and Bandicoot Bay (Figure 8-21). The Marine Park is comprised of a Sanctuary Zone that encompasses the Biggada Reef coral assemblages and the surrounding limestone reef.

A large area off the east coast of Barrow Island is currently a designated port (Figure 8-21). The Barrow Island port was created under the *Shipping and Pilotage Act 1967* and vested in the Minister for Transport under the *Marine and Harbours Act 1981* (refer Chapter 14).

Most of the islands in the region are either nature reserves or conservation parks. The terrestrial reserves in the region include:

- Barrow Island Nature Reserve (Class A nature reserve)
- Boodie, Double, Middle Islands Nature Reserve (reserve with a conservation order, previously referred to a Class C nature reserve)
- Great Sandy Islands Nature Reserve (Class B nature reserve).

The boundaries of these reserves extend to the low water mark, thereby encompassing the intertidal zone. This provides all the intertidal fauna with protection under the *Conservation and Land Management Act 1984.*

Marine Macrophytes

The marine flora comprises vascular, flowering plants such as mangroves and seagrasses and non-vascular, non-flowering plants such as macroalgae and microalgae. Samphire plants inhabit the upper intertidal zone in isolated, sheltered pockets throughout the region.

The marine macrophytes of the Montebello/Lowendal/Barrow Island region are generally widespread within the region although they tend to be restricted to particular substrates within a given area. The Leeuwin Current connects the marine plant assemblages of the Montebello/Lowendal/Barrow Island region with assemblages in the Dampier Archipelago and the Rowley Shoals to the north.

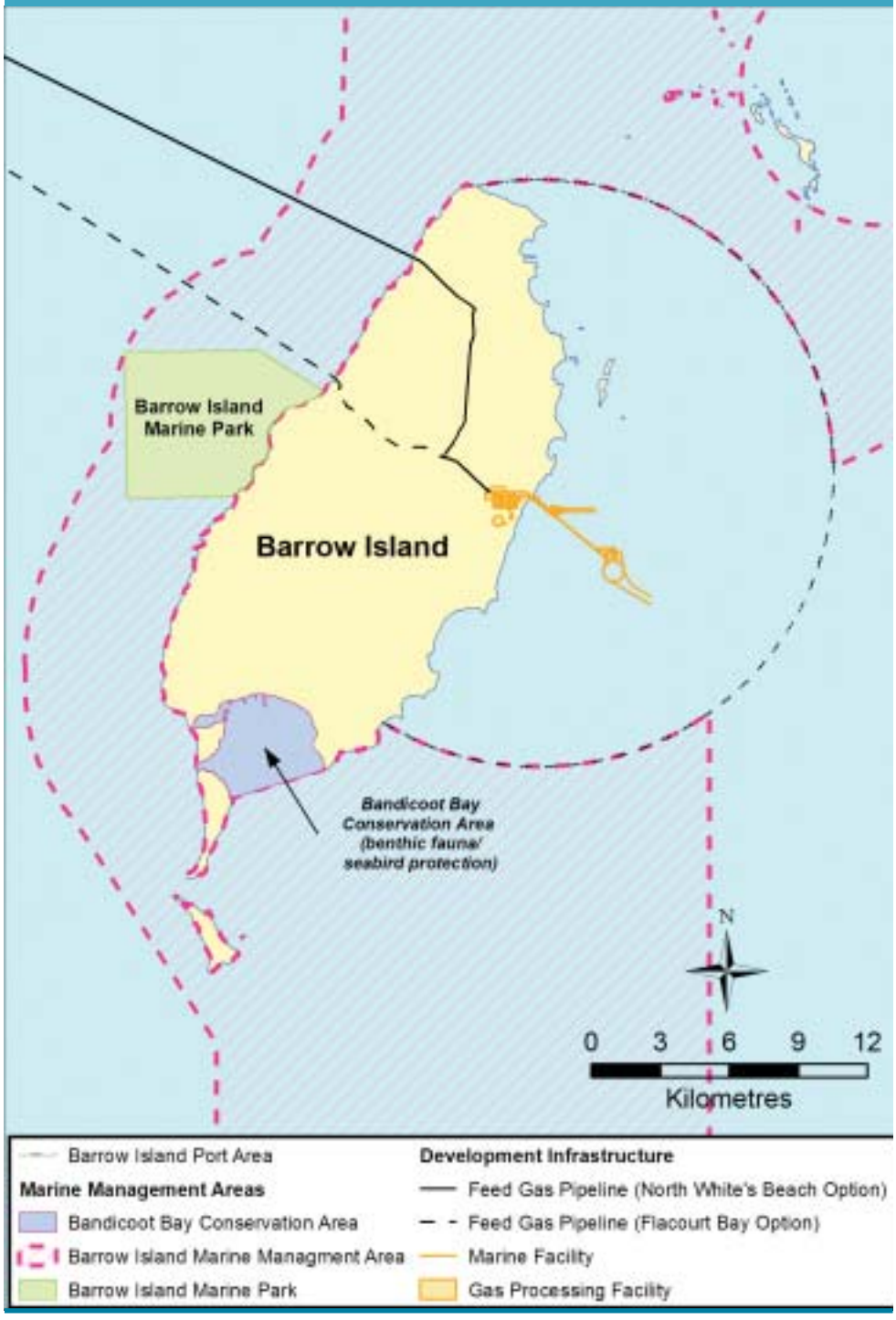
The distribution of marine macrophytes is dependent on substrate type, light availability and wave exposure. The biomass of most species varies seasonally in response to reproductive and growth cycles, water temperature and exposure to wave energy. Microalgae including the phytoplankton, zooxanthellae (coral symbionts) and benthic microalgae are ubiquitous and, being of low conservation significance, are not considered further in this assessment.

Marine macrophytes were surveyed during intertidal and subtidal habitat surveys. The distribution of subtidal macrophytes was derived largely from knowledge of habitat associations, from video surveys and aerial photography. Intertidal macrophyte surveys included reef walks at low tide with collection and subsequent identification of samples. Technical reports are included in Technical Appendices C8 and C9.

Regional

Mangroves – Mangrove forests are extensive and very well developed on the mainland Pilbara coast but restricted to sheltered embayments and coasts in the Montebello/Lowendal/Barrow region. The most common mangrove species in the Pilbara region are *Avicennia marina* and *Rhizophora stylosa.* Other species that occur in the region are *Ceriops tagal, Aegialitis annulata, Aegiceras corniculatum* and *Bruguiera exaristata.*

Figure 8-21:
Montebello – Barrow Islands Marine Conservation Reserves (Source: CALM 2004)



Mangroves in the Pilbara region are important primary producers and provide shelter for a vast array of fauna. They are generally of high conservation significance and the EPA (2001) has identified areas of very high conservation significance on the mainland coast.

Seagrass – Seagrasses are generally subtidal (down to approximately 15 m water depth), but some species also grow as stunted ecomorphs in very shallow coastal areas and intertidal rock pools. The main seagrasses of the region are small, ephemeral species that grow on soft sediments and have a seed bank in the surficial sediments that allows them to recover quickly from disturbance. Common species include *Halophila ovalis, Syringodium isoetifolium,* and *Halodule uninervis.* Less common species known from the region are *Cymodocea angustata, Halophila spinulosa, Thallassia hemprichii* and *Thalassodendron ciliatum.* Most seagrasses grow in soft sediments; however, *Thalassodendron* attaches to rock.

Macroalgae – Macroalgae are the dominant macrophyte in the Montebello/Lowendal/Barrow Island region, occupying approximately 40% of the benthic habitat area of the region (CALM 2004). The most numerically, and probably gravimetrically, abundant macroalgae are the species of *Sargassum* that cover the shallow subtidal rock platforms around the islands. Seasonally *Sargassum* grows large foliose thalli that generally produce reproductive structures and dehisce each year. When the reproductive thalli are shed, the plant persists as a short stipe on the rock. Consequently, the biomass of the macroalgal beds varies greatly with these seasonal changes. Other abundant taxa include *Halimeda, Caulerpa, Dictyopterus, Dictyota, Cystoseira, Padina, Codium* and *Laurencia.* Macroalgae are generally attached to hard substrates such as rock. *Caulerpa* is one of the few macroalgae that attach to soft sediments and often grows in association with *Halophila* seagrass meadows.

Barrow Island

Mangroves – Mangroves are restricted to a few small *Avicennia marina* species on the east and southern coast of Barrow Island. There are mangroves at Mattress Point, south of the Chevron camp, near the airstrip, at Stokes Point and near Pelican Island on the western side of Bandicoot Bay. CALM (2004) calculated that mangroves make up approximately 6% of the coastline of Barrow Island. These mangroves are generally poorly developed and consist of a narrow band only a few trees in width. In comparison, the mangroves on the adjacent mainland coast are very well developed and extend up to 1 km inland from the coastline.

Seagrass – Ephemeral seagrasses are widespread along the east coast of Barrow Island on subtidal sands and in intertidal pools. The most common species are *Halophila ovalis* (Plate 8-21) on the deeper subtidal sand and *Halophila, Halodule* and *Syringodium* in the rock pools.

Plate 8-21:
Sparse Seagrass Meadow in Intertidal Rock Pool

Macroalgae – At least 132 macroalgal taxa occur in marine habitats around Barrow Island and most of these are believed to be distributed widely in the tropical Indo-Pacific region (Huisman J 2004, pers. comm.). Some species are known only from Barrow Island as systematic collections have not been undertaken for other north-west sites. For example, *Boergesenia forbessii, Yamadaella caenomyce, Halimeda velasquezii, Neomeris vanboseae, Gracillaria urvillei,* and *Valoniopsis pachynema* have only been recorded in Western Australia during surveys for the Gorgon Development.

The macroalgal habitats on the east coast of Barrow Island are typified by a horizontal platform reef with a thin layer of sediments. Macroalgal diversity is highest in the rock pools and towards the deeper edge of the intertidal zone. The dominant macroalgae on the east coast platforms are *Cystoseira trinodis, Sargassum* spp., *Caulerpa* spp. and *Halimeda.* Macroalgal turfs are widespread on the intertidal pavement reef and comprise red algae such as *Laurencia, Chondria, Ceramium, Centroceras clavulatum, Gelidiopsis* and *Hypnea.*

Large stands of *Sargassum* grow on both the west and east coasts of Barrow Island. On the west coast, the *Sargassum* grows mainly on shallow nearshore reefs, whereas on the east coast the *Sargassum* stands are on the gently sloping pavement reef. The ridge of rock running south from the Lowendal Shelf supports variable cover of *Sargassum.*

Other species in the area, such as *Avrainvillea* sp. and *Halimeda macroloba,* appear to be restricted to the east coast. *Udotea* grows on soft sediments on both coasts.

Gorgon Development Area

Mangroves – There are no mangroves in any of the proposed Development areas on Barrow Island. The closest mangroves to any proposed Development activities are in a small area at the Donald River mouth, approximately 5 km north of Town Point.

Seagrass – There are no significant seagrass meadows present in any of the proposed Development areas around Barrow Island. *Halophila* forms sparse meadows on soft sediments along the east coast. These meadows are spatially and temporally dynamic and are expected to occur where there are soft sediments throughout the area in waters less than 15 m deep. All of the areas of soft sediments off the east coast of Barrow Island are considered to be benthic primary producer habitats as they are likely to support seagrass at various times of year.

Macroalgae – All proposed Development areas with exposed, or seasonally exposed, hard substrate in the shallow waters (<15-20 m water depth) are likely to support macroalgae.

Fissures and holes in the shallow subtidal platform reef in the nearshore zone at North White's Beach support a dense macroalgal assemblage. The high profile reef offshore from North White's Beach supports dense and foliose macroalgal beds. Subtidal boulders and reef to the south of the proposed shore crossing at North White's Beach support better developed macroalgal assemblages and turtles have been observed browsing on the algae in that area.

The alternative feed gas pipeline shore crossing at Flacourt Bay crosses high profile reef near the shore that supports seasonal stands of dense *Sargassum.* The intertidal and shallow subtidal reef at Flacourt Bay is exposed to high wave energy and the macroalgal assemblage is limited to a dense turf of algae covering the rocks.

The broad intertidal reef platform and large rock pools at Town Point support a stunted assemblage of macroalgae on the exposed pavement and a better developed macroalgal assemblage, dominated by *Sargassum* and *Cystoseira,* around the edge of rock pools. The length of the *Sargassum* thalli increases with increasing water depth further from shore. The phaeophyte assemblage diversifies towards the offshore edge of the platform where there is a greater proportion of *Dictyopterus* and other large phaeophytes and chlorophytes.

Mainland – Domestic Gas Pipeline Shore Crossing

Mangroves – The proposed domestic gas pipeline would cross the mainland coast 50 m south of the existing Apache Energy Sales Gas Pipeline. The mangrove forest along the existing easement is dense and well developed (Plate 8-22). The forest comprises large *Avicennia marina* trees at the seaward edge, backed by tall *Rhizophora stylosa* trees and more *Avicennia* further inland. Scattered *Ceriops tagal* and *Aegiceras corniculatum* are also present. The inland edge of the mangrove comprises scattered small *Avicennia* and patches of samphire. Technical Appendix C1 contains a description of the results of the preliminary botanical survey on the mainland coast.

The proposed domestic gas pipeline route will affect a 30 m wide corridor through the mangrove zone to the south of the existing clearing for the Apache Energy Sales Gas Pipeline (Figure 8-22). The proposed pipeline route passes through two narrow zones of dense mangroves and a broader area of medium to low density mangroves. In total 2.3 ha of mangrove community and 3.5 ha of samphire community would be directly affected by the pipeline.

Plate 8-22:
Mainland *Avicennia marina* Mangrove with Existing Apache Energy Sales Gas Pipeline Corridor

Seagrass – The proposed domestic gas pipeline will cross the mainland coast adjacent to the existing Apache Energy Sales Gas Pipeline. The sandflats in the nearshore subtidal area and lower intertidal area support patchy, sparse meadows of *Halophila ovalis, H. spinulosa* and *Halodule* seagrass. These sandflat meadows appear to be extensive. The distribution of these seagrasses in areas further offshore is unknown. Mapping from aerial photography is not possible due to high water turbidity in coastal areas. It is assumed that all shallow sediments along the coast and between Barrow Island and the mainland support seagrass meadows at various times of year.

Macroalgae – There are no well developed macroalgal assemblages in the vicinity of the proposed domestic gas pipeline shore crossing.

Optical Fibre Cable Route

Mangroves – The proposed optical fibre cable route does not pass through any areas of mangrove. The shore crossing at Onslow will avoid the mangroves at Beadon Creek.

Seagrass – The proposed optical fibre cable route will cross scattered seagrass meadows in areas of soft sediments along the east coast of Barrow Island, between Barrow Island and the mainland and at the shore crossing at Onslow. Shallow subtidal pavement reef with sand veneers and sandflats at Onslow, in the vicinity of the proposed shore crossing, are expected to support better developed seagrass meadows. This will be confirmed and a final route selected to avoid important areas of seagrass.

Macroalgae – Macroalgal assemblages along the proposed optical fibre cable route are expected to be limited to the *Sargassum*-dominated assemblages on the pavement reef adjacent Barrow Island and areas of shallow reef offshore from Onslow.

Marine Fauna

The marine fauna of the Barrow Island area includes listed species of marine mammals, waterbirds, sea turtles, sea snakes, fishes and a vast array of lesser known vertebrate and invertebrate species that contribute significantly to regional biodiversity but are not listed individually as taxa of conservation significance.

The following sections provide a brief overview of the marine fauna of the proposed Development sites in relation to the conservation status of these fauna and their distribution throughout the region.

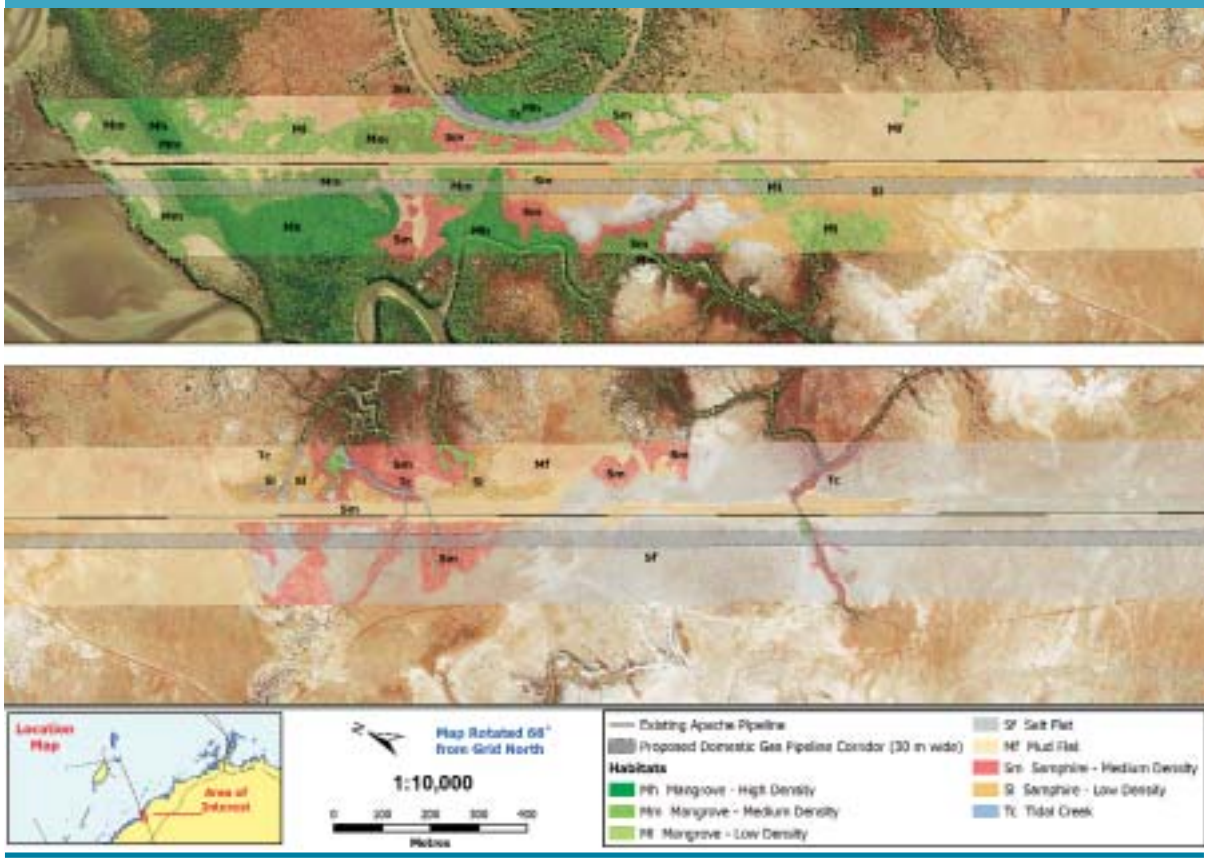
Marine fauna of high conservation significance, in particular species listed under state or Commonwealth legislation or international treaties, are described in more detail in Technical Appendix C3 (seabirds and shorebirds), Technical Appendix C6 (marine mammals, reptiles and fish) and Technical Appendix C7 (sea turtles).

Marine Mammals

Marine mammals are an important component of the biodiversity and ecology of the West Pilbara bioregion. The region supports migratory, transient and resident marine mammals such as whales, dolphins and dugong.

The suite of marine mammal species that are likely to occur in the Development area was derived from a desktop review of the available literature on marine species, liaison with state and federal government departments, liaison with research personnel, review of information from previous surveys and opportunistic observations during field surveys. A full technical report is included in Technical Appendix C6.

Figure 8-22:
Mainland Mangrove Communities in the Vicinity of the Proposed Domestic Gas Pipeline Route



Regional

Whales – The regional distribution of whales is generally poorly known and while many species may occur in the Pilbara region, most are likely to be transients or occasional visitors. All whales are protected under Schedule 1 of the Wildlife Conservation Act and the EPBC Act (refer Technical Appendix C6).

Humpback whales *(Megaptera novaeangliae)* are regular visitors to the region. Whale species that may occasionally visit the region include the short-finned pilot whale *(Globicephala macrorhynchus),* false killer whale *(Pseudorca crassidens),* killer whale *(Orcinus orca),* Bryde's whale *(Balaenoptera edeni),* minke whale *(Balaenoptera acutorostrata),* sei whale *(Balaenoptera borealis),* pygmy blue whale *(Balaenoptera musculus brevicauda),* fin whale *(Balaenoptera physalus),* melon-headed whale *(Peponocephala electra)* and the sperm whale *(Physeter macrocephalus).* Of these whales only the humpback whales are known to be regular visitors to the area. Pygmy blue whales *(Balaenoptera musculus brevicauda)* and other species may pass through the area (Appendix C6).

Dolphins – The regional distribution of dolphins is generally poorly known and while many species may occur in the Pilbara region, most are likely to be transients or occasional visitors. All dolphins are protected under Schedule 1 of the Wildlife Conservation Act and the EPBC Act (refer Technical Appendix C6).

Bottlenose dolphins *(Tursiops truncatus)* and Indo-Pacific humpback dolphins *(Sousa chinensis)* are resident throughout the shallow waters of the inner Rowley Shelf. Other dolphins known from the region include common dolphins *(Delphinus delphis),* striped dolphins *(Stenella coeruleoalba),* spinner dolphins *(Stenella longirostris),* Risso's dolphins *(Grampus griseus),* spotted dolphins *(Stella attenuata)* and rough-toothed dolphins *(Steno bredanensis)*.

Dugong – Dugong *(Dugong dugon)* are known to occur around the islands of the Rowley Shelf such as Barrow Island, the Lowendal Islands and the Montebello Islands, although their distribution within this region is poorly understood. Dugong populations are greater in Exmouth Gulf or Shark Bay than around the offshore islands

(Prince 1986; Prince 2001). They are protected under Schedule 4 of the Wildlife Conservation Act and are listed as threatened (Vulnerable) under the EPBC Act.

Barrow Island

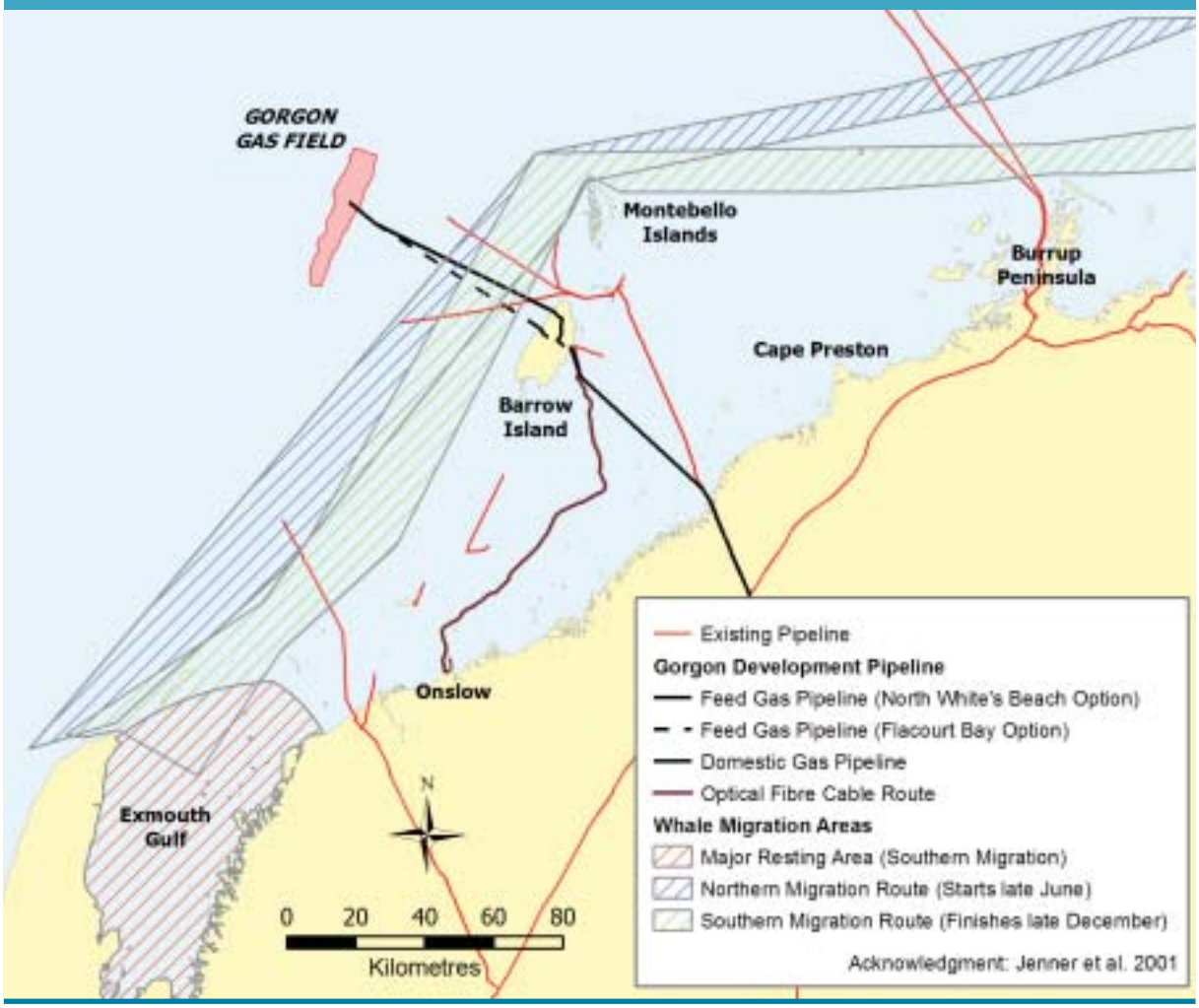
Whales – Humpback whales *(Megaptera novaeangliae)* pass through the Montebellos/Barrow Island region during June to October on their annual migration between their feeding grounds in Antarctic waters and their calving grounds in Pilbara/Kimberley waters. Their migration patterns, calving and rest areas are shown in Figure 8-23 and are described in Technical Appendix C6.

Northbound whales tend to remain on, or within, the 200 m contour, while southern migratory whales tend to be more dispersed. Southbound whales tend to come in closer to Barrow Island (Jenner et al. 2001). Small groups of humpbacks visit the coastal waters off both coasts of Barrow Island during both the northward and southward migration, but are more common on the west side.

Dolphins – Bottlenose dolphins *(Tursiops truncates)* and Indo-Pacific humpbacked dolphins *(Sousa chinensis)* have resident populations within the shallow waters of the inner Rowley Shelf, including Barrow Island. Bottlenose dolphins are abundant on both coasts of Barrow Island. Spinner dolphins *(Stenella longirostris),* common dolphins *(Delphinus delphis)* and striped dolphins *(Stenella coeruleoalba)* are also abundant in the waters around Barrow Island. These are generally oceanic species and are likely to be most abundant on the west coast of the island.

Risso's dolphins *(Grampus griseus),* spotted dolphins *(Stella attenuata)* and rough-toothed dolphins *(Steno bredanensis)* occur in the Barrow Island area. Rough-toothed dolphins have stranded on Barrow Island (Baker 1990).

Figure 8-23:
Whale Migrations



Dugong – Dugong are generally associated with shallow seagrass meadows on which they feed and have been observed in the shallow waters over the Barrow Shoals, along the east coast of Barrow Island and over the Lowendal Shelf to the north east. They are likely to be occasional visitors to any area of subtidal seagrass in the vicinity of the proposed east coast Development areas. There are no known major seagrass meadows along the east coast of Barrow Island that are likely to be critical feeding habitats for dugong.

Gorgon Development Area

Whales – Humpback whales are likely to be present in the offshore Development areas off the west coast of Barrow Island during the June to October migration period. They are also expected to occasionally visit the offshore areas of the proposed Development on the east coast, for example the tanker turning area and dredged shipping channel. There are no known critical habitats, such as feeding or calving grounds, for any whales in the water around Barrow Island.

Humpback and other whales are unlikely to occur in the shallower waters over the shelf between Barrow Island and the mainland where the domestic gas pipeline, optical fibre cable would run. Most whale species are more abundant in deeper waters and are expected to be rare visitors to the offshore waters close to the western shore of Barrow Island and are unlikely to visit the shallow, turbid inshore waters in the vicinity of the proposed domestic gas pipeline or optical fibre cable shore crossings.

Dugong – Dugong occur throughout the shallow waters between the offshore islands and the mainland and are expected to occasionally visit the areas proposed for the domestic gas pipeline and optical fibre cable route. Extensive, ephemeral seagrass meadows along the mainland coast in the vicinity of the proposed domestic gas pipeline shore crossing are likely to be feeding areas for dugong, however, no feeding scars were observed during surveys of the area. The seagrass habitats are very widespread along the Pilbara coast and the area in the vicinity of the shore crossings is not expected to be significant habitat for dugong.

Dolphins – Bottlenose dolphins *(Tursiops truncatus),* common dolphins *(Delphinus delphis)* and striped dolphins *(Stenella coeruleoalba)* are likely to visit the offshore Development areas on the west coast of Barrow Island. Bottlenose dolphins are also likely to be regular visitors to the east coast Development areas.

Bottlenose dolphins are abundant over the Pilbara inshore region and may occur along all parts of the proposed domestic gas pipeline, optical fibre cable route and in the vicinity of the mainland shore crossings.

Marine Avifauna

Marine avifauna studies conducted for the Gorgon Development have revealed that Barrow Island is an internationally important site for migratory shorebirds. Prior to these studies, little was known about the seasonal changes in the abundance of migratory shorebirds on Barrow Island, or about the relative importance of different areas of habitat around the island. The information presented in the following section represents a significant advance in the knowledge of shorebirds in the region. The methodology used in the surveys is outlined in Box 8-8. The full technical report is included in Technical Appendix C3.

Box 8-8:
Avifauna Survey Methodology

Surveys of shorebirds (birds that utilise coastal environments) involved monthly counts around Barrow Island and detailed observations on the coastline north and south of Town Point. Monthly counts were carried out at high tide, when shorebirds were concentrated in beach and headland roosts. Surveys were carried out on foot by experienced observers and birds were identified using binoculars and spotting telescopes. Shorebirds were counted individually where possible, but when large flocks were encountered, standard approaches to estimation were used (Technical Appendix C3).

Shorebird assemblages expected to occur in the general vicinity of the proposed domestic gas pipeline and optical fibre cable shore crossings on the mainland were determined from the Birds Australia listings for these areas (Birds Australia 2004). While this gives an indication of the assemblages in the general area, the importance of potential roosting areas behind the mangroves near Robe River to migratory shorebirds will be determined in surveys later in 2005.

Regional

The marine avifauna of the Pilbara region includes migratory and resident shorebirds and seabirds (birds that frequent coastal waters and the open ocean). Many of the migratory species are protected under the international JAMBA/CAMBA treaties, the Wildlife Conservation Act and the EPBC Act.

Generally, migratory species visit the Pilbara from the northern hemisphere or close to the equator and pass through the region on their way southward, or may stay in the Pilbara region until ready to journey back to breed. Resident species remain in the Pilbara region throughout the year, but may move around within the region.

The Montebello/Lowendal/Barrow Island region has significant rookeries of 15 seabird species including the wedge-tailed shearwater *(Puffinus pacificus),* crested tern *(Sterna bergii),* bridled tern *(Sterna anaethetus)* and the roseate tern *(Sterna dougallii).* Of these, the wedge-tailed shearwater and the bridled tern are protected as migratory species under the EPBC Act. The offshore islands are also important feeding grounds for migratory shorebirds. The mainland areas of the Pilbara are frequently less suitable for shorebirds due to disturbance from humans and introduced predators.

Barrow Island

Barrow Island's marine avifauna comprises at least 67 species, including 25 species of migratory shorebirds and 20 resident shorebirds. A complete species list is included in Technical Appendix C3. The assemblage of EPBC listed species includes 14 seabird species and 25 wetland/littoral species (Table 8-12).

Although the 25 EPBC listed wetland/littoral species may occur on Barrow Island, none of the Development areas contain critical habitats for these species.

Ruddy turnstones are seasonally abundant on Barrow Island and the island represents an internationally important site for this species. While ruddy turnstones are one the more abundant species at Town Point during spring and summer, their densities in the proposed Development areas are much lower than in the south and south–eastern areas of Barrow Island (Technical Appendix C3). These are highly mobile birds that are not restricted to any of the habitats near Town Point.

Table 8-12:
EPBC Act Listed Marine Avifauna

Seabird Species	Wetland/Littoral Species
• wedge-tailed shearwater – *Puffinus pacificus* • yellow-nosed albatross – *Diomedea chlororhynchos* • Wilson's storm petrel – *Oceanites oceanicus* • masked booby – *Sula dactylatra* • brown booby – *Sula leucogastar* • lesser frigatebird – *Frigata ariel* • eastern reef egret – *Ardea (Egretta) sacra* • great egret – *Ardea (Egretta) alba* • osprey – *Pandion haliaetus* • common tern – *Sterna hirundo* • little tern – *Sterna albifrons* • bridled tern – *Sterna anaethetus* • caspian tern – *Sterna caspia* • white-winged black tern – *Chlidonias leucoptera*	• black-tailed godwit – *Limosa limosa* • bar-tailed godwit – *L. lapponica* • little curlew – *Numenius minutus* • whimbrel – *N. phaeopus* • eastern curlew – *N. madagascariensis* • marsh sandpiper – *Tringa stagnatalis* • common greenshank – *T. nebularia* • wood sandpiper – *T. glareola* • terek sandpiper – *T. (Xenus) terek* • common sandpiper – *T. hypoleucos* • grey-tailed tattler – *T. brevipes* • ruddy turnstone – *Arenaria interpres* • great knot – *Calidris tenuirostris* • red knot – *C. canutus* • sanderling – *C. alba* • red-necked stint – *C. ruficollis* • sharp-tailed sandpiper – *C. acuminata* • curlew sandpiper – *C. ferruginea* • pacific golden plover – *Pluvialis fulva* • grey plover – *P. squatarola* • lesser sand plover – *Charadrius mongolus* • greater sand plover – *C. leschenaultia* • oriental plover – *C. veredus* • oriental pratincole – *Glareola maldivarum* • Australian pratincole – *Stiltia isabella*

Barrow Island ranks equal tenth amongst 147 sites in Australia that have been identified as important for migratory shorebirds, due to the high abundance of grey-tailed tattlers, ruddy turnstones, red-necked stints, sanderlings, greater sand-plovers and lesser sand-plovers on the island (Bamford et al. in press).

Studies suggest that Barrow Island is both a staging site and an important non-breeding site for migratory shorebirds. Migratory shorebird abundances increase on the island as the birds arrive from the north during September to December. The abundances of some migratory shorebirds continue to increase during January and February, suggesting local movements of birds from the mainland to Barrow Island. Abundances decrease as the migratory species leave the region to return north at the end of summer.

The highest abundances of shorebirds on Barrow Island (over two-thirds of records for most species) are associated with the south-eastern and southern coasts of the island, from the existing Chevron camp to Bandicoot Bay. These concentrations appear to be associated with the extensive tidal mudflats in these areas.

Listed wedge-tailed shearwaters and bridled terns nest on Double Island, two rocky islets off the east coast of Barrow Island and the shearwaters nest on Boodie Island off the south end of Barrow Island.

Gorgon Development Area

Despite the presence of broad intertidal reef platforms adjacent to Town Point, only 1% of shorebirds on Barrow Island were observed foraging on the intertidal reef platforms near the proposed causeway in 2003 and 2004. The red-necked stint, grey-tailed tattler, ruddy turnstone, bar-tailed godwit, lesser sand plover, greater sand plover, silver gull, common tern and the fairy tern are the most abundant shorebird species that forage at Town Point. The distribution of shorebird roosts in areas surrounding the proposed gas processing facility area on the east coast of Barrow Island is shown in Figure 8-24.

Cormorants, eastern reef egrets, silver gulls and oystercatchers roost on the rocks at Town Point and the large-eyed northern race of the sooty oystercatcher *(Haematopus fuliginosus ophthalmicus)* nests on the headland (Plate 8-23). Barrow Island appears to be an important site for large-eyed sooty oystercatchers, with approximately 1% of the known world population. This race has not been censused thoroughly across northern Australia and is likely to be more abundant than the current estimate indicates. With approximately 30-40 breeding pairs of this race on the island, the nesting pair at Town Point represents approximately 2.5-3.3% of the island stock. Other shorebirds such as the pied oystercatcher *(Haematopus longirostris),* Caspian tern *(Sterna caspia),* red-capped plover *(Charadrius ruficapillus)* and osprey *(Pandion haliaetus)* may nest in the general area, but were not observed to nest there during surveys. No potential nesting habitats in the Town Point area are restricted to that area and it is not considered of local importance to any EPBC listed shorebird species.

The high-energy beaches at Flacourt Bay and North White's Beach on the west coast do not provide significant shorebird habitat and abundances are generally low in these areas.

Small flocks (10s) of shorebirds were observed on the extensive samphire flats inland from mangroves along the mainland coast and are likely to feed over wide areas of this habitat. The narrow strip of mangrove and samphire in the path of the proposed domestic gas pipeline route is unlikely to be more important for shorebirds and seabirds than adjacent areas of similar habitats. Further surveys during the southward migration in 2005 will further elucidate the distribution of shorebird habitat near the proposed shore crossing.

The sandy beaches in the vicinity of the shore crossing for the optical fibre cable at Onslow are likely to be seasonal roosts for a variety of migratory and resident shorebirds. The nearshore islands are also breeding sites for shorebirds and seabirds, such as terns *(Sterna* spp.). None of the nearshore islands are in the path of the proposed pipeline. As with most mainland areas, breeding will be reduced on the Onslow beaches due to feral animal predation and human disturbance.

Double Island, approximately 5 km north of Town Point off the east coast of Barrow Island, is a regionally significant rookery for bridled terns and a locally significant rookery for wedge-tailed shearwaters. The wedge-tailed shearwater rookery is small in comparison with other rookeries in the immediate region.

Plate 8-23:
Nesting Sooty Oystercatchers at Town Point

Marine Reptiles

The marine reptile fauna of the area comprises sea turtles and sea snakes (including kraits). Crocodiles may make rare visits to the region.

The methods used for surveying marine reptiles on Barrow Island are outlined in Box 8-9. Full technical reports are included in Technical Appendices C6 and C7.

Box 8-9:
Marine Reptile Survey Methodology

Marine turtle nesting activity on beaches around Barrow Island was surveyed by beach monitoring and track identification during the 2003-2004 and 2004-2005 breeding seasons (Technical Appendix C7). The surveys were aimed at determining the relative importance of different parts of the Barrow Island coast for sea turtle nesting. The regional importance of the Barrow Island sites was derived from literature.

The likely distribution of sea snakes and kraits in the area was derived from literature.

Regional

Sea Turtles – Six species of sea turtle are known from the Montebello/Lowendal/Barrow Island region: green turtles *(Chelonia mydas);* flatback turtles *(Natator depressus);* hawksbill turtles *(Eretmochelys imbricata);* loggerhead turtles *(Caretta caretta);* leatherback turtles *(Dermochelys coriacea);* and olive ridley turtles *(Lepidochelys olivacea)* (Figure 8-25). All Australian sea turtles are protected under Schedule 1 of the Wildlife Conservation Act, by the Bonn Convention for the protection of migratory animals and listed as threatened under the EPBC Act. Loggerhead turtles and olive ridley turtles are listed as endangered under the EPBC Act and the other species are listed as vulnerable.

Sea turtles in the region generally migrate over large distances and return to the same area to breed. The region also supports foraging grounds for turtles that nest elsewhere in Western Australia. Increasing pressure on these turtles in other parts of the world, make the Australian habitats and breeding areas globally important.

Green turtles *(Chelonia mydas)* are the most abundant sea turtles in northern Western Australian waters. The north-western Australian population is important due to high predation pressures on nesting and inter-nesting turtles in other parts of the Indo-Pacific region. The major green turtle rookeries in the region are at the Lacepede Islands with lesser rookeries on Barrow Island, North West Cape, the Muiron Islands, Serrurier Island and in the Dampier Archipelago (Prince 1990).

Flatback turtles *(Natator depressus)* are the second most abundant sea turtles in northern Western Australian waters (Pendoley 1997). They nest only in northern Australia and there are regionally important rookeries at Cape Thouin/Munda Station, Barrow Island, Lacepede Islands, Dampier Archipelago, Port Hedland, the Montebello Islands and the Lowendal Islands.

The Western Australian populations of hawksbill turtles, although small, are the largest remaining in the Indian Ocean (CALM 2004). Hawksbill turtles *(Eretmochelys imbricata)* have major rookeries on Rosemary Island in the Dampier Archipelago and have lesser rookeries within the Lowendal/Montebello Islands. Barrow Island is not a regionally important nesting site for hawksbill turtles.

Loggerhead turtles appear to be the least abundant of the marine turtles in the Western Australian region (Prince 1990). Loggerhead turtles nest on the Muiron Islands off Exmouth Gulf and at Dirk Hartog Island in Shark Bay.

Leatherback turtles and olive ridley turtles are not known to nest in Western Australian waters. Leatherback turtles are uncommon, but regular visitors to the region. Olive ridley turtles appear to frequent the far northern coastal waters of Western Australia in small numbers (Prince 1990).

Figure 8-24:
Shorebird Roosts in Areas Surrounding the Proposed Development Area on the East Coast of Barrow Island

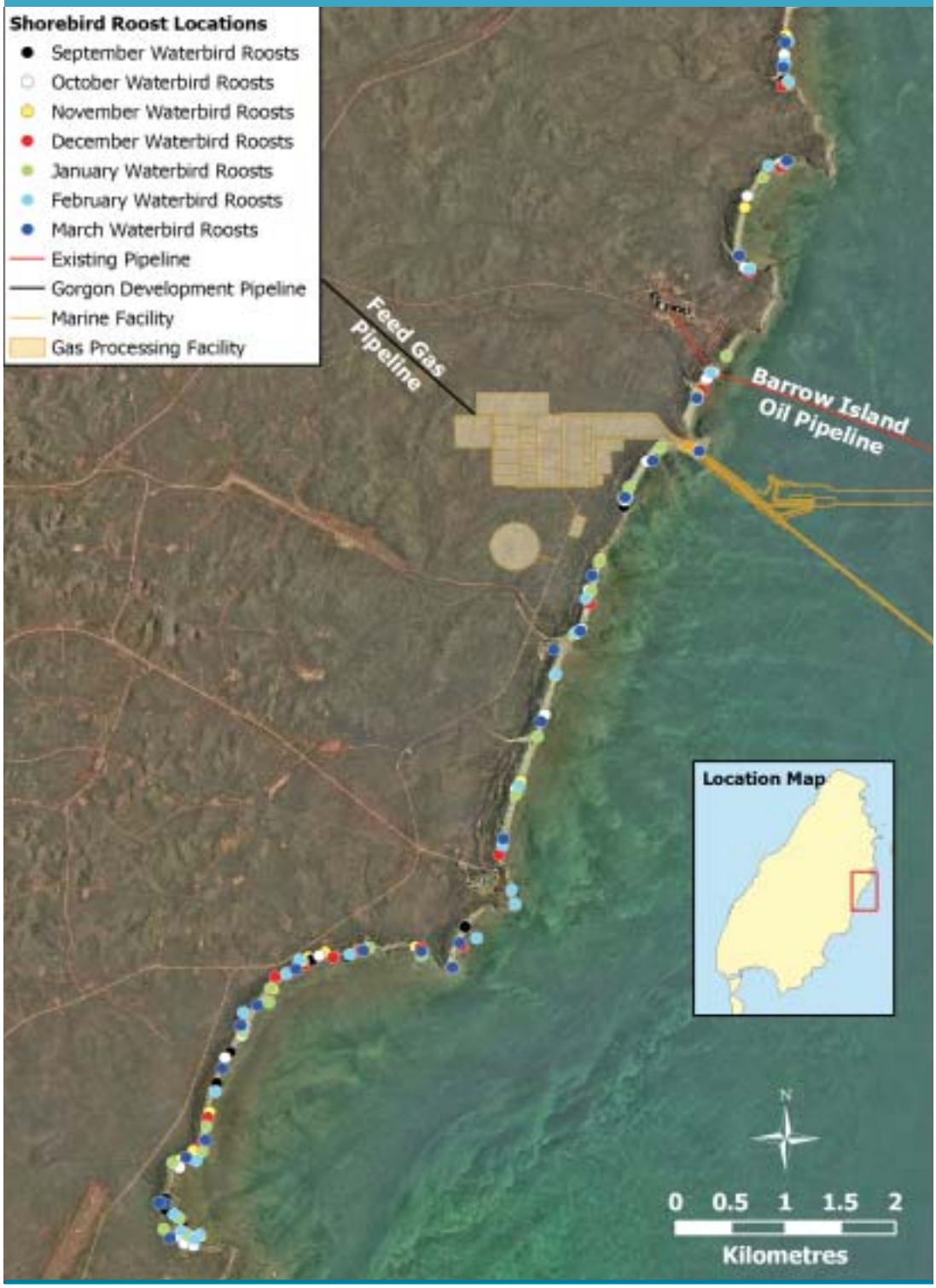
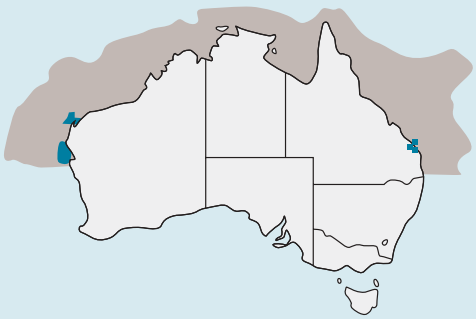
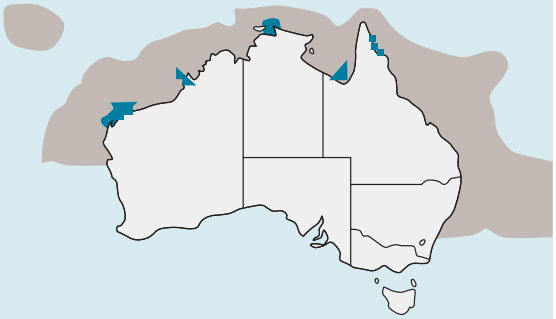


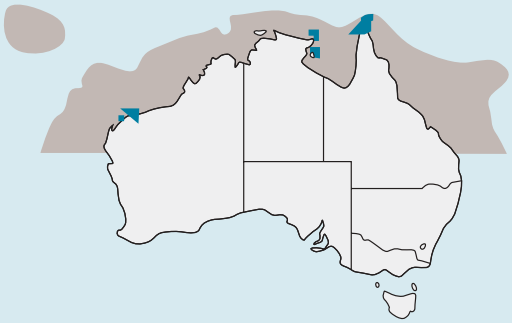
Figure 8-25:
Distribution of Australian Marine Turtles (Source: Environment Australia 2003)



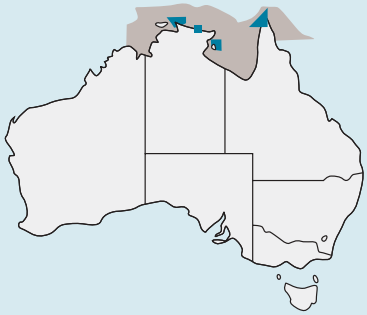
Loggerhead Turtle
Caretta caretta



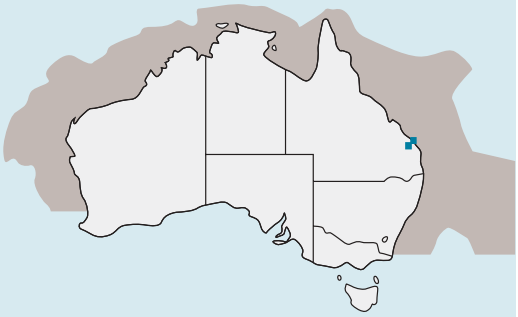
Green Turtle
Chelonia mydas



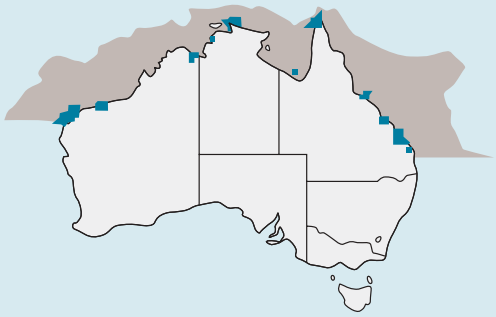
Hawksbill Turtle
Eretmochelys imbricata



Olive Ridley
Lepidochelys olivacea



Leatherback Turtle
Dermochelys coriacea



Flatback Turtle
Natator depressus

Source: General distribution as indicated in Cogger, H. (1996). Reptiles and Amphibians of Australia. Reed. Breeding (rookery) distribution based on areas defined by Limpus, C.J. (1995) Conservation of marine turtles in the Indo-Pacific. Draft: 1 October 1995. Report to Australian Nature Conservation Agency; and Wildlife Management Section, Environment Australia and Marine Turtle Recovery Team (1998) Draft Recovery Plan for Marine Turtles in Australia.

Recorded Breeding Sites
Distribution within Australian

Projection: Geographics

Map produced by ERIN, Environment Australia, Canberra, July 2003.

Sea Snakes and Kraits – Sea snakes and kraits are highly mobile and can cover large distances. Many species are restricted to relatively shallow coastal waters and some species must return to land to eat and rest.

Sea snakes and kraits are widespread throughout the Pilbara region in offshore and nearshore habitats. Storr et al. (1986) estimate nine genera and 22 species of sea snakes and kraits occur in Western Australian waters; however, little is known of the distribution of individual species. There is also very little known of sea snake and krait ecology, population sizes and dynamics. Sea snakes and kraits are protected under the Wildlife Conservation Act and the EPBC Act.

Barrow Island

The use of beaches around Barrow Island by nesting sea turtles was poorly known prior to the current study. Patterns of beach usage have been studied over the last two summer breeding periods.

Barrow Island is a regionally important nesting area for green turtles and flatback turtles. Hawksbill turtles nest at low densities around the island and loggerheads have been only occasionally recorded from the island.

The occurrence of green turtles and flatback turtles, both EPBC listed threatened species, on Barrow Island is described in the following sections.

Green Turtles – Green turtles nest predominantly on the sandy west coast beaches on Barrow Island (Figure 8-26, Table 8-13). In addition to nesting, green turtles mate and forage close to Barrow Island during the summer breeding season. Green turtles nest mainly in spring and summer and hatchlings emerge through summer and early autumn. While most green turtles migrate away from the area after breeding, some appear to be resident at Barrow Island, remaining near the island during the winter.

In addition to breeding beaches, the Barrow Island area appears to provide important inter-nesting and foraging habitats for green turtles. Green turtles feed on marine macrophytes (seagrass and macroalgae) on the seabed and jellyfish in the water column (Heithaus et al. 2002). Aggregations of green turtles have been reported from the shallow areas along the west coast of Barrow Island and the turtles forage on and around nearshore reefs. Green turtles have also been observed to the south and south-east of Barrow Island, around Dugong Reef and over the Barrow Shoals. Shallow subtidal, macroalgal covered reef platforms are widespread in the Montebello/Lowendal/Barrow Island region and no areas of critical inter-nesting or foraging habitat have been identified around Barrow Island.

Inter-nesting green turtles frequent nearshore waters and rest on the sandy beach during the summer breeding season. Resident turtles browse on the nearshore macroalgal dominated platform reefs all along the west coast of Barrow Island when the sea is calm. Their foraging areas are likely to be more restricted during rough weather.

The national Recovery Plan for Marine Turtles in Australia (Environment Australia 2003) identifies Barrow Island and all waters within a 20 km radius of the island as critical habitat to the survival of green turtles.

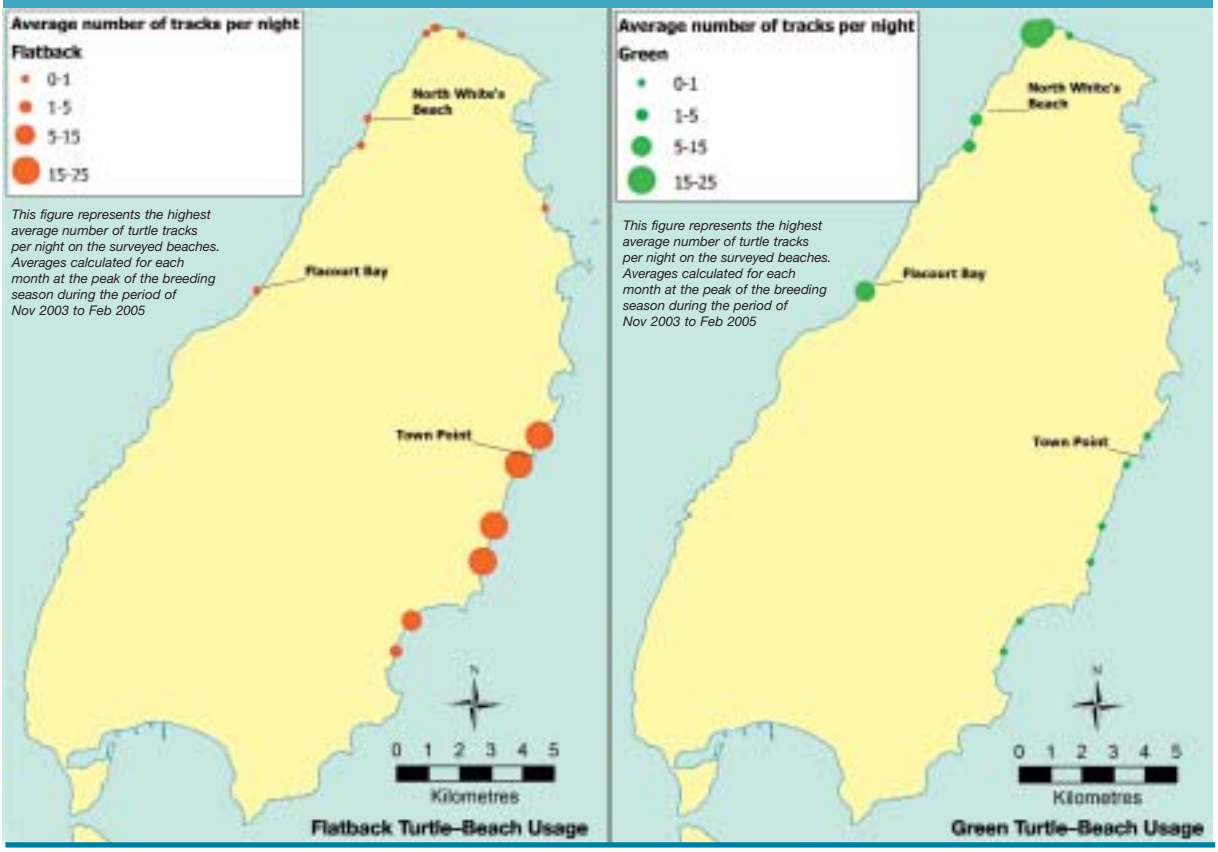
Plate 8-24:
Green Turtle *(Chelonia mydas)* in the Intertidal Zone at Barrow Island

Table 8-13:
Average Nesting Densities of Green Turtles (nests/night/km) on the West Coast of Barrow Island

Beach	V Beach	Tortuga	Flacourt	North White's	White's
2003/2004	138	43	83	–	–
2004/2005	–	50	60	4	28

Location of beaches is shown in Figure 8-2.

Figure 8-26:
Distribution and Intensity of Sea Turtle Nesting Across Barrow Island



Flatback Turtles – Nesting flatback turtles favour mid-east coast beaches on Barrow Island. The beaches either side of the proposed Development area at Town Point (Terminal Beach and Bivalve Beach) are important components of this regionally significant rookery (Figure 8-26). The highest density of flatback turtle tracks was recorded in January 2004 on Bivalve Beach (Table 8-14). In the summers of 2003-2004 and 2004-2005, flatback turtle nesting densities were highest on the central east coast between Mushroom Beach and Yacht Club South Beach, and decreased in a north and south direction (Table 8-14).

Little is known of the distribution and habitat use of flatback turtles during inter-nesting and outside the breeding period. Post-nesting females commonly sleep on the intertidal platform off the east coast rookery at low tide. Inter-nesting and foraging habitats for flatback turtles on the east coast of Barrow Island have not been identified. However, flatback turtles favour soft bottom habitats (Parmenter 1994) and during the inter-nesting period may frequent areas of sandy substrates off the edge of the wide intertidal platform that runs the length of the east coast.

Table 8-14:
Average Nesting Densities of Flatback Turtles (nests/night/km) on the East Coast of Barrow Island

Beach	Terminal	Bivalve	YCN	Bed	Junction
2003/2004	30	49	37	–	–
2004/2005	30	40	26	1	7

Location of beaches is shown in Figure 8-2.

Sea Snakes and Kraits – Sea snakes are common in shallow waters around Barrow Island, in offshore waters west of the island and in inshore waters between Barrow Island and the mainland. Little is known of the distribution of individual species within the area.

Gorgon Development Area

Green Turtles – The area of the proposed feed gas shore crossing at North White's Beach is not a locally important green turtle nesting site, probably due to the shallow sand and the emergent beach rock (Appendix C7). Other beaches in this area with deeper sand, such as V beach, White's Beach and Tortuga Beach support much higher nesting densities of green turtles (Table 8-13).

Flacourt Bay, where the alternative pipeline shore crossing is proposed, is an important green turtle nesting habitat (Plate 8-24). Surveys in the summers of 2003-2004 and 2004-2005, indicated that nesting densities at Flacourt Bay were consistently high in relation to other west and north-west beaches on the island (Table 8-13).

Green turtles are likely to occur across the shallow shelf between Barrow Island and the mainland and are likely to visit all areas of the proposed domestic gas pipeline route and optical fibre cable route to Onslow. The proposed shore crossing for the domestic gas pipeline is in mangroves and mudflats. While green turtles may feed in this area, the absence of sandy beaches makes it unsuitable for nesting.

Heavy fishing pressure on local sea turtle populations in the Onslow area last century is likely to have reduced the breeding stock in this area. Nesting densities are very low along the beaches adjacent to the optical fibre cable crossing at Onslow (K Pendoley 2005, pers. obs.).

Flatback Turtles – The beaches either side of the proposed Development area at Town Point are preferred flatback turtle nesting beaches. No flatback turtles were observed on the seabed during extensive towed video surveys of the seabed off Town Point for the current study and there are no benthic habitats restricted to the area of the proposed development at Town Point (Appendix C8). Surveys in winter 2005 will determine whether the sandy seabed off Town Point is important to inter-nesting or hibernating flatback turtles.

Flatback turtles occur across the shallow shelf between Barrow Island and the mainland and are likely to visit all areas of the proposed domestic gas pipeline route and optical fibre cable route to Onslow. The proposed shore crossing for the domestic gas pipeline is in mangroves and mudflats. While flatback turtles may feed in this area, the absence of sandy beaches and vast expanses of intertidal salt-flats behind the mangroves make it unsuitable for nesting.

A flatback turtle rookery has recently been identified at Back Beach, Onslow (K Pendoley 2005, pers. obs.). The limited information available on this rookery suggests it is not as large as the Munda Station rookery to the north or the Thevenard or Barrow Island rookeries offshore.

Sea Snakes and Kraits – Sea snakes are highly mobile and are likely to occasionally visit all of the deep offshore, shallow offshore and mainland Development areas.

The extensive mangroves along the mainland coast provide important habitat for these marine reptiles. However, all habitats in the proposed shore crossing area are well represented outside the proposed Development area. Sea snakes are expected to visit the mangrove area, nearshore islands and Onslow nearshore reefs to forage, but are not expected to be dependent on the small zone proposed for the shore crossings.

Fish

Fish are a ubiquitous component of the biodiversity of marine ecosystems. Most marine fish have a pelagic egg and larval phase that promotes dispersal over large distances. Consequently, the majority of species are widespread throughout the Indo-West Pacific region. However, some larger species, particularly sharks, are both migratory and endangered and are protected by state and federal legislation. Some species are also subject to fishing pressure and are protected under the Western Australian *Fisheries Resources Management Act 1994*.

The likely distribution of fish species of conservation significance, both within the proposed Development area and region, was derived from the literature. Further information is included in Technical Appendix C6.

The Montebello Islands region supports higher species richness of marine fish than most other parts of tropical Western Australia. The fish fauna (ichthyofauna) of the region is very species rich with over 450 species of fish recorded from the Montebello Island group alone (CALM 2004). In the Barrow Island area, no areas of regional importance to fish were identified during seabed surveys of the proposed Development areas. Pelagic fish are likely to be attracted to the high profile reef in 40-50 m water depth on the proposed feed gas pipeline route and trevally were observed schooling in this area in January 2004. These high profile reefs off the west coast of Barrow Island are likely to be home to a diverse fish assemblage, possibly including protected *Epinephelus* cod species.

Potato cod *(Epinephelus tukula)* are protected under the Wildlife Conservation Act and all large Serranid grouper are protected under the *Fisheries Resource Management Act 1994.* Other fish in the area are protected from over-fishing by legislated catch restrictions in Western Australian waters.

Regional

Sharks – The whale shark *(Rhincodon typus),* grey nurse shark *(Eugomphodus taurus)* and the great white shark *(Carcharodon carcharias)* may occasionally visit the Barrow Island area and are protected under both the Wildlife Conservation Act and the EPBC Act.

The whale shark *(Rhincodon typus)* is a listed migratory species under the EPBC Act and occurs along the northern Western Australian coast, including the offshore islands of the Montebello/Lowendal/Barrow Island region. Whale shark movements are thought to be associated with local productivity events (Last and Stevens 1994). Whale sharks congregate each year around March – April off Ningaloo Reef at Exmouth probably in response to local food availability.

Grey nurse sharks are widely distributed around Australia, from the surf zone down to at least 190 m water depth (Last and Stevens 1994). In Western Australia, they occur at Ningaloo Reef, Barrow Island and in temperate south-western waters.

Little is known of the conservation status of grey nurse sharks in Western Australia (Appendix C6). There have been no surveys of the grey nurse shark distribution in Western Australian waters. Therefore no aggregation sites or other sites critical to the survival of grey nurse sharks have been identified in Western Australia (Environment Australia 2002).

Sygnathids – Pipefish, pipehorses and sea horses are widely distributed in Western Australian waters, but the distribution of individual species within the region is little known. These fish are protected under the EPBC Act.

The Commonwealth Department of the Environment and Heritage (DEH) database indicates that Barrow Island lies within the general distribution area of 30 species of listed pipefish and seahorses. *Hippocampus hystrix* and *Phoxocampus belcheri* are the only listed species recorded from Barrow Island (G Moore 2004, Western Australian Museum, pers. comm.). The distribution of the other protected species is known only from a few records from the Pilbara region. It is assumed that they may be present in the Barrow Island and mainland areas with the exception of *Hippocampus kuda,* which is listed, but is not known from Australian waters.

Gorgon Development Areas

Sharks – Whale sharks are expected to be occasional visitors to the proposed Development area on either side of Barrow Island. Little is known of population sizes of the Western Australian stocks. There are no known up-welling areas, or other spatially restricted habitats, in the vicinity of any of the proposed Development area.

Grey nurse sharks are expected to occur in areas of the deeper, high profile reefs off the west coast of Barrow Island along the proposed route of the feed gas pipeline.

Great white sharks are highly mobile, but favour temperate waters and would rarely be encountered in the Development area. Barrow Island is the northern extreme of the documented distribution for great whites.

Sygnathids – Pipefish and seahorses are expected to be widespread through the shallower benthic habitats of the area. Some of the protected species are expected to occur in the vicinity of the proposed pipeline routes and nearshore infrastructure on the east coast of the island and on the mainland coast. Some pipefish or seahorse species may inhabit the mangrove areas and subtidal reefs of the mainland coast; however, the proposed crossing locations do not include any spatially restricted habitats and are not expected to be of particular significance to these species.

Marine Invertebrates

Marine invertebrates are a major component of the regional biodiversity. The group includes the molluscs (octopus, snails and squid), crustaceans (prawns, lobsters and crabs), echinoderms (sea stars, sea urchins and sea cucumbers), cnidarians (hard corals, soft corals, anemones and jellyfish) and annelids (worms). In addition to these well-known taxa, there are myriad other cryptic and minute species.

Marine invertebrate assemblages are typically diverse because they live in a range of habitats including the water column, soft sediments (infauna and epifauna), macrophyte and coral habitats (epifauna) and rocky reefs (filter-feeders).

The conservation significance of invertebrate assemblages within the Development area and region was derived from the literature. Additional information is included in Technical Appendix C6, Technical Appendix C8 and Technical Appendix C9.

Regional

The marine invertebrate fauna of the Montebello/Lowendal/Barrow Island region is species rich due to the diversity of habitats available. Invertebrate species richness is high at the Montebello Islands in comparison with other parts of tropical Western Australia. For example, there are 150 species of hard coral, 633 species of mollusc and 170 species of echinoderm (CALM 2004).

The marine invertebrate fauna of the Montebello/Lowendal/Barrow Island region has strong affinities with other areas of the Indo-West Pacific due to natural oceanographic links with these areas. This connectivity depresses levels of endemism within the region.

No marine invertebrates from the region have specific legislated protection status. Some species are of commercial interest and are protected under the *Fisheries Resource Management Act 1994* which regulates their harvest. The gastropod, *Amoria macandrewi,* is endemic to sand bars within the Montebello/Lowendal/Barrow Island region and is of higher conservation significance.

The invertebrate fauna of the rocky shores and intertidal mud and sand flats on the leeward sides of the offshore islands have strong affinities with the fauna of the nearshore intertidal areas of the mainland.

Barrow Island

The invertebrate assemblages of Barrow Island are typical of the region showing high diversity, strong affinities with more northern areas and divergence in assemblages between exposed and sheltered coasts.

The markedly different habitats of the western and eastern shores of Barrow Island support similarly different invertebrate assemblages. Of the 316 species of mollusc recorded from the shores of Barrow Island, less than a third occur on both coasts. Differences in the molluscan assemblage between the two sides of Barrow Island relate to the higher proportion of bivalve species in the muddier habitats on the east coast and more coral reef gastropod species on the west coast.

Invertebrate assemblages of the western and northern shores of the island are typical of the Pilbara offshore bioregion and have affinities with assemblages of the west coast of the Montebello Islands. Invertebrate assemblages of the eastern and southern shores are more similar to assemblages in the Pilbara nearshore bioregion along the mainland coast.

The giant clam, *Tridacna derasa,* was found on the east coast of Barrow Island during recent marine surveys. This is the first record for this species in Western Australia. *Tridacna derasa* occurs near Town Point and further south near Perentie suggesting a broad east coast distribution. This species has since been found off Dampier indicating that it has much wider distribution in Western Australia than thought previously (P Tod 2004, pers. comm.).

Coral habitats and rocky reefs around Barrow Island support highly diverse invertebrate assemblages. For example, 32 species of echinoderm and 75 species of shelled mollusc were found on the intertidal reef at Biggada Reef (Bowman Bishaw Gorham 1996). Crown-of-thorns seastars *(Acanthaster planci)* have been observed at low densities in coral areas east of Barrow Island (J Fitzpatrick 2004, pers. obs.).

Gorgon Development Area

All of the invertebrate assemblages in areas proposed for development are associated with habitats that are widely distributed in adjacent areas of the coast and regionally. None of the invertebrate assemblages are considered to be of high conservation significance.

The soft sediments on the seabed in the vicinity of the proposed subsea wellheads are heavily bioturbated indicating an active infauna assemblage. This assemblage type is typically dominated by polychaete worms and crustaceans that burrow into the sediment, together with larger demersal fish and crustaceans. This assemblage is probably very widely distributed in similar depths along the edge of the continental shelf. For example, the infaunal assemblages at the East Spar facility off the west coast of Barrow Island, in 80–90 m water depth, are similarly dominated by polychaete worms and crustaceans (Kinhill 1999). This is similar to most infaunal assemblages of northern Australia (Long and Poiner 1994).

The proposed feed gas pipeline route crosses large expanses of bare sediments and localised high profile reefs in 40-50 m water depth. The reefs support filter-feeding invertebrates including lithophagic sponges, gorgonians, black corals (cf. *Cirripathes*), seawhips, ascidians and bryozoans.

There are no invertebrate assemblages of particular significance where the proposed feed gas pipeline crosses the shore at Flacourt Bay or North White's Beach.

The broad intertidal reef platform and large rock pools at Town Point support diverse invertebrate assemblages typical of the east coast platform reefs. The invertebrate assemblage of the upper intertidal zone is dominated by barnacles, limpets, turbinid snails *(Turbo),* littorine *(Nodilittorina)* snails and rock oysters *(Saccostrea).* The large rock pools support a diverse assemblage of very small corals *(Turbinaria),* holothurians, chitons, hermit and portunid crabs, molluscs nudibranchs, squid, *Octopus,* ceriths, muricids *(Australium, Tridacna),* branching, encrusting and vasiform sponges.

The deeper parts of the pavement reef support soft corals *(Sarcophyton, Lobophyton, Dendronephthya,* and *Sinularia)* and hard corals *(Goniastrea, Euphyllia, Porites, Lobophyllia, Pleaseastrea, Favia, Favites, Turbinaria, Platygyra* and *Acanthastrea).* These taxa are all widespread along the east coast of Barrow Island.

The dense *Sargassum* bed covering the platform is home to a diverse assemblage of epifauna dominated by crustaceans, molluscs, small fish and worms. No significant invertebrate assemblages occur along the proposed causeway route or within the proposed access channels.

The soft sediments, where the tanker turning basin is proposed to be dredged, are largely bare of epifauna, with patches of seapens and occasional branching gorgonians. Outcropping rock on the ridge running south from Lowendal Shelf supports soft corals *(Rumphella),* seawhips *(Junceella),* gorgonians, fans, hydroids and small hard corals.

The infaunal assemblages of the dredged shipping channel are expected to be similar to those in the turning basin. Epifaunal assemblages on soft sediments in the turning basin and along the access channel are dominated by seapens and echinoderms (heart urchins, seastars, crinoids and holothurians) with seapens, sponges, hydroids and occasional gorgonians on exposed hard substrates.

All of the invertebrate taxa and assemblages along the proposed domestic gas route are expected to be widespread throughout the nearshore bioregion. The giant clam, *Tridacna derasa,* is only known from two locations on Barrow Island and one on the mainland and should be considered an evolutionary significant unit until its wider distribution can be confirmed.

The extensive intertidal sand and mud flat in the area of the mainland shore crossing supports a sparse invertebrate assemblage of crinoids, mud crabs *(Scylla),* molluscs *(Pinna, Polinices, Syrinx, Nassarius),* digitate sponges and sand dollars. This assemblage is typical of these habitats and well represented in adjacent parts of the coast.

Invertebrates inhabiting the mangroves in the vicinity of the shore crossing include barnacles attached to the trunks of the mangrove trees and fiddler crabs.

The invertebrate assemblages of the intertidal and subtidal pavement reefs and sandflats at Beadon Point and Beadon Beach are not of high conservation significance (LeProvost Environmental Consultants 1992). The habitats and assemblages in the vicinity of the optical fibre cable crossing at Onslow are expected to be well represented locally and regionally.

8.4 Social Environment

8.4.1 Introduction

This section summarises the area and regional demographics, population and lifestyle trends and livelihood, government policies and plans, land and sea tenure and use, aesthetics and existing cultural heritage aspects related to the Gorgon Development.

8.4.2 Population Trends and Demographics

The Pilbara region comprises the four local government areas of Port Hedland, Roebourne, Ashburton and East Pilbara. The vast majority of Pilbara residents are located in the western third of the region, which includes the main townships of Karratha, Port Hedland and South Hedland. A small number of Indigenous communities occur in the eastern portion of the region.

In 1993, the population of the Pilbara region was approximately 43 000 people. By June 2001, this had decreased to less than 40 000 people. This represents around 2% of Western Australia's population. Department of Local Government and Regional Development (2003a) statistics show that there has been a general population decline between 1996 and 2001 in the Pilbara Region (refer Table 8-15).

The following demographic trends have been identified for the Pilbara population:

- the population is generally younger, with less representation in the over 65 and 15-24 age categories, than for the state
- there is a higher proportion of Indigenous people as a portion of the population (13%) than for the state (3%)
- there is an uneven gender distribution within the region as compared to the state, with significantly more men (12%) than women living in the Pilbara.

8.4.3 Lifestyles and Livelihood

The development of the Pilbara has coincided with the discovery of vast deposits of iron ore and oil and gas resources in the region. Resource projects are the main economic and employment generators in the region and impact on the social profile and communities that support them.

The cyclical nature of many resource projects (i.e. peak workforce during construction phase, and a much smaller workforce during operations) leads to a corresponding boom/bust economy and transient populations in many service centres. Many operations also use a fly-in fly-out regime from Perth.

Pilbara residents generally earn an above average wage. Combined with an unemployment rate that is substantially lower than the state average, there is greater lifestyle flexibility available for Pilbara residents.

Because of the proximity of the majority of the regional population to the coast, fishing, diving and other marine-based recreational pursuits are common. In addition to this, the region's main towns contain many recreational facilities.

The region is also culturally and environmentally diverse, and is well-known for its heritage assets. While not in the specific Gorgon Development area, there are numerous examples of Aboriginal rock art

Table 8-15:
Regional and State Population Trends between 1996 and 2001

Region	1996	2001	Percent Change 1996–2001
Shire of Ashburton	7 379	5 945	–19%
Shire of East Pilbara	6 937	5 843	–15.85%
Town of Port Hedland	12 281	12 615	2.7%
Shire of Roebourne	13 829	14 841	7.3%
Pilbara Region	40 426	39 461	–2.4%
Perth Metropolitan Area	1 244 320	1 339 993	7.7%
Western Australia	1 726 095	1 851 252	7.3%

Source: Department of Local Government and Regional Development website: 'Regional Trends and Indicators' *(June 2003b): http://www.regional.wa.gov.au/rti/index.asp*

throughout the Pilbara, and there are also a variety of natural attractions in the region, including the Karijini and Millstream/Chichester National Parks and the Dampier Archipelago.

Provision of social services in the Pilbara varies. While the main Pilbara towns have a reasonable level of social service provision, it is generally recognised that the health and welfare services in the remote communities of the Pilbara region are inadequate (Pilbara Development Commission 2003).

8.4.4 Government Policies and Plans

Overview

The Gorgon Development requires assessment under both federal and state legislation (refer to Chapter 4), and as such should consider government policies and plans at the federal, state, regional and local levels.

At the federal level, the Commonwealth Government is responsible for broad policy direction and decision making on issues of national applicability. States have reduced fiscal responsibility and power, but should assume responsibilities such as service provision under the general policy direction of the Commonwealth. Within Western Australia, local government authorities (LGAs) are responsible for service provision and are generally limited in terms of income generation and statutory responsibility. The Shires of Ashburton and Roebourne would be the two LGAs most affected by the proposed Gorgon Development.

Relevant Policies and Strategies

There are a wide range of existing government policies and strategies which are relevant to the proposed Gorgon Development. Relevant government policies are outlined in Table 8-16. The extent to which the Development meets current government policies and strategies is discussed in Chapter 14.

8.4.5 Land and Sea Tenure and Use

Commonwealth and State Jurisdiction

The Gorgon Development has components that will be located in both federal and state jurisdictions. The upstream well development will be within Commonwealth waters (outside the 3 nautical mile boundary west of Barrow Island), while the majority of the pipelines, gas processing facility, and marine infrastructure will be located on state land or within state waters (includes both 'internal' and 'coastal' waters).

Barrow Island Tenure and Use

Barrow Island was declared a Class A nature reserve in 1910 under the *Permanent Reserves Act 1899.* It was therefore deemed to be reserved under section 41 of the *Land Administration Act 1997* (schedule 3, clause 2(3) *Land Administration Act 1997).*

In 1966, the State Government of Western Australia granted a Petroleum Lease (L1H) to West Australian Petroleum Pty Ltd (WAPET). The *Petroleum Act 1936* was amended in order to allow WAPET to produce oil; however, the Class A nature reserve status of the island was not relinquished. Although the *Petroleum Act 1936* was repealed by the *Petroleum Act 1967,* the earlier Act continues to apply to the Barrow Island lease and its renewal. The lease is currently held by Chevron Australia, Santos Offshore and Mobil Australia Resources Company (the Barrow Island Joint Venture) and covers all but two small exploration areas (EP 61 and EP 62) held solely by Chevron Australia. Management of the nature reserve is overseen by CALM.

Land use on Barrow Island is restricted due to its classification as a reserve for conservation purposes. Barrow Island has been actively used for petroleum exploration purposes since 1964, and has since become Australia's largest onshore oilfield. Access to the island is restricted to personnel associated with oilfield operations and CALM.

The State Agreement provides that no more than 300 ha in total of uncleared land is to be leased, or the subject of licences or easements, for gas processing projects. Of this 300 ha, 150 ha of uncleared land is reserved for the Gorgon Development and 50 ha is reserved for easements for any petroleum pipelines, control lines and ancillary services.

Mainland Tenure and Use

A significant pastoral lease (Mardie Station) extends across the mainland coastline in the vicinity of the proposed domestic gas pipeline route. The lease is 226 445 ha in area and is held by Chininara Pty Ltd (Lease No. 453.1984 – formerly 3114/1027). The lease area contains numerous reserves for 'Water' purposes and the property is traversed by the De Grey – Mullewa Stock Route and unsurveyed public roads. The land is used for pastoral purposes.

Table 8-16:
Summary of Relevant Government Policies and Strategies

Government Policy or Strategy	Purpose/Objectives
'Stronger Regions, A Stronger Australia' (Commonwealth Department of Transport and Regional Services 2001; Commonwealth Government Regional Policy Statement)	In 2003, an Action Plan for the implementation of this Policy was created by an independent panel. The Action Plan assesses regional development issues according to the broad subject areas of business, government, people and infrastructure.
'Hope for the Future – The Western Australian State Sustainability Strategy' (Sustainability Policy Unit 2003)	This Strategy provides a framework for a whole of government approach to the state's development in accordance with sustainability objectives.
'The State Planning Strategy' (Western Australian Planning Commission 1997)	This Strategy indicates that, 'in the next three decades, the Pilbara region will be a world leading resource development area focusing on mineral extraction, petroleum exploration and production and the primary stages of downstream processing…'.
'Regional Western Australia – A Better Place to Live' (Department of Local Government and Regional Development 2003a)	This Policy provides a framework for the development of the state's non-metropolitan regions to achieve 'social, economic and environmental progress in a sustainable way'.
Western Australian Government's (draft) 'Pilbara Land Use Strategy'	The Pilbara Land Use Strategy is a strategic 25-year plan for the Pilbara, based on the principles of ecologically sustainable development and multiple land use principles. The Strategy sets broad objectives for the development of the Pilbara.
'Pilbara Regional Priority Plan' (Pilbara Development Commission 2003)	The Pilbara Regional Priority Plan was formulated in response to a Cabinet Standing Committee on Regional Policy determination in June 2003. The Plan was developed using the sustainability framework provided in the State Sustainability Strategy and involved the engagement of stakeholders. The Plan attempts to achieve the creation of a social environment that attracts and retains a skilled workface, and provides an attractive and safe environment for residents.
'Karratha Area Development Strategy' Western Australian Planning Commission (1998)	The Karratha Area Development Strategy was prepared as a comprehensive, integrated and far-sighted strategy to guide the rapid growth of Karratha, and the wider surrounding area. It is intended to resolve conflicting land and water use demand, guide and control the use of land and water, and coordinate infrastructure provision and urban expansion for the next 25 years. 'Town Planning Scheme No. 8'
Shire of Roebourne Town Planning Scheme No. 8 (2000)	The Shire of Roebourne's Town Planning Scheme (TPS) controls the planning and development of land within the Shire's jurisdiction. The Karratha Area Development Strategy, although a non-statutory planning document, provided guidance for aspects for the Roebourne TPS.
Shire of Ashburton Town Planning Scheme No. 7 (2004)	The Shire of Ashburton's TPS controls the planning and development of land within the Shire's jurisdiction.

Sea Tenure and Use

Barrow Island is located within the jurisdiction of the State Government of Western Australia. Any petroleum related exploration or production within state jurisdiction is controlled by the Western Australian *Petroleum (Submerged Lands) Act 1982.*

Beyond the 3 nautical mile state waters boundary, west of Barrow Island, the sea falls under Commonwealth jurisdiction for a further 200 nautical miles. Any petroleum related exploration or production within these waters is subject to the provisions of the Commonwealth *Petroleum (Submerged Lands) Act 1967.* The Gorgon gas field is located in Commonwealth waters and comprises a significant number of petroleum titles (Figure 1-2, Chapter 1).

There are several other tenures that should be considered:

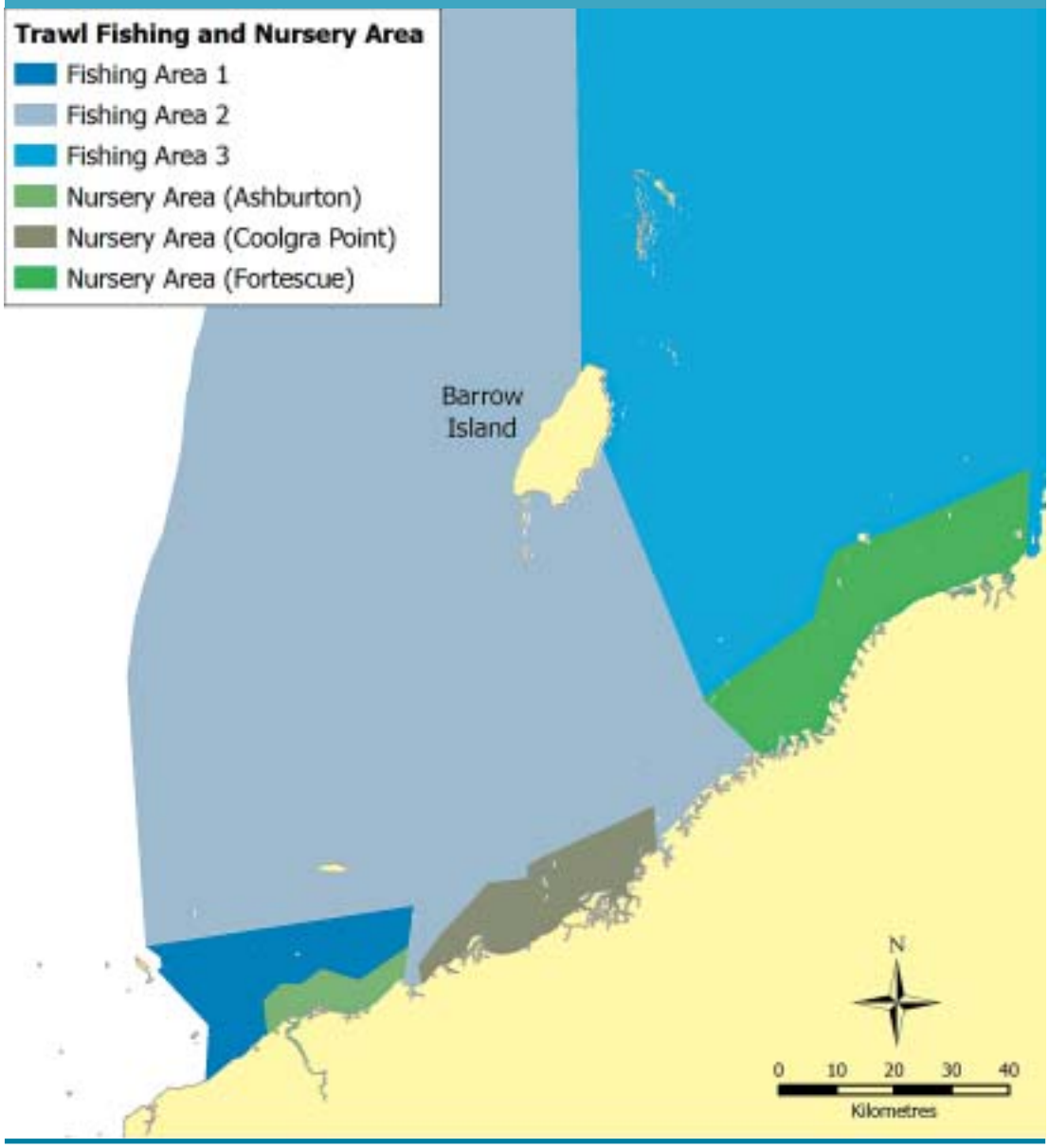
- Barrow Island port limit – pursuant to Section 10 of the *Shipping Pilotage Act 1967*, this limit enables the harbourmaster to restrict all shipping movements within the port limit (refer to Figure 8-21).
- Recommended track – this is the recommended path for shipping movements according to surveyed conditions. As such, a high level of shipping traffic may be expected along this route.
- Prohibited entry areas – these exclusion zones around wells, platforms and other oil and gas infrastructure vary between 4.5-9 nautical miles.
- Oil and gas pipelines – there are a number of subsea pipelines and wellhead platforms/monopods in the vicinity of the Gorgon Development, including: the Chevron Australia export pipeline located within the Barrow Island Port boundary; the Apache Energy East Spar; Wonnich, Harriet, and Double-Island pipelines (with their associated topside monopods and wellhead platforms); and two export natural gas pipelines running between Varanus Island and the mainland. There are also gas and oil processing and storage facilities on Thevanard and Varanus islands. Other oil and gas developments are located to the south (Griffin, Thevanard, Crest, Roller, Saladin and Yammaderry) as well as to the north (Goodwin, N. Rankin, Perseus, Cossack, Stag and Wandoo), but these are at a significant distance (> 40 km) and would not be affected by the construction and/or operation of the Gorgon Development.
- Montebello – Barrow islands marine conservation reserves – The Development falls within the multiple use area. Petroleum exploration, drilling and pipelines and dredging activities are subject to the *Environmental Protection Act 1986* and subject to assessment by relevant government agencies. The primary role of reserve management in relation to hydrocarbon exploration and production is ensure that these activities are ecologically and socially sustainable and to ensure equitable access to the proposed reserve for the industry (Figure 8-21).
- The proposed feed pipeline from the gas fields to Barrow Island transects an area (Zone 1 of the Pilbara Fish Trawl Interim Managed Fishery) that has been lightly trawled in the past and is the site of a trawl research area. However this area is currently not trawled.
- Pearl culture – There are no pearling areas/zones crossed by the proposed Gorgon Development. Pearl farms may be floating or fixed structures with associated moorings, generally marked by buoys or beacons. The nearest is on the Montebello Islands.
- Great Sandy Island Nature Reserve – A portion of the domestic gas pipeline and an optical fibre cable would cross this large nature reserve which extends from east of Cape Preston, approximately 110 km west towards Onslow (refer to Figure 1-5 in Chapter 1).

The busiest Australian ports, in terms of tonnes of cargo handled in 2000-2001 were Dampier, Newcastle, Port Hedland, Hay Point, Gladstone, Port Walcott, Port Kembla, Brisbane, Melbourne and Sydney (Bureau of Transportation and Regional Economics 2003). Barrow Island Port handles very few ships and very little cargo volume in comparison to these ports.

The north-west shelf supports an active commercial fishing, marine based tourism and recreation, and oil and gas exploration and production fleet. The Onslow Prawn Managed Fishery (OPMF) contributed $1.7 million in revenue to local fishers in 2001 (Department of Fisheries 2003).

The OPMF targets western king prawns, brown tiger prawns, endeavour prawns and banana prawns. Regulations ensure that prawn trawling is restricted to three areas (shown in Figure 8-27) with associated nurseries (Ashburton nursery, Coolgra nursery and Fortescue nursery). Prawn fishing is controlled by:

Figure 8-27:
Map Showing Commercial Fishing Boundaries



- limited entry
- seasonal and area closures
- gear controls
- boat size restrictions
- catch reduction devices (introduced in 2003).

There are currently 12 prawning vessels operating over the three management areas, employing approximately 25 people, including 10 local processing staff. Data obtained from the Western Australian Department of Fisheries indicates that the stretch of water between Barrow Island and the mainland supports a level of prawning activity at 60-130 tonnes for 2000/2001, which is well short of the catches in the Exmouth or Shark Bay fisheries. The trawling patterns indicate the highest level of activity in 'Area 3' within the Fortescue nursery and close to the mainland shore. Trawling within nursery areas is permitted except at those times when prawns are breeding. This generally occurs anytime between March and November and the Department of Fisheries operates rolling closures during this period in response to seasonal conditions.

8.4.6 Visual and Aesthetics

Offshore

The subsea gas-gathering system will be located on the sea floor at the Gorgon gas field, approximately 70 km west of Barrow Island, and so would not have any visual impact implications above the waterline.

Onshore – Barrow Island

The landscape of Barrow Island is arid and rugged. The coastline consists of weathered rocky headlands, interspersed with white sandy beaches. Landscape form consists of limestone uplands, dry creek beds, red sands, white dunes, beaches, clay and salt flats, and intertidal flats. There are five landscape units identified on the island. These units and a brief description of each are provided in Table 8-3.

Due to the arid climate, vegetation cover is low and generally sparse. Existing oil extraction infrastructure, including wells and associated pumping equipment are intermixed throughout the central region of the island with the tallest structure being the communication tower (120 m high) situated on the highest central upland point (65 m above sea level).

Onshore – Mainland

One option is to route the domestic gas pipeline parallel and adjacent to the existing Apache Energy Sales Gas Pipeline. This route would cross low-elevation (0-50 m AHD) and sparsely vegetated rural pastoral lands. The new pipeline will be buried underground, so will have very limited and temporary visual impacts.

8.4.7 Cultural Heritage

Barrow Island

Barrow Island occupies a potentially important position in the Indigenous archaeology of north-western and continental Australia. It is located between the Cape Range Peninsula and the Montebello Islands, both of which were initially occupied by Indigenous people at 34 200 ± 1050 years Before Present (BP) and 27 220 ± 650 years BP respectively. The presence of two areas with such long occupation records either side of Barrow Island strongly suggests that Barrow Island may also contain Indigenous archaeological material of great antiquity in both rock shelter and possibly stratified sites in sand dunes.

A search of the Register of Aboriginal Sites (the Register) held by the Department of Indigenous Affairs (DIA) indicates that no ethnographic sites are listed on Barrow Island. The Register indicates that the DIA has records of 13 archaeological sites located on Barrow Island (refer to Chapter 14 and Technical Appendix E2 for a description of these artefact scatter sites). The proposed pipeline routes, including shore crossings, and gas processing plant site area have been examined by archaeologists and no new Indigenous cultural sites or materials were discovered in areas likely to be disturbed. The possibility of finding new Aboriginal sites or materials, particularly along the coastal areas and drainage channels exists.

Mainland

The general area of the Pilbara coastline, where the domestic gas pipeline is proposed to come ashore, contains a range of archaeological sites that include shell scatters and middens, artefact scatters near claypans and Indigenous burials in dunes. These sites generally date to the last 7000-years when the coastline approximated its current position.

A number of Indigenous archaeological assessments have been conducted in the vicinity of the proposed onshore pipeline route. In this respect, the Register indicates that there are two ethnographic sites located close to the proposed pipeline route on the mainland. Altogether, there are nine identified cultural heritage sites within the vicinity of the onshore pipeline route.

Maritime Heritage

Records indicate that there are no known shipwreck sites along the proposed Gorgon Development subsea pipeline routes. However archival sources suggest that a number of significant vessels have been lost in the Onslow/Barrow Island region; and there is potential for lugger shipwreck sites to occur in the vicinity of Barrow Island. The existence of any residual wreckage (which would constitute an archaeological site) can only be determined on discovery. The proposed pipeline shore approaches, the MOF and shore areas around the proposed gas processing plant site area have been examined by a marine heritage expert and no shipwreck sites were discovered. Although shipwreck sites most often occur in shallow reef areas, sites may also occur in deep water. Marine underwater video survey work and review of side-scan sonar results to date have not revealed the presence of any shipwreck material.

8.4.8 Native Title

Barrow Island and Offshore Waters

There are no lodged Native Title claims over the Gorgon gas field and Barrow Island. However Native Title rights over onshore and offshore seas have been recognised by Australian courts, and it is possible that a future Native Title claim could be made to the offshore areas of the Gorgon gas fields.

In terms of Barrow Island, the High Court in the *Ward Case* (August 2002) held that vesting of reserves under the *Land Act 1933* has extinguished Native Title. Accordingly, the vesting of Barrow Island as a nature reserve will have extinguished Native Title to the island.

Mainland

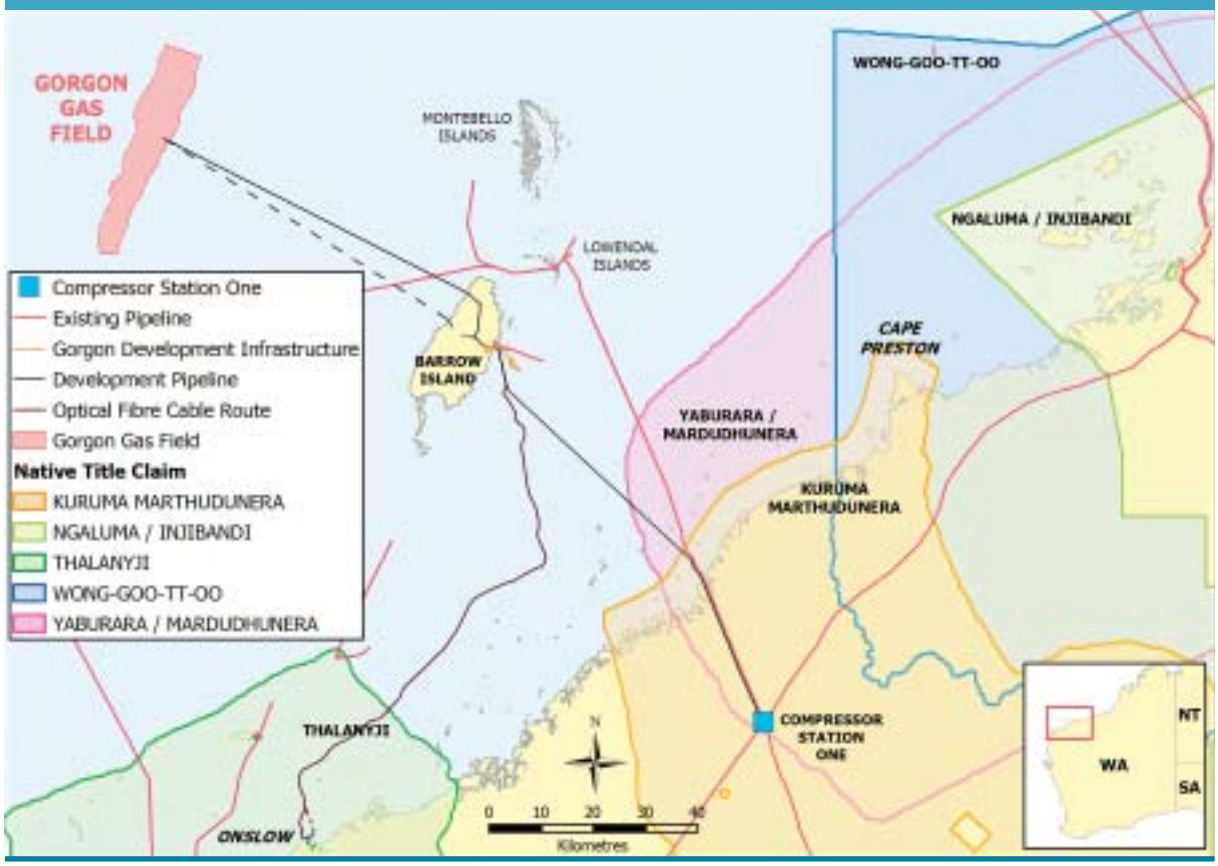
There are currently three registered Native Title claims that may overlap the proposed domestic gas pipeline route and onshore seas approach to the mainland (refer to Figure 8-28):

- Yaburara and Mardudhunera people (Tribunal No. WC96/89)
- Wong-goo-tt-oo (Tribunal No. WC98/40)
- Kuruma Marthudunera (combined) (Tribunal No. WC99/12).

Australian courts have upheld that a pastoral lease does not necessarily extinguish Native Title, and that various Native Title rights and interests can co-exist with the rights and interests of a pastoral lessee. However, where those native title rights and interests are inconsistent, the rights of the pastoral lessee may prevail. In other words, while Native Title is not necessarily extinguished by a pastoral lease, it cannot affect the ongoing operation of a pastoral lease.

These registered claims allow claimants to have procedural rights in relation to the compulsory acquisition of land for the proposed onshore pipeline easement. In addition, the claimants have a right to object within two months of being notified of the proposed grant of the easement, in so far as it affects their registered native title rights and interests (including rights and interests claimed in the onshore sea approaches to the mainland).

Figure 8-28:
Native Title Claim Boundaries in the Vicinity of the Development Area



8.5 Economic Environment

8.5.1 National Economy

The resource industry contributes largely to the Australian economy:

- mineral and petroleum production makes up 35% of Australia's good and service exports
- capital investment in the resources sector accounts for 12% of annual private capital investment in Australia.

Australia's balance of payments is critically dependent on a successful resources sector. In particular, Western Australia's resources sector is very significant in terms of the national economy, accounting for:

- over 48% of the nation's mining and petroleum production
- over 60% of the nation's mineral exploration investment
- 70% of the nation's petroleum exploration investment
- 79% of the nation's oil and condensate production
- 100% of the nation's LNG production.

Western Australia's extensive energy reserves provide a significant competitive advantage to the state. This state is now the major oil and gas producer in Australia and has more than three-quarters of Australia's identified natural gas resource within its jurisdiction and in adjoining Commonwealth waters. This means that Western Australia will continue to be an important contributor to the expected growth in global LNG supply over the medium-term. For example, the NW Shelf development, commissioned some 20 years ago, constitutes Australia's only operating large-scale, gas export project. In 20 years of operation, the NW Shelf project has supported significant economic activity, both directly and indirectly, through:

- significant export trade
- substantial revenue flows to the Australian and Western Australian communities via their governments, allowing for lower income and other taxes and higher disposable income
- better trade relations in the Asia-Pacific region for Australian industry, as well as improved international reputation as a reliable and competitive supplier of strategic goods
- employment opportunities and industrial growth
- an economic base to develop remote areas in the region
- substantial supply of natural gas to Western Australia, providing a cheaper and more greenhouse-friendly energy product to households and industry.

8.5.2 State Economy

The economy of Western Australia is dominated by the resources sector, and to a lesser extent, by the agriculture sector. The state economy is very export-oriented, which differs from the Australian economy as a whole. In 2002–03, the state resources sector (DoIR 2003):

- provided over 78% of the state's total exports, estimated at $25 billion in 2002–03
- contributed 23% of the state's Gross State Product (GSP), mainly through export income as well as downstream manufacturing and processing
- directly employed 5% of the state's workforce
- indirectly employed an additional 15% of the state's workforce.

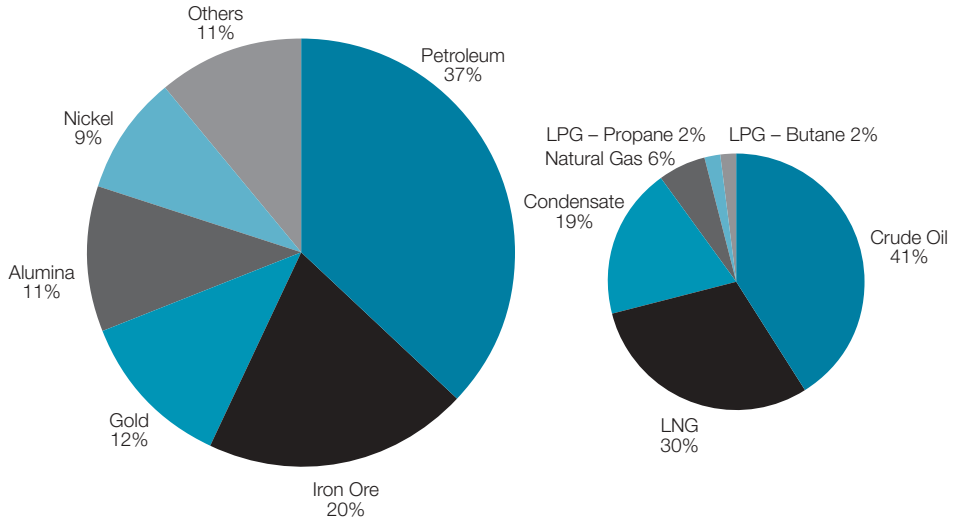
Petroleum and related products accounted for 37% of resource sales, as shown in Figure 8-29.

Western Australia is a major player in the resources sector with almost 500 projects and some 50 different minerals in commercial production. Over 60 State Agreements between the state and industry underwrite the contribution that the resources sector provides to the state economy (DoIR 2003):

- Western Australia's business investment in 2002–03 recorded a solid 19% increase compared to the previous year. Business investment in the state is highly dependent on activity in the state's resource sector, with around 55% or $3.9 billion of capital expenditure being accounted for by the mining sector in 2002–03.
- Within Western Australia, mining investment rose by 26% to $3.9 billion in 2002–03, compared to $3.1 billion in 2001–02.
- Western Australia accounted for 43% of the total Australian mining investment of $9.0 billion in 2002–03. This compares to 43% of Australian mining investment of $7.3 billion in 2001–02.

Comparisons of total new investments within Western Australia and Australia over recent years are presented in Figure 8-30.

Figure 8-29:
State Resources Sales 2002–03 – $27.9 billion

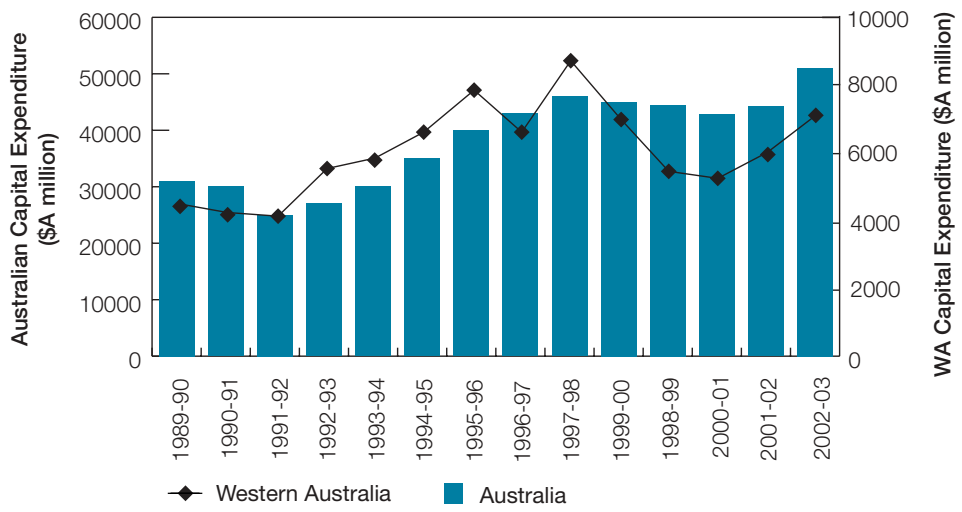


8.5.3 Regional Economy of the Pilbara

The Pilbara is one of the most vital and dynamic wealth producing regions in Western Australia, responsible for the production of goods and services worth more than $16 billion per annum. The mining and petroleum industries continue to be the predominant earners for the region, with a total value of production of $15.3 billion per annum, which accounts for more than 55% of the state's total mineral and energy production. While the mineral and petroleum sectors will continue to be the mainstay of the Pilbara's economy, the region is continuing to diversify and expand its economic base with the continued development of its tourism, retail, trade and agricultural industries.

The Pilbara economy is based primarily on petroleum, iron ore and solar salt production. The value of petroleum products contributes around 65% of the region's wealth derived from the mineral and petroleum industry. Sales of the main three output products of the proposed Gorgon Development, namely natural gas, petroleum condensate and liquefied natural gas, are

Figure 8-30:
Private New Capital Expenditure – Western Australia and Australia



increasing. In 2001–02 the production of natural gas was valued at $622 million, which was 97% of the state's natural gas production. The value of petroleum condensate for 2001–02 was $1.7 billion, virtually all of the state's production. LNG production was valued at $2.6 billion in 2001–02, all from the NW Shelf project located in the Pilbara (ChevronTexaco Australia 2003b).

Table 1-3, in Chapter 1, shows planned and proposed projects, their reported project value, employment characteristics and reported construction commencement dates. The viability of these projects is strongly tied to economics, including world market demand, commercial arrangements and many on the world cost to finance these endeavours.

8.5.4 Economic Policies Influencing the Gorgon Development

Barrow Island Act 2003

The *Barrow Island Act 2003* sets out and authorises an agreement between the state and Joint Venturers for the proposed Gorgon Development. Schedule 1 of the Act contains various conditions for the proposed Development, of which the relevant economic conditions are outlined in Table 8-17.

Australian Industry Participation Policy

The Joint Venturers have prepared a public policy regarding the support of Australian Industry for the Development (ChevronTexaco Australia 2003b, Appendix 6).

This policy benefits Australian industry, by:

- providing information and project briefings to Australian industry so that local suppliers have adequate time to identify potential opportunities and establish their competitive position
- assisting Australian industry in forming strategic joint ventures or alliances with offshore companies
- establishing a supplier diversity program and work with regional organisations, Indigenous organisations and Industrial Supplies Office to establish links between the Gorgon Development and local business, including a capability register and capacity building activities.

This issue is discussed further in the section on management of economic impacts (refer to Chapter 15).

Petroleum Resource Rent Tax

The Joint Venturers will be liable to pay Petroleum Resource Rent Tax (PRRT) to the Commonwealth Government of Australia. Royalty payments from the NW Shelf project are shared between the Commonwealth and Western Australia under a special arrangement. In the absence of a revenue sharing agreement, the Commonwealth will derive most of the tax revenue flowing from the Gorgon Development.

Greenhouse Policies

The *Barrow Island Act 2003* requires the Joint Venturers to submit proposals for management of carbon dioxide recovered from gas processing, by injection or sale. In the absence of such proposals, the Minister may decide not to consider proposals for activities and infrastructure on Barrow Island. The Act also contains clauses to enable disposal of carbon dioxide by injection, as the legal status of carbon dioxide disposal has been unclear.

The Western Australian Greenhouse Strategy was released in September 2004 (Western Australian Greenhouse Task Force 2004). The document contains a series of recommended 'Greenhouse Response Actions', some of which would apply to the proposed Development.

Currently there are no Commonwealth requirements for greenhouse gas management, although the Joint Venturers are participating in various voluntary programs.

Table 8-17:
Barrow Island Act Economic Conditions

Condition	Purpose
Section 7 – Proposals	• The Joint Venturers should submit detailed proposals for relevant activities and infrastructure. • If the proposals do not include a proposal to inject carbon dioxide recovered during gas processing, the Minister may decide not to consider the proposals. • This section links project approval with disposal of carbon dioxide from gas processing. It is discussed further in the section on greenhouse gas emissions.
Section 11 – Net Conservation Benefits	• Total amount of $40 million, indexed in accordance with the Consumer Price Index (CPI). • Special purpose Trust Account to be established pursuant to section 69 of the Western Australian *Conservation and Land Management Act 1984* (CALM Act). • Arrangements subject to agreement between Joint Venturers and the Barrow Island Minister in consultation with the CALM Act Minister. • Any proposal to increase the nameplate capacity of the LNG or other production facilities will attract a proportional increase in the amount to be paid. • This section of the Agreement is very important, as it seeks to establish a mechanism for economic management of the risks to conservation values.
Section 12 – Cost Recovery for Department of Conservation and Land Management	• This section requires the project to pay for additional costs to the Department of Conservation and Land Management. These costs include such aspects as monitoring and the salary of agreed CALM staff on Barrow Island.
Section 15 – Local Content	• Report regularly to the Minister on local content. • In summary, this section seeks to increase local content, and specifically, the employment of local workers from the Pilbara region. The Industry Participation Policy discussed below also addresses this point. This issue is discussed further in the chapter on management of economic impacts.
Section 17 – Domestic Gas	• Proposals for a domestic gas project by 2010, and first gas by 2012. • Process for determining whether domestic gas is commercially viable. • This section seeks to commit the Joint Venturers to producing gas for the domestic market. In particular, it recognises the risk that domestic gas may not be commercially viable, and sets out a process for determining this in the event of a disagreement.
Section 19 – No Discriminatory Charges	• No discriminatory taxes, rates or charges beyond those in the Agreement. • This section prevents state or local governments from applying discriminatory charges. However this does not appear to preclude general taxes or charges (such as carbon charges).