12. RECEIVING ONSHORE ENVIRONMENT: LNG FACILITIES

12.1 Introduction

This chapter provides a description of the onshore physical and biological environment associated with the LNG Facilities site and environs.

The onshore component of the LNG Facilities is located between the villages of Boera and Papa on Caution Bay, 20 km northwest of Port Moresby in the Central Province (Figure 12.1 and see also Figure 4.1). The site is vacant land that will be entirely contained within a lease perimeter fence to the north, east and south, and the coastline to the west. An existing public roadway provides access between the site and Port Moresby.

The landform is a coastal plain with low hills of predominantly savanna and grassland, sloping gently seaward. It was largely cleared of vegetation in the early 20th Century for agricultural purposes (mainly cattle grazing) but is no longer actively used for agriculture. The majority of the area remains substantially modified: the frequent grassfires during the dry season have restricted the recovery of the eucalypt woodland typical of the unmodified surrounding area. A coastal strip of mangroves exists on the shoreline, which includes beach ridges that support forest patches and grassland. Behind (to landward) of the mangroves and beach ridges are open mudflats that receive intermittent tidal inundation during extreme spring high tides via the Vaihua River and tidal creeks, but when not inundated, become dried and are then called saltflats. Behind the swamps and mudflats, the land rises gently into savanna grassland vegetation that has been invaded by weeds (Plate 12.1). Further inland, open eucalypt *Melaleuca* woodland occurs on low-lying hills, and patches of riparian forest and grassland occupy riverine areas. The Vaihua River, North Vaihua River and Karuka Creek are located in the area of the LNG Facilities site and discharge to the sea via the Vaihua and the North Vaihua estuaries. Karuka Creek flows to Mokeke Creek and then to Mokeke Creek estuary (see Figure 12.1).

The area is used by local people from the coastal villages for gardening and fishing along the coast, as well as firewood and mud crab collection along the mangrove coastal strip.

Other remnant vegetation includes areas of riparian forest that persist along the river between the mangroves and Lea Lea Road and isolated *Pandanus* and low trees on shallow drainage lines.

A variety of distinct habitats occurs but with few fauna recorded at the LNG Facilities site (see Section 12.3, Terrestrial Biological Environment, and Appendix 12, Biodiversity Impact Assessment), probably due to the disturbed overall habitat quality. However, the estuarine, freshwater and terrestrial habitats of the Vaihua River are exceptions, providing a seasonal habitat for a wide variety of waterbirds, including migratory shorebird species. The estuaries support a higher abundance and diversity of aquatic fauna than any other habitat on the site (see Section 12.4, Aquatic Biological Environment, and Appendix 13, Aquatic Fauna Impact Assessment).

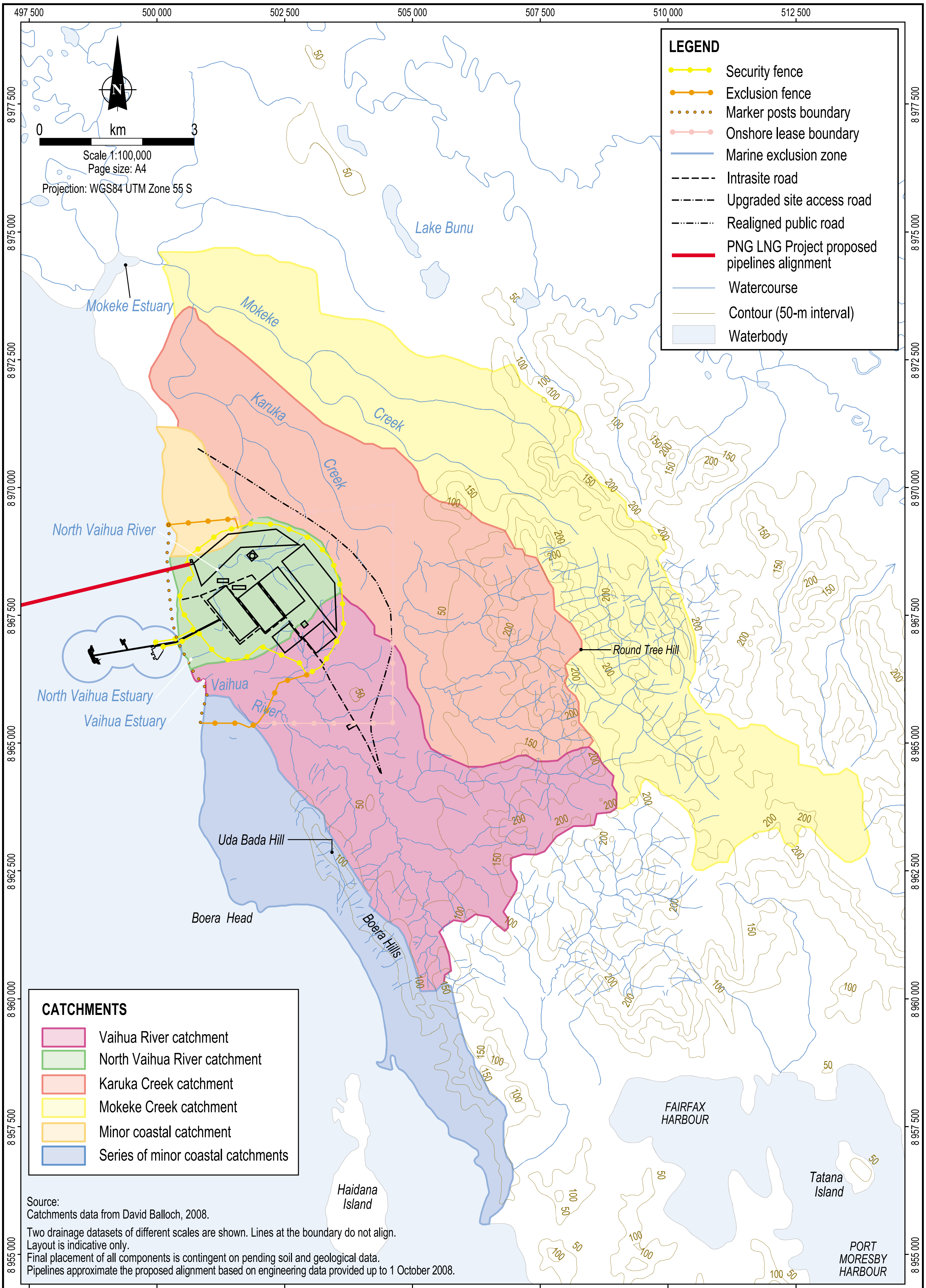

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Plate 12.1
Grasslands on the LNG Facilities site

Plate 12.2
Mangroves at the LNG Facilities site

Plate 12.3
Backwater at the LNG Facilities site

12.2 Physical Environment

The physical environment of the LNG Facilities site and environs is described by location and geomorphology (Section 12.2.1), landforms (Section 12.2.2), tectonic setting and regional seismicity (Section 12.2.3,), geology and hydrogeology (Section 12.2.4), soils (Section 12.2.5, Soils), climate (Section 12.2.6), river systems and hydrology, bed sedimentation and water quality (Sections 12.2.7, 12.2.8 and 12.2.9, Water), noise (Section 12.2.10) air quality (Section 12.2.11), and visual setting (Section 12.2.12).

12.2.1 Geomorphology

Elevations on the site range from sea level along the coastal strip and along the banks of the Vaihua and North Vaihua rivers to 75% of the site at elevations between 5 and 50 m above sea level. Overall, the topography slopes from the hills in the east down to the coast in the west where there is a gradient of generally less than 1°.

A number of north-northwest to south-southeast trending hills, referred to as the Boera Hills, exist to the south of the site. The orientation of these hills reflects the general topographic trend of the area and its local geology, which is more apparent in the southern and eastern parts of the site where relief is greatest.

In the northwest part of the site (in the vicinity of the former Fairfax Cattle Station), the land is termed as gilgai country, which is a geomorphological term for flat country (less than 1° gradient) dominated by mounds and depressions on black cracking clays (Golder, 2007). Gilgais form on clay soils (vertisols, soils with more than 35% clay content) due to the swelling of the clay when wet and subsequent shrinkage upon drying. Characterisation of soils on the site is given in Section 12.2.5, Soils.

Further east (i.e., east of the section of the public Lea Lea roadway on the site), the terrain undulates between 30 and 50 m. Bedrock is close to the surface in the low rises and rock outcrops at crests. In between low hills, the land is relatively flat and black soil development is apparent. Moving further east, there are a number of low hills that lead into gently rolling terrain in the north-central part of the site where the vegetation becomes savanna woodland with scattered eucalypt trees.

The western edge of the site consists of a 100- to 600-m-wide strip of coastal mangrove flats and, along the estuaries of the Vaihua and North Vaihua rivers, riverine mangroves penetrate inland by up to 1,500 m and 1,850 m respectively (Plate 12.2). Landward of the coastal and riverine mangroves are areas subject to occasional tidal inundation that form, depending on the volume of water, a series of mudflats or a backwater system (Plate 12.3). This land has become separated from the sea by a series of sandy beach ridges that rise to approximately 4 m above highest astronomical tide[1]. There are two main backwaters present along the coastal boundary of the site and they are referred to as the landward backwater (back swamp) and the seaward backwater (seaward swamp) (Golder, 2007).

[1] The highest level of water that can occur under any combination of astronomical conditions.

The LNG Facilities site is surrounded by dominant rocky headlands with Redscar Head to the north and Boera Head to the south.

12.2.2 Landforms

The LNG Facilities site falls within the Southern Plains and Lowlands Region of Papua New Guinea that extends from the south coast, north to the foothills of the Central Ranges. Very poorly drained or swampy alluvial plains dominate most of this region. These plains are traversed by meandering river channels with off-channel waterbodies, such as oxbow lakes and swamps, on the floodplain. Near the coast, there are extensive tidal flats that are interspersed with narrow bands of beach ridges and swales. Mangrove swamps form part of these tidal flats. Landforms are described in detail in Appendix 17, Soils and Rehabilitation Impact Assessment, and environmental impacts and mitigations in Section 20.2, Soils and Landforms.

The LNG Facilities site and surrounding area is characterised by three distinct land systems identified in the CSIRO Land Research Series No. 14 for the Port Moresby−Kairuku area (Mabbutt et al., 1965).

Figure 12.2 shows landforms derived from the PNGRIS database, which support these land systems.

12.2.2.1 The Coastal Papa System

This system consists of tidal flats, saltflats, estuarine mudflats, dunes and beach ridges on grey clayey or sandy peats to brown sticky clays. It is vegetated with mangroves, other salt-tolerant communities and grassland (Plate 12.4).

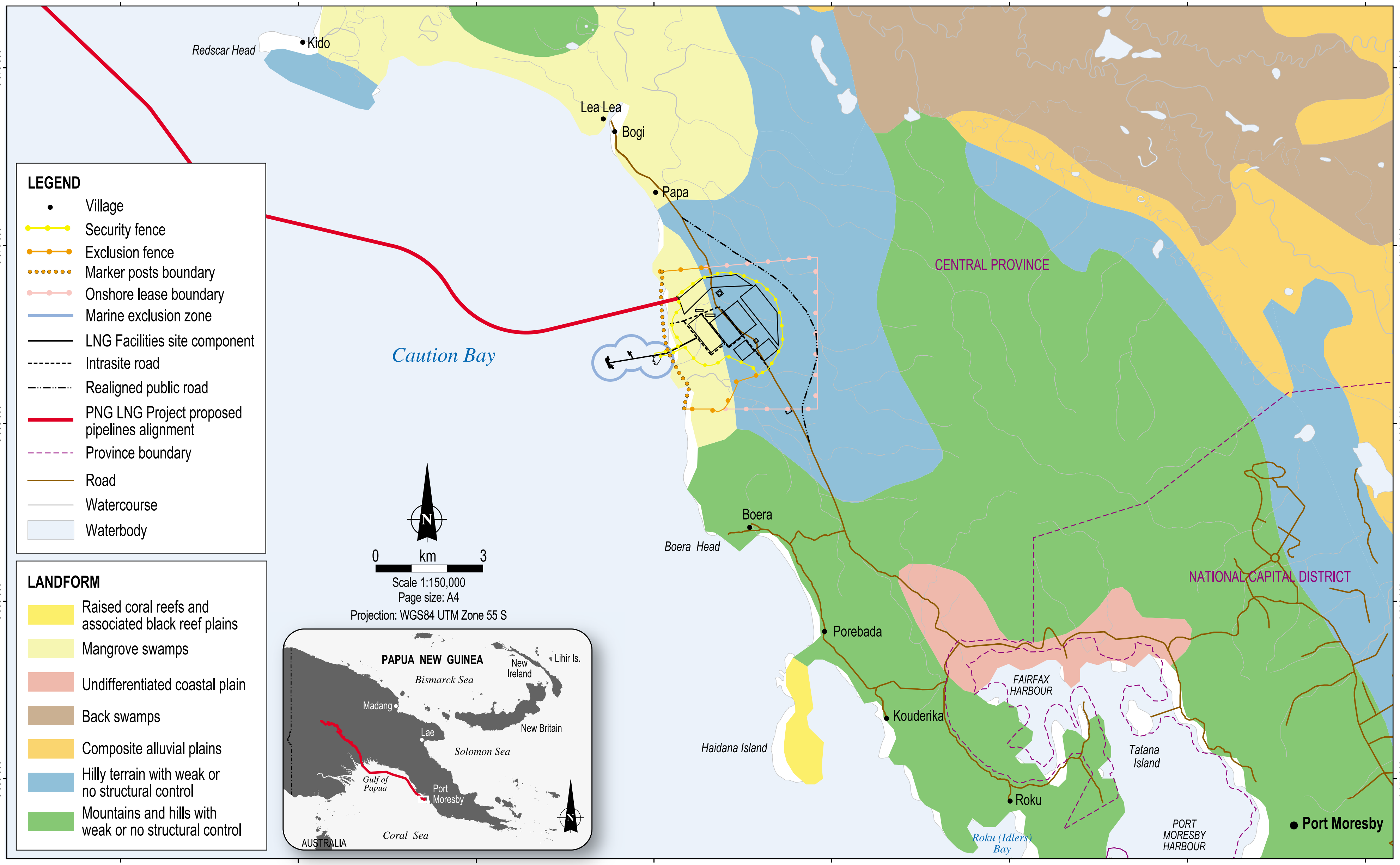
12.2.2.2 The Boroko System

The Boroko System lies inland from the Papa system and comprises alluvial plains with cracking grey soils and floodplains with olive silty clays. It is largely cleared (hilly terrain with weak or no structural control) (Plate 12.5).

12.2.2.3 The Fairfax System

This system covers the eastward (inland) and southern parts of the LNG Facilities site. It consists of low plateaus and hills with undulating plains with brown clay soils, and is dominated by open eucalypt savanna with narrow strips of riparian forest along the seasonal waterways (hilly terrain with weak or no structural control leading onto mountains and hills with weak or no structural control) (Plate 12.6).

Environmental impacts and mitigations associated with the project affecting the described landforms are discussed in Section 20.2, Soils and Landforms.



Source: Landform data from PNG Resource Information System, 1998.
Note:
Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

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Landforms of the LNG Facilities site and surrounds

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Plate 12.4
Mudflats, dunes and beach, and mangroves, typical of Coastal Papa System (northern end of study area)

Plate 12.5
Grassland and cleared terrain (central part of LNG Facilities site), typical of Boroko System

Plate 12.6
Savanna on hilly terrain near Boera (eastern part of LNG Facilities site), typical of Fairfax System

12.2.3 Tectonic Setting and Regional Seismicity

Figure 10.4 shows the tectonic plates and major fault lines of Papua New Guinea. The LNG Facilities site is located in the northern portion of the tectonic Indo-Australian tectonic plate.

The seismicity of the project area is classified as Zone 4, which is the least seismically active classification under PNG building standards (PNGS, 1982). Figure 10.5 shows the location of all earthquakes recorded in PNG from 1900 through 2007. There is no record of earthquakes centred in the vicinity of the LNG Facilities site, with most seismicity activity located along the east coast of Papua New Guinea.

A thorough geohazard analysis will be conducted as part of the FEED detailed design stage (see Chapter 27, Environmental Hazard Assessment).

12.2.4 Geology and Hydrogeology

12.2.4.1 Geology

Figure 12.3 illustrates the geology of the LNG Facilities site.

Southeast Papua New Guinea is geologically complex, containing not only metamorphosed sedimentary rocks (course and fine grained) of Cretaceous and Jurassic age but also many basic igneous Tertiary rocks. The hills and bedrock in the region generally comprises siliceous argillites, cherts, calcarentites, mudstones, basalts and tuffs, as well as gabbro intrusive in some areas. Alluvial deposits have formed within the valleys and depressions in the region of the LNG Facilities site. Estuarine deposits dominate the area around Lea Lea and Papa, including the coastal strip of the LNG Facilities site and along river mouths of the Vaihua and North Vaihua rivers, which discharge to Caution Bay. The alluvial deposits attain thicknesses of up to 25 m (Rooke, 1988a). Colluvial and talus deposits exist at the base of the hills, and these deposits inter-finger with alluvial clays on the coastal plain (Rooke, 1988b).

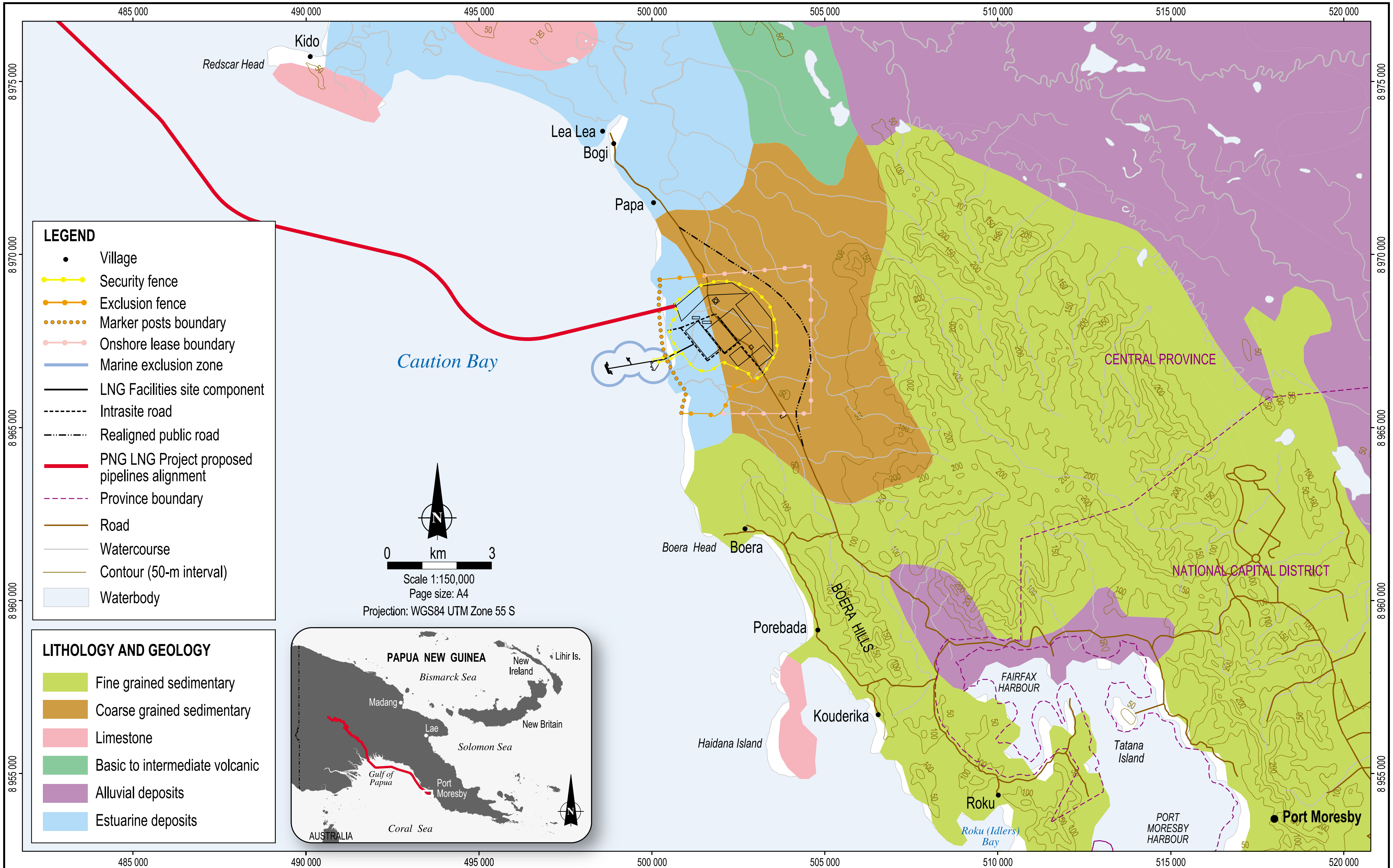
Reef flats fringe the coast at Caution Bay. Fine grey sediments accumulate on the surface of the reef and muds are captured within the mangroves.

The Boera Hills to the south of the facilities site have been mapped by Mabbutt et al. (1965) as Cretaceous chert, limestone, siltstone and tuff that can also contain volcanic flows. These limestone ridges do not outcrop on the site. However, it is possible that they may be present at depth beneath the Holocene and Pleistocene reef and seabed sediments fringing the site.

The generally flat and geologically stable conditions of the site (see Section 12.2.3, Tectonic Setting and Regional Seismicity) present a solid base for the development of the facilities without requiring major earthworks and associated soil and spoil management issues that a more hilly or complex site would involve. Other features of the site that resulted in it being preferred over other sites investigated are discussed in Section 7.5, LNG Facilities Location Options.

12.2.4.2 Hydrogeology

The main groundwater resources in the vicinity of the LNG Facilities site are associated with alluvial deposits of the coastal plain. Potential alluvial aquifers hosted by these sediments are 5 m to 15 m thick and are typically overlain by 5 m to 10 m of low permeability clayey sediments,



Source: Landform data from PNG Resource Information System, 1998.
Note:
Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
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Lithology and geology of the LNG Facilities site and surrounds

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which have the capacity to retard upward hydraulic gradients and the mobility and infiltration of contaminants, if released (see Appendix 16, Groundwater Impact Assessment).

A survey of baseline conditions at five groundwater wells, including three on the LNG facilities site and one each at the neighbouring villages of Papa and Boera, where residents are dependent on groundwater for the majority of water supply. In terms of WHO (2004) water guidelines for salinity groundwater, the results showed that the water was unpalatable at one well at Papa village and one on the LNG Facilities site, but palatable at the other three sites (see Appendix 16, Groundwater Impact Assessment). Levels of manganese and lead were elevated above drinking water standards at one well in the centre of the LNG Facilities site and at Boera village respectively; otherwise metal concentrations were at levels below the guidelines. Generally, better quality groundwater was present on the southern parts of the site.

Previous assessments of groundwater resources identify a well that draws groundwater from a calcareous silty sandstone that possibly represents a fractured rock aquifer. This well is low yielding but produces the freshest groundwater reported during the study (Kidd, 1975). Investigations by Golder Associates (Golder Associates, 2007) identified that groundwater levels are shallow under the gilgai soils. These soils are located in depressions with greater exposure.

Results of testing during the present and previous studies suggest that groundwater supply for the project is not feasible and has been discounted as a source of supply: yields are low, quality brackish and would require some treatment to be used for potable purposes.

Environmental impact and mitigation measures associated with the project and this resource are described in Section 20.3, Groundwater.

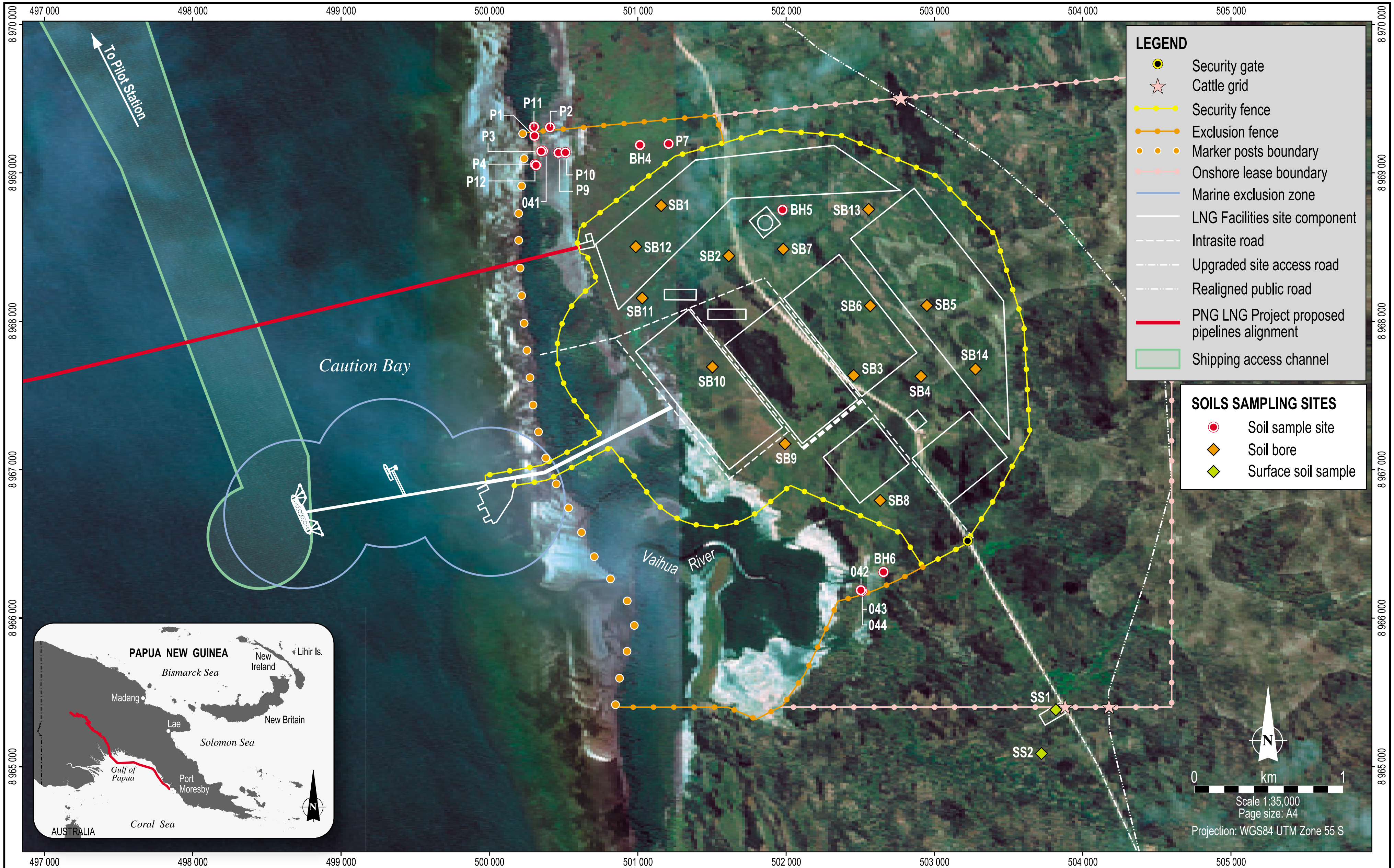
12.2.5 Soils

The soil impact assessment conducted for the LNG Facilities site involved identification of soil profiles, analysis of selected soils for baseline fertility properties and testing for acid sulfate soils in selected coastal swamps and soil stability (Appendix 17, Soils and Rehabilitation Impact Assessment). Soil sampling sites are shown in Figure 12.4.

Results of the study identified two main soil orders: entisols and vertisols.

Entisols form in the swamps and beach areas of the site and are typically very young soils with little or no profile except for a thin humic surface horizon. They are comprised of littoral and fluviatile deposits, including gravel, sand, silt and clay. The sandy soils of the beach ridge comprise thick, poorly graded sands containing shell fragments. The coastal mangrove soils consist of silt- or clay-rich sedimentary layers with a high content of finely dispersed organic matter intermixed with thin organic layers that laboratory analyses have confirmed are soils with acid sulfate soil potential. Acid sulfate soils contain naturally occurring iron sulfide that is stable in reduced oxygen conditions below the watertable and are commonly associated with tidal mangroves. Oxidation of the disturbed soil commonly results in the formation of leachable sulphuric acid. These acids if not managed may have a localised impact on vegetation, soil, surface water and groundwater (see Section 20.2, Soils and Landforms).

Vertisols occur inland from the coastal strip and are characteristic of areas with low and seasonal rainfall. This soil order is usually found on calcareous rocks, such as limestone and shale, and on



Source: Soil sample site data from Howard Rogers, 2008. Soil bore and surface soil sample data from SKM, 2008.
Note:
Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

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LNG Facilities soil sampling sites

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alluvial or colluvial deposits. Vertisols are uniformly textured soils with a high clay content and very low permeability, and are subject to shrinking and cracking on a seasonal cycle associated with wetting and drying. They are known as ‘black cracking clays’ and may be dispersive and highly eroded if disturbed (Plate 12.7). Usually vertisols have a high sodium content (sodic soils) that additionally causes the clays to swell and disperse. These soils persist across most of the LNG Facilities site. The surface clays form polygonal cracking patterns that can become over-consolidated with material falling into the cracks. In the wet season, these cracks close resulting in pressures that can cause the ground surface to heave. Cracks have been noted up to 50 mm wide and up to 0.5 m deep. Sometimes when water drains into open cracks causing the clay to erode, crabholes (erosion holes) develop in the clay surface.

All of the soils tested at the LNG Facilities site and surrounding area are susceptible to erosion if exposed to high rainfall intensity. However, sandy soils occurring on the site have a high porosity and high rates of infiltration, which reduces their susceptibility to erosive rainfall. The black cracking clays (vertisols) may be dispersive[2] because of elevated sodium levels causing the clays to swell and disperse (Appendix 17, Soils and Rehabilitation Impact Assessment). In a comprehensive study on soils of Papua New Guinea, black cracking clays were regarded as having the highest erodibility risk of all PNG soils (Bleeker, 1983).

A soil contamination assessment was conducted on the LNG Facilities site as part of the groundwater impact assessment for the project (Appendix 16, Groundwater Impact Assessment). The assessment indicated there is a potential for impact to soil and water associated with the past agriculture, although documentation of historical agricultural activities on the land stating that activities causing contamination were not identified. There was no visual evidence of chemical contamination on the site. Soil pH was neutral to slightly alkaline and the soil analytical program confirmed that, of the sites sampled, there was no evidence of contamination that could potentially pose a risk to human health (Appendix 16, Groundwater Impact Assessment).

Potential environmental impacts to soils due to project activities and proposed mitigation are described in Section 20.2, Soils and Landforms.

12.2.6 Climate

The climate of the Port Moresby region is sufficiently representative of climate conditions where the LNG Facilities site is located. A weather station is in operation at the LNG Facilities site but this does not have complete data sets for analysis[3].

The climate of the Port Moresby area is seasonal, with a dry southeast trade winds season from May to October and a wet northwest monsoon season from December to March. April and November are the transition periods.

Monsoon surges with strong northwest winds have been observed in the region of Port Moresby. Tropical cyclone frequency in the low latitudes decreases westward towards the PNG mainland.

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[2] Dispersive soils are soils that are structurally unstable and disperse in water into basic particles i.e., sand, silt and clay. Dispersible soils tend to be highly erodible and present problems for successfully managing earth works.

[3] The weather station was established in February 2008 and will be used for input to baseline monitoring at the site in the future.

Plate 12.7
Black cracking clays (vertisols) on the site

Plate 12.8
The mouth of the Vaihua River

Plate 12.9
Remnant pool of the Vaihua River

The wind patterns in PNG are consistent. Strong wind speeds are rarely destructive and tropical cyclones with surface winds of greater than 34kt (62km/h) rarely occur (McAlpine et. al., 1983).

12.2.6.1 Air Temperature

Ambient air temperature assessment is important for engineering design of the LNG Plant and facilities.

Table 12.1 provides the average minimum and maximum daily temperatures in Port Moresby for each month.

Table 12.1 Air temperature statistics for Port Moresby

°C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Daily Minimum	24	24	24	24	24	23	23	23	23	24	24	24
Average Daily Maximum	32	31	31	31	30	29	28	28	29	30	31	32

Source: BBC Weather, 2006

The coolest months are July and August when the mean daily maximum and minimum are 28°C and 23°C respectively. The warmest months are December and January when the mean daily maximum and minimum are 32°C and 24°C respectively.

12.2.6.2 Rainfall and Humidity

Port Moresby has a mean annual rainfall of around 1,200 mm, which can drop below 1,000 mm in a drought year. This is a reflection of the areas dry subhumid classification of 1,000 to 1,500 mm per year for the area (McAlpine et. al., 1983).

Table 12.2 provides the mean rainfall and mean number of rain days occurring in Port Moresby for each month.

Table 12.2 Rainfall statistics for Port Moresby

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Rainfall* (mm)	192	141	190	105	56	22	14	12	14	15	40	98
Mean Number of Rain Days*	18	16	18	11	9	**6**	4	4	5	5	6	12

*Climatological information is based on monthly averages from 1973 to 2007.

Source: World Weather Information Service, 2008

Mean monthly rainfall is highest from December through April during the wet season. On average, about 80% of rainfall falls within this period.

Humidity generally ranges between 60% and 80% throughout the day and during most of the year. The highest monthly humidity percentages are recorded during the period February to May (McAlpine et. al., 1975).

12.2.6.3 Evaporation

Annual evaporation from the Port Moresby area has been recorded at 1,716 mm (Mc Alpine et. al., 1975). This is high in comparison to other recorded sites in Papua New Guinea where estimates range within the low to mid 1,000 mm. The data provided in Table 12.3, indicates evaporation is highest during November, December and January.

Table 12.3 Mean monthly evaporation recorded at Port Moresby

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Evaporation[1] (mm)	170	139	144	120	117	110	121	131	140	162	178	184	1716

Source: McAlpine et. al., 1975.

1. Actual data on evaporation for Port Moresby are measured using the Australian Standard Sunken Tank method (McAlpine et. al., 1975).

12.2.6.4 Winds

Wind patterns in the Caution Bay area are highly seasonal and influenced by the northwest monsoon and southeast trade winds.

Global Environmental Monitoring Systems Pty Ltd (GEMS) analysed three years of offshore Mesoscale Limited Area Prediction System (MesoLAPS) wind data and the wind data collected from the AWS near Caution Bay (Appendix 22, Hydrodynamic Modelling). Results are summarised in Table 12.4. The results identified three main features of the ambient wind conditions in Caution Bay:

- The dominance of the southeast trade winds offshore.
- The existence of katabatic winds from the northeast off the coastal topography.
- The difference in the wind regime between onshore and offshore sites.

Table 12.4 Summary of the analysis of MesoLAPS and AWS data

Parameter	3 years of MesoLAPS Data (July 2005 to July 2008)	3 months of AWS Data (February 2008 to April 2008)
Mean Hourly Wind Speed	4.8 m/s (17.3 km/h)	3.1 m/s (11.2 km/h)
Mean Wind Direction	300 deg	85 deg
Average of Top 100 Wind Speeds	11.5 m/s (41.4 km/h)	8.8 m/s (31.7 km/h)
Average Direction of Top 100 Wind Speeds	314 deg	134 deg

Port Moresby also experiences gubas during the northwest season (see Section 11.2.3.1, Winds) about five times a year (McAlpine et. al., 1983).

The incidence of cyclones is discussed in Section 13.2.3.4, Waves.

12.2.7 River Systems and Hydrology

This section describes the existing physical characteristics of the river systems and hydrology of the LNG Facilities site and environs. It is based on Appendix 14, Hydrology and Sediment Transport Impact Assessment.

The LNG Facilities site and associated offsite infrastructure is located across three catchments:

- Vaihua River.
- North Vaihua River.
- Karuka Creek.

These river systems and catchments are briefly described below. Potential impacts of land disturbance and modification of the hydrological regimes of these three waterways are discussed in Section 20.4, Hydrology and Sediment Transport, together with the proposed mitigation measures and residual impacts.

The lower estuarine reach of Mokeke Creek is also mentioned here, as Karuka Creek is a tributary of Mokeke Creek.

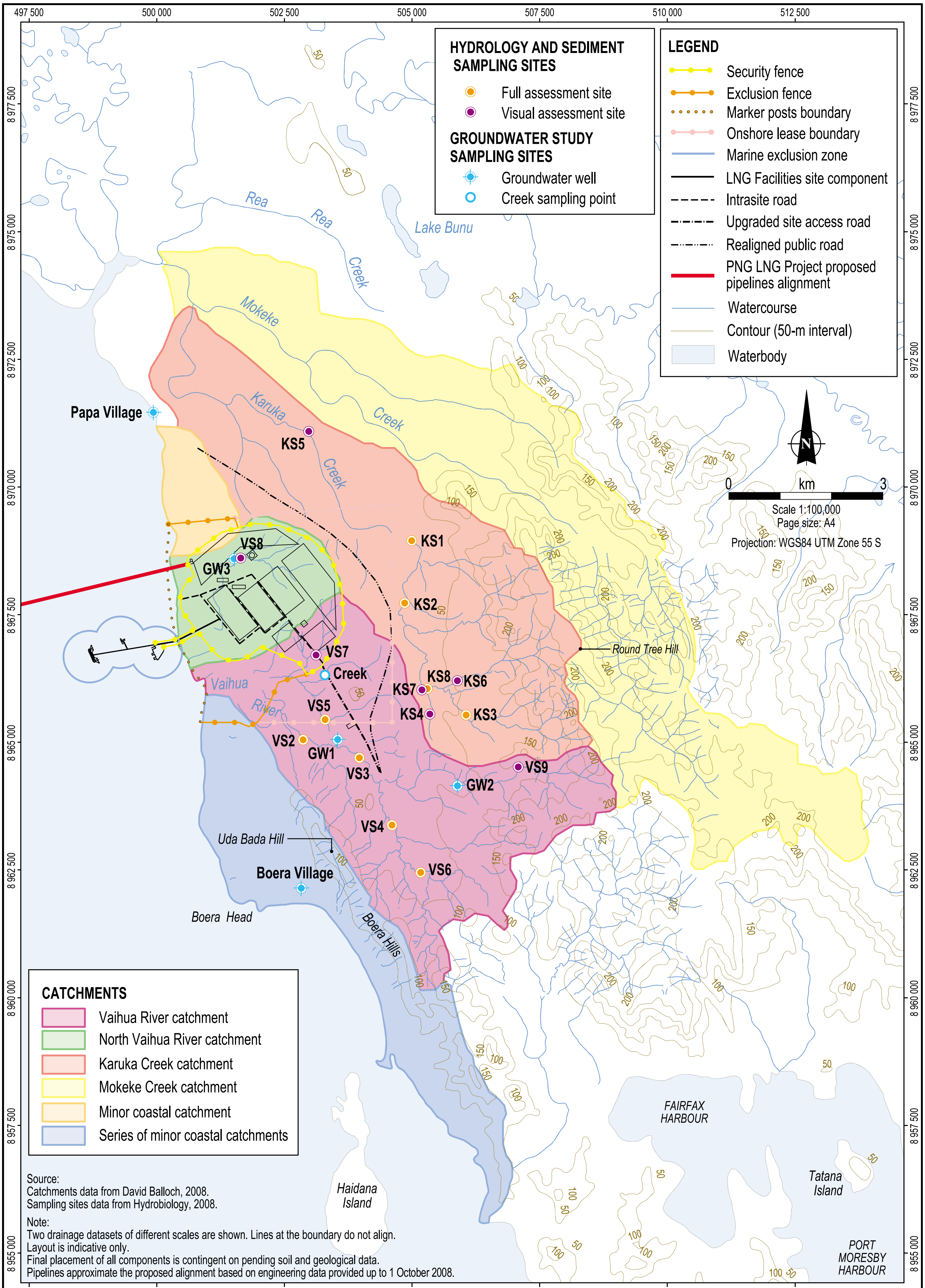
12.2.7.1 Vaihua River

The Vaihua River is located within a 1,950-ha coastal catchment and drains into the Vaihua River estuary (Plate 12.8 and Figure 12.5). A minor part of the LNG Facilities site is located within the catchment of the Vaihua River.

Hydrology

The hydrology of the Vaihua River reflects the climate of the region, with highest flows occurring between December and March during the wet northwest monsoon season, low or intermittent flows between May and October during the dry season, and moderate flows during the transitional months of November and April. The intermittent flows in the main channel of the Vaihua River in the mid to upper catchment during the dry season leave remnant but isolated pools of standing water that result from past flows (Plate 12.9) and minor groundwater recharge. However, most tributary streams of the Vaihua River are ephemeral and flow for only short periods following rainfall (Mc Alpine et. al., 1983). The relatively impervious nature of the high-clay-content soils in the catchment results in high rates of rainfall runoff and causes streamflows to rise and fall rapidly. Many of these tributary streams have small cross-sectional areas that are incapable of supporting larger flows, and frequent overbank inundation of floodplain areas occurs.

At the time of the hydrology and sediment transport assessment study (Appendix 14, Hydrology and Sediment Transport Impact Assessment), the main channel of the Vaihua River was not flowing and is considered an intermittent stream. Notwithstanding, peak flows that are expected to occur every 2, 5, 10, 25, 50 and 100 years for the Vaihua River were calculated using the regional flood-frequency equations developed by the PNG Flood Estimation Manual (SMEC, 1990). The bankfull, two-year recurring peak flow (Q2) at site VS2 (see Figure 12.5) was estimated to be 30 m^3/s. Peak flows above this value enter the floodplain by overbank flow.



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Natural erosion by mass movement is absent in the area of the North Vaihua River subcatchment located within the LNG Facilities site, owing to a lack of both steep slopes and high rainfall. Natural erosion of soils and in-stream bed sediments is more episodic and only occurs during infrequent flood flows. River bank erosion by streamflow undercutting has led to some minor localised sediment inputs to the river main channel in the mid and lower reaches of the Vaihua River. However, most bed sediment material is sourced from upstream river reaches.

Catchment Geomorphology

The catchment upstream of the Vaihua River estuary has been divided into three geomorphic units for description and environmental assessment: floodplain channels, undulating landscape channels and upper reaches of the catchment (Plate 12.10).

Floodplain Channels

This portion of the catchment consists of the meandering system flowing through a flat alluvial floodplain (gilgai country), which is characterised by cracking clays and poor drainage. The Vaihua River and its tributaries in this area are generally incised with a high potential for bank overflow.

Channel slopes are low (less than 1°) and the main channel banks are generally composed of material with high clay content. Some banks consist of several sedimentary units, indicating some past channel downcutting and lateral movement. Channel bed sediments are composed of large amounts of sand and gravel, ranging from clayey sands, clayey gravels and silty sands. Only scattered cobbles were observed in the main channels of the Vaihua River and its tributaries, suggesting a low-energy system and low potential for sediment transport.

Riparian vegetation is scattered along some river reaches, offering little stabilisation for river and stream banks. In other areas, pasture grasses encroach on the river banks and provide stability.

Undulating Landscape Channels

This portion of the Vaihua River catchment includes a meandering channel within undulating lowlands, influenced in some locations by the surrounding terrain (upstream reaches of the Vaihua River). The channel is narrower with lower and more gradual stable banks (of 1 to 2°), similar in composition to those within the floodplain system. The bed of the main channel is largely composed of coarse gravel with some eroding base material upstream.

Upper Reaches

The upper reaches section of the Vaihua River catchment is a partly confined system within low hill terrain (the headwater tributaries of the Vaihua River). This section is characterised by a much higher energy flow due to a greater channel slope (greater than 3°) and presence of confined, steeper valley sides. The predominance of high flows and stormflows in the upper catchment streams is reflected by the presence of coarser substrata (i.e., cobbles and boulders) in the main channels. The stream banks are composed of bedrock, which provides high stability. Dense vegetation in this area also assists in the stability of the system.

Plate 12.10
Upper reaches of the Vaihua River

Plate 12.11
Flowing reach of Karuka Creek

Plate 12.12
Noise and air quality monitoring equipment
at Metago Bible College

12.2.7.2 North Vaihua River

The North Vaihua River is located within a small 550-ha coastal catchment and drains into the North Vaihua River estuary (see Figure 12.5). Most of the LNG Facilities site and associated offsite infrastructure are located within this small catchment.

The flow regime of the main channel of North Vaihua River and its tributaries is intermittent with flows occurring immediately after rainfall, with most annual flows associated with the wet season from December to March. The catchment presents a distinctive landscape of dry watercourses and drainage lines. Some of the drainage lines are indistinct, and sheetflow across the grassland slopes occurs during rainfall. During the wet season, flood flows in the North Vaihua River main channel overflow into the floodplain and recharge the backwater systems, such as the mudflats, as well as the coastal and riverine mangroves.

The upper reaches of the North Vaihua River estuary landward of the mangroves are similar to those of the Vaihua River estuary and are dominated by very flat, expansive clay and mudflats with wide but shallow distributary channels that are inundated periodically during high tides and high rainfall events. Channel slope is gradual (less than 2°) and channel size is smaller than the Vaihua River, with bed sediments consisting of silts and clays from the banks, and sands and gravels derived via sediment transport from upstream reaches. With the exception of the lower banks, the banks are stable and largely supported by dense grasses.

12.2.7.3 Karuka Creek

Karuka Creek (known locally as Kauka Creek) is located within a 2,325-ha inland catchment and drains to Mokeke Creek about 1 km upstream from the Mokeke Creek estuary (see Figure 12.5). Sections of the proposed public road upgrade and re-alignment are located within the catchment of Karuka Creek.

Karuka Creek is an irregular, meandering system migrating from a narrow valley. The creek and its tributaries are more confined than the other two catchments in the region, with only a narrow floodplain existing throughout the catchment. All Karuka Creek tributaries are intermittent or ephemeral, flowing only for short periods and following rainfall (Plate 12.11). The eastern tributaries of this system are of higher energy, draining steeper catchments of the north-northwest to south-southeast trending ranges to the east of the LNG Facilities site. The western tributaries are only minor depressions draining small, gradually sloping catchments. The bed sediments of the eastern tributaries consist of cobbles or gravels and those of the western tributaries comprise clays and silts. Most of the banks of the main channels of Karuka Creek and its tributaries are stable being composed of consolidated sediments with high silt and clay content (Appendix 14, Hydrology and Sediment Transport Impact Assessment). Some exceptions were reaches where the banks contain multiple facies of old bed material. Channel bed slope is low (less than 2°) in all reaches except the eastern tributary headwaters.

12.2.7.4 Mokeke Creek

The catchment of Mokeke Creek has a total area of 3,125 ha and lies to the east of Karuka Creek catchment and the LNG Facilities site. There are no project components located within this catchment. However, Karuka Creek is a major tributary of Mokeke Creek and enters the latter 1 km upstream of the Mokeke River estuary. Consequently and, due to the potential influence of

Karuka Creek, the Mokeke River estuary was sampled as part of the LNG Facilities site assessments (Appendix 15, Water and Sediment Quality Baseline Impact Assessment).

12.2.8 Bed Sediment Characterisation

Bed sediments from both the freshwater and estuarine reaches of the Vaihua and North Vaihua rivers, and the catchment watercourses of the Karuka Creek were sampled (see Figure 12.5) and have been assessed in accordance with the ANZECC / ARMCANZ (2000) Interim Sediment Quality Guidelines[4] (ISQGs) for the protection of aquatic ecosystems. Bed sediment metal concentrations from all tested catchments were generally below the ISQG-low guidelines, indicating that sediment disturbance would have little or no biological impact on the organisms inhabiting that sediment. The following exceptions were, however, recorded:

- Arsenic concentration within the North Vaihua River estuary (saltwater) exceeded the ISQG-low guideline[5] but not the ISQG-high guideline[6].
- Nickel concentrations at all sites except one in the North Vaihua River estuary exceeded the ISQG-low guideline but not the ISQG-high guideline.
- Nickel concentrations at one site within Karuka Creek (freshwater) and one site within the Vaihua River (freshwater) exceeded the ISQG-low guideline as well as the ISQG-high guideline.
- Silver concentrations at all sites exceeded the ISQG-low guideline but were below the ISQG-high guideline.

These concentrations of metals in sediments most likely reflect the local geology of the region as well as some possible historical anthropogenic influence in relation to agricultural and World War II artillery (see Section 16.4.4.2, Non-indigenous Archaeological Sites) use in the area. The effect of construction activities and operations on streambed sediment quality and measures to ameliorate those impacts are discussed in Section 20.5, Water Quality.

12.2.9 Water Quality

This section describes the existing quality of surface waters in the LNG Facilities site and surrounding area.

12.2.9.1 Surface Waters

Appendix 15, Water and Sediment Quality Baseline Impact Assessment, provides baseline water quality characterisation of the river systems within and around the LNG Facilities site. Freshwater and estuarine water have been delineated on the basis of reduction-oxidation (redox) potential, conductivity and salinity. Results of the analyses are provided in Table 12.5 and water sampling locations are shown in Figure 12.6.

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[4] The ISQGs provide values in relation to contaminants that, if exceeded, are a prompt for further investigations to determine environmental risk.

[5] As referenced in the guidelines, when an ISQG-low guideline is exceeded, an adverse effect is occasionally observed.

[6] When an ISQG-high guideline is exceeded, an adverse effect is frequently observed.

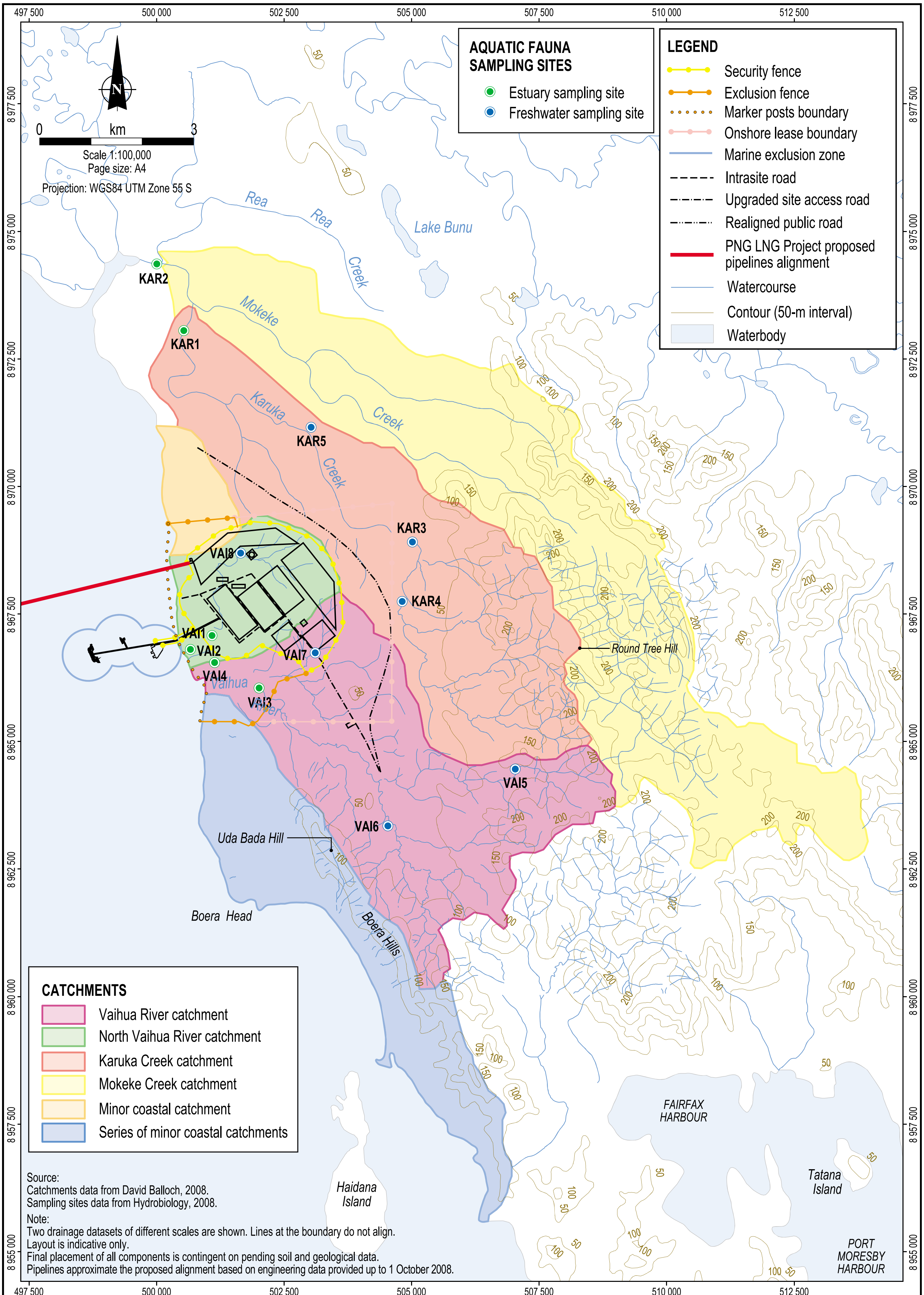
Table 12.5 Quality of surface waters sampled on the LNG Facilities site and environs

Location	Site	pH	Temperature	Turbidity	Oxidation-reduction Potential	Salinity	Conductivity
			(°C)	NTU	mV	ppt	mS/cm
North Vaihua Estuary	VAI1	7.2	26.51	27	287	37.9	56.8
North Vaihua Estuary	VAI2	7.7	28.29	-	242	37.5	56.4
Vaihua Estuary	VAI3	7.6	27.83	21	243	38.0	57.0
Vaihua Estuary	VAI4	7.9	28.34	21	205	37.3	56.0
Karuka Estuary	KAR1	7.0	27.40	40	222	37.5	56.4
Karuka Estuary	KAR2	7.6	28.40	-	205	37.0	55.7
Vaihua River	VAI5	7.5	25.83	-	131	0.6	1.2
Karuka Creek	KAR3	8.1	26.66	-	184	0.4	0.8
Karuka Creek	KAR4	7.7	25.70	-	186	0.5	0.9
Vaihua River	VAI6	8.5	29.20	-	153	0.4	0.8
Karuka Creek	KAR5	8.0	27.68	-	177	0.4	0.8

Source: Appendix 15, Water and Sediment Quality Baseline Impact Assessment. °C = degrees Celsius; NTU = nephelometric turbidity units; mV = millivolts; ppt = parts per thousand; mS/cm = milliSiemens per centimetre.

At the time of sampling in early June (Appendix 15, Water and Sediment Quality Baseline Impact Assessment.), the water quality data show that surface waters within the heads of the estuaries were hypersaline (salinity range 37.0 to 37.9 ppt), suggesting that little or no freshwater flows enter the estuaries during the long dry season and that evaporation rates are high. Surface freshwaters also had very low conductivities (ranging from 0.8 to 1.2 mS/cm). Note also that Schedule 1 of the Environment (Water Quality Criteria) Regulation 2002 for turbidity in freshwater require no alteration greater than 25 nephelometric turbidity units (i.e., above background).

The water quality was analysed by measuring the concentrations of thirteen dissolved metals at the seven saltwater and five freshwater sites (see Table 12.5). In the majority of cases, metal concentrations were too low to detect, that is below the limit of reporting (LOR). Dissolved metal concentrations that were higher than the LOR were compared with two relevant guidelines: Schedule 1 of the Environment (Water Quality Criteria) Regulation 2002 and the Australian and New Zealand Guideline for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). Metal concentrations that exceeded one or more of the guidelines are shown in bold in Table 12.6.



PNG LNG	Date: 31.10.2008 MXD: PNG_LNG_Project_GIS.mxd File Name: 1284_09_F12.06_GIS_HB	Esso Highlands Limited PNG LNG Project	Catchment areas and aquatic fauna sampling locations	Figure No: 12.6

Table 12.6 Comparison of water quality results against guidelines

Saltwater											
Metal	**Units**	**LOR**	**NIC (1)**	**NIC (2)**	**VAI1**	**VAI2lt**	**VAI2ht**	**VAI3**	**VAI4**	**KAR1**	**KAR2**
Aluminium	µg/L	50			<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Arsenic	µg/L	50	50		<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Boron	µg/L	500	2,000		**5,280**	**4,780**	**4,680**	**4,390**	**4,310**	**4,640**	**4,700**
Cadmium	µg/L	5	1	5.5	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Chromium	µg/L	5	10	27.4	<LOR	<LOR	<LOR	6	6	5	6
Copper	µg/L	50	30	1.3	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Iron	µg/L	500	1,000		560	<LOR	<LOR	<LOR	<LOR	500	<LOR
Lead	µg/L	5	4	4.4	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Manganese	µg/L	5	2,000		23	14	12	24	9	44	6
Nickel	µg/L	50	1,000	70	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Selenium	µg/L	50	10		<LOR	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Silver	µg/L	5	50	1.4	11	<LOR	<LOR	<LOR	<LOR	<LOR	<LOR
Zinc	µg/L	50	5,000	15	135	150	<LOR	75	55	<LOR	60
Freshwater											
Metal	**Units**	**LOR**	**NIC (1)**	**NIC (2)**	**VAI5**	**VAI6**	**KAR3**	**KAR4**	**KAR5**		
Aluminium	µg/L	10		55	<LOR	10	<LOR	<LOR	<LOR		
Arsenic	µg/L	1	50	13	<LOR	1	<LOR	1	1		
Boron	µg/L	50	1,000	370	70	60	60	50	60		
Cadmium	µg/L	0.1	10	0.2	<LOR	**0.4**	<LOR	**0.3**	<LOR		
Chromium	µg/L	1	50	1	<LOR	<LOR	<LOR	<LOR	<LOR		
Copper	µg/L	1	1,000	1.4	1	**2**	1	1	1		
Iron	µg/L	50	1,000		<LOR	<LOR	<LOR	<LOR	<LOR		
Lead	µg/L	1	5	3.4	<LOR	**7**	<LOR	<LOR	<LOR		
Manganese	µg/L	1	500	1900	86	9	1	2	43		
Nickel	µg/L	1	1,000	11	<LOR	2	<LOR	<LOR	<LOR		
Selenium	µg/L	10	10	11	<LOR	<LOR	<LOR	2	<LOR		
Silver	µg/L	1	50	0.05	<LOR	<LOR	<LOR	<LOR	<LOR		
Zinc	µg/L	5	5,000	8	25	304	97	69	20		

LOR = Limit of reporting (i.e., detection limit).

NIC = Nominated investigation criteria.

1. Schedule 1 of the Environment (Water Quality Criteria) Regulation 2002.
2. ANZECC/ARMCANZ (2000) 95% species protection level for ‘slightly to moderately disturbed’ systems.

Most notably, boron exceeded Schedule 1 of the Environment (Water Quality Criteria) Regulation 2002 for all saltwater sites and zinc exceeded the ANZECC/ARMCANZ (2000) for all sites (excluding those where concentrations were below LOR). Quality control analysis indicated that the elevated zinc concentrations may be due to sample contamination. Also notable is freshwater site VAI6 on the Vaihua River, as several metals are elevated at this site, four above the ANZECC/ARMCANZ (2000) guideline.

The dissolved metal concentrations from the freshwater and estuarine ecosystems of the LNG Facilities site and surrounding area are not unusual given the past history of agricultural activity

The dissolved metal concentrations from the freshwater and estuarine ecosystems of the LNG Facilities site and surrounding area are not unusual given the past history of agricultural activity and human disturbance. The metals of most concern for the protection of aquatic life include copper, chromium, nickel, selenium and mercury. The concentrations of these metals, in general, were below the detection or guideline level. The results have identified elevated concentrations of some metals at freshwater site VAI6.

Nutrient data indicated some elevated concentrations of nitrogen and phosphorus in the LNG Facilities site watercourses (Appendix 15, Water and Sediment Quality Baseline Impact Assessment). Total nitrogen and total phosphorus concentrations at all estuary sites exceeded the ANZECC/ARMCANZ (2000) trigger values for total nitrogen and total phosphorus in 'slightly disturbed' Australian tropical estuaries, with the exception of KAR1. Total nitrogen concentrations in freshwater did not exceed trigger values. Total phosphorus concentrations in freshwater were also generally lower than those in estuarine waters but still exceeded ANZECC/ARMCANZ (2000) trigger values for southeast Australian 'low-land rivers', with the exception of KAR5. The nutrient conditions in these estuaries were not observed to be linked to any obvious eutrophication impacts to fauna (Appendix 13, Aquatic Fauna Impact Assessment) and the conditions may reflect the history of agricultural land use and settlements in the area, combined with the lack of flushing freshwater flows.

A detailed water quality baseline monitoring program will be developed for the project to confirm that project site discharges comply with water quality goals and the requirements of the environment (waste discharge) permit established for the project. The monitoring program will take into consideration variations in seasonal flows at the site.

Environmental impacts and mitigation measures are discussed in Section 20.5, Water Quality.

12.2.10 Noise

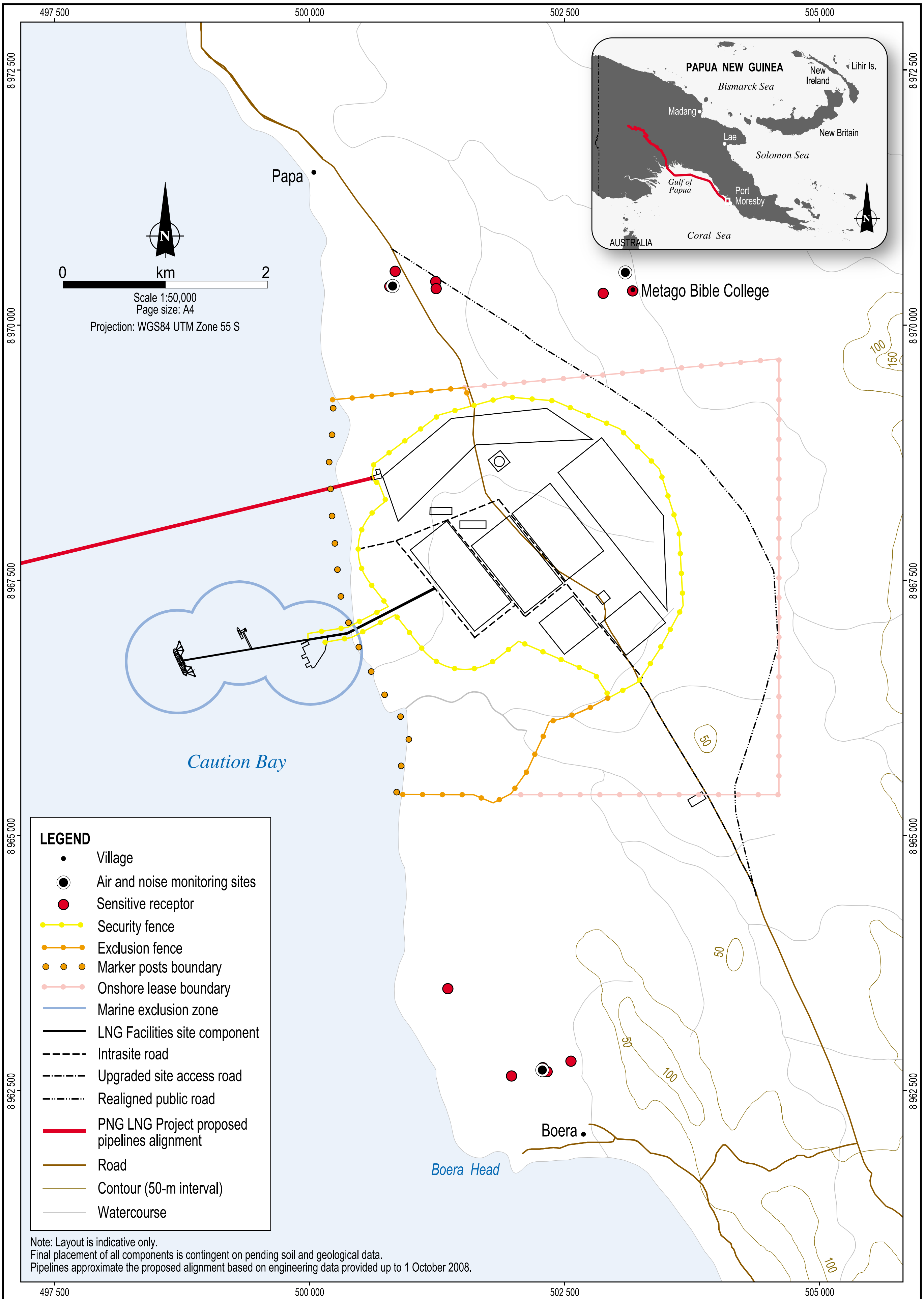
Existing ambient and background noise levels within and surrounding the LNG Facilities site were monitored during April to May 2008 as part of a noise assessment conducted for the project (Appendix 19, Noise Impact Assessment).

Three village communities have been identified as being the most sensitive noise receptors to the LNG Facilities site (Figure 12.7), and hence have been monitored as part of the noise assessment. Environmental impact and mitigation measures are discussed in Section 20.9, Noise.

12.2.10.1 Noise Receptors

Papa Village

The population of the Papa village is approximately 1,000 people. The nearest potentially affected noise sensitive receptors are located on the southern outskirts of the village area approximately 2.5 km to the north of the LNG Facilities site. The houses are generally isolated with garden-style agricultural plots, and are of lightweight construction, built of fibro-cement sheet, timber weatherboard or tin, and often elevated.



PNG LNG	Date: 31.10.2008 MXD: PNG_LNG_Project_GIS.mxd File Name: 1284_09_F12.07_GIS_HB	Esso Highlands Limited PNG LNG Project	Sensitive receptors potentially affected by noise and air emissions	Figure No: 12.7

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Metago Bible College

The Metago Bible College community is located approximately 2 km to the east of Papa. The community consists of a dozen or more houses, classroom, open-air chapel and agricultural gardens. It has a population of approximately 100.

Boera

Approximately 5 km to the south of the LNG Facilities site is the village of Boera. The village centre is on the beach, with a number of houses built out over the reef. The village has a school and isolated houses and garden-style agricultural plots extend to its north. The population of Boera village is approximately 1,300.

12.2.10.2 Measuring Background Noise

Background noise levels have been described in terms of dBA and statistical noise level detectors. The subjective character of a sound is also a significant parameter that needs to be considered, and includes the frequency, the tone and the impulsiveness of the sound. Plate 12.12 shows noise monitoring at Metago Bible College.

The level of a sound in dBA is considered a good measure of the loudness of that sound. It is measured using the 'A-weighting' filter incorporated in sound-level meters. These filters have a frequency response corresponding approximately to that of human hearing. People's hearing is most sensitive to sounds at mid frequencies (typically 500 Hz to 4000 Hz) and less sensitive at lower and higher frequencies.

As environmental noise usually varies in levels over a particular period, it is common to present the results of environmental noise testing in the form of statistical descriptors. A description of noise level descriptors typically used for assessing the noise environment include:

- L_{Amax}. The maximum A-weighted noise level associated with a noise measurement interval.
- L_{A1}. The noise level exceeded for 1% of a given measurement period. This parameter is often used to represent the typical maximum noise level in a given interval.
- L_{A10}. The A-weighted sound pressure level exceeded for 10% of a given measurement interval and is utilised normally to characterise average maximum noise levels.
- L_{Aeq}. The A-weighted equivalent continuous sound level. It is defined as the steady sound level that contains the same amount of acoustical energy as a given time varying sound over the same measurement interval. Can be loosely thought of as the average.
- L_{A90}. The A-weighted sound pressure level exceeded for 90% of a given measurement interval and is representative of the average minimum sound level. Often used to describe the background level.

12.2.10.3 Background Noise Environment

Table 12.7 provides a general summary of the average background noise levels for daytime, evening and nighttime periods together with the average L_{A10} and L_{Aeq} noise levels. All measurements were conducted with Acoustic Research Laboratories ARL Type 316 noise loggers that were set to log 15-minute statistical intervals, including L_{A1}, L_{A10}, L_{A90} and L_{Aeq}

noise level descriptors.

Table 12.7 Summary of ambient and background noise levels

Ambient Noise Level, dBA									
Location	Day (7 a.m. to 6 p.m.)			Evening (6 p.m. to 10 p.m.)			Night (10 p.m. to 7 a.m.)		
	L_{A90}[1]	L_{A10}[1]	L_{Aeq}[2]	L_{A90}[1]	L_{A10}[1]	L_{Aeq}[2]	L_{A90}[1]	L_{A10}[1]	L_{Aeq}[2]
Papa Village	32	43	50	41	46	50	43	48	48
Metago Bible College, Papa	30	42	53	45	49	63	46	50	52
Boera Village	42	52	62	49	56	53	46	49	48

Source: Appendix 19, Noise Impact Assessment

[1] L_{A10} and L_{A90} levels are the arithmetic average of the 15-minute data for each day/evening/night.

[2] L_{Aeq} level is the steady time level that contains the same amount of acoustic energy as a given time-varying sound logarithmically averaged over all days.

In order to supplement the unattended logger measurements and to assist in identifying the source and character of ambient noise sources, operator-attended daytime surveys were also conducted at all background noise monitoring sites. The operator-attended measurement surveys and results are summarised in Table 12.8.

Table 12.8 Operator-attended ambient noise environment

Location	Weather	Measurement Description	Primary Noise Descriptor dBA re 20 μPa				Description of Noise Emission and Typical Maximum L_{Amax} - dBA
			L_{Amax}	L_{A10}	L_{A90}	L_{Aeq}	
Papa Village	Partly cloudy W=1m/s SE Temp=32°C	Ambient	50	38	30	35	Breeze in trees, bird calls and insects, some distance talking =30-39 Rattling tins on fence
Metago Bible College	Partly cloudy W=1m/s SE Temp=32°C	Ambient	60	45	36	39	Breeze in grass and trees, birds and insects, distant talking = 36-40 Occasional plane at altitude 50-60
Metago Bible College	Partly cloudy W=2-3m/s SSE Temp=31°C	Ambient	55	47	44	46	Breeze in trees, bird calls and insects, some talking = 43-45 Occasional distant village singing and hammering

Source: Appendix 19, Noise Impact Assessment

Results from both surveys show that background noise levels are higher during the evening and at nighttime than during the day period. Operator-attended surveys indicated that the noise environment at all monitoring locations was similar in character, with the main sources being of natural origin such as wind in foliage, insects, birds, periods of heavy rain and domesticated animals, together with typical village activities. Infrequent aircraft flyovers were also observed.

Digital audio recorder results taken during the night period showed insect noise as the main source of ambient noise levels during evening and night periods.

The assessment noise criteria are provided in Section 18.9, Noise. Impacts and mitigation measures associated with the LNG facility are discussed in Section 20.9, Noise. A detailed baseline noise monitoring program will be established for the site to confirm that noise emission goals proposed for the project are met during construction and operations.

12.2.11 Air Quality

Ambient air quality and potential air pollution sources in the surrounding area have been assessed as part of an air quality assessment for the project (Appendix 18, Air Quality Impact Assessment).

12.2.11.1 Ambient Air Quality Standards

The key methods used to manage air quality are to (1) specify concentration limits for pollutants in the ambient air and (2) to specify concentration limits at the point of emission (i.e., in-stack concentration limits, also known as emission limits). Ambient concentrations depend not only on the in-stack concentration, but also on the volume flux of the emission (i.e., the size of the source), the plume rise, the stack height, existing levels of pollution from other sources and the dispersive capacity of the atmosphere. It is the ambient concentrations that are critical for protecting the environment. Emission limits are set to ensure that equipment functions efficiently and that appropriate technology is used, taking account of the environment in which it is operated.

The PNG LNG Project will be required to comply with ambient air quality standards designed to protect human health, flora and fauna and other aspects of the environment. Ambient air quality standards include the effects of emissions from the project and from all other sources including natural sources and nearby industrial and domestic sources that could give rise to cumulative effects. Ambient air quality assessment standards have been determined for this project and are provided in Table 18.26 in Section 18.8.1, Impact Assessment Criteria.

12.2.11.2 Existing Air Quality

The only significant sources of existing anthropogenic pollutants that could affect ambient air quality at the LNG Facilities site are Port Moresby (located approximately 20 km away) and the InterOil Refinery at Napa Napa (located approximately 15 km from the LNG Facilities site).

The Environmental Plan for the InterOil Refinery (Kinhill Kramer, 1997) provides information on the effect of emissions from the refinery. The predictions do extend out to the LNG Facilities area but interpolation of the available data indicates that the 99.9 percentile 1-hour average sulfur dioxide (SO_2) concentrations are unlikely to exceed 2 ppb (5.7 $\mu g/m^3$) and annual average concentrations are unlikely to exceed 0.5 ppb (1.4 $\mu g/m^3$). Similarly for nitrogen dioxide (NO_2), the model predictions indicate that the 99.9 percentile of 1-hour average concentrations are expected to be less than 2 ppb (4 $\mu g/m^3$) and annual average concentrations are expected to be well below 1 ppb (2 $\mu g/m^3$) at the LNG Facilities site (Appendix 18, Air Quality Impact Assessment).

Given the distance from the potential sources, it is unlikely that any significant concentrations of industrial pollutants exist on the LNG Facilities site (Appendix 18, Air Quality Impact Assessment). To test this assumption, a screening-type baseline monitoring program was undertaken. Passive monitors comprise adsorbent and chemically treated substrates on cartridges that, when exposed to ambient air containing specific pollutants, either adsorb the pollutants (in the case of hydrocarbons) or chemically react with the material in the substrate. After exposure, the cartridges are returned to the laboratory for analysis. The analysis provides information on the average concentration of pollutant at the site over the period that the cartridge was exposed.

Cartridges to monitor a suite of hydrocarbons, including the following BTEX compounds[7] and SO_2 and NO_2 (Appendix 18, Air Quality Impact Assessment) were exposed at the three locations where noise monitoring was undertaken at Papa and Boera (see Figure 12.7 and Plate 12.12) over a period of five days in late April and early May 2008 (see Appendix 18, Air Quality Impact Assessment):

- Benzene.
- Bromochloromethane.
- Butanol.
- 2-butoxyethanol.
- Butyl acetate.
- Cyclohexane.
- Cyclohexanone.
- n-decane.
- 1, 2-dichloropropane.
- Ethyl acetate.
- Ethyl benzene.
- Ethyl-ter-butyl ether.
- n-hepthane.
- n-hexane.
- Isobutanol.
- Isooctane.

All parameters measured were present at very low concentrations compared with the relevant assessment criteria and were mostly below detection limits, confirming the overall unpolluted air quality of the LNG Facilities site. Sulfur dioxide was present at detectable levels (between 2.6 and 3.4 $\mu g/m^3$) at all three monitoring locations. The WHO annual average criteria for SO_2 is 40 to 60 $\mu g/m^3$.

From observations made during the five-day monitoring campaign and a review of existing land use in the area, concentrations of total suspended particulates (TSP) are estimated to reach 40 $\mu g/m^3$ due to episodic wind erosion and smoke from fires. Annual average concentrations of PM_{10} (a health indicator for respirable dust capable of being inhaled into the lungs) are not likely to exceed 20 $\mu g/m^3$, but may be higher over shorter periods (e.g., 24 hours) when concentrations of TSP are also elevated. The project objectives for air quality are to not exceed the parameters of issued approvals and the applicable standards and guidelines for air quality. A detailed air quality baseline monitoring program will be established for the site to confirm that the air quality goals proposed for the project are met during construction and operations.

[7] BTEX is an acronym for benzene, toluene, ethyl benzene and xylenes. These compounds are some of the volatile organic compounds found in petroleum derivatives such as petrol.

Impacts and mitigation measures associated with the LNG facility are discussed in Chapter 20 Section 20.8 Air Quality.

12.2.12 Visual and Landscape

A visual and landscape character assessment has been conducted for the area surrounding the LNG Facilities site (Appendix 20, Visual Impact Assessment).

The landscape of the broader coastal plain in the environs of the LNG Facilities site is typified by plateaus between 100 and 400 m high, dissecting valleys and flood plains, vegetated with riverine communities.

12.2.12.1 Visual and Landscape Character

The existing visual and landscape character of the environs surrounding the LNG Facilities site has been described in relation to the following settings.

- Regional: More than 5 km from the LNG Facilities site.
- Subregional: Between 1 km and 5 km from the LNG Facilities site.
  – Distant Subregional: Between 2.5 km and 5 km from the LNG Facilities site.
  – Near Subregional: Between 1 km and 2.5 km from the LNG Facilities site.
- Local: Within 1 km of the project area.

Elements of the environment, in terms of vegetation cover and landscape character units, used in the visual characterisation are depicted in Figures 12.8 and 12.9, respectively.

Regional Setting

- Port Moresby, the nation's capital, is located 20 km to the southeast of the LNG Facilities site. It supports industry and residential areas extending inland and along the coastline for approximately 10 km.
- The villages of Kido and Lea Lea are located on the coastline to the northwest of the site, and Kouderika and Porebada are located to the southeast. Primary landuse is agricultural, comprised of grazing and cropping/cultivation. Existing forests are used as a resource for construction materials and firewood.
- Offshore, the coastal zone is used as a transport route between coastal villages as well as for fishing. The intertidal zone is used for the gathering of food and materials.
- The coastal plain is bounded by Redscar Head to the northwest and Boera Head to the southeast. It extends from the Kido River estuary in the northwest to Uda Bada Hill inland of Boera Head. Further inland, the coastal plain transitions to a series of northwest to southeast aligned low hills ranging in elevation between 100 and 400 m above sea level (ASL).
- The areas of elevated topography are generally separated by broad valleys, with water courses, many of which are ephemeral, flowing during and after the wet season but not throughout the dryer times of the year (Appendix 15, Water and Sediment Quality Baseline Impact Assessment). This setting comprises a relatively open vegetation cover that is classified as savanna. Taller and more dense vegetation is primarily confined to steeper

slopes, more elevated areas and watercourses or drainage lines. The coastal zone is fringed by dense stands of mangroves.

Subregional Setting

- The villages of Papa and Boera are located to the north and south of the LNG Facilities site respectively.
- A large proportion of the area is cleared and used for agricultural activities.
- The coastal zone is used for inter-village transport as well as fishing and intertidal zone gathering.
- Round Tree Hill, to the northeast of Boera, is the most elevated location with most of the area being less than 50 m ASL.
- Scattered trees, predominantly eucalypts, are present on higher hills and along waterways and drainage lines, and dense bands of mangroves line the coastline. The dominant vegetation type throughout the setting is tall grassland. The landscape is flat to slightly undulating and views are open and expansive. The higher hills to the northeast provide a backdrop to the coastal plain.

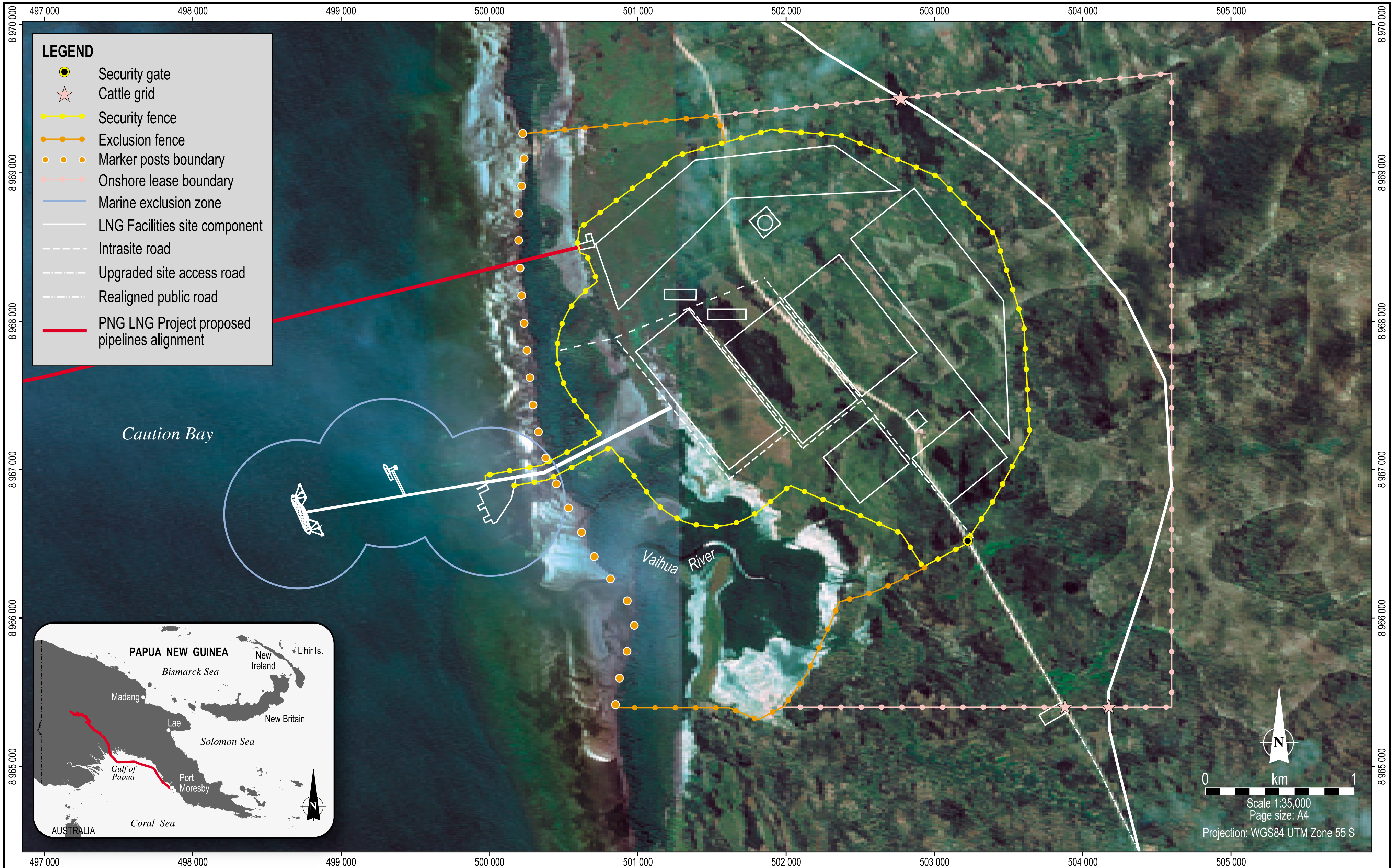
Local Setting

- There are no villages within the local setting.
- The land was previously used for cattle grazing and is currently unused.
- The coastal zone is used for fishing and intertidal zone gathering.
- The topography is generally less than 40 m ASL. The catchment of the North Vaihua River is contained within the LNG Facilities site. The coastal zone within the local setting includes the coastal mudflat and the near-shore shallows.
- The dominant vegetation over the site is tall grasses; the trees having been cleared previously. Mangroves along the intertidal zone are the dominant taller vegetation community. Other stands of taller and denser vegetation are present mainly along the drainage lines.
- The local setting is generally flat to slightly undulating. Views are generally open and expansive. However, the coastal mangroves confine the extent of views from non-elevated locations.

12.2.12.2 Absorptive Capability

The definition of landscape absorptive quality is how well a landscape setting is able to accommodate change or a development (Appendix 20, Visual Impact Assessment).

The key factors considered in determining absorptive capability are topography and vegetation. In areas of flatter topography, overlooking is not possible and a low and thin band of vegetation is able to screen views to a development from a given viewpoint. In areas of undulating or elevated topography, overlooking can occur and vegetation needs to be higher and dense to achieve effective screening. Intervening undulating topography also has the potential to block views in certain landscapes.



Note:
Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

PNG LNG	Date: 04.09.2008 MXD: PNG_LNG_Project_GIS.mxd File Name: 1284_09_F12.08_GIS_HB	Esso Highlands Limited PNG LNG Project	Satellite imagery depicting local visual setting

Figure No: 12.8

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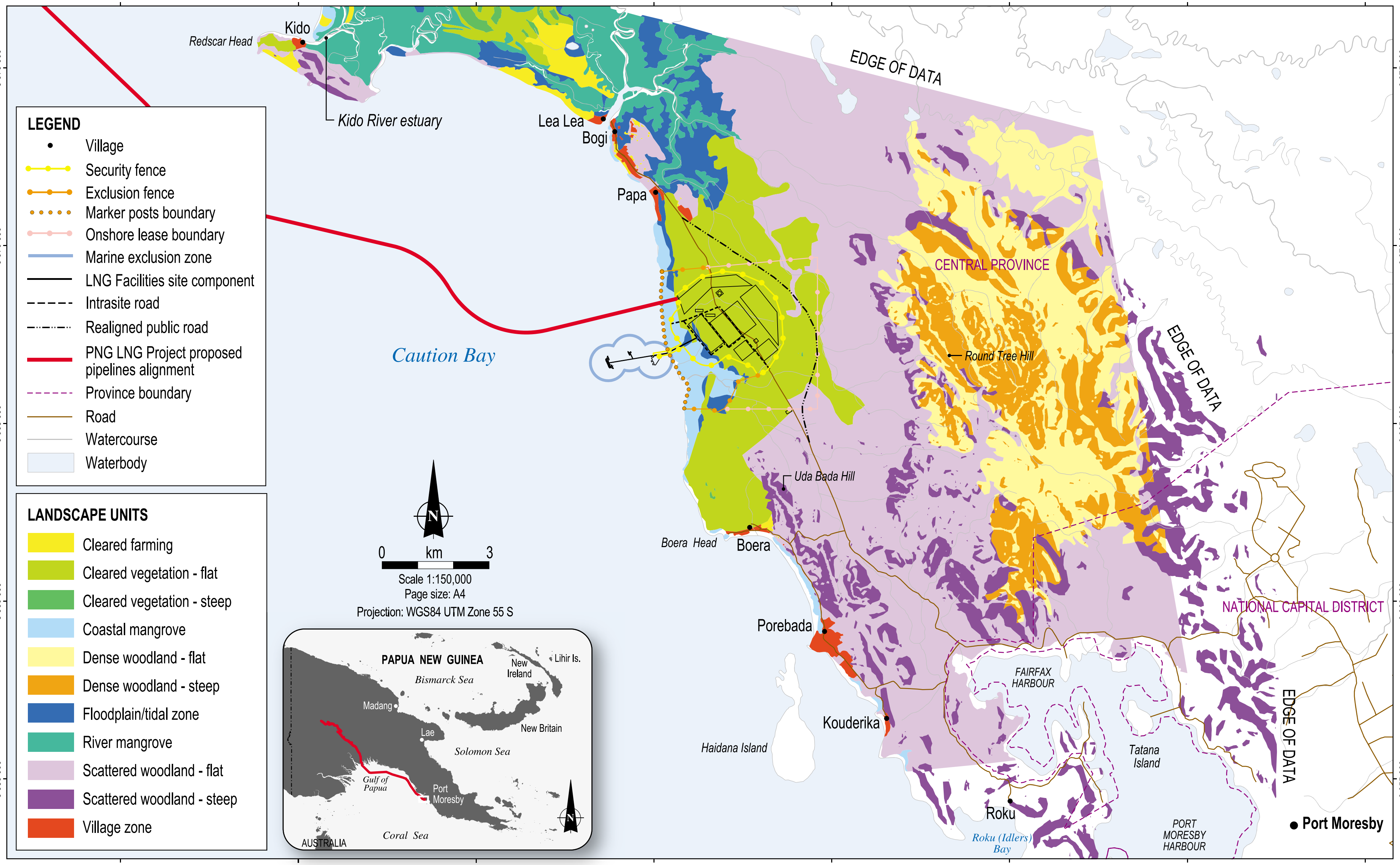

Source: Landscape units data from EDAW, 2008.
Note: Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

PNG LNG	Date: 28.10.2008 MXD: PNG_LNG_Project_GIS.mxd File Name: 1284_09_F12.09_GIS_HB	Esso Highlands Limited PNG LNG Project	Landscape character units	Figure No: 12.9

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The landscape settings of the LNG Facilities site and its environs have the following absorptive capabilities;

Regional Setting

To the south and east, the topography increases in elevation with slopes varying from 20% to greater than 30%. Therefore, in these locations, the potential for overlooking increases, reducing absorptive capability. However, viewing locations with potential for overlooking are sparse. Vegetation density and height also increases in these locations, which reduces the potential for overlooking views and increases absorptive capability.

Subregional Setting

The landscape within the near subregional setting is generally flat and the lack of intervening vegetation to screen views limits the ability of the setting to absorb change.

Within the distant subregional setting, increasing density of vegetation and topographic variation increases the absorptive capability of the setting.

A number of viewing locations exist within the subregional setting.

Local Setting

The landscape within the local setting is generally flat and the lack of intervening vegetation to screen views limits the ability of the setting to absorb change.

Few viewing locations exist within the local setting.

Environmental impacts and mitigation measures are discussed in Section 20.10, Visual.

12.3 Terrestrial Biological Environment

The terrestrial biodiversity of the LNG Facilities site is described according to its vegetation and flora (Section 12.3.2), and terrestrial fauna (Section 12.3.3). These sections are summaries of the findings of the biodiversity surveys undertaken as part of the assessment and impact analysis of terrestrial biodiversity at the LNG Facilities site and detailed in Appendix 12, Biodiversity Impact Assessment.

12.3.1 Survey Methods and Limitations

Figure 12.10 shows the vegetation and habitat regional context. For the purposes of the Terrestrial Biodiversity Study area, the study area comprised a 4,450-ha area shown as the dashed-line rectangle on Figure 12.10, and in more detail in Figure 12.11, with the LNG Facilities site located in the northwest corner. The flora and fauna study area equated to the boundary of Portion 152 and the previous Fairfax Station. The study experienced some limitation due to the discovery of unexploded ordnance (UXO) from World War II artillery. Additional pre-clearance surveys targeting rare and endangered fauna species will be conducted in the period between clearance of UXO and the start of construction.

12.3.1.1 Onsite Surveys

Field surveys of the study area were conducted between 12 and 21 April 2008 along walking trails or by boat along the Vaihua River and tributary. Figure 12.12 shows the survey transects. Table 12.9 shows survey effort and habitats for each transect. Additional information was gathered while driving or walking along the Lea Lea and Boera roads. Birds, reptiles, amphibians and non-volant (non-flying) mammals were surveyed using standard, recognised methods as described in Appendix 12, Biodiversity Impact Assessment.

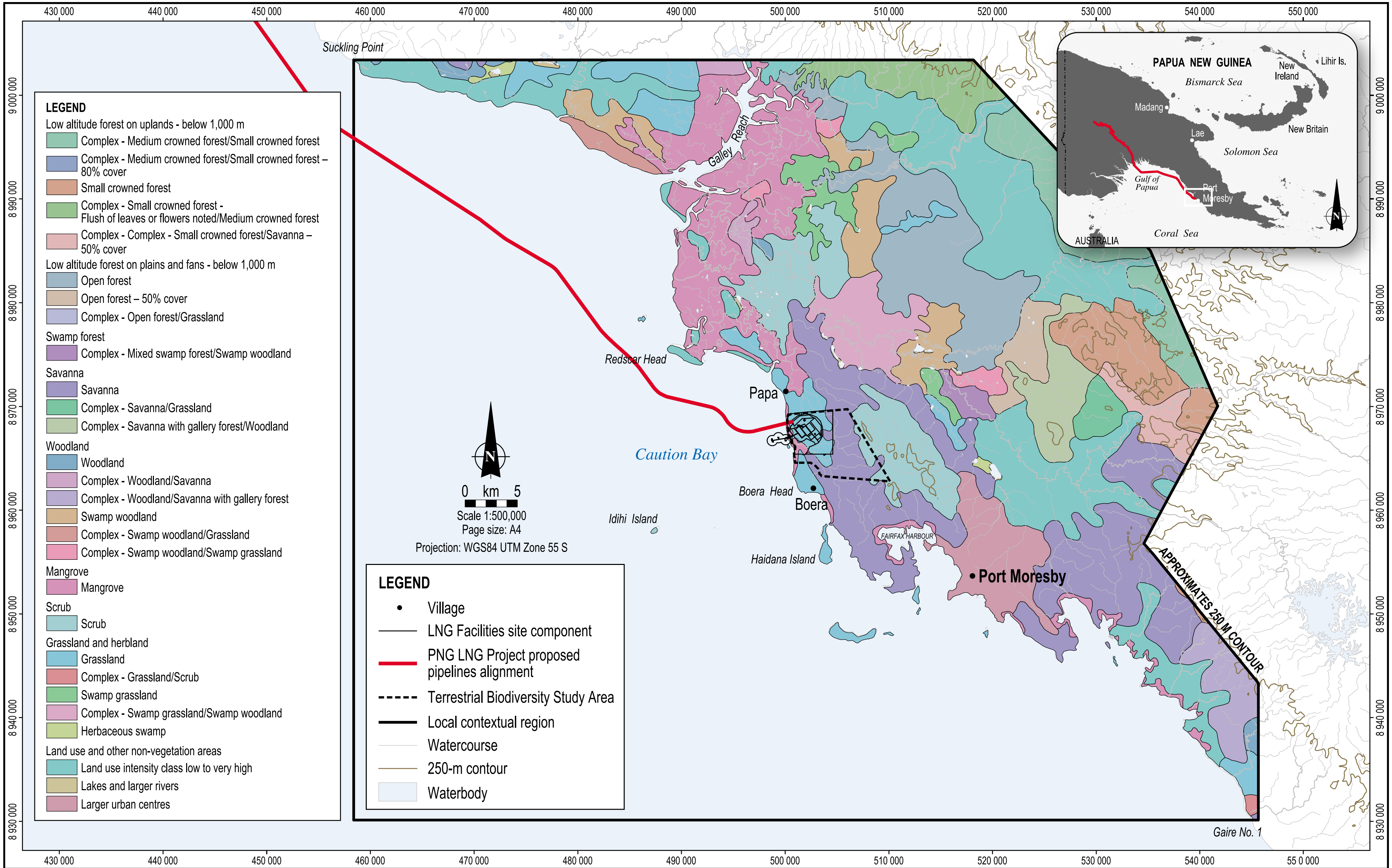
Table 12.9 Transects, habitat and fauna survey effort

Transect	Habitat	Bird, Reptile and Amphibian Surveys				Mammal Surveys		
		Date	Time Start	Time Finish	Total Time (hrs)	Trap Dates	No. Traps	No. Trap Nights
Vaihua River	Coastal, Mangrove	17 April	07:30	11:00	3.5			
Lea Lea Road North	Grassland, Open Woodland	18 April	10:00	12:15	2.25			
Beach Track	Grassland, Open Woodland, Woodland, Mangrove	18 April 19 April	16:30 07:20	17:30 10:35	1 3.25	18 to 21 April	25	3
Lea Lea Road South	Savanna, Open Woodland, Gallery[8] Forest, Grassland	19 April	14:30	17:00	2.5			
South Track	Savanna, Open Woodland, Gallery Forest, Grassland	20 April	06:45	09:30	2.75	18 to 21 April	25	3
Central Track	Savanna, Open Woodland, Gallery Forest, Grassland, Woodland	20 April	14:45	16:30	1.75			
Total					**17**		**50**	**3**

Source: Appendix 12, Biodiversity Impact Assessment.

Small mammals were systematically surveyed by walking transects and setting small Elliot traps along the Beach Track and South Track transects. A total of 25 traps was set at least 10 m apart along each transect from 18 to 21 April for a total of 150 trap nights (see Table 12.9).

[8] Also known as riparian forest.



Source: Vegetation data from PNG Forest Inventory and Mapping System, 1998.

Note: Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

PNG LNG

Date: 07.11.2008
MXD: PNG_LNG_Project_GIS.mxd
File Name: 1284_09_F12.10_GIS_HB

Esso Highlands Limited

PNG LNG Project

Vegetation and habitat regional context

Figure No: 12.10

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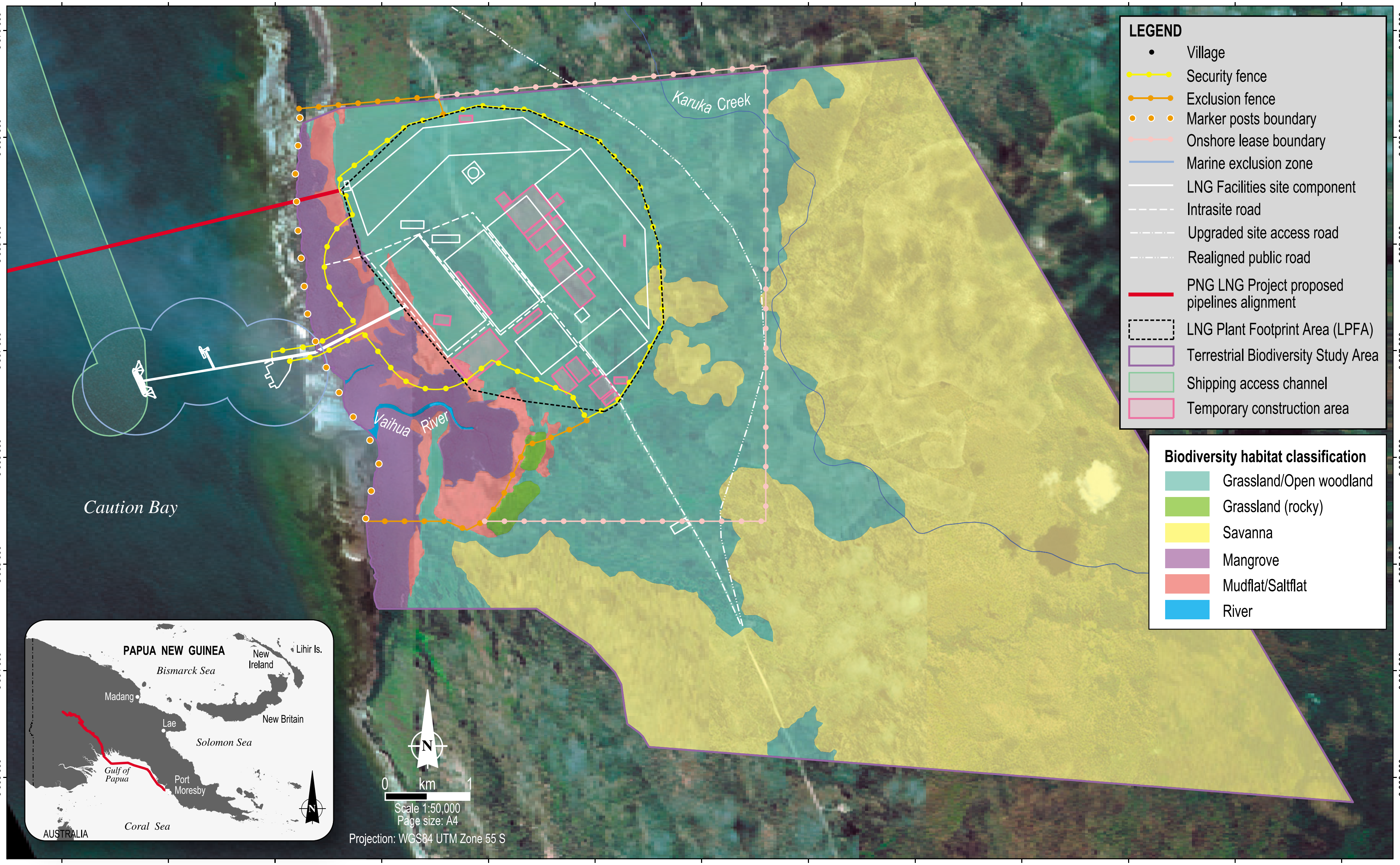

Note:
Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

PNG LNG

Date: 03.09.2008
MXD: PNG_LNG_Project_GIS.mxd
File Name: 1284_09_F12.11_GIS_HB

Esso Highlands Limited

PNG LNG Project

Terrestrial Biodiversity Study Area and habitat classification

Figure No: 12.11

PGGP-EN-SRENV-000001-001
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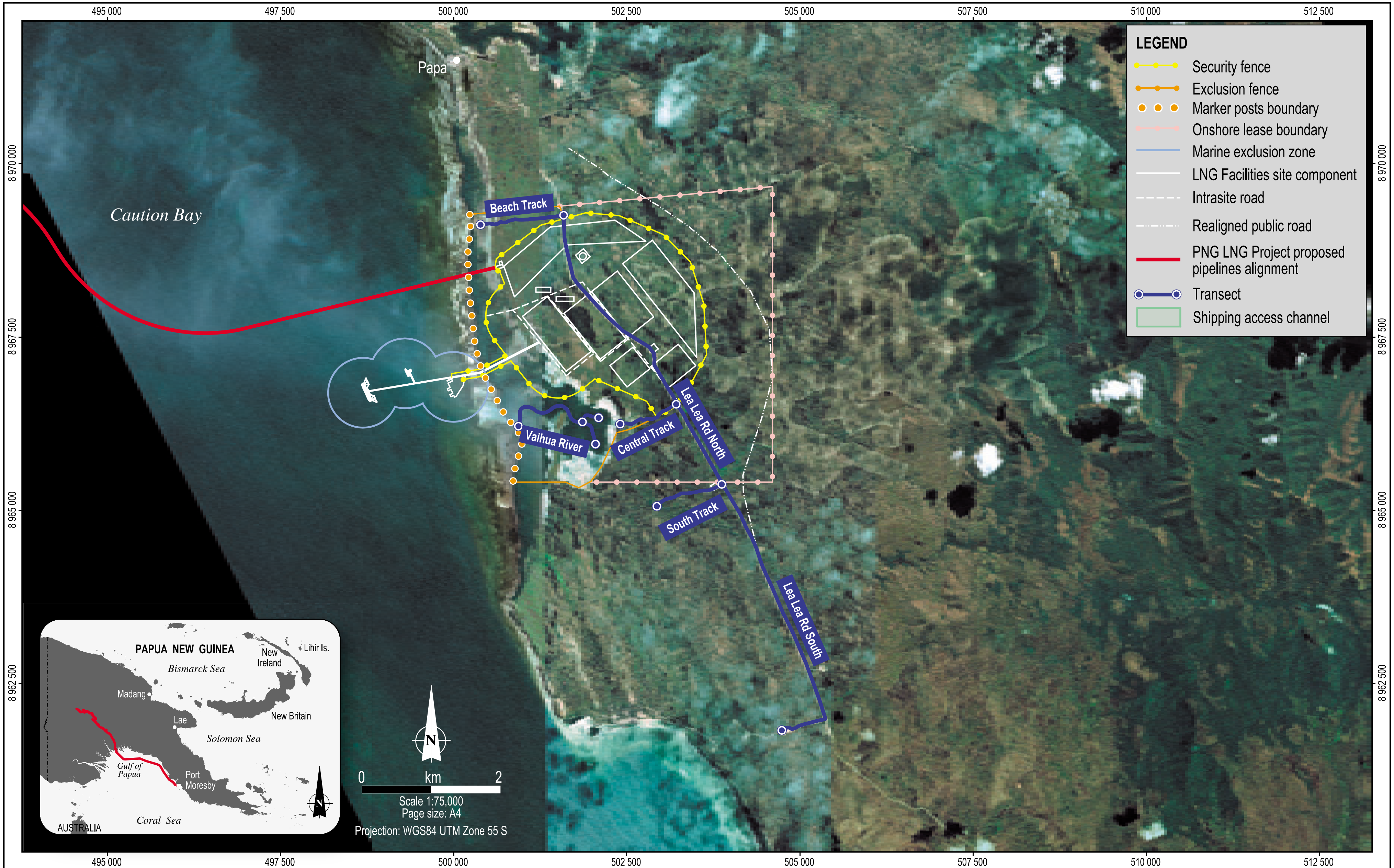

Note:
Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

PNG LNG

Date: 05.09.2008
MXD: PNG_LNG_Project_GIS.mxd
File Name: 1284_09_F12.12_GIS_HB

Esso Highlands Limited

PNG LNG Project

Fauna survey transects (April 2008)

Figure No: **12.12**

PGGP-EN-SRENV-000001-**001**
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The study area surveys were constrained largely by the limitation of all EIS survey work to transects already cleared of UXO. Better access would most likely have resulted in more species being recorded. This assessment has therefore had to place greater reliance on the supplementary list of potentially occurring species generated through desktop assessments (see Section 12.3.4, Conclusion, regarding future preconstruction surveys at the site).

12.3.1.2 Village Interviews

Local landowners were asked about mammals that they had seen or hunted in the area, and these were identified from pictures in Flannery (1995, as cited in Appendix 12, Biodiversity Impact Assessment). Local residents were not interviewed about birds or herpetofauna during the April 2008 surveys, although some information was collected during a previous visit to the site between 21 and 26 May 2007.

12.3.1.3 Desktop Assessments

The species directly observed and recognised during village interviews constitute a subset of the fauna that possibly could occur at the study area. A supplementary list of species that could occur has been compiled from published information and the personal experience of team members about species distribution and habitat preferences (see Appendix 12, Biodiversity Impact Assessment). No bats were recorded during the survey, and so the list for this group is based entirely on potential occurrence (see Appendix 12, Biodiversity Impact Assessment).

The supplementary lists generated for additional species of non-volant mammals and herpetofauna may nonetheless be incomplete, because the distribution and ecological requirements of most species are still relatively poorly understood. For these taxa, potential additional species include those listed in the IUCN (2007, as cited in Appendix 12, Biodiversity Impact Assessment) and nationally protected species that may be present. Based on potential habitat and occurrence ranges, the lists of species of conservation significance compiled from desktop studies are considered a reasonably complete representation of listed species that possibly could occur at the site. Preconstruction surveys will assist in elucidating the possible occurrence of listed species.

12.3.2 Vegetation and Flora

12.3.2.1 Local Regional Context

The study area is located within a regional context of similar vegetation and habitat. The local region covers approximately 110 km of coastal lowlands (measured as a straight line) from Suckling Point (situated 55 km northwest of the study area) south to Gaire No. 1 (a coastal village 33 km southeast of Port Moresby and 58 km southeast of the study area) (see Figure 12.10). The local region covers a land area of 228,865 ha between the coast and an inland boundary that approximately follows the 250-m-ASL contour. It includes 28 Forest Inventory Mapping System (FIMS) vegetation types (Hammermaster and Saunders, 1995, as cited in Appendix 12, Biodiversity Impact Assessment).

Habitat of the LNG Facilities site has been heavily modified by human activities. Much of the site was cleared early in the twentieth century for agriculture on what was then the Fairfax Station. There are no longer any active agricultural activities on the site, but seasonal fires contribute to the severely modified grassland and savanna habitat that now occupies most of the area.

12.3.2.2 Vegetation and Habitats

Vegetation and habitats at the study area include grassland and open woodland (35%), savanna with small patches of gallery forest (57%), mangroves (6%) and subcoastal wetlands/mudflats (2%) in addition to oceans and coastal marine habitats. Figure 12.11 shows the approximate distribution of the four main terrestrial vegetation types at the study area.

Grassland and Open Woodland

Grassland on alluvial plains is the dominant habitat in the northwest of the study area in the vicinity of the proposed LNG Facilities site. The flora is dominated by speargrass (*Heteropogon*) and pasture grass (*Dichanthium*) species native to southern Papua New Guinea but has a diverse alien component that includes many noxious weeds (e.g., *Alysicarpus vaginalis*, *Atylosia scarabaeoides*, *Clitorea ternatea*, *Panicum maximum*, *Passiflora foetida*, *Sida acuta* and *Tridax procumbens*). A species of cycad (*Cycas schumanniana*) was present in the study area but is not among the IUCN-listed cycad species and is not of conservation concern.

A variety of open woodland communities occurs across the grassland-dominated areas, including areas with scattered trees on alluvial flats, patches of introduced rain trees (*Samanea saman*), and *Pandanus* woodland that line the minor drainage systems (Plate 12.13).

The roughly 1,550 ha of grassland and open woodland in the study area (see Figure 12.11) comprise some 10% of the grassland-dominated habitats in the local region.

Savanna and Gallery Forest

Savanna is characteristic of a long dry season and is dominated by a variety of eucalypt species with a predominantly grassy understorey that includes cycads and banksias. Small patches of gallery forest may occur in sheltered areas.

Savanna in the Port Moresby area is known to support a large number of fauna species, many of which are found almost exclusively in this habitat. However, in contrast to the high degree of endemism found in Papua New Guinea's forests, the flora and fauna of the island's savannas are largely of Australian origin. Moreover, savanna at the study area is heavily disturbed and likely to support only a portion of those taxa found in this habitat throughout the local region.

Understorey vegetation is dominated by the alien-rich *Heteropogon-Dichanthium* community that characterises the site's grasslands and open woodlands. Human disturbance has severely reduced tree densities in many areas, with *Eucalyptus alba* and *E. confertiflora* the dominant species. An endangered sandalwood (*Santalum macgregoriae*) is probably the only plant of significance that could be present. However, these trees have not been seen in the Port Moresby area since the 1970s (Takeuchi, 2005, as cited in Appendix 12, Biodiversity Impact Assessment) and, in light of current population pressures, are probably extinct in the area.

There is an area of riparian (sometimes referred to as gallery) forest within savanna along the Vaihua River between the Lea Lea Road and the subcoastal habitats (Plate 12.14). Riparian forest is often densely clothed in vines and provides potential habitat for forest fauna that are less tolerant of drier habitats, including a variety of birds-of-paradise. However, although its true extent within the study area remains unknown, gallery forest near the LNG Facilities site is likely to be small, isolated, heavily disturbed and rich in non-native flora. For these reasons, the fauna will be a depauperate subset of the complement that is to be found in similar habitat throughout the local region.

Approximately 2,510 ha of savanna occur in the study area on hilly terrain in the south and east of the site and on the alluvial flats in areas that have not been cleared (see Figure 12.11), comprising some 6% of savanna present across the local region.

Mangroves and Subcoastal Mudflats

The study area includes an integrated system of mangroves and subcoastal mudflats that extends along most of the site's coastline and north towards Papa village. Most of this system consists of relatively narrow, fringing habitats, although there are relatively large blocks of mangrove surrounding the mouth of the Vaihua River immediately southwest of the proposed LNG Facilities site and within the proposed fenced exclusion area (Plate 12.15 and see Figure 12.11).

The quality of mangrove habitat varies considerably within the study area. Many areas are fragmented and disturbed by firewood collection. However, intact, closed-canopy mangrove forest does remain in some areas, particularly along the shoreline where taller species predominate. Mangrove communities are dominated by *Rhizophera* sp., with small patches of other species such as *Bruguiera* sp., *Sonneratia alba*, *Ceriops* sp. and *Avicennia* sp. The structure and composition of vegetation communities in the mangroves and saltflats/mudflats are described in detail in Chapter 13, Receiving Offshore Environment.

Ecosystem dynamics of the site's mudflats will reflect tides and freshwater inflows but are poorly known. However, subcoastal mudflats may be inundated during the wet season. In the dry season, the mudflats contract significantly, leaving large areas of mudflats that dry even further to become saltflats. Consultation with local people confirmed that resource utilisation is focussed mainly on the nearshore and mangrove areas rather than these open mudflat areas (see Appendix 24, Resource Use Survey of Caution Bay).

New Guinea's mangroves support a rich biota that includes a variety of mangrove specialist fauna, including a number of reptiles and birds, including resident and migratory shorebirds and other waterfowl. These habitats may also provide important ecosystem services by regulating hydrology, contaminant levels and system pH.

Elsewhere, large areas of mangrove forest and subcoastal wetlands occur locally along the Vanapa River/Brown River system, which drains into Galley Reach approximately 30 km north of the LNG Facilities site.

The study area supports some 261 ha of mangroves and 12 ha of mudflats. The combined area of these habitats within the site amounts to just over 1.5% of the mangrove and subcoastal mudflats in the local region.[9]

Mangrove and subcoastal mudflat habitats lie between the LNG Facilities' proposed onshore and offshore infrastructure and some (approximately 13.7 ha, or 5.3% of the mangroves that occur

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[9] The FIMS vegetation classification system does not distinguish between areas of mangroves and subcoastal wetlands/flats within the local region.

Plate 12.13
Grassland and open woodland extending east from Lea Lea Road

Plate 12.14
Riparian forest along the Vaihua River

Plate 12.15
Mangroves and subcoastal wetlands/mudflats around the Vaihua River

within the LNG Facilities site and less than 0.1% regionally; see 'Mangroves' in Section 20.7.4.1, Significance of Impacts on Habitats and Special Areas) will need to be cleared for the combined LNG Jetty/Materials Offloading Facility causeway and for the LNG Project Gas Pipeline easement from the Caution Bay Landfall to the LNG Plant (see Figure 12.11).

Vaihua River Ecosystem Complex

The Vaihua River Ecosystem Complex (Figure 12.13 and Plate 12.16) stands out in this otherwise much modified landscape for its contribution to the overall biodiversity of the study area. This complex covers a range of habitat types that exhibit high connectivity, including:

- Submerged and intertidal coastal marine reefs and sediments.
- The study area's largest intact non-coastal fringing area of mangrove and mudflats.
- The coastal approaches of the site's two main watercourses, including the Vaihua River.
- Rocky ridges with grassland and open woodland (including *Melaleuca*).
- A small inland buffer zone of grassland and open woodland on alluvial flats.

In the regional context, the Vaihua River Ecosystem Complex is relatively small and isolated. In the context of the study area, however:

- It is a relatively large area of intact habitat with few invasive species.
- It is the most important ecological entity on the study area.
- It is a locally important habitat for waterfowl and migratory shorebirds, with its diverse and well-connected coastal marine, subcoastal and freshwater foraging habitats and a variety of potential roost sites on spits and in the mangroves.
- It may support habitat endemics, near-threatened and/or nationally listed and IUCN-listed species.

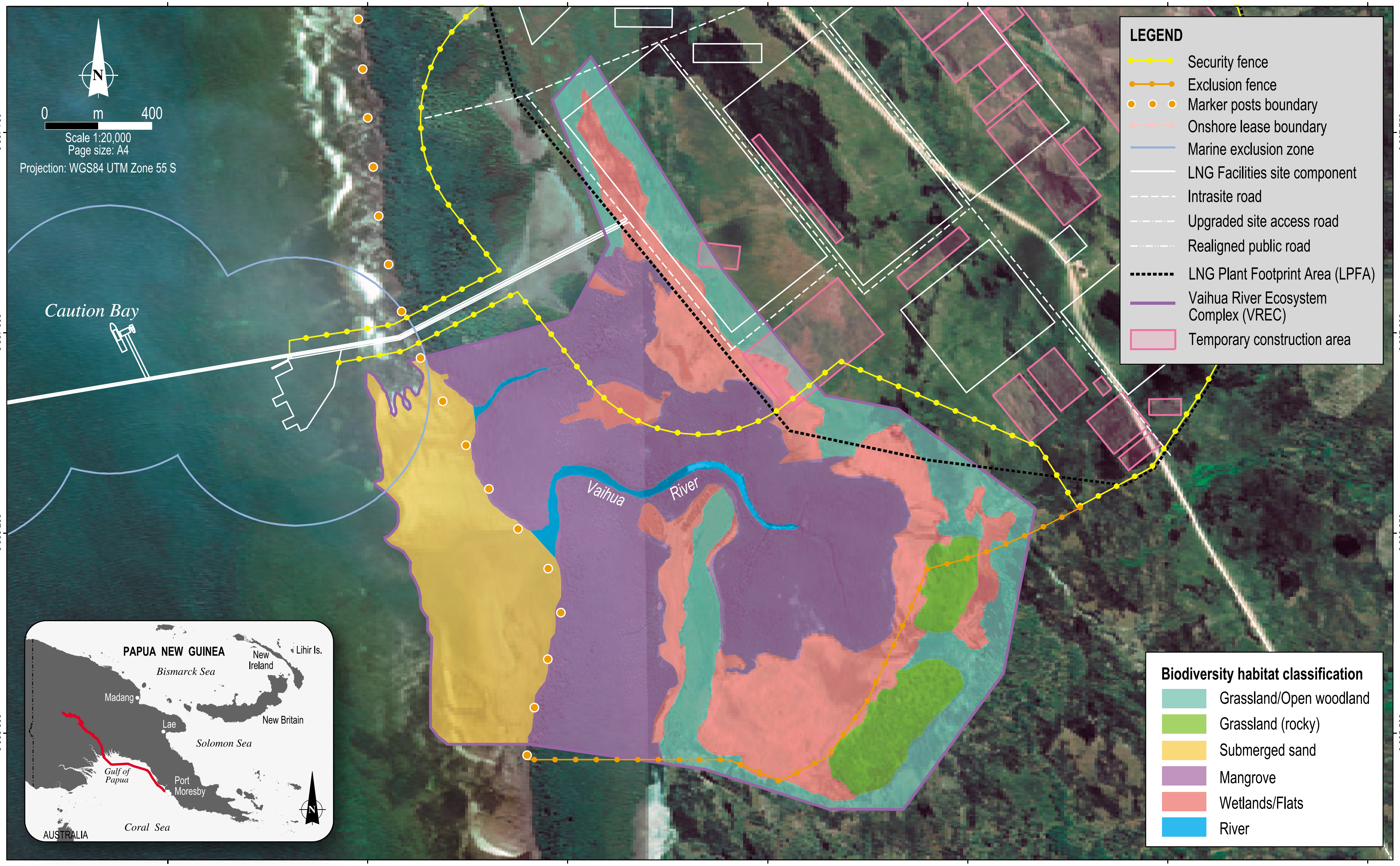
It is a complex physical and biological assemblage that, following disturbance, may not be easy to restore or regenerate if its current hydrological and other ecosystem functions are interrupted. However, since completion of Appendix 12, Biodiversity Impact Assessment, the length of the causeway of the Materials Offloading Facility has been reduced to maintain the natural nearshore hydrodynamic and sedimentation processes at the Vaihua River estuary, and thereby avoid these impacts.

Impacts to vegetation and flora from construction and operations of the LNG Facilities site is discussed in Section 20.7, Terrestrial Biodiversity.

12.3.3 Terrestrial Fauna

12.3.3.1 Non-volant Mammals

Table 12.10 lists the three non-volant mammals recorded in 2008, other species that could be present, based on suitable habitat and range distributions obtained from desk studies, and their respective preferred habitats.



Note:
Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.

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Date: 03.09.2008
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PNG LNG Project

The Vaihua River Ecosystem Complex and habitats

Figure No: 12.13

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Plate 12.16
Mangrove along the Vaihua River

Plate 12.17
Eastern tributary of Karuka Creek
(dry season)

Plate 12.18
Western tributary of Karuka Creek
(dry season)

Table 12.10 Non-volant mammals recorded in 2008 and potentially in study area

Scientific Name	Common Name	Status[1]		Habitat[2]			
		IUCN	IUCN	Sv	GF	OW	G
Observed							
Macropus agilis	Agile wallaby			✓			
Melomys lutillus	Grassland melomys						✓
Mus musculus	House mouse						✓
Local informants							
Phalanger intercastellanus	Southern common cuscus				✓		
Rattus leucopus	Cape York rat			✓	✓		
Rattus rattus	Black rat						✓
Possible additional species							
Peroryctes broadbenti	Giant bandicoot	DD	R		✓		
Planigale novaeguineae	New Guinean planigale	VU	R	✓		✓	
Rattus sordidus	Dusky field rat	NT		✓		✓	✓

[1] Conservation status indicates species listed by the IUCN as vulnerable (VU), near threatened (NT) or data deficient (DD) and mammals that are trade restricted (R) under PNG law.

[2] Habitats include savanna (Sv), gallery forest (GF), open woodland formations (OW) and grassland (G). For species directly observed in 2008, only the habitat in which they were encountered is indicated. A range of potential habitats is indicated for species recognised by local informants and possible additional species.

Source: Appendix 12, Biodiversity Impact Assessment.

The three non-volant mammals comprised two rodents, grassland melomys (*Melomys lutillus)* and the introduced house mouse (*Mus musculus*) that were trapped in grassland, and an agile wallaby (*Macropus agilis*) observed in savanna in the southern half of the study area. Local residents also recognised from photographs the southern common cuscus (*Phalanger intercastellanus*), Cape York rat (*Rattus leucopus*) and introduced black rat (*Rattus rattus*).

None of the three native mammals recorded or reported during the survey is of national or international conservation concern.

Additional non-volant mammals possibly occurring at the site include three IUCN-listed species: the New Guinean planigale (*Planigale novaeguineae*, vulnerable – VU), the giant bandicoot (*Peroryctes broadbenti*, data deficient – DD), and the dusky field rat (*Rattus sordidus*, near-threatened – NT). The New Guinean planigale and giant bandicoot are also defined as restricted trade species (R) under PNG law.

Savanna and gallery forest may support some larger mammals. Local people confirmed that they hunt for cuscus and wallabies in the inland forests, but if these species occur at all near the LNG Facilities site, then hunting pressure will probably mean that they are few in number and locally isolated.

12.3.3.2 Bats

The field investigation of the study area identified three potential bat habitat types: cleared pasture, mangroves and savanna/woodland.

Twenty-three bat species could occur, including seven IUCN-listed species: the critically endangered (CR) New Guinea big-eared bat (*Pharotis imogene)*, Troughton's sheathtail-bat (*Saccolaimus mixtus,* VU), greater long-eared bat (*Nyctophilus timoriensis*, VU), big-eared mastiff-bat (*Otomops papuensis*, VU), yellow-bellied sheathtail-bat (*Otomops papuensis*, NT), Papuan pipistrelle (*Pipistrellus papuanus*, NT), and Watt's pipistrelle (*Pipistrellus papuanus*, NT). Habitats at the study area preferred by these species are listed in Table 12.11. The New Guinea big-eared bat (*Pharotis imogene)* may be extinct and is unlikely to be present.

Table 12.11 IUCN-listed bat species potentially occurring at the study area

Scientific Name	Common Name	Status[1]	Habitat[2]			
		IUCN	Sv	GF	OW	Mv
Saccolaimus flaviventris	Yellow-bellied sheathtail-bat	NT	✓	✓	✓	
Saccolaimus mixtus	Troughton's sheathtail-bat	VU	✓	✓	✓	
Nyctophilus timoriensis	Greater long-eared bat	VU	✓	✓	✓	
Pharotis imogene	New Guinea big-eared bat	CR	✓	✓	✓	
Pipistrellus papuanus	Papuan pipistrelle	NT	✓	✓	✓	
Pipistrellus wattsi	Watt's pipistrelle	NT	✓	✓	✓	✓
Otomops papuensis	Big-eared mastiff-bat	VU	✓	✓	✓	

[1] Conservation status indicates species listed by the IUCN as critically endangered (CR), vulnerable (VU) or near threatened (NT).

[2] Habitats include savanna (Sv), gallery forest (GF), open woodland formations (OW) and mangroves (Mv).

Source: Appendix 12, Biodiversity Impact Assessment.

An additional 33 species (4 of which are vulnerable and 4 near threatened) have distributions that overlap the study area. However, neither the caves that they need for diurnal roost sites nor the forest needed for foraging appear to be present.

12.3.3.3 Birds

A total of 70 bird species was recorded during the survey, including 4 nationally protected species: osprey (*Pandion haliaetus)*, little egret (*Egretta garzetta)*, intermediate egret (*Mesophoyx intermedia*) and great egret (*Ardea alba*). No IUCN-listed bird species were recorded. The highest number of species was recorded in savanna (23) and other open woodland formations (26), followed by mangroves (21) and wetlands (18).

Three bird species were recorded as endemic to the area (Papuan marsh harrier, white-shouldered fairy wren and brown oriole). A high proportion of migratory species was also recorded. Sixteen species (23%) occur in Papua New Guinea only as non-breeding migrants, and 14 species (20%) have resident populations augmented by seasonal migrants. All species with both resident and migrant populations are of Australo-Papuan origin, with migrant populations arriving in New Guinea as non-breeding visitors from Australia. Most wholly migratory birds occur in wetlands (11 species) or coastal marine habitats (3 species). Wetland migrants included 10 Arctic-breeding shorebirds (the wader family *Scolopacidae,* and plovers and lapwings in the family *Charadriidae*) that visit tidal and coastal mudflats during the austral summer (September to April).

The study area includes habitat suitable for another 198 bird species known from the region, including six IUCN-listed species and five species protected under PNG law. IUCN-listed and nationally protected species are presented in Table 12.12 along with their habitat preferences.

Table 12.12 IUCN-listed and nationally protected bird species observed or possibly occurring at the study area

Scientific Name	Common Name	Status[1]		Habitat[2]				
		IUCN	PNG	Sv	GF	W	Mv	OC
Observed								
Pandion haliaetus	Osprey		P					✓
Egretta garzetta	Little egret		P			✓		
Ardea alba	Great egret		P			✓		
Mesophoyx intermedia	Intermediate egret		P			✓		✓
Possible additional species								
Limosa limosa	Black-tailed godwit	NT				✓	✓	✓
Limnodromus semipalmatus	Asian dowitcher	NT				✓	✓	✓
Esacus giganteus	Beach thick-knee	NT						✓
Ephippiorhynchus asiaticus	Black-necked stork	NT				✓		✓
Pseudobulweria rostrata	Tahiti petrel	NT						✓
Puffinus heinrothi	Heinroth's shearwater	VU						✓
Manucodia atra	Glossy-mantled manucode		P	✓	✓			✓
Manucodia keraudrenii	Trumpet manucode		P		✓			
Ptiloris magnificus	Magnificent riflebird		P		✓			
Cicinnurus regius	King bird-of-paradise		P		✓			
Paradisaea raggiana	Raggiana bird-of-paradise		P	✓	✓			

[1] Conservation status indicates species listed by the IUCN as vulnerable (VU) or near threatened (NT) and birds that are protected (R) under PNG law.

[2] Habitats include savanna (Sv), gallery forest (GF), mudflats/saltflats (W), mangroves (Mv) and oceans and coastal habitats (OC). For species directly observed in 2008, only the habitat in which they were encountered is indicated.

Source: Appendix 12, Biodiversity Impact Assessment.

12.3.3.4 Herpetofauna

Three frog and eight reptile species were recorded at the study area, and all except one are common in the savanna habitats of southern Papua New Guinea. No species of conservation concern are expected to occur in the study area.

The small skink (*Cryptoblepharus yulensis)* is a recently described species known from four sites around Port Moresby, Yule Island, and a single, unknown site in Western Province. It probably has a broad distribution along coastal areas of southern Papua New Guinea.

No dangerously venomous snakes were encountered, but taipans (*Oxyuranus scutellatus canni*) occur throughout the region and are highly likely to be present in grassland and woodland throughout the study area. Papuan black snakes (*Pseudechis papuanus*) are rare in the area, but likely to be present.

Frog species recorded include the green tree frog (*Litoria caerulea*), white-lipped tree frog (*L. infrafrenata*) and introduced cane toad (*Bufo marinus*).

The mangroves along the Vaihua River are less disturbed and provide habitat for the widespread homalopsine snakes *Fordonia leucobalia* and *Myron richardsoni* and for the mangrove monitor (*Varanus indicus*). The possibility of saltwater crocodiles, (*Crocodylus porosus*), occurring in these mangroves cannot be discounted.

Section 20.7, Terrestrial Biodiversity details impacts to fauna at the LNG Facilities site.

12.3.4 Conclusion

Despite surveying a variety of distinct habitats, low species diversity was recorded reflecting a low to moderate overall habitat quality.

Low mammal trap catch rates and low frog and reptile diversity are a reflection of the high degree of past and continuing habitat disturbance from historic clearing and current burning and hunting over most of the site. The estuarine, freshwater and terrestrial habitats of the Vaihua River Ecosystem Complex are the exception, being both diverse and relatively undisturbed. In particular, the subcoastal mudflats provide seasonal habitat for a wide variety of waterbirds, including some IUCN-listed migratory shorebird species.

The surveys recorded no IUCN-listed species, although a number of threatened or near-threatened species may occur. Six nationally listed birds, including four protected species, were recorded in various habitats, and a number of other nationally listed species may occur. No terrestrial reptiles or amphibians of conservation concern are expected to occur at the LNG Facilities site.

Additional fauna surveys will be conducted at the LNG Facilities site area and will focus on remnant areas of habitat, wetlands and mangroves with potential to support migratory bird species and species of conservation significance. These surveys will be conducted as part of preconstruction surveys of the site when UXOs have been fully cleared.

12.4 Aquatic Biological Environment

The aquatic biological environment is described according to its aquatic habitats (Section 12.4.2), aquatic flora (Section 12.4.3,), fish fauna (Section 12.4.4), macroinvertebrate fauna (Section 12.4.5) and other aquatic fauna (Section 12.4.6) in accordance with the findings of the aquatic biological surveys undertaken on the LNG Facilities site in May to June 2008 and detailed in Appendix 13, Aquatic Fauna Impact Assessment, Appendix 14 Hydrology and Sediment Transport Impact Assessment, and Appendix 15, Water and Sediment Quality Baseline Impact Assessment.

The catchments of three rivers are present within the LNG Facilities site; namely, the Vaihua River, North Vaihua River and Karuka Creek (see Figure 12.6). Karuka Creek is a tributary of Mokeke Creek and is also known locally as Kauka Creek. At the time of the aquatic biological survey, dry conditions predominated at the LNG Facilities site and many watercourses were dry. However, some remnant and isolated pools along watercourse channels acted as freshwater habitat refuges.

There are two estuaries within Caution Bay that are adjacent to the LNG Facilities site; namely, the Vaihua and the North Vaihua estuaries. During the dry season (April to November), freshwater inputs to the estuaries are negligible and freshwater losses from the estuaries via evaporation are high and, as a result, the estuaries may be classified as 'negative' estuaries i.e., the salinity gradient increases landwards from the mouth. However, during the short wet season (December to March), freshwater inputs to the estuaries are significant and evaporative losses are low and, as a result, the estuaries may be classified as normal or 'positive' and salinity gradients increase from the landward to the seaward margins.

The rivers and streams and their catchments within the LNG Facilities site are affected by the past and present disturbances of the area, and generally, the freshwater environments adjacent to the public road and within the LNG Facilities site are of lower environmental value than the habitats closer to the headwaters of the Vaihua River and Karuka Creek. The aquatic fauna of the mangrove-lined estuaries was considerably more diverse than the freshwater habitats, and consequently has greater resource value to local people (see Section 12.2.7, River Systems and Hydrology).

12.4.1 Data Sources

Given the small size of the rivers and catchments, there is little information or scientific data on the freshwater environments of the LNG Facilities site. As part of the environmental studies carried out in support of the PNG LNG Project, a series of hydrological, water and sediment quality and aquatic biological surveys were undertaken. These aquatic environmental surveys were conducted concurrently during the period 30 May to 8 June 2008. The locations of the aquatic biological sampling sites are shown in Figure 12.6. Standard sampling methods are described in Appendix 13, Aquatic Fauna Impact Assessment, and are not included here.

12.4.2 Aquatic Habitats

Three primary aquatic habitat types have been identified within the LNG Facilities site and surrounding area:

- Freshwater rivers and streams.
- Hypersaline wetlands (mudflats and saltflats[10]).
- Estuarine tidal creeks and mangroves.

These aquatic habitats are described below.

[10] The distinction between mudflat and saltflat habitat depends on the amount of available water, as described in Section 12.3, Terrestrial Biological Environment.

12.4.2.1 Freshwater Rivers and Stream Habitats

Freshwater habitats that occur within the LNG Facilities site include those within the Vaihua and North Vaihua rivers and Karuka Creek. There are no freshwater lakes in the study area. The nearest lakes (Iaraguma and Bunu lakes) are located 6 km to the northeast.

At the time of the aquatic environmental surveys in early June 2008 (i.e., at the height of the dry season), the main channels of some watercourses had low flows (Plates 12.17 and 12.18 and see Plates 12.9 and 12.11) and many of the other watercourses were reduced to dry channels, with remnant isolated pools. However, these permanent remnant pools provide important refuge habitats for freshwater aquatic life during the protracted dry season. Typically, watercourses of the LNG Facilities site may be classified as ephemeral or intermittent due to low rainfall and high evaporation. During the field surveys, it was observed that some seemingly isolated pools had perceptible but small flows, suggesting that there may be some groundwater recharge of surface water within the main channels. However, the physicochemical properties of groundwater in the LNG Facilities site varied markedly and there was no clear 'marker' identified in the groundwater study (Appendix 16, Groundwater Impact Assessment) that would suggest that some of the surface freshwaters sampled in this study could have a groundwater origin.

During the wet season (December to March), flows from the main channel to the estuaries return, and overbank inundation of floodplain areas, returning the saltflats to mudflats and forming temporary wetlands. Environmental impact and mitigation measures are discussed in Chapter 20, Section 20.5 Water Quality.

12.4.2.2 Hypersaline Wetland (Mudflat and Saltflat) Habitats

Hypersaline wetlands within the LNG Facilities site are represented by saltflats, which result from the semi-arid to arid climatic conditions that prevail to the west of Port Moresby. These saltflats lie within the intertidal and supratidal zone and are inundated episodically by high tides, particularly spring and king tides. In general, the saltflats are immersed at very high tides or during rain, but dry for the majority of the dry season.

The saltflats are largely bare areas that occur landward of the coastal mangroves located in the lower reaches of the Vaihua and North Vaihua rivers and Karuka Creek, and are hypersaline due to salt deposits left from evaporating seawater. They are essentially the 'unvegetated' equivalents of the vegetated salt marshes found in regions with a more uniform rainfall.

At the time of the aquatic biological survey, the saltflats and feeder channels were dry and, therefore, aquatic fauna and flora could not be sampled.

During the wet season (December to March), overbank flows from rivers and streams may also inundate these saltflats. For example, during the terrestrial flora and fauna study of the LNG Facilities site, it was observed that these saltflats became inundated after a night's heavy rainfall (Plates 12.19 and 12.20; and see Appendix 12, Biodiversity Impact Assessment).

Plate 12.19
Mudflat inundated after a night's heavy rain

Plate 12.20
Mudflat and grassland inundated after a night's heavy rain

Plate 12.21
Evidence of mangrove wood harvesting in Vaihua River

12.4.2.3 Estuarine Tidal Creek and Mangrove Habitats

Tidal creeks and mangroves within the LNG Facilities site are located within the lower reaches of the Vaihua River and the North Vaihua River (see Plate 12.16). During negative estuary conditions, when there is little to no flow from the creek systems, the mangroves experience predominantly saline conditions trending to hypersaline in the upper reaches. For example, during the June 2008 survey, the salinity range in the Vaihua Estuary head ranged from 37.3 to 38.0 parts per thousand, However, during the wet season (December to March) and at other times of heavy rainfall when river discharges are present, the salinities will be reduced significantly by these freshwater flows.

The substrata are predominantly sands at the estuary mouths, trending towards soft muds upstream at the estuary heads. The mangrove vegetation provides important stabilisation of sediment as well as providing very important shelter, nursery and feeding habitats for a variety of fish and invertebrates within the estuaries. Environmental impact and mitigation measures are discussed in Section 20.5, Water Quality, and Section 20.7, Terrestrial Biodiversity.

12.4.2.4 Habitat Connectivity and Ecosystem Processes

The aquatic biology survey (Appendix 13, Aquatic Fauna Impact Assessment) has shown that the estuaries within the LNG Facilities site support the highest abundance and diversity of aquatic fauna and that freshwater habitats support low abundance and diversity. The estuaries are more productive than the freshwater environments and are more heavily exploited by local people for aquatic biological and terrestrial resources. During the survey, local people were regularly observed to be fishing in estuaries using gill nets and spears, and evidence of wood collection, by the presence of freshly cut mangroves trees, was observed (Plate 12.21) in places easily accessible. In contrast, no resource utilisation of the freshwater areas was observed.

Estuaries are generally highly variable environments with respect to fish populations. At various times, estuary fish populations may be comprised of a mixture of estuarine specialists, juveniles of coastal marine species and migrating ‘freshwater’ species.

The LNG Facilities site lies within the dry-tropical environment characteristic of coastal areas near Port Moresby, Central Province, which has a long dry season (April to November) and a shorter wet season (December to March). It is expected that the communities occurring within the fresh water and estuarine habitats, and the functions of those habitats, will differ between wet and dry conditions.

During the dry season, estuarine and coastal marine species utilise the estuarine habitat, and there is no (or very little) freshwater connectivity with the onshore river and stream habitats. The heads of the Vaihua and North Vaihua estuaries tend towards hypersalinity and, as such, behave as negative estuaries. The coastal rivers and streams of the LNG Facilties site are ephemeral and the freshwater environment during the dry season is confined to a series of poorly connected pools or sections of perennial but reduced flows. These isolated pools or areas of reduced flow sustain the bulk of freshwater biodiversity during the dry season and as such, provide dry-period ‘refuges’ for aquatic fauna with minimal opportunity for movement between freshwater habitats.

During the wet season, connectivity between the freshwater riverine habitats and those of the estuaries is re-established. The seasonal wet conditions trigger movement and breeding and dispersal of freshwater species, most of which are amphidromous (i.e., they move between freshwater and the sea; and the eggs may be then transported downstream into estuaries and juveniles migrate back upstream to freshwater). Under these circumstances, the aquatic fauna of the estuaries would include some ‘freshwater’ species, and penetration of ‘estuarine’ species further upstream would be also expected. During the wet season, rainfall runoff and lateral overbank inundation from rivers and streams are also expected to flow into the saltflats landward of the mangrove fringe.

The elevated flows in the rivers and streams of the LNG Facilities site during the wet season enables freshwater species to breed and re-distribute, and also helps to restore water quality of the pools prior to the return of dry conditions. Environmental impact and mitigation measures are discussed in Section 20.6, Aquatic Ecology, and Section 20.7, Terrestrial Biodiversity.

12.4.3 Aquatic Flora

At the time of the aquatic biological survey in late May to early June 2008, many watercourse channels were dry except for some remnant but isolated pools within which little or no aquatic vegetation was observed (Appendix 13, Aquatic Fauna Impact Assessment). Freshwater algae can only survive in these remnant or perennial pools by forming desiccation-tolerant dry biofilms on the substrata of the main channels.

12.4.4 Fish Fauna

A survey of the fish of six estuarine and five freshwater sites was sampled within the LNG Facilities site and environs. Details of the sampling locations and methods are given in Appendix 13, Aquatic Fauna Impact Assessment and Figure 12.6 and examples shown in Plates 12.22 and 12.23.

The fish fauna sampled or visually observed in both estuarine and freshwater habitats are listed in Table 12.13. None of the species listed in Table 12.13 is listed nationally or internationally as rare or threatened.

Table 12.13 Fish species recorded in estuarine and freshwater habitats

Common Name	Species Name	Family
***Estuarine species**:*		
Estuarine glass perchlet	*Ambassis macrocanthus*	Ambassidae
Mangrove cardinalfish	*Apogon hyalosoma*	Apogonidae
Longtom	*Strongylura krefftii*	Belonidae
Bigeye trevally	*Caranx sexfasciatus*	Carangidae
Mangrove whipray	*Himantura granulata*	Dasyatidae
Ambon gudgeon	*Butis amboinensis*	Eleotridae
Ebony gudgeon	*Eleotris melanosoma*	Eleotridae
Freshwater anchovy	*Thryssa scratchleyi*	Engraulididae
Estuary cod	*Epinephelus coioides*	Epinephelidae
Common toothed ponyfish	*Gazza minuta*	Gerridae
Threadfin silver biddy	*Gerres filamentosus*	Gerridae
Goby	Goby sp.1	Gobiidae

Table 12.13 Fish species recorded in estuarine and freshwater habitats (cont'd)

Common Name	Species Name	Family
Goby	Goby sp.2	Gobiidae
Goby	Goby sp.3	Gobiidae
Goby	Goby sp.4	Gobiidae
Goby	Goby sp.5	Gobiidae
Goby	Goby sp.6	Gobiidae
Goby	Goby sp.7	Gobiidae
Fly River garfish	*Zenarchopterus novaeguineae*	Hemiramphidae
Mangrove jack	*Lutjanus argentimaculatus*	Lutjanidae
Spotted-scale seaperch	*Lutjanus johnii*	Lutjanidae
Ox-eye herring	*Megalops cyprinoides*	Megalopidae
Bluetail mullet	*Valamugil buchanani*	Mugilidae
Striped threadfin	*Polydactylus plebius*	Polynemidae
Spotted scat	*Scatophagus argus*	Scatophagidae
Vermiculated spinefoot	*Siganus vermiculatus*	Siganidae
Great barracuda	*Sphyraena barracuda*	Sphyraenidae
Narrow-lined pufferfish	*Arothron manillensis*	Tetraodontidae
Reticulated pufferfish	*Arothron reticularis*	Tetraodontidae
Banded archerfish	*Toxotes jaculatrix*	Toxotidae
Freshwater species		
Tilapia	*Oreochromis mossambica*	Cichlidae
Snakehead gudgeon	*Ophieleotris aporos*	Eleotridae
Papuan rainbowfish	*Melanotaenia papuae*	Melanotaenidae
Goby	*Goby sp.7*	Gobiidae

12.4.4.1 Estuarine Fish Fauna

A total of 30 fish species representing 20 families was recorded from the estuarine habitats (see Table 12.13). All of the species collected are wide ranging and most were common to the Vaihua, North Vaihua and Karuka estuaries. These species are widespread and typical of the mangrove-fringed estuaries of southern Papua New Guinea.

Many of the fish sampled were juveniles of coastal marine species that are known to frequent the estuaries for shelter, feeding and nursery habitat. Adults and juveniles of estuarine specialists were also observed.

There were very few large predators sampled or observed during the fish fauna survey, with only single specimens of the mangrove jack (*Lutjanus argentimaculatus*) and the estuary cod (*Epinephelus coioides*) being recorded. However, this may be a reflection of the relatively small size of the estuarine habitat, but may also indicate some fishing pressure on the large fish that are targeted by local people. For example, during the fish survey, local people were observed to be fishing intensively using large gill nets in both the Vaihua River and Karuka Creek estuaries.

Plate 12.22
Gill netting to sample fishes

Plate 12.23
Fyke-net recovery at high tide

Vaihua and North Vaihua Estuaries

Most fish species collected in the estuaries of Vaihua and North Vaihua Rivers were recorded in low numbers and consequently low biomass. The mangrove cardinalfish (*Apogon hyalosoma*) was the most abundant fish species at most sites, while biomass in the Vaihua River was dominated by bluetail mullets (*Valamugil buchanani*). Single records of the large mangrove jack (*Lutjanus argentimaculatus)* and the oxeye herring (*Megalops cyprinoids)* contributed disproportionately high biomass to the catch in the upper Vaihua River.

Karuka Creek Estuary

In common with the estuaries of the Vaihua and North Vaihua Rivers, fish catches in the Karuka River were numerically dominated by the mangrove cardinalfish (*A. hyalosoma)*. In general, fish catches were low and many species were represented by single specimens, including a large estuary cod (*Epinephelus coioides*), which dominated the biomass.

12.4.4.2 Freshwater Fish Fauna

Sampling at freshwater sites within the Vaihua and North Vaihua rivers and Karuka Creek resulted in the collection of four species of fish (see Table 12.13). These species are common to coastal rivers and streams of southern Papua New Guinea.

Very low fish catches were recorded at some freshwater sites, possibly as a result of the reduced efficacy of the electroshocking apparatus in pool waters of low electrical conductivity. Constricted access to some areas also reduced the efficiency of seine netting; however, visual observations were a successful method of identifying fish at some sites.

Fish population densities were low at the freshwater sites. No fish were recorded from the Vaihua River at the road crossing sites (VAI6 and VAI7; see Figure 12.6). Four species were recorded at the Karuka Creek sampling sites and two at the Vaihua River sites.

12.4.5 Macroinvertebrate Fauna

Large macroinvertebrate fauna, such as decapod crustaceans, were sampled in the estuarine and freshwater sites using electroshocking and seine netting. Freshwater benthic macroinvertebrate fauna (benthos) were sampled separately by grab sampling bottom sediments. Results are summarised below.

12.4.5.1 Decapod Crustaceans

Table 12.14 presents a list of decapod crustaceans sampled and Appendix 13, Aquatic Fauna Impact Assessment, gives details of sampling methods and the location of sampling sites.

Table 12.14 Decapod crustaceans recorded in the estuarine and freshwater habitats.

Common Name	Species Name	Family
Estuarine species:		
Prawn	*Macrobrachium sp.1*	Palaemonidae
Prawn	*Macrobrachium sp.2*	Palaemonidae
Prawn	*Macrobrachium sp.3*	Palaemonidae
Mudcrab	*Scylla serrata*	Portunidae
Ghost shrimp	Thalassinidea	*Unidentified*
Freshwater species:		
Prawn	*Macrobrachium sp4*	Palaemonidae
Giant freshwater prawn	*Macrobrachium lar*	Palaemonidae

Estuarine Decapod Crustacean Fauna

Five species of decapod crustaceans were caught at the estuarine sampling sites and included mudcrabs, ghost shrimps and three unidentified prawns of the *Macrobrachium* genus. While the taxonomy of the Papuan species of *Macrobrachium* is incompletely described, these species are widespread and typical of coastal mangrove-fringed estuaries of southern Papua New Guinea.

There was insufficient sample replication to establish between-estuary or between-site differences. However, all of the species collected are wide ranging and most species were common to both the Vaihua and Karuka estuaries.

The mudcrab (*Scylla serrata*) was the most abundant decapod crustacean found in the Vaihua Estuary.

Freshwater Decapod Crustacean Fauna

Two species of decapod crustaceans were visually observed in the rivers and streams draining the LNG Facilities site. The giant freshwater prawn (*Macrobrachium lar*) was observed in the Vaihua River and the North Vaihua River and an unidentified prawn (*Macrobrachium* sp. 3 was observed in the Karuka Creek downstream of the LNG Facilties site.

The efficacy of using the electroshocking apparatus was limited due to low electrical conductivity in the freshwater pools sampled. It is likely that other freshwater prawn species may be present in the rivers and streams of the LNG Facilities site and environs.

12.4.5.2 Estuarine Benthic Macroinvertebrate Fauna

Benthic macroinvertebrates were sampled by collecting sediments using a Van Veen® grab sampler. Sampled sediment was then sieved to 500 µm and animals were preserved in 70% ethanol. The processing and identification of samples were undertaken by an Australian laboratory (Ecowise Environmental, Brisbane).

Table 12.15 summarises the main benthic macroinvertebrate families found during the survey, taken from the raw abundance data in Appendix 13, Aquatic Fauna Impact Assessment.

Table 12.15 Macroinvertebrate families recorded

Major Taxon	Family
Bivalva	Galaeommatidae
Cumacea	Leuconidae
Gastropoda	Trochidae
Nematoda	
Oligochaeta	Tubificidae
Ostracoda	
Polychaeta	Amphinomidae
	Capitellidae
	Cossuridae
	Glyceridae
	Nephtyidae
	Spionidae

These communities were compared using multivariate statistical techniques (see Appendix 13 Aquatic Fauna Impact Assessment), which found no distinct groupings, suggesting no differences in the macroinvertebrate communities between estuaries. However, analysis to assess similarity of upstream and downstream macroinvertebrate assemblages indicated significant differences between communities (numbers and types of species) between upstream and downstream areas.

12.4.6 Other Aquatic Fauna

Other aquatic fauna or water-associated fauna that are present or expected to occur in the LNG Facilities site and environs are described below.

12.4.6.1 Frogs

Three frog species were recorded in the LNG Facilities site during terrestrial biodiversity survey (Appendix 12, Biodiversity Impact Assessment), although it is likely that frog diversity is higher. However, there were no species recorded or expected to occur that were listed as rare or threatened in Papua New Guinea or internationally (Section 12.3.3.4, Herpetofauna).

12.4.6.2 Freshwater Turtles

The ephemeral nature of the watercourses within and draining the LNG Facilities site is likely to preclude the presence of freshwater turtles, which tend to rely on perennial rivers and streams. Remnant pools may act as refuges during the dry season; however, no freshwater turtles were observed during the survey.

12.4.6.3 Saltwater Crocodiles

It is possible that saltwater crocodiles (*Crocodylus porosus*) occur in the open estuaries and mangrove-lined tidal creek habitats. However, given the frequent use made of the area by local people for fishing and gathering wood, it is not likely that any local populations of crocodiles remain (see Section 12.3.3.4, Herpetofauna).

Environmental impact and mitigation measures are discussed in Section 20.6, Aquatic Ecology.

12.5 Terrestrial and Aquatic Resource Use

The terrestrial resource use is described according to the terrestrial resource use (Section 12.5.1) and aquatic resource use (Section 12.5.2).

12.5.1 Terrestrial Resource Use

Much of the land within the LNG Facilities site was cleared in the early twentieth century for agriculture on what was then the Fairfax Cattle Station, for which the savanna grasslands provided forage for the cattle. At present, there are no longer any agricultural activities on the property; however, local residents regularly hunt on the site, periodically burn the grasslands and collect other natural resources, such as mangrove wood for firewood and for construction (Section 13.4.3, Mangrove Resource Use). Local people are commonly observed selling firewood along the Lea Lea Road and this activity is likely to be an important source of cash income for people living within the environs of the PNG LNG Facilities site.

12.5.2 Aquatic Resource Use

Aquatic resource use includes the access to freshwater sources for water supplies, predominantly groundwater bores. During the dry season, there is insufficient surface water in the area of the LNG Facilities site for use as a source of water or food. This is supported by the findings of the aquatic fauna survey (Appendix 13, Aquatic Fauna Impact Assessment), which found only small numbers of fish or crustaceans in freshwater streams. Estuarine and marine resource use, such as fishing and collecting crabs in the Vaihua River and surrounding mangroves, is covered in Section 13.4, Resource and Shipping Use.

The primary source of drinking water is groundwater via bores or treated-water mains supplies from Port Moresby. Other surface water sources are only reliably present during the short wet season (December to March), with little or no flows during the dry season (April to November).

The four villages in the vicinity of the LNG Facilities site all face severe problems accessing regular supplies of safe potable water, especially during the prolonged dry season. There is a lack of mains water in the villages of Boera, Lea Lea, and Papa, and the local water supplies are of poor quality. Water supplies for these villages are described below.

12.5.2.1 Boera Village

Drinking water in Boera is provided from a single main bore, which has a powered pump, although there are also smaller bores that are privately owned and which are utilised in the village. Some of the houses have piped this water directly to their houses, for which they pay a weekly fee. Those villagers whose houses are not connected pay for 20-L containers from a public tap.

12.5.2.2 Lea Lea Village

Drinking water in Lea Lea comes from a single well that is located about 2.5 km north of the village and is accessible only by foot. On average, women have to make four trips a day to fetch water from the well, meaning that each woman walks 20 km a day just for water collection. There are rain tanks in the village, and rainfall can help cut down the number of trips to the well. During the dry season, Lea Lea villagers supplement their water supplies with commercial water brought by truck from Port Moresby.

12.5.2.3 Papa Village

Papa village has access to groundwater supplies from a number of bores. However, the quality of the water is poor (see Section 12.2.4.2, Hydrogeology). Papa also appears to be the village that is most dependent upon drinking water supplies trucked in from Port Moresby.

12.5.2.4 Porebada Village

Porebada is the only village with access to Port Moresby mains water. There are 12 mains water taps in the village, and people pay per 5 litres.

The prime aquatic resource uses by the community are access to safe potable water in groundwater bores, especially during the dry season, as well as a habitat for the aquatic fauna that are a source of food for the community and found within the Vaihua River and surrounding mangroves.

Impacts to aquatic and resource use at the LNG Facilities site is discussed in Section 23.9, Agriculture, Fisheries, Forestry and Subsistence.

12.6 Implications for Upstream Facilities Planning, Design and Management

The LNG Facilities site is relatively flat and for the most part disturbed. The mangrove fringe and the estuary of the Vaihua River are the principal natural conservation assets of the site. The remnant habitat is generally a small proportion of what occurs regionally but the mangroves and, especially the estuary of the Vaihua River are locally important remnant features and the facilities will need to be arranged to minimise their disturbance.

As well, the Vaihua River estuary will be sensitive to changes to the sediment regime of the lagoon and interruptions to longshore currents will need to be limited so as not to interfere with the morphology of the estuary.

At the same time, most of the site is unconstrained, which turns the mitigation focus for direct impacts onto construction management of active works areas, so as to maintain drainage, control fugitive sediment and test for and if necessary deal with acid sulfate soils. As important will be measures to control the indirect impacts of weeds and pests, fire and poaching.

The site offers views in from vantage points on land and offshore, but is generally typical of the settled coastal plain and backing low hills of this part of the Papuan coast.

The perimeter security fence around the site will establish a land exclusion zone according to safety criteria. Background noise levels and air pollution are low, and so facilities design to meet standards at the nearest villages will not have the problem of an increment over already high background levels.

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