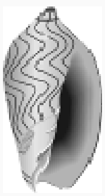
BHP BILLITON IRON ORE

PROPOSED OUTER HARBOUR DEVELOPMENT

PORT HEDLAND

MARINE TURTLE USAGE WITHIN THE PORT HEDLAND REGION AND IMPACTS ASSESSMENT



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For

SKM on behalf of BHP Billiton Iron Ore

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1.0 INTRODUCTION

1.1 Background

BHP Billiton Iron Ore operates a port in the Port Hedland region of Western Australia. The current port operations consist of processing, stockpiling and ship loading facilities at Nelson Point and Finucane Island (referred to as the Inner Harbour), located on opposite sides of the Port Hedland Harbour.

BHP Billiton Iron Ore is currently assessing further expansion proposals at Port Hedland. These proposed expansions include additional berths within the Inner Harbour and the development of a new Outer Harbour. To meet the expected global demand for iron ore, BHP Billiton Iron Ore is embarking on a development programme to achieve a target of 350 Mtpa of installed capacity by 2015 at its Port Hedland operations. BHP Billiton Iron Ore is proposing to develop new port facilities, offshore from Finucane Island, as part of the proposed Outer Harbour Development. The proposed Outer Harbour Development is the subject of an environmental assessment under the *Environmental Protection Act 1986* and the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*.

The proposed Outer Harbour Development includes marine and terrestrial works, and will be established in four stages, with incremental expansions of the infrastructure brought online to reach the maximum capacity. Expansion stages will occur through four separate stages, each with a nominal capacity of 60 Mtpa. The first two stages of the project will deliver a throughput of up to 120 Mtpa. Future expansion to 240 Mtpa throughput capacity will occur in Stages 3 and 4.

The marine construction activities include dredging and the development of a new jetty/wharf structure, berths and ship-loading infrastructure. All dredged material will be disposed of offshore, in Commonwealth waters. The terrestrial works include the development of a rail spur and loop from the existing BHP Billiton Iron Ore rail line, the construction of stockyards at Boodarie and a conveyor corridor to transfer the ore to the ship-loading facilities (**Figure 2**).

1.2 Scope of Works and Objectives

Pendoley Environmental was commissioned by SKM on behalf of BHP Billiton Iron Ore to undertake the following scope of works:

- quantify the usage of identified marine turtle nesting beaches within the marine study area;
- identify feeding ranges and utilisation patterns of marine turtles within the marine study area;
- identify migratory paths of marine turtles within the marine study area;
- undertake risk and impacts assessment; and
- preparation of Marine Turtle Management Plan.

The assessment was undertaken in two stages:

- Stage 1 - a desktop review; and
- Stage 2 – marine turtle field surveys.

The desktop assessment was undertaken by Pendoley Environmental to review the marine turtle habitat usage within the region, and identify what was known from the region and any gaps in the information that needed to be addressed.

The purpose of the field surveys was to validate the desktop information and address the gaps in knowledge that were identified from the desktop review. .

In order to address knowledge gaps for marine turtles within the Port Hedland region, a number of marine turtle field surveys were required over different seasons. This report presents the results of the desktop study and the results of marine turtle field surveys undertaken within the survey area identified in **Figure 1** during 2008 and 2009 by Pendoley Environmental, which included:

- land-based aerial survey (summer) to identify locations of nesting beaches;
- water-based aerial surveys (summer and winter) to map turtle presence/absence in offshore waters;
- boat surveys to ground-truth nesting beaches identified from the aerial survey;
- track census counts on selected beaches close to the proposed development to quantify nesting activity; and
- tracking data from satellite transmitters attached to nesting females on Cemetery Beach to provide information on internesting habitat and migratory pathways.

1.3 Ongoing/Additional Studies

Pendoley Environmental is currently undertaking a series of studies to assess potential impacts on marine turtles as a result of the proposed Outer Harbour Development. In addition to the results presented in this report, the following studies are still ongoing and in time will provide additional information on marine turtle usage within the Port Hedland region. These studies are:

- Stable Isotope Analysis of turtle material and potential food sources to help identify foraging habitat– these results will be provided as a separate report that is planned for the end of 2009.

- Satellite Tracking Study to identify internesting habitat and migratory pathways – results to date (11 August 2009) are provided in this report (see **Appendix A** for full report). If the transmitters continue to operate and more data are gathered, these results will be added as an addendum to this report.

1.4 Acknowledgements

This programme was designed by Dr Kellie Pendoley. Field staff who conducted the surveys were Dr Kellie Pendoley, Dr Nancy FitzSimmons and Dr Jessica Oates. The aerial surveys were flown by Polar Aviation in Port Hedland. The boat surveys were conducted using Serious Fun, skippered by Hayden Webb and Tuff Punt, skippered by Ben Brayford (SKM). The satellite transmitters were attached by Paul Tod (Crackpots Pty Ltd) and Nic Sillem (Pendoley Environmental) with the assistance of Kelly

Howlett and volunteers from Care for Hedland Environmental Association. Kelly Howlett (Care for Hedland Environmental Association) provided data from Cemetery Beach and Pretty Pool for use in this report. Some figures were produced using Google Earth Pro Ref ID# 1839881. Other figures were produced by SKM on behalf of Pendoley Environmental.

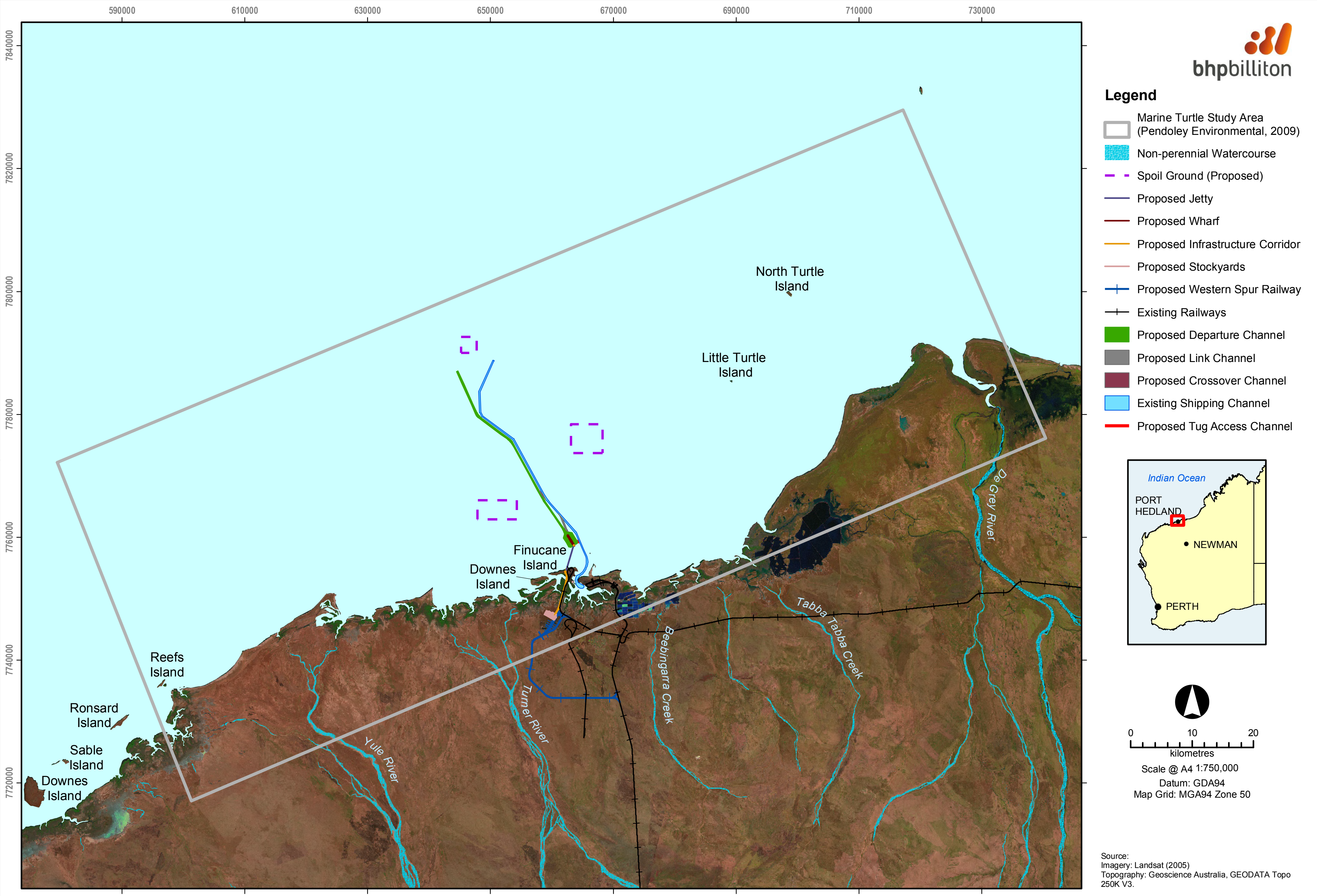

Figure 1 Marine Study Area

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2.0 BACKGROUND INFORMATION

2.1 Project Description

The proposed Outer Harbour Development will be a new port facility in Port Hedland with an export capacity of approximately 240 Mtpa of iron ore (**Figure 2**). Construction will be in stages (referred to as Stages 1-4) with first ore shipments anticipated in 2013. Construction is proposed to commence in 2010/2011.

Proposed landside development will include:

- rail connection from the existing BHP Billiton Iron Ore mainline to proposed stockyards at Boodarie;
- rail loops at Boodarie;
- stockyards at Boodarie; and
- an infrastructure corridor (including conveyors, access roadway and utilities) from the stockyards to a transfer station on Finucane Island that connects to a marine jetty.

Proposed marine structures and activities will include:

- a marine jetty extending from Finucane island to a wharf with eight berths;
- associated transfer stations, ore conveyors and ship loaders; and
- dredging for berth pockets, basins and channels.

The key construction and operational activities potentially impacting the marine environment offshore of Port Hedland are described below.

2.1.1 Dredging and Spoil Disposal Programme

The construction of the Outer Harbour Development will require dredging to enable vessel access to the wharf infrastructure. The existing seabed varies within the project footprint from less than +1.4 m CD to over approximately -25 m CD. Dredging operations will be carried out in the creation of new berth pockets, swing basins, arrival and departure basins, a link channel to the existing inner harbour shipping channel and a new 34 km departure channel.

The total volume of dredge spoil is estimated to be approximately 54 million cubic metres (Mm^3) of material, including over-dredging. The material will be removed by a trailer suction hopper dredger (TSHD), and a cutter suction dredger (CSD). Dredging operations will be conducted 24 hours per day, 7 days per week.

It is envisaged that dredging will occur in a stages, as follows:

Stage 1 – Approximately 22 Mm^3 dredging, of berth pockets, eastern arrival and departure basins and a link channel to the existing channel to provide two loading berths with a single ship loader.

Stage 2 – Approximately 25 Mm^3 dredging, of the western arrival and departure basins and widening of the link channel to provide two additional loading berths and a ship loader. This module also includes the dredging works for the new 34 km departure channel.

Stage 3 – Approximately 7 Mm^3 dredging for the extension of the berth pockets and the arrival and departure basins to accommodate another four loading berths and an additional two ship loaders.

There is no dredging required for **Stage 4**.

Dredging is scheduled to commence in 2010/2011 and continue for approximately 50 months for Stages 1 and 2, with a proposed 12-24 month gap, dependant on market demands, prior to commencing dredging for Stage 3, which has an expected duration of 7 months.

The disposal of dredged material will be carried out in accordance with a Dredge Spoil Disposal Management Plan. The suitability of a number of potential spoil locations has been investigated and there are three preferred offshore locations. All of these offshore spoil grounds will be located in Commonwealth waters in depths of greater than **-**10 m CD.

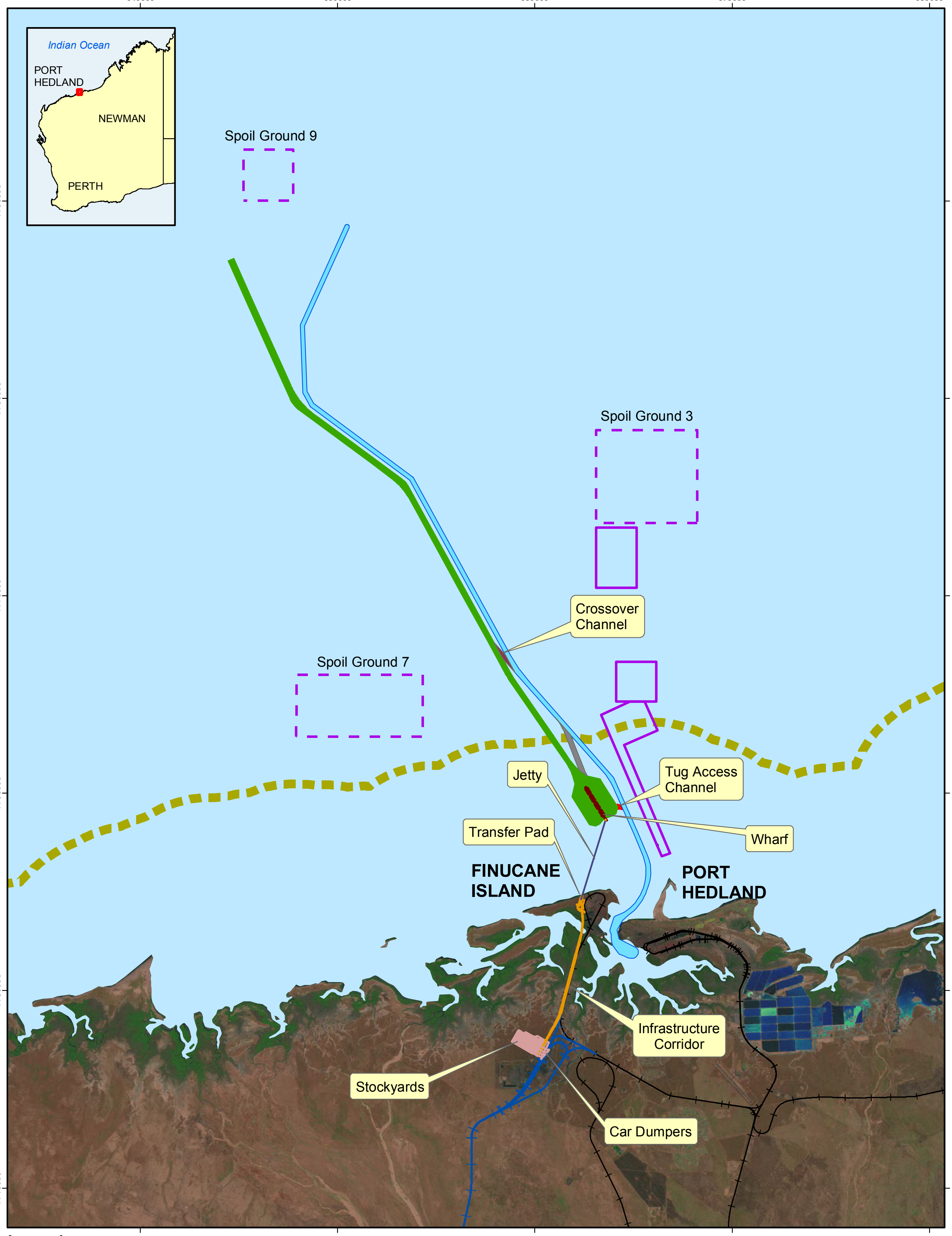
2.1.2 Construction of the Marine Infrastructure

Construction of the jetty trestle will involve four jack up barges to drive piles with additional jack up barges and cranes for erecting headstocks and prefabricated topside modules for the deeper sections of the access jetty.

This approach will also be used to install piles by jack up barges in constructing the tail end deck, wharf and dolphins.

Overall, approximately 1500 piles will be driven over a total of approximately three years. Most pile driving work will take place between 0700 and 1900 hrs, 7 days per week, with potential need to drive a pile to finish beyond 1900 to 2200 hrs. In addition, it may be necessary to drive piles 24 hours per day in response to unplanned circumstances such as to achieve schedule following unplanned stoppages or to drive a pile to a stable depth after drilling for safety reasons.

A work force of approximately 500 persons will be involved in the construction of the marine civil works; approximately 40 vessels will be used including supply boats, tugs, barges and all other marine craft to transport all supplies, materials, equipment, consumables and personnel necessary for the installation and construction work. The marine vessels used during construction will be refuelled at the Port Hedland public berth.



Legend

- Spoil Ground (Existing)
- Spoil Ground (Proposed)
- Proposed Western Spur Railway
- Existing Railways
- Proposed Jetty
- Proposed Wharf
- Proposed Infrastructure Corridor
- Proposed Stockyards
- Proposed Departure Channel
- Proposed Link Channel
- Existing Shipping Channel
- State/Commonwealth Jurisdiction Boundary

0 2.5 5
kilometres

Scale @ A4: 1:250,000
Datum: GDA94
Map Grid: MGA94 Zone 50

bhpbilliton

Source:
Imagery: Landsat Mosaic (2005)
State Boundary: AMBIS (2006)
Topography: Geoscience Australia, GEODATA Topo 250K V3
(Copyright Commonwealth of Australia, 2006)

Figure 2 Proposed Outer Harbour Development showing construction, dredging and potential spoil grounds

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2.2 Biology and Ecology of Marine Turtles in the North West Shelf Waters of Western Australia

Six species of marine turtles from two families (*Cheloniidae, Dermochelyidae*) inhabit Western Australian waters (**Table 1**). All six species are considered endangered or vulnerable and are protected by state and federal legislation and international organisations (**Table 1**).

Table 1: The conservation status of marine turtle species occurring in Western Australian waters.

Species	*Wildlife Conservation Act 1950*	*Environment Protection and Biodiversity Conservation (EPBC) Act 1999*	Convention on Migratory Species (CMS) Appendix (as at June 2008)	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix (as at 12 Feb 2008)	International Union for Conservation of Nature (IUCN) Status (as at July 2008)
Loggerhead Turtle *Caretta caretta*	Schedule 1*	Endangered	I & II	I	Endangered
Green Turtle *Chelonia mydas*	Schedule 1	Vulnerable	I & II	I	Endangered
Hawksbill Turtle *Eretmochelys imbricata*	Schedule 1	Vulnerable	I & II	I	Critically Endangered
Olive Ridley Turtle *Lepidochelys olivacea*	Schedule 1	Endangered	I & II	I	Vulnerable
Flatback Turtle *Natator depressus*	Schedule 1	Vulnerable	Not listed	I	Data Deficient
Leatherback Turtle *Dermochelys coriacea*	Schedule 1	Vulnerable	I & II	I	Critically Endangered

* Schedule 1. Fauna that is rare or likely to become extinct

Of these six species, only four are known to be reproductively active in the North West Shelf region of Australia. Among these populations, Prince (1994*a*, 1994*b*) and Pendoley (2005) have identified the following as being of regional significance (**Figure 3**):

- Green turtle rookeries at Barrow Island, within the Montebello Island complex and at the Lacepede Islands;
- Hawksbill turtle rookeries at Rosemary Island in Dampier Archipelago, Beacon, Bridled and Varanus Islands in the Lowendal group, and Ah Chong Island and SE Island in the Montebello group;
- Flatback turtle rookeries at Barrow Island, within the Montebello Island complex, on Bridled and Varanus Islands within the Lowendal Island complex, on Cowrie Beach at Mundabullangana Station, and at Eighty Mile Beach in the southern Kimberley region; and
- Loggerhead turtle rookery at the Muiron Islands.

Knowledge of loggerhead turtle populations within the study region is sparse. No large olive ridley turtle rookeries have been recorded in Australia, although low density nesting occurs in northern

Australia. Leatherback turtles are occasional visitors to Western Australian waters and have not been documented nesting.

The remainder of this report, therefore, addresses primarily green, flatback and hawksbill turtle populations. However, where information pertaining to the loggerhead turtle is available it is included.

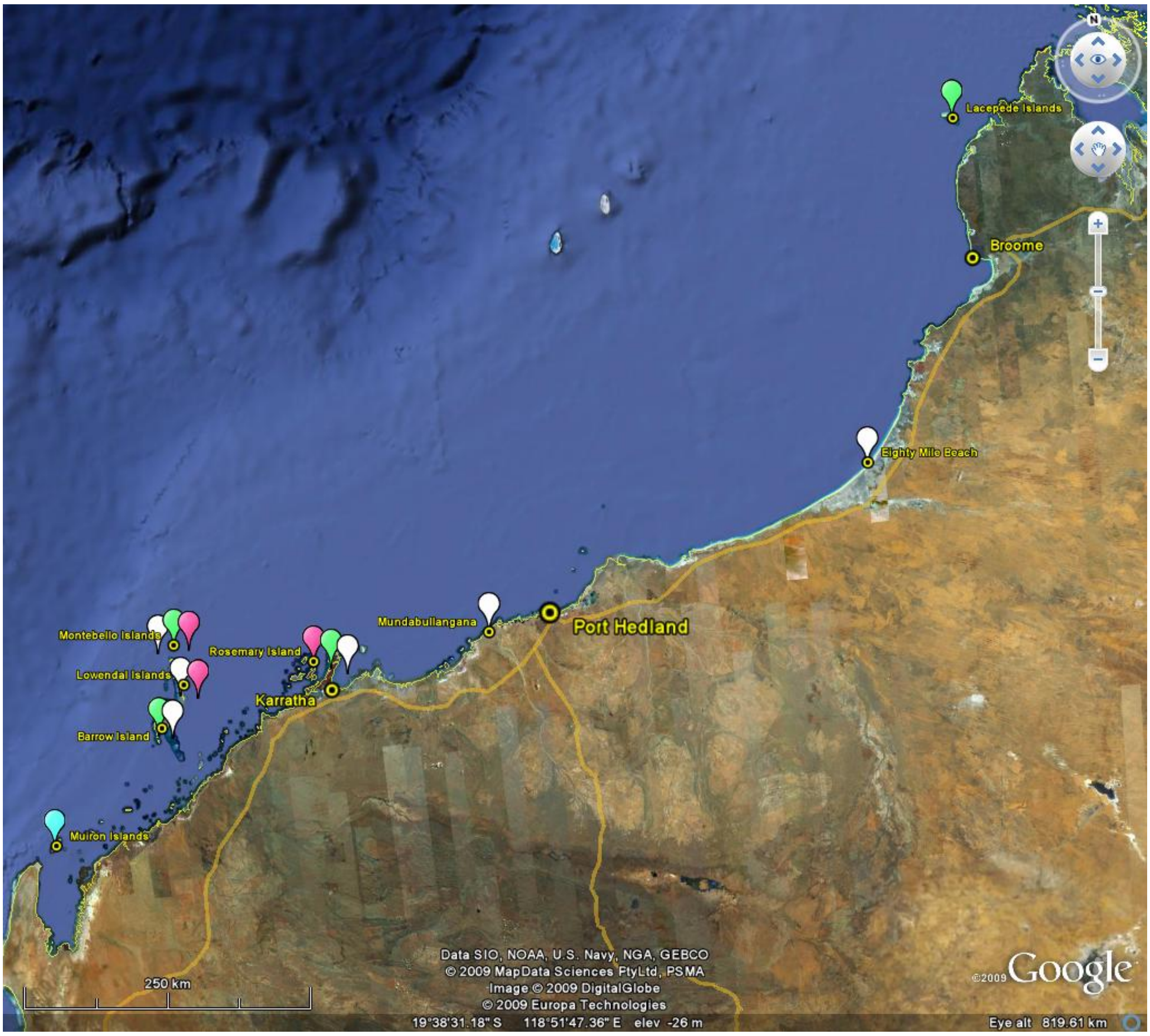

Figure 3: Location of regionally significant nesting sites for the most commonly encountered marine turtle species in the Pilbara region. Green balloons indicate major green rookeries, white balloons indicate major flatback rookeries, pink balloons indicate major hawksbill rookeries and aqua balloon indicate major loggerhead rookery. Proposed development is located at Port Hedland.

2.2.1 Overview of Marine Turtle Biology and Significant Habitat

Marine turtles are long-lived, slow to mature animals that occupy multiple, discrete habitats throughout each life stage (**Figure 4**). Whilst each life-stage is common to all species, habitat type and use vary among species, thus the following overview describes habitat use as determined by life stage. **Table 2** provides a summary of marine turtle life history and non specific habitat use.

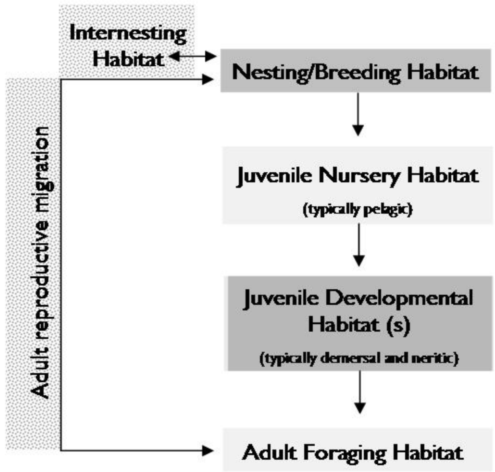

Figure 4: Schematic of marine turtle life cycle detailing shifts in habitat use. Note: Specific habitat types and use varies among species at each life stage.

Typically, newly hatched marine turtles swim away from nesting beaches into open waters where they have an initial oceanic pelagic phase. Flatback turtles are the exception to this. There is evidence that flatback hatchlings grow to maturity while remaining within the waters of the continental shelf (Pendoley *et al.* 2003; Walker & Parmenter 1990). Among species with an oceanic phase (green, hawksbill and loggerhead), juveniles return to nearshore coastal waters at around 15 years of age, where they settle into foraging habitat which is typically remote (10s – 100s km) from their natal beaches. Once they reach sexual maturity at 30 – 50 years of age they commence breeding migrations to beaches in the vicinity of their natal beaches. Breeding females spend 2 - 3 months, every 1 – 5 years at their nesting grounds (depending on the species and population). Over the course of the breeding season females will typically lay 3 - 4 clutches of eggs at two-weekly intervals. The period between laying clutches is called the internesting period.

The four habitats used by marine turtles throughout their life histories and most likely to be found within the Port Hedland region are foraging, mating, nesting and internesting habitats, described in detail below and summarised in **Table 2**.

2.2.1.1 Foraging habitat

Foraging habitat varies among turtle species and life stage.

Post-hatchling green and hawksbill turtles use an oceanic nursery habitat and typically feed on small animal life associated with marine debris at convergence zones in the open ocean (Bjorndal 1996; Witherington 2002). The location of flatback turtles during this life stage is not known but post-hatchling flatbacks have been reported to feed on macrozooplankton (Limpus 2009).

Adult green turtles are predominately herbivorous, feeding on seagrass and algae, and are therefore most often found feeding on seagrass beds or, more commonly in the Pilbara waters, on reefs hosting abundant algal communities. Adult and juvenile flatback turtles feed predominantly on bottom-dwelling organisms (invertebrates) such as holothurians, sea pens and soft corals, as well as jelly fish. Loggerhead turtles typically feed on free living and sessile invertebrates such as crustaceans and molluscs, while juvenile and adult hawksbill turtles generally feed on sponges and other reef dwelling invertebrates (Bjorndal 1996). The most comprehensive feeding study in Australia of olive ridley turtles documented mostly gastropod and bivalve molluscs from the stomachs of adults (Conway 1994) and crabs, shrimp, tunicates, jellyfish, salps and algae have been found in their diet in studies outside Australia (Bjorndal 1996; Mortimer 1982).

Algae-dominated foraging habitat for green turtles occurs throughout the Pilbara coastal waters and is most evident on shallow rocky platforms surrounding islands and the mainland coast, e.g. the west coast of Barrow Island and algae reefs fringing all of the nearshore Pilbara Islands from Serrurier Island to the Dampier Archipelago.

Hawksbill foraging has been confirmed for the reef systems in the Mary Anne group (Pendoley *et al.* 2003) and is expected to occur on all sponge habitats in the Pilbara waters.

Flatback foraging habitat has not been identified in Western Australia, however, preliminary satellite tracking programmes suggest flatback turtles are foraging on yet to be identified food sources in waters 30 – 50 m deep (Pendoley, unpublished data; www.seaturtle.org). Similarly, foraging habitat for post-hatchling flatback turtles has not been identified but is expected to occur across the continental shelf waters of the North West Shelf.

In continental shelf waters of northern Australia, large immature and adult-sized olive ridley turtles have been recorded in soft-bottomed habitats (Harris 1994). An adult olive ridley turtle was recorded from a prawn trawler in Nickol Bay, Karratha (G. Kessel, pers. comm.) and it is possible they may occur within the Port Hedland area.

2.2.1.2 Mating habitat

Mating occurs within the marine environment either en route, or adjacent to, nesting beaches (Pendoley 2005).

Green turtles: Mating aggregations of green turtles are known to occur off Barrow, Thevenard, Serrurier and Montebello Island beaches during early summer. No further mating habitat has been identified elsewhere in the Pilbara at this time. However, mating is expected to occur close to green turtle nesting sites in the nearshore mainland and coastal island waters.

Hawksbill turtles: Mating of hawksbill turtles has been observed in shallow water off the nesting beaches at Rosemary and Delambre Islands (A. Vitenbergs, pers. obs.) and off Varanus Island (K. Pendoley, pers. obs.).

Flatback turtles: The location of mating grounds for flatback turtles is unknown.

2.2.1.3 Nesting habitat and reproductive periods

Nesting beaches used by female turtles for egg laying are generally sandy. Eggs incubate within nesting beaches over a 6 - 8 week period, following which, hatchlings emerge and head into the water.

Nesting beach habitats most commonly associated with the three turtle species typically found in the Pilbara region has been described by Pendoley (2005) as follows:

- Green turtles nest on high energy, steeply sloped beaches comprising deep, well sorted, medium grain sized sand, with a deep water approach to the beach independent of tide state (i.e. the intertidal zone is narrow or absent, e.g. west coast of Barrow Island and exposed beaches of North West and Trimouille Islands in the Montebello group).

- Hawksbill turtles are associated with beaches located close to nearshore coral reefs and the beach sediment typically comprises a shallow bed of coarse sand and coral rubble (e.g. Beacon Island and Rosemary Island).

- Flatback turtles favour low energy beaches that are typically narrow, with moderate grain size and a low to moderate beach slope. The beach bed is often shallow (underlain by rock platform or clay) and the beach approach obstructed by broad intertidal mud or limestone intertidal platforms (e.g. east coast of Barrow Island, south coast of Thevenard Island and Mundabullangana).

It is worth noting that this description represents currently known preferred habitat only and is not exclusive of others types of unknown, less preferable or potentially less suitable habitat types.

Breeding seasons (encompassing mating, nesting and hatchling emergence periods) are different for individual species. Typical breeding seasons for the three most common nesting species in the Pilbara region are:

- Green Turtles: November to April with peak nesting in December to January;

- Hawksbill Turtles: August to April with peak nesting in October to November; and

- Flatback Turtles: November to March with peak nesting in December to January.

Low level, year round nesting may also occur in hawksbill and green turtle populations, though this varies from year-to-year.

2.2.1.4 Internesting habitat

The internesting habitat is the area that a breeding female turtle occupies between nesting events within a nesting season. The female turtle will not feed during this time while eggs for the next clutch are developing. For green and hawksbill turtles this habitat is typically located in shallow water, within several kilometres of the nesting beach (Pendoley 2005). Satellite tracking data from the Pilbara region show that flatback turtles use internesting grounds within 5 to 10 km of their mainland nesting beaches (K. Pendoley, pers. comm.; http://www.seaturtle.org/tracking). There is evidence that flatback turtles nesting on offshore islands also travel to the mainland to internesting habitat located within 5 – 10 km of the mainland coast.

Table 2: Summary of currently known habitat types for various life stages of the most commonly encountered marine turtle species in the Pilbara region.

Life Stage		***Green turtle***	***Flatback turtle***	***Hawksbill turtle***
Post-hatchling		Oceanic nursery/pelagic	Coastal waters	Oceanic nursery/pelagic
Adult	Mating	Offshore from nesting habitat.	Currently unknown in the Pilbara.	Offshore from nesting habitat.
	Foraging	Neritic habitats associated with seagrass/algal beds and mangrove habitat.	Currently unknown in the Pilbara.	Shallow reef, patch reef habitat.
	Nesting	High energy, steeply sloped beaches. Deep well sorted medium grain size. Deep water approach.	Low energy, narrow beaches. Moderate grain size. Low to moderate beach slope.	Shallow coarse sand and coral rubble associated with nearshore coral reefs.
	Internesting	Shallow coastal waters within several kms of the nesting beach.	Shallow nearshore coastal waters within 5-60km of nesting beach.	Shallow coastal waters within several kms of the nesting beach.

3.0 METHODOLOGY

3.1 Desktop Review

The approach of the desktop review was to review the publicly available information found in peer-reviewed published work, conference proceedings and publicly available reports. As data from these sources were very limited, the review was extended to include the findings of Dr. Pendoley and her co-workers, who have been working in the Pilbara marine region since the mid 1980s. Only one known broad-scale survey of marine turtles has been carried out along the Pilbara coastline and nearshore island groups: a one off, snapshot aerial survey conducted by Prince *et al.* (2001). Apart from this survey, there is very limited field survey information available for the area of interest.

Information on marine turtle habitat usage in the Pilbara region has been collected using a variety of methods, including aerial survey track counts, aerial survey in-water animals counts, ground based census 'snap shot' (overnight survey), ground based counts of tracks and boat based in-water counts of turtles

These data sets have been collected both opportunistically and as part of systematic marine turtle or marine biological field surveys. Variation in approach does not always allow direct comparison between the results of various studies.

3.2 Field Surveys

3.2.1 Aerial Track Count Survey

A land-based aerial survey was conducted as a preliminary assessment to identify locations of nesting beaches along the mainland coast between Mundabullangana and the De Grey River (approximately 145 km of coastline), and offshore islands including Reefs, Weerdee, Downes and Finucane Islands.

The land-based aerial survey was conducted along the coastline between Mundabullangana and the De Grey River at the peak of the nesting season in summer (December). The survey was conducted over two mornings (0700-1030) on the 5 and 6 December 2008 by Dr Jessica Oates and Dr Nancy FitzSimmons. The survey was conducted in the early morning as the low sun angle casts a shadow behind the tracks making them more visible. An aircraft was flown at an altitude of no less than 155 m and a ground speed of 100 knots approximately 200 m off the coastline. Two observers sat on the same side of the plane and the location and number of pairs of turtle tracks on the beaches was recorded using a handheld GPS and voice recorder, and later transferred onto datasheets.

Attempts were made to count only fresh pairs of tracks each day; however, this was not always possible to determine. Therefore the counts are likely to include both old and new crawls, and the second day of counts is likely to include tracks already counted on the first day. The independent counts by each observer were averaged for each day and the count reported is a mean of the two independent counts.

3.2.2 Aerial In-water Surveys

A water-based aerial survey was conducted in December 2008 to map turtle presence/absence in offshore waters. It is impossible to determine whether the turtles observed are foraging, mating, internesting or migrating through the area at the time of the survey. Therefore, a winter survey was also conducted in April 2009 to identify resident foraging turtles, as presumably breeding adults will not be present at this time of year.

The water-based aerial survey was conducted within offshore waters from Mundabullangana to the De Grey River, out to the 20 m isobath, which is generally situated 20 to 45 km offshore. The summer survey was conducted over two days in the afternoon on the 5 and 6 December 2008 by Dr Jessica Oates and Dr Nancy FitzSimmons. The winter survey was conducted over one full day on 20 April 2009 by Dr Kellie Pendoley and Dr Jessica Oates. Flights were conducted as close to noon as possible for maximum visibility and to minimise the glare.

Strip transects were flown approximately perpendicular (NW-SE) to the coastline out to the 20 m isobath. Separation from the coast to the 20m isobath was generally between 20 and 45 km. All transect lines followed the same methodology as Prince *et al.* (2001) and were spaced at 2.5' latitude (4.65 km or 2.5 nm). The same methodology as Prince *et al.* (2001) was followed as it is an accepted method, allowed comparison of results between the two surveys. The location of the 30 aerial transects are shown in **Figure 5**. Observations were made at an altitude of no less than 155 m and a ground speed of 100 knots. Two observers independently scanned 200 m wide survey strips on each side of the aircraft. The 200 m transect width was marked using tape on the wing struts. The number and species (if possible) of turtles were relayed into a voice recorder and the location was recorded onto a handheld GPS. This information was later transferred onto datasheets. The weather conditions during the summer aerial surveys were favourable with winds generally between 10-15 knots from the south to south-west, and minimal cloud cover, haze and glare. Visibility was generally suitable for the sighting of turtles from the aircraft. The weather conditions during the winter aerial survey were generally favourable with winds between 10-15 knots, however, cloud cover ranged from 0-80%, reducing visibility at times. Visibility in winter meant it was more favourable for sighting turtles compared with during the summer survey.

An additional survey was flown along the coastline from Mundabullangana to Port Hedland to survey the shallow inshore waters. The single transect was flown at the same operating conditions as stated above.

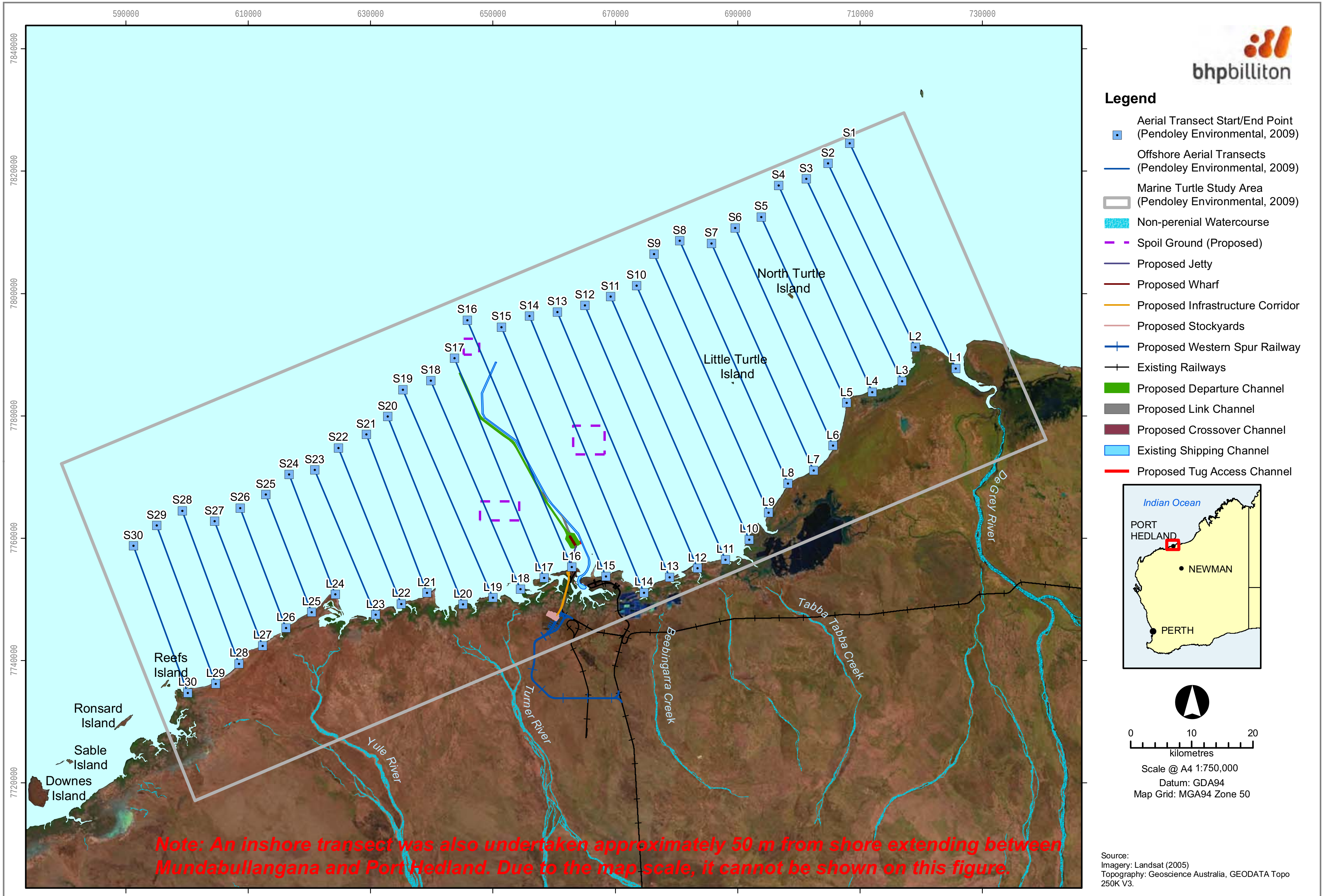

Figure 5 Location of the Offshore Water Aerial Transects

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3.2.3 Snapshot and Track Census (Ground) Beach Surveys

Beach surveys were conducted to:

- ground-truth the potential nesting beaches identified from the aerial surveys;
- identify the species present; and
- quantify the level of nesting activity on selected beaches.

Track census counts were conducted on two selected beaches; Downes Island and Paradise Beach (North), over four consecutive mornings from 8-12 December 2008 (**Figure 6**). These beaches were selected based on proximity to the proposed development, level of nesting identified from aerial surveys and the steaming time to reach the beaches each day. Track counts from Cemetery Beach and Pretty Pool were obtained from the Care for Hedland Environmental Association in order to put the results of this survey into a more regional context.

The track census counts were conducted by Dr Kellie Pendoley and Dr Jessica Oates. The track census survey methodology used for this programme is based on techniques developed for beach surveys within the Barrow/Montebello/Lowendal Island complex (Pendoley 2005) and consistent with IUCN SSC Marine Turtle Specialist Group methodology (Schroeder and Murphy 1999). Access to the beaches for the survey was by boat.

During the first morning, a 'snapshot' survey of the beach was conducted by recording all nesting activity on the beach as well as the physical characteristics of the beach. During the first morning, a line was drawn in the sand above the high tide mark. Snapshot surveys are limited by a lack of replication and that they only represent a small timeframe within the nesting period. Overnight track census counts were then conducted on the next three mornings, recording all turtle tracks that crossed the line. The line was redrawn daily and new counts made. Two different track counts were conducted, across the line and below high tide (BHT). Across the line counts record all turtles that cross the line drawn in the sand and represent the total turtle activity overnight, including nests. Up and down tracks were counted and each fresh track was walked and examined to determine whether the turtle had nested. BHT counts are the number of tracks that are present since the overnight high tide and do not account for the turtles crawling up and down the beach before high tide. Information including species of turtle, signs of predation, wind, weather and tide conditions was also recorded each day. The approximate lengths of the track census survey beaches were 0.55 km at Downes Island and 1.5 km at Paradise Beach (North).

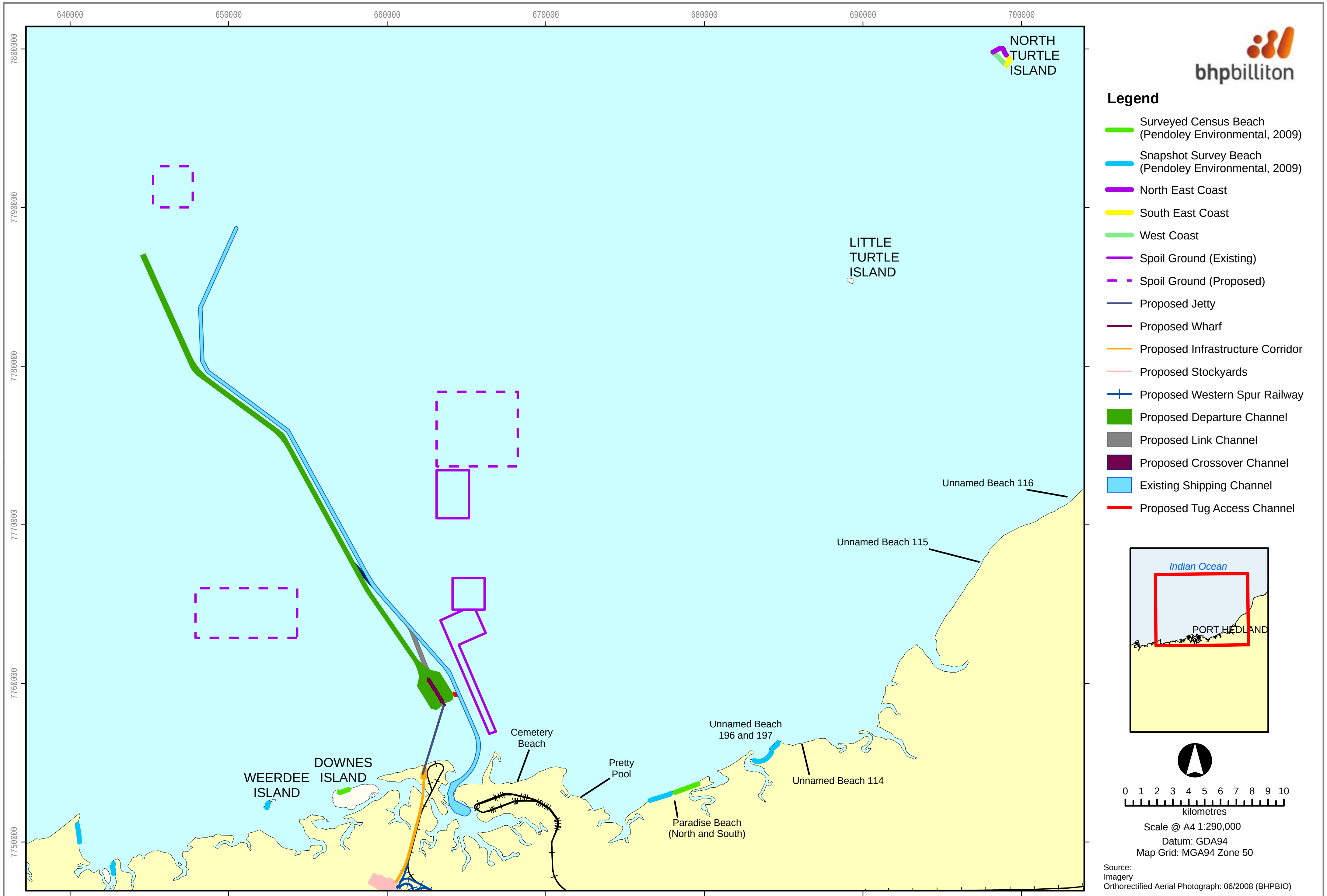

Figure 6 Location of Census and Snapshot Beaches within the Marine Study Area

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Additional snapshot surveys were carried out on all accessible, sandy and potentially suitable nesting beaches within a 25 km radius of Port Hedland, as well as at North Turtle Island, which is located approximately 60 km north-east of Port Hedland. All beaches were accessed by boat. Beaches surveyed to the south of Port Hedland included Weerdee Island and two beaches south and south-east of False Cape Thouin (**Figure 6**). Beaches surveyed to the east of Port Hedland included Paradise Beach (South), two unnamed beaches (Beach 196 and 197) and North Turtle Island (**Figure 6**).

If personnel were unable to access the beaches due to the shallow bathymetry and tidal movements in the area, the beaches were surveyed from the boat using binoculars. The primary data collected from each snapshot survey are listed below:

- *Turtle tracks BHT.* These tracks indicate the number of animals attempting to nest since the overnight high tide. This is therefore an underestimation of the number of turtles traversing the beach overnight as it does not account for animals crawling up and down the beach before the high tide.
- *Turtle tracks above high tide level (AHT).* This information provides an indication of the marine turtle activity on the beach in the recent past. This could be days to months, depending on the metocean conditions (e.g. cyclones, storms and tidal surge will wipe the beach clean), along with the size, orientation and sediment characteristics of the beach. Secondary visual cues are also used to determine the age of past nesting attempts, such as crab burrow holes through less-recent tracks, overlay of hermit crab, Perentie lizard or bird tracks and erosion level of crawls.
- *Observations of turtles on the beach and in the water.* The behaviour of the animals in the water provides an indication of habitat usage and might include mating aggregations, developmental habitat or foraging ground.
- *Number of nests.* It is not possible to be completely accurate about this figure since the only way to get an accurate figure is to dig up each nest and confirm the presence of eggs, and because of dense-usage beaches one body pit often overlays that of another turtle. Indicators used to assess whether eggs have been laid include the size, shape and compaction of sand at the potential nest site, and track characteristics (where observable).
- *Hatchling emergence.* Nests emerging within the recent past, as seen by expanding 'fans' of hatchling tracks from a distinct source point. As stated for track counts this count is dependent on, and much more susceptible to the metocean conditions of the previous days and months.
- *Nest predation.* Nest predation is recorded for nests that clearly show evidence of animal and human foot prints and digging to egg/hatchling depth. Eggs, egg shell or hatchling remains may be visible.
- *Quantification of nesting effort* is assessed subjectively using the following density scale:
    - low density = 1 track or crater per 10m+, very widely spaced tracks or craters with large areas of fresh sand visible;
    - medium density = 1 track or crater per 5m – 10m; or
    - high density = 1 track or crater per metre, tracks and craters may be overlapping each other and little fresh sand is visible on the beach.

3.2.4 Satellite Tracking Study

Satellite transmitters were attached to nesting females on Cemetery Beach to identify their internesting habitat, migratory pathways and location of their remote foraging grounds. Five Platform Terminal Transmitters (PTTs) were deployed as outlined in **Appendix A**.

3.2.5 Limitations of the Surveys

The limitations associated with the marine turtle surveys for the proposed Outer Harbour Development are listed below:

- Marine turtle nesting is cyclic and consequently short-term studies such as this only provide information pertaining to that particular day and cannot be extrapolated out to represent what happens on a yearly basis. The survey was conducted during the peak flatback and green turtle nesting period, and therefore, may have underestimated hawksbill turtle nesting as their peak occurs earlier in the season (October/November).
- Aerial surveys of beaches by fixed-wing aircraft are limited by speed and height requirements for safe operation. Tracks are difficult to count from the air if they have been weathered at all, potentially reducing the track census figures for some beaches.
- Aerial surveys of turtles in water are limited by water clarity. Turtles were generally only sighted when they were at the surface and turtles more than 2 m below the surface were unable to be sighted. Therefore, the number of turtles recorded is likely to be an underestimate of the number of turtles in the water.
- The number of track census beaches was limited to two beaches in close proximity to Port Hedland due to tides and the sailing time required to reach the beaches.
- Track census counts were originally planned to be conducted on North Turtle Island. However, the bathymetry of this island is such that it is only accessible by boat over a seven-day period each month and, together with the sailing time required to get to this island, only a snapshot survey could be conducted.
- Only beaches within approximately 25 km radius of Port Hedland were ground-truthed due to sailing time of the boat.
- Access onto some beaches by boat was restricted due to very broad areas of very shallow bathymetry and tidal movements at the time. These beaches were surveyed from the boat with binoculars.
- One of the five PTTs attached to nesting females at Cemetery Beach was not turned on. The animal subsequently returned twice to nest; however, attempts to activate this transmitter were unsuccessful.
- Three of the four satellite tagged flatback turtles from Cemetery Beach programmed to transmit data for at least two years have stopped transmitting at the time of this report. Data on both internesting and migration were collected from all turtles before the transmitters ceased operation. The PTTs can cease transmitting prematurely and there is no way to predict if and when this may occur. Cessation of transmitters may be due to loss of battery power, battery bleed, loss of the PTT and harness (the harness is attached with corrodible wire to ensure it eventually falls off), loss of the aerial or fouling of the saltwater switches of the PTT unit. However, PTTs may also start transmitting again after ceasing operation.

3.3 Risk Impacts Assessment

A preliminary risk assessment was undertaken (**Table 5**) which identified the relative level of risk of potential impacts by scoring the likelihood and consequence of the specific activities without any management using BHP Billiton Iron Ore's risk assessment matrix (see **Appendix B**). The risk assessment was undertaken by Pendoley Environmental, SKM and BHP Billiton Iron Ore personnel.

4.0 RESULTS OF DESKTOP REVIEW – PROJECTED MARINE TURTLE HABITAT USE IN AND ADJACENT TO DEVELOPMENT

Having previously described typical habitat types used by each species of marine turtle during each life stage of relevance to this project (**Section 2**), this information is now applied to the proposed Port Hedland Outer Harbour Development area. Please note this review was not exhaustive, and was based only on what was currently known regarding marine turtles in the region and the species in general when it was undertaken in 2008, prior to the field surveys being conducted in the 2008/09 summer season by Pendoley Environmental.

4.1 Areas within Proposed Development Area

4.1.1 Port Hedland and Harbour

4.1.1.1 Nesting

Nesting habitat for female flatback turtles has been confirmed at Cemetery Beach, Pretty Pool and Cooke Point (Prince, 1994*a*), which are located approximately 6 km, 9 km and 7 km to the east of the proposed development, respectively. There is no sandy nesting habitat within the Port Hedland Inner Harbour area. Any suitable sandy nesting beach on Finucane Island (adjacent to the proposed development) and Downes Island (3 km to the west of the proposed development) may support flatback turtle nesting. Recent surveys confirmed that Downes Island supported low level density nesting (discussed in Section 5.3).

The three identified nesting areas in the vicinity of Port Hedland are approximately 6 km or more to the east of the proposed development and comprise a small rookery (100s of turtles rather than 1000s) relative to those identified at Eighty Mile Beach, Mundabullangana Station, Barrow Island, Dampier Archipelago and the Montebello Islands. This finding is consistent with the estimates made by Prince (1994*b*). Two of these beaches (Cemetery Beach and Pretty Pool) have been monitored using track and inferred nest counts by the Port Hedland community group, Care for Hedland Environmental Association Inc, since 2004.

4.1.1.2 Internesting

Preliminary results from satellite tracking of flatback turtles from Mundabullangana suggest that their internesting grounds are close to their mainland rookeries (within 5-10 km) and are expected to occur in the coastal waters near Cemetery Beach, Pretty Pool and Cookes Point. To date, none of the internesting flatback turtles studied has been confirmed using creeks or rivers as internesting habitat (K. Pendoley, unpubl. data; http://www.seaturtle.org/tracking). Therefore, internesting flatback turtles are not expected to occur in the Port Hedland Harbour, however, this has not been confirmed by any study to date.

4.1.1.3 Foraging

The review found two records of adult green turtles stranded in the Harbour area (2006 and 2009) suggesting that adult green turtles may forage in the Inner Harbour and tidal creeks. While mangrove plants are not considered a primary food source for adult green turtles, they are probably used as a supplemental or opportunistic food source by Pilbara green turtles (Pendoley and Fitzpatrick 1999). In addition, an anecdotal report of an adult loggerhead turtle in the Port Hedland

Harbour to the south of Finucane Island was reported in 2007 (K. Walley, pers. comm.) and therefore loggerhead turtles may use the area for foraging.

During 2006 and 2007, P. Everson (pers. comm. 2007) spent over 40 days surveying the waters within the Port Hedland Harbour and associated creeks and reported that juvenile turtles are common throughout the area although he was unable to identify the species. While species has not been confirmed by a qualified marine turtle biologist, the descriptions of the animals and their behaviour suggest these are primarily juvenile greens (C. Wilson, 2007; K. Howlett, 2007, pers. comm.) and possibly juvenile flatback turtles (C. Wilson, 2007, pers. comm.). Four recent records of juvenile green turtles either captured or stranded in the harbour area support this assumption. Juvenile green turtles are herbivorous, feeding on seagrasses and algae (Bjorndal 1996). They have localised, restricted home ranges and are dependent upon the food sources within these ranges (Makowski *et al*. 2006). Green algal mats have been identified within the Harbour area and *Sargassum* species within the surrounding creeks (FMG 2008).

Though benthic flora is of limited abundance in the Harbour area, mangrove habitats provide an additional food source and a suitable protective environment for juveniles. Juvenile turtles utilise the seaward fringes of the mangrove habitat, remaining on the periphery of the root system, presumably to avoid the risk of entanglement and drowning in the densely tangled roots found deeper inside. It is probable that they would be found associated with these systems along much of the shoreline within the project area. Juvenile green turtles are commonly sighted in shallow water adjacent to beaches and mangrove root systems/tidal creeks in the Pilbara region (K. Pendoley, pers. obs.).

Juvenile flatback turtles also use the shallow nearshore waters of the Pilbara. This has been confirmed from reports and West Australian Museum records of post-hatchling and juvenile material that was collected from Pilbara waters (Pendoley *et al*. 2003) and islands (Pendoley and Ford 2000; Pendoley and Vitenbergs 2003). Anecdotal reports indicate juvenile flatback turtles are present within the creeks of the Port Hedland Harbour and adults are known to share foraging grounds with juveniles in this species. Biota (2004) reported that flatback turtles are known to utilise habitats within the tidal creeks of Port Hedland harbour, though information regarding size and/or age-class is not given. There have also been anecdotal reports of juvenile and adult flatbacks observed in creeks by local residents.

4.1.2 Mainland Coast

Limited survey information indicates that marine turtles occur in densities of approximately 2.46 turtles per km^2 inshore of the 20 m isobath (**Figure 7**; Prince *et al.* 2001). These data sets were collected in April 2000 and may therefore have limited seasonal and temporal value. The timing of the survey near the end of the nesting season means that many of the documented animals are likely to be resident turtles and not migrant breeding turtles. This value is conservative as their distribution extends beyond the 20 m isobath, and juveniles are less easy to spot by aerial survey. The majority of sightings were assumed by the author, based on observational experience, to be green turtles, with smaller populations of flatback, hawksbill and loggerhead turtles. The resident marine turtle population detected by the survey (breeding aggregations were not surveyed) was widely distributed across the Pilbara coastal waters, although turtles were found to be concentrated in certain areas, which may indicate a particular preference for feeding or resting grounds (Prince *et al*. 2001).

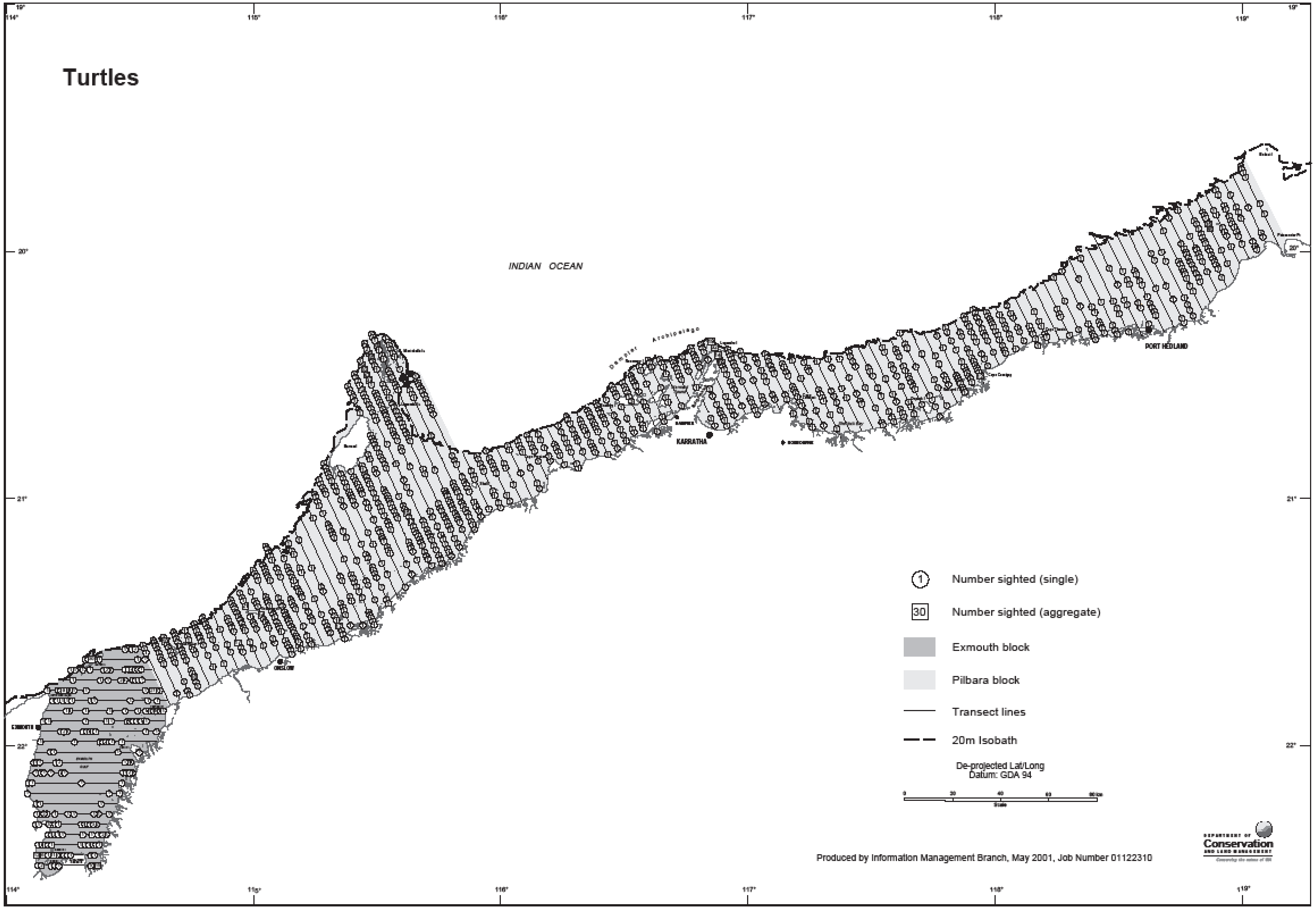

Figure 7: Results of April 2000 aerial surveys for turtles in the offshore waters of the Pilbara region (source Prince *et al.* 2001).

4.1.2.1 Mundabullangana to De Grey River

The coastline between Mundabullangana and the De Grey River (approximately 145 km in length) consists primarily of mangrove lined creeks and rivers interspersed with rocky shoreline and small sections of sandy (possibly marine turtle nesting) habitat. The possible nesting sandy habitat consists of wide beaches with a low slope that gradually grades into a wide shallow muddy intertidal and subtidal zone, typical of the nesting habitat favoured by flatback turtles (Pendoley, 2005). The water offshore is typically highly turbid.

Satellite tracking data show that green, flatback, hawksbill and loggerhead turtles all migrate along the Pilbara coastline from their nesting beaches to their foraging grounds (http://www.seaturtle.org/tracking); however, the migratory corridors are further offshore from the study area.

Juvenile green turtles are commonly sighted in shallow water adjacent to beaches and mangrove root systems in the Pilbara region (K. Pendoley, pers. obs.). It is probable that they would be found associated with these systems along much of the coastline within the survey area.

4.1.3 Offshore Islands

Weerdee Island is approximately 12 km west of the entrance to the Port Hedland Harbour and 1.8 km offshore of the mainland, located within the proposed project development area. The island is predominantly sandy with areas of mangrove and a rocky beach area. The sandy areas on the south coast may support turtle nesting (there is no published or anecdotal information to confirm this).

The intertidal platform is rocky and covered with rock oysters, barnacles and leptograpsid crabs (SKM 2009). The subtidal reef area is shallow and comprised of patchy areas of either macroalgae, a combination of macroalgae and sparse hard corals or patches entirely comprised of small bivalves (SKM 2009). The subtidal reef area may therefore be used by green turtles for foraging habitat.

4.2 Areas Adjacent to Proposed Development Area

4.2.1 Mundabullangana (West of Cape Thouin)

Mundabullangana, located approximately 50 km to the east of the proposed development, is a regionally important flatback turtle rookery providing nesting and internesting habitat. Recent population modelling indicate that the Mundabullangana flatback nesting population is substantial, supporting greater than 1700 nesting females each year (Pendoley *et al.* in press) comprising one of the largest flatback nesting populations in the world. Others are identified as the Cape Domett population in the northern Kimberley with an estimated 3250 turtles per annum (Whiting *et al.* 2008), which is possibly from the Northern Territory genetic stock, and the Crab Island population from the Gulf of Carpentaria genetic stock (Limpus *et al.* 1993; Sutherland and Sutherland 2003).

4.2.2 De Grey River

The De Grey River, located approximately 70 km north-east of the study area, may be an important foraging ground for marine turtles. Female flatback and green turtles from Barrow Island, female hawksbill turtles from Varanus Island and female loggerhead turtles from Ningaloo Marine Park were found to spend some time in the De Grey River/Turtle Island region (Pendoley 2005; http://www.seaturtle.org/tracking).

Two green turtles fitted with transmitters between 2001 and 2003 spent in excess of two weeks in the De Grey River following migration from their nesting grounds, indicating they were foraging in the De Grey River area (Pendoley 2005, http://www.seaturtle.org/tracking). Another turtle may have also been foraging in the De Grey area, however as its transmitter failed two days after it reached the area, this is not conclusive (Pendoley 2005, http://www.seaturtle.org/tracking).

One female flatback turtle fitted with a satellite transmitter on Barrow Island headed directly to what appears to be her foraging ground near Turtle Island, west of the De Grey River mouth and was there for two months before the transmitter failed (Pendoley unpubl. data; http://www.seaturtle.org/tracking).

Two hawksbill turtles fitted with satellite transmitters on Varanus Island also ended their post-nesting migration in the De Grey River/Turtle Island area (Pendoley 2005).

Satellite tracking of nesting loggerhead turtles from Ningaloo Marine Park as part of the Ningaloo Turtle Programme showed that one female tagged on 21 December 2007 spent approximately 100 days just east of the De Grey River area, presumably foraging before the transmitter failed (http://www.seaturtle.org/tracking).

Although these data sets are limited, they indicate that the De Grey River area may be an important post-nesting foraging ground for a number of marine turtle species nesting in the region.

4.2.3 Eighty Mile Beach

Eighty Mile Beach is believed to support high levels of flatback nesting, similar to that seen at Mundabullangana, although at a much lower density. To date there are no detailed studies to confirm this (Prince 1994*a*). Although this flatback rookery lies over 60 km (north east) from the proposed development, the biology of the species dictates that a regional perspective is maintained when assessing potential development impacts. Reproductive populations are comprised of animals from varying foraging assemblages in locations often >100 km away.

4.2.4 Offshore Islands

4.2.4.1 North Turtle Island

North Turtle Island is approximately 20 km from the coast and 58 km north-east of the entrance to the Port Hedland Harbour. It has a fringing subtidal area that extends in all directions from the island shore to a distance of 1.3-3 km. The intertidal platform is rocky, with numerous shallow pools of varying size. The surface is dominated by a diversity of macroalgae; however there are also small colonies of encrusting and massive corals and sponges (SKM 2009). Numerous juvenile and fewer adult green turtles were observed within the pools of the intertidal platform (SKM 2009), between December 2007 and February 2009, presumably using the area to forage.

The area around Little and North Turtle Islands may also be foraging habitat for flatback turtles, as one female turtle from Barrow Island spent over two months in the area, presumably foraging (Pendoley unpubl. data, http://www.seaturtle.org/tracking). Hawksbill turtles have also been recorded from satellite transmitters as spending time in the vicinity and may also use the area surrounding the island for foraging, given the presence of sponges. High density aggregations of resident marine turtles (aggregations of 35-46 turtles within 1 km^2) were also observed near North Turtle Island during the April 2000 aerial water surveys (**Figure 7**; Prince *et al*., 2001).

Closer to the island is an area of shallow sand over pavement, increasing in depth towards a sandy beach area. This beach appears to support some turtle nesting, as turtle tracks and signs of nesting were noted by the SKM marine team (SKM 2009). Based on photographs the tracks are possibly from flatback turtles (K. Pendoley 2008, pers. comm.). Green turtles are unlikely to nest on the island as they tend to prefer deeper water access to nesting beaches. Hawksbill turtles may use the island for nesting, as suitable habitat is present.

4.2.4.2 Little Turtle Island

Little Turtle Island is approximately 8 km from the coast and 40 km north-east of the entrance to Port Hedland Harbour. The island is approximately 0.5 km long and is almost awash at high tide and is therefore unlikely to support nesting turtles.

It has a fringing subtidal area that extends over 1.1 km to the north-west and marginally around the rest of the island. The intertidal area of the island was found to be predominantly rocky, with shallow pools (SKM 2009). The subtidal area in the vicinity of Little Turtle Island was comprised of a combination of sand, rubble and rock. The percentage cover of biota was predominantly macroalgae, sponges and hard corals dominated by encrusting and massive varieties. The site also had a small amount of soft corals and hydroids. A single green turtle was observed within the intertidal zone by the SKM marine team (SKM 2009). Hawksbill turtles may also use this area as a foraging ground.

4.3 Other Offshore Sites

During SKM's marine habitat assessment (SKM 2009), areas of vertical relief corresponding to a series of limestone ridges that lie parallel to the coast were evident within the study area. Whilst these areas support hard corals and other Benthic Primary Producers (BPPs), the cover is sparse (5 % of the area is predicted to be hard substrate with biota) and not complex in nature (SKM 2009). Within the entire marine study area, soft corals were predicted to occur 0.9 % of the area, sponges over 2.2 %, invertebrates over 5.6 % and macroalgae 4.4 % (SKM 2009). Sediment was by far the most prominent substrate class mapped and was predicted to occur over 88 % of the study area (85 % of the total area was predicted to be bare sediment without biota).

5.0 RESULTS OF FIELD SURVEYS

5.1 Aerial Track Count Survey

The results of the aerial survey are presented in **Table 3** and the locations of beaches where turtle nesting activity was recorded are shown in **Figure 8**. The results indicated that Mundabullangana had the highest level of nesting activity (with 317 and 543 tracks) when compared with all of the other beaches. Mundabullangana South 1, the beach just to the south of Mundabullangana had the next highest density of turtle nesting with 78 and 87 pairs of tracks counted each day. There were no visible turtle tracks recorded on the stretch of coastline from Cape Thouin east to Downes Island. Beaches that recorded low to moderate levels of nesting included Cemetery Beach, Pretty Pool, Paradise Beach and Unnamed beaches 196 and 197, all located east of Port Hedland. Further east of these beaches there was very low level, diffuse nesting activity (0.02 – 0.15 tracks.km^{-1}) along the coastline to the De Grey River.

Table 3: Turtle tracks counted along the mainland coast between Mundabullangana and the De Grey River
Note the counts presented are an average of the two independent observer's counts for that day.

Place	Length of beach	GPS Coordinates (WGS84)		Track Counts (pairs)	
		Start	End	Day 1	Day 2
Reefs Island	1.3 km	20°28.557'S, 117°55.057'E	20°28.275'S, 117°59.151'E	11	7
Mundabullangana South 2	3.1 km	20°27.193'S, 118°01.396'E	20°25.944'S, 118°02.551'E	20	20
Mundabullangana South 1	0.8 km	20°25.410'S, 118°02.856'E	20°25.014'S, 118°03.516'E	78	87
Mundabullangana	3.0 km	20°24.900'S, 118°03.912'E	20°23.871'S, 118°05.535'E	317	543
Mundabullangana North	3.8 km	20°23.871'S, 118°05.535'E	20°20.665'S, 118°10.209'E	2	2
Downes Island	0.55 km	20°18.659'S, 118°30.186'E	20°18.569'S, 118°30.486'E	3	1
Cemetery Beach	0.8 km	20°18.480'S, 118°36.233'E	20°18.176'S, 118°36.905'E	14	31
Pretty Pool	0.9 km	20°18.634'S, 118°38.584'E	20°18.815'S, 118°39.217'E	19	15
Paradise Beach (North & South)	3.0 km	20°18.925'S, 118°41.270'E	20°18.227'S, 118°43.055'E	46	53
Unnamed beaches 196 & 197	2.0 km	20°17.357'S, 118°45.513'E	20°16.852'S, 118°46.135'E	16	13
Unnamed beach 114	0.2 km	20°16.812'S, 118°46.957'E	20°16.756'S, 118°47.046'E	2	1
Unnamed beach 115	0.8 km	20°11.136'S, 118°53.029'E	-	1	1
Unnamed beach 116	1.0 km	20°08.752'S, 118°56.022'E	20°08.384'S, 118°56.641'E	1	1
Spit Point	3.5 km	20°02.014'S, 119°00.160'E	20°01.763'S, 119°01.098'E	8	4
Larrey Point	2.2 km	20°57.817'S, 119°05.480'E	-	2	2

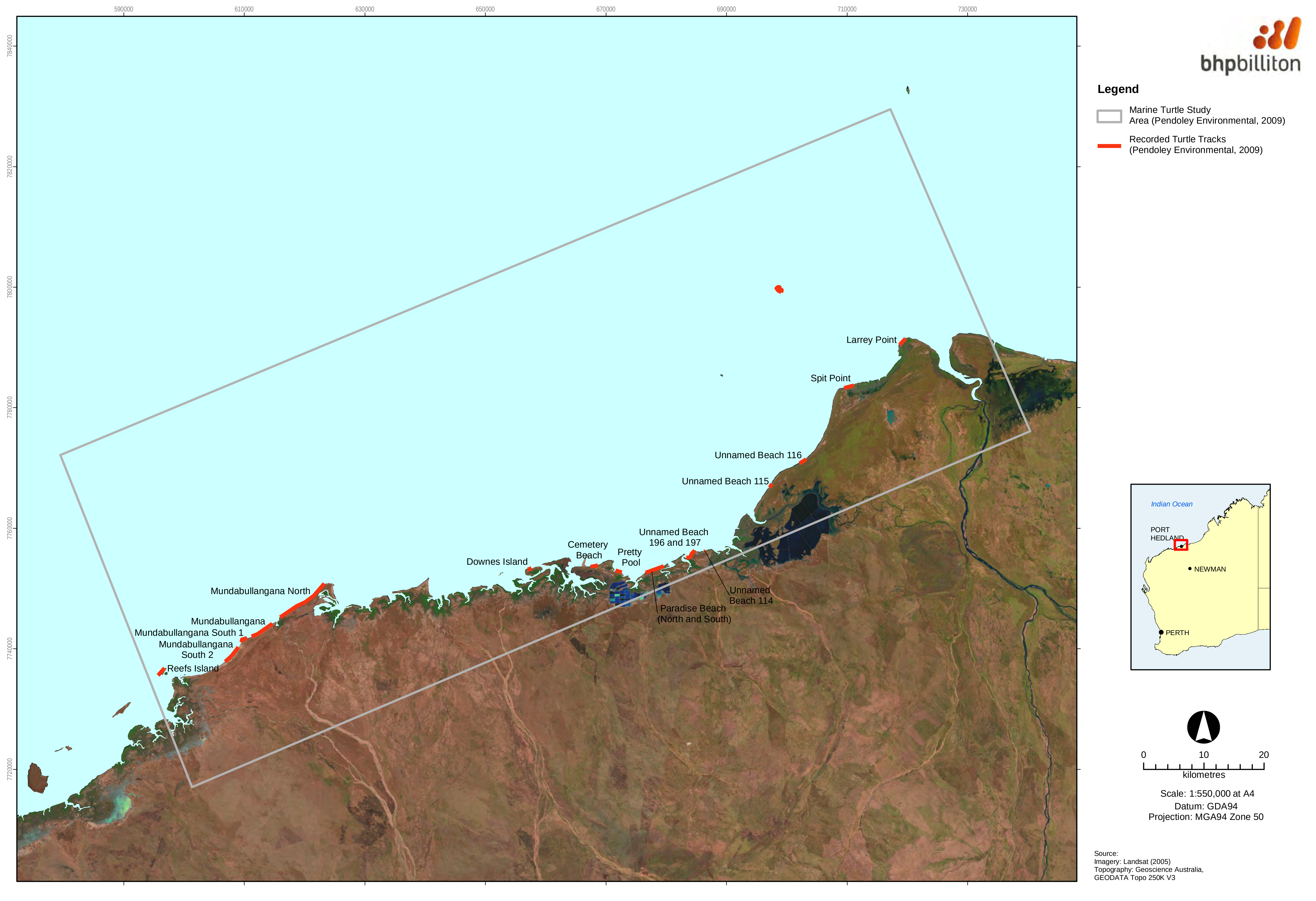

Figure 8 Areas of Turtle Nesting Activity Identified During the Aerial Survey

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5.2 Aerial In-water Surveys

A total of 65 and 226 turtles were sighted during the off-shore transect surveys in summer and winter respectively (**Figure 9**). Only Chelonid turtles were sighted with the possible exception of one sighting during the summer survey, which may have been a leatherback turtle. Species identification of the sightings was not possible and species sighted may have included green, flatback, loggerhead or hawksbill turtles. The estimated number of turtles within the survey area (boundaries defined as the mainland coast, 20 m isobath line and the first and last transect lines) was approximately 713 individuals at an average density of 0.15 turtles per km^{-2} during the summer survey and 2478 turtles at an average density of 0.53 turtles per km^{-2} during the winter survey. Prince *et al.* (2001) recorded a density of 2.46 turtles per km^{-2} for the entire Pilbara block extending from the De Grey River to the Exmouth Gulf; however, this includes a correction for turtles that are too far below the surface to be seen. Generally, turtles were only sighted by observers if they were at the surface of the water. Turtles more than 2 m below the surface were not sighted due to strong tidal movements and high turbidity of the water. Therefore, the numbers of turtles sighted during the off-shore surveys in this study are likely to be an underestimate, as no correction factors were applied to these data. More turtles were sighted during the winter survey due to more favourable survey conditions, including tidal movements and visibility.

Generally, the turtles sighted on the transects were widely and evenly distributed across the survey area. However, there higher density aggregations of Chelonid turtles were observed occasionally during the survey. Turtles appeared to be particularly abundant over reef and shallow water areas, particularly on intertidal platforms along the coast during the summer survey. During the winter survey, these aggregations were not seen, however, large aggregations of turtles were recorded around North Turtle and Little Turtle Islands and out from the De Grey River. These winter survey results indicate that these aggregations of turtles around the offshore islands are foraging turtles. The aggregation of turtles at North Turtle Island was confirmed during the boat surveys where hundreds of small juvenile green turtles were sighted on the intertidal platform surrounding the island.

An additional coastal transect from Mundabullangana to Port Hedland was flown, due to high numbers of turtles sighted in the shallow inshore waters during the summer survey. This survey recorded a total of 74 turtles. Turtles tended to be concentrated in certain areas along the coast including Mundabullangana, around the tip of Cape Thouin and False Cape Thouin, off the beach south-west of Weerdee Island and off Downes and Finucane Islands (**Figure 10**). Given that similar numbers of turtles were not observed in these locations during the winter survey, these turtles may have been breeding or internesting turtles.

Other marine fauna sighted during the surveys included dolphins, sea snakes, sharks and manta rays. Between nine and eleven dugongs were sighted during the summer survey, comprising three individuals and one pod of six to eight individuals. Three individual dugongs were sighted during the winter survey (**Figure 9**).

The transects in this survey were terminated at the 20 m isobath (generally between 20 and 45 km offshore). Satellite tracking data show that flatback and green turtles tend to use internesting grounds close to their nesting beaches, which are generally within 0 - 10 m water (K. Pendoley, pers. comm.;

http://www.seaturtle.org/tracking). However, turtles are not confined to this water depth and are found at greater depths. For example, satellite tracking data show that green and flatback turtles migrating from their nesting to foraging grounds are generally found further out to sea in 25-100 m water depth (K. Pendoley, pers. comm.; http://www.seaturtle.org/tracking).

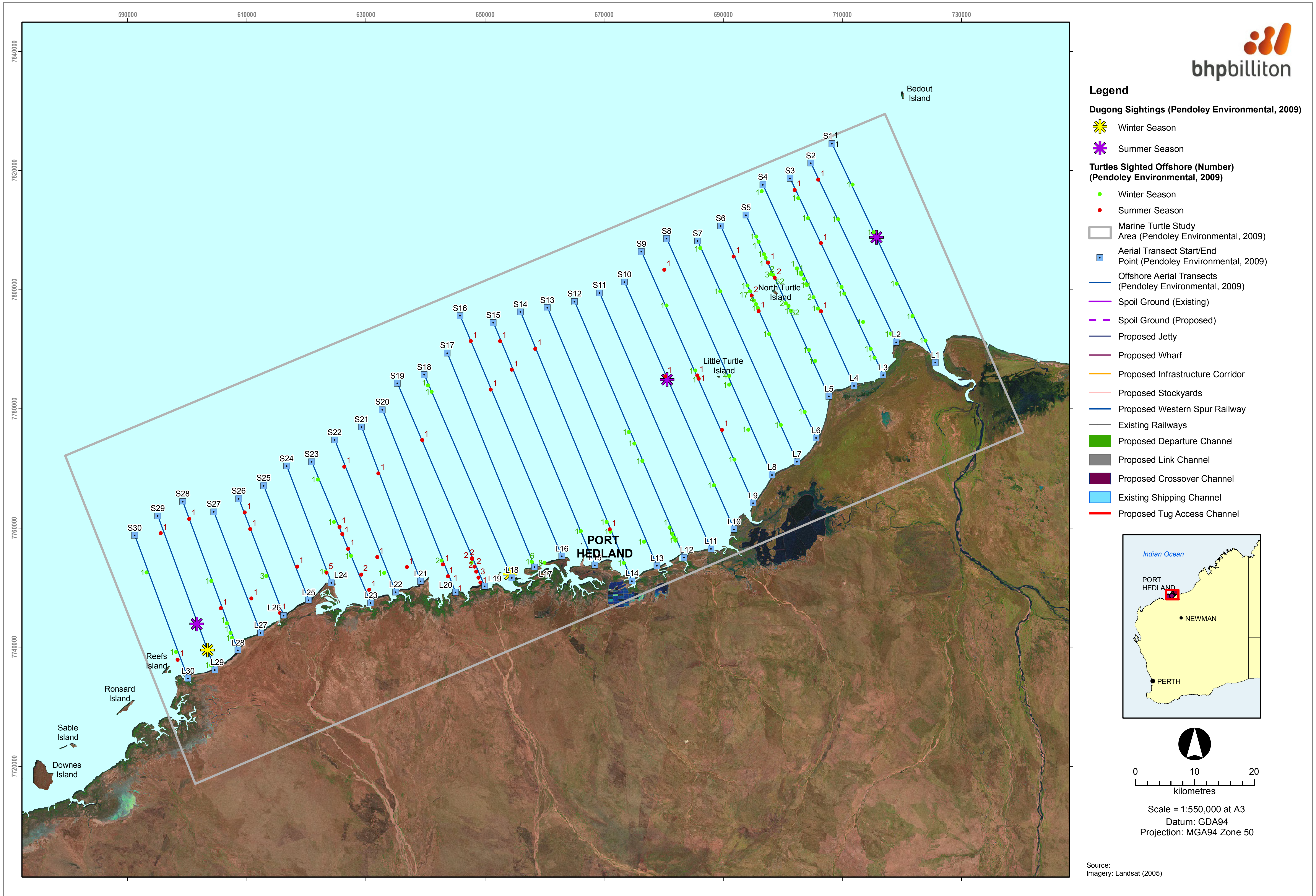

Figure 9 Locations of Turtles Recorded on Transects During Off-Shore Aerial Surveys in Summer and Winter

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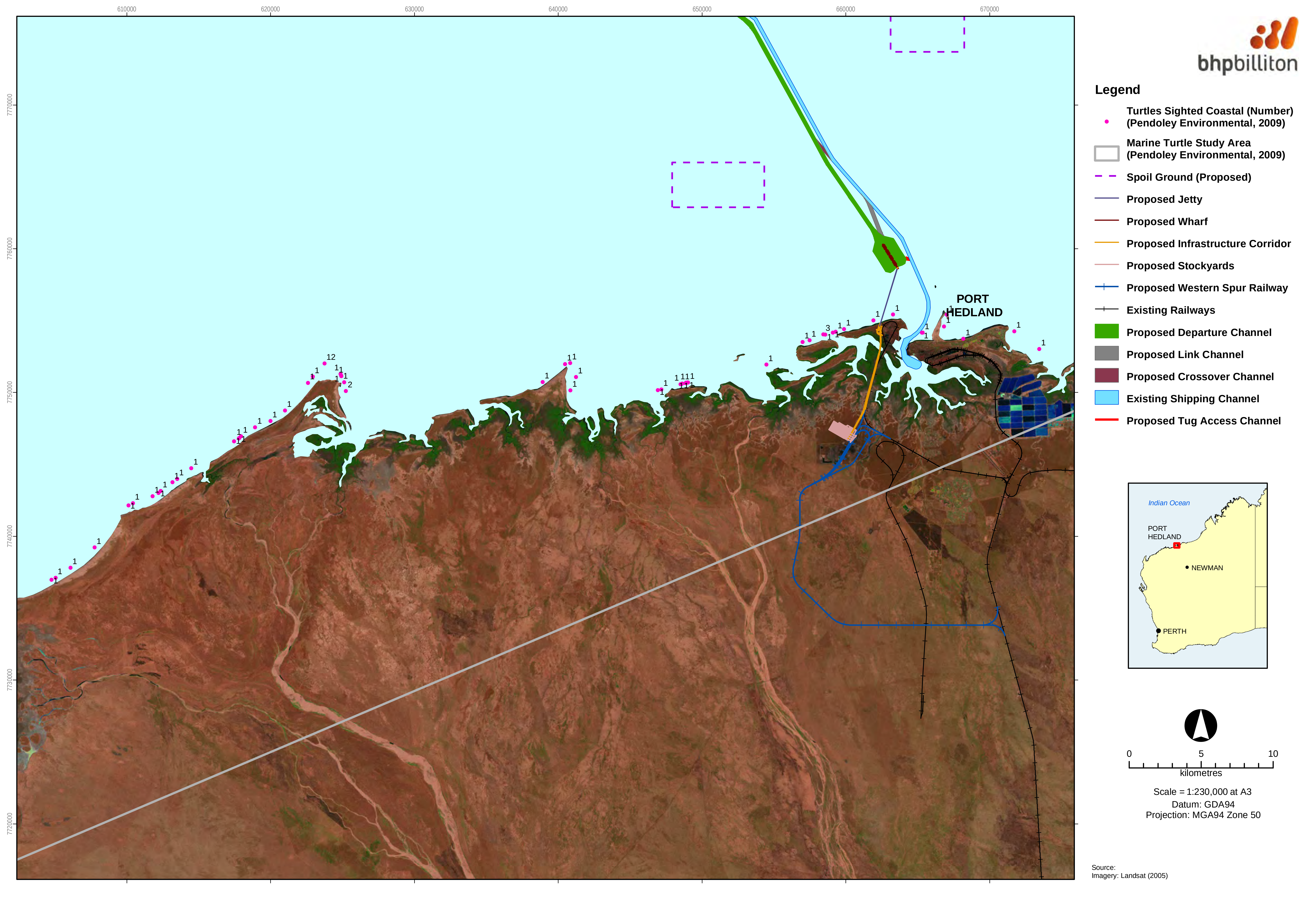

Figure 10 Locations of Turtles Recorded on Coastal Transect Survey

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5.3 Census Beaches

Table 4 shows the daily track counts (BHT) recorded for the census surveys conducted at four beaches. Census counts on Cemetery Beach and Pretty Pool were not conducted by Pendoley Environmental as track counts were undertaken on these beaches by the Care for Hedland Environmental Association as part of their monitoring programme. The data for these beaches presented in **Table 4** were provided by the Care for Hedland Association.

Table 4: BHT track counts on census beaches between 8 and 11 December 2008

Beach	Distance from proposed development	Track Counts (BHT)				No. tracks/night	Length of beach	Mean density (no. tracks/night/km)
		8 Dec	9 Dec	10 Dec	11 Dec			
Downes Island	3 km	0	1	0	2	0.75	0.55 km	1.4
Cemetery Beach	6 km	22*	36*	24*	19*	25.25	0.8 km	31.6
Pretty Pool	9 km	4#	1#	1#	1#	1.75	0.9 km	1.8
Paradise Beach N	15 km	13	10	10	6	10	1.5 km	6.7

* Data provided by Kelly Howlett, Care for Hedland Environmental Association.
# Data provided by Kelly Howlett, Care for Hedland Environmental Association. Track counts are an average as census was not conducted daily.

5.3.1 Paradise Beach North

Paradise Beach North is a long beach (1.5 km long) and approximately 40 m in width to the highest spring tide (HST). The beach is characterised by fine to moderate reddish sand. The beach is low energy with a moderate slope (**Plate 1**). The intertidal zone is typically wide mudflats (**Plate 2**). The dune system comprises small (< 5 m) primary dunes and taller secondary dunes of 5 - 10 m in height. The supratidal zone is approximately 5 - 10 m wide. The beach was heavily trafficked by vehicles along the entire length of the beach (**Plate 4**). Many of the turtle nests on the beach were predated by humans and one butchered flatback turtle was found on the beach. In one night approximately 100 % of the visible nests had been dug up by humans. Fresh dog and fox tracks were recorded on the beach each day.

Paradise Beach North supported a low to moderate density of flatback turtle nesting. On the first day when the census line was installed, 123 tracks were recorded AHT and 13 down tracks were recorded BHT. Two sets of green turtle tracks were recorded, one set during the first day line in and one set on the second census day. A total of 10, 10 and 6 sets of flatback turtle tracks were recorded over the three days of census counts. It appeared that 22 of the 26 crawls (85 %) resulted in nests being laid. An example of an up and down track of a flatback turtle is shown in **Plate 3**. Two emerged nests were recorded on the third day of census counts (11 December 2008; **Plate 5**).

5.3.2 Downes Island

Downes Island is located to the west of Finucane Island. The majority of the island is fringed by mangroves except on the north and east coasts which consist of a rocky coastline with only a small section of sandy habitat at the west end of the north coast that was surveyed for track counts. No tracks were recorded on the remainder of the north coast, which consisted of rocky habitat with extensive oyster rock and was therefore considered unsuitable nesting habitat. The beach is moderate to high energy with a moderate slope (**Plate 6**). The beach consists of yellow to red sand that is moderate to coarse. At the southern end of the beach there was a large outcropping of oyster rock. There is a rocky intertidal limestone platform approximately 200-300 m wide (**Plate 7**) and juvenile green turtles were observed on this platform. The beach appears to be exposed to windy conditions and as such, tracks were windblown. Dog/fox tracks were recorded on the island.

Downes Island supported very low density flatback turtle nesting. Five old craters and nine flatback turtle tracks AHT were recorded on the first day line in. Over the three consecutive days, 0, 1 and 2 sets of flatback turtle tracks were recorded across the line (**Plate 8**). All of the crawls appeared to result in nests being laid.

5.3.3 Regional Comparison of Beaches

Cemetery Beach supported a moderate density of flatback nesting and Paradise Beach North supported a low to moderate flatback nesting density (**Table 4**). Downes Island and Pretty Pool, when compared with the other census beaches, supported a lower density of flatback nesting activity (**Table 4**). However, none of these rookeries are considered regionally significant when compared with Mundabullangana, located approximately 50 km to the west, which supports >1700 nesting females per annum (Pendoley *et al*. in press) and recorded a high density of tracks during the same period. Similarly high levels of flatback nesting are believed to exist on Eighty Mile Beach as on Mundabullangana (Prince, 1994*a*), but quantitative data for Eighty Mile Beach are not currently available.

5.4 Snapshot Beaches

5.4.1 Paradise Beach South

Paradise Beach South is approximately 1 km in length and separated from Paradise Beach North at the eastern end by a small rocky headland. The western end of the beach ends at mangroves. The beach is typically low energy and is characterised by a low slope (**Plate 9**). The sand is red, fine to moderate and very compact in some sections. The intertidal platform is wide and consists of both muddy and rocky flats (**Plate 9**). There were fewer vehicle tracks on this beach compared with Paradise Beach North.

The beach appeared to support low density flatback turtle nesting. Nine sets of flatback turtle tracks were recorded AHT during the snapshot survey. The flatback turtle tracks were concentrated at either end of the beach.

5.4.2 Unnamed Beaches 196 and 197

Unnamed beaches 196 and 197 are located approximately 3 km north-east of Paradise Beach. Unnamed beach 196 is a long (approximately 1.5 km), low energy beach with a low beach slope (**Plate 10**). The beach is characterised by fine to coarse firm sand. There is a broad intertidal platform at the northern end of the beach and a narrower and rocky intertidal platform at the southern end. Unnamed beach 196 appeared to support a low to moderate density of flatback turtle nesting. A total of 52 sets of flatback turtle tracks were recorded AHT, with three sets recorded BHT during the snapshot survey. Flatback turtle nesting appeared to be more concentrated at the southern end of the beach where the intertidal zone was narrower. Car tracks were visible along the beach.

Unnamed beach 197 is approximately 600 m long with a 100 - 200 m wide rocky intertidal zone (**Plate 11**). The beach is characterised as a low energy and low sloped beach. Access onto the beach was not possible, however, three sets of turtle tracks BHT were observed from the boat with binoculars. It was not possible to count the tracks AHT from the boat. The species of turtle could not be determined, but it was considered likely that they were flatback turtle tracks. Car tracks were also visible through the binoculars.

5.4.3 Weerdee Island

Weerdee Island is approximately 12 km west of the entrance to the Port Hedland Harbour and 1.8 km offshore of the mainland. The island is approximately 1.5 km long with a rocky intertidal area that extends east and west to increase the length of the island to 6 km at low tide. The island is predominantly sandy with areas of mangrove and a rocky beach area. The sandy area of beach is approximately 400 m long, low energy and gently sloping (**Plate 12** and **13**). The sand is very fine and softly compacted. No evidence of turtle nesting was recorded on Weerdee Island. The island appeared to be an important bird site, with flocks of Sooty Oystercatchers, Australian Pelicans, Crested Terns, Lesser Crested Terns, Seagulls and Eastern Reef Egrets recorded during the snapshot survey.

5.4.4 Beaches South of False Cape Thouin

Neither of these two beaches was accessible due to the wide shallow intertidal flats and low tide conditions. The beaches were assessed from the boat using binoculars. The beach to the south of False Cape Thouin is approximately 2 km in length and the beach to the south-east is approximately 650 m long. Both beaches are wide, sandy beaches with a gentle slope (**Plates 14** and **15**). No turtle tracks were visible on either beach. One set of car tracks were visible on the smaller beach south-east of False Cape Thouin.

5.4.5 North Turtle Island

North Turtle Island is approximately 58 km north-east of the entrance to the Port Hedland Harbour. The island is approximately 1.2 km long and 0.7 km wide. It has a fringing subtidal area that extends in all directions from the island shore to a distance of 1.3 - 3 km. The intertidal platform is rocky with numerous shallow pools of varying size. Closer to the island is an area of shallow sand over pavement, increasing in depth towards a sandy beach area.

North Turtle Island is characterised by a moderate to high slope and low energy beaches that are moderated by the wide intertidal platform. The sand is generally moderate to coarse grained, and red to black in colour, with yellow shell grit. The island was divided into three sections based on beach profiles; west, south-east and north-east coasts. The south-east coast is characterised by a rocky intertidal area and high (5 - 10 m) primary dunes (**Plate 16**). The west coast is characterised by a sandy intertidal area and low primary dunes (**Plate 17**). The north-east coast is similar to the west coast; however, it has higher primary dunes (approximately 5 m) and a steeper beach slope (**Plate 18**).

Low to moderate flatback turtle nesting was evident across the island. A total of 106 sets of flatback turtle tracks were recorded since the last high spring tide 12 days before, giving an average of nine tracks per night. Three of these flatback tracks were recorded BHT. Moderate flatback nesting density was recorded on the west coast (68 tracks AHT), low to moderate density on the north-east coast (30 tracks AHT) and low density nesting on the south-east coast (8 tracks AHT). The low number of flatback turtles nesting on the south-east coast was probably due to the rocky intertidal area that they would have to traverse to access the beach (**Plate 19**). One set of green turtle tracks was recorded on each of the west and south-east coasts. The majority of the flatback turtle nests were located high up the beach, at the base of the dunes and vegetation.

Hundreds of small (approximately 20 - 50 cm) juvenile green turtles were observed within the shallow intertidal zone during the snapshot survey (**Plate 20**), which are presumably using the area for foraging and shelter.

5.5 Satellite Tracking Data

5.5.1 Internesting Habitat

All turtles returned to re-nest at Cemetery beach, with two turtles returning twice (**Figure 11**). Internesting intervals ranged from 11 to 18 days, with a mean of approximately 14 days. During the internesting period turtles remained in shallow coastal waters less than 3 m in depth, although some moved great distances (> 40 km) from the nesting beach (**Figure 11**). During the two shortest inter-nesting periods (11 days) turtles remained closer to the nesting beach than they did during longer inter-nesting periods. Three turtles spent the internesting period in water to the north-east of the nesting beach, while the fourth turtle (89759) utilised habitat both north-east and north-west of Cemetery Beach, remaining closer to the beach overall (**Figure 11**).

Although no data are yet to be found in published literature, other satellite tracking programmes have also found the internesting movements of flatback turtles to be variable. Some individuals remain relatively close to the nesting beach (within 10 km), while others have been observed to travel over 50 km from their nesting beach during the internesting period (http://www.seaturtle.org/tracking).

The principal internesting habitat utilised by these turtles was to the north and north-east of the nesting beach, away from the proposed development, with only one turtle (89759) internesting to the west of Cemetery Beach, in the vicinity of the proposed development (**Figure 11**). From these data it appears that the most important internesting habitat for flatback turtles nesting at Cemetery Beach is the nearshore zone extending 50 km north-east along the coast. This warrants further investigation however, as the sample size of this study was very small (*n* = 4), and may simply reflect individual habitat selection rather than the behaviour of the population overall.

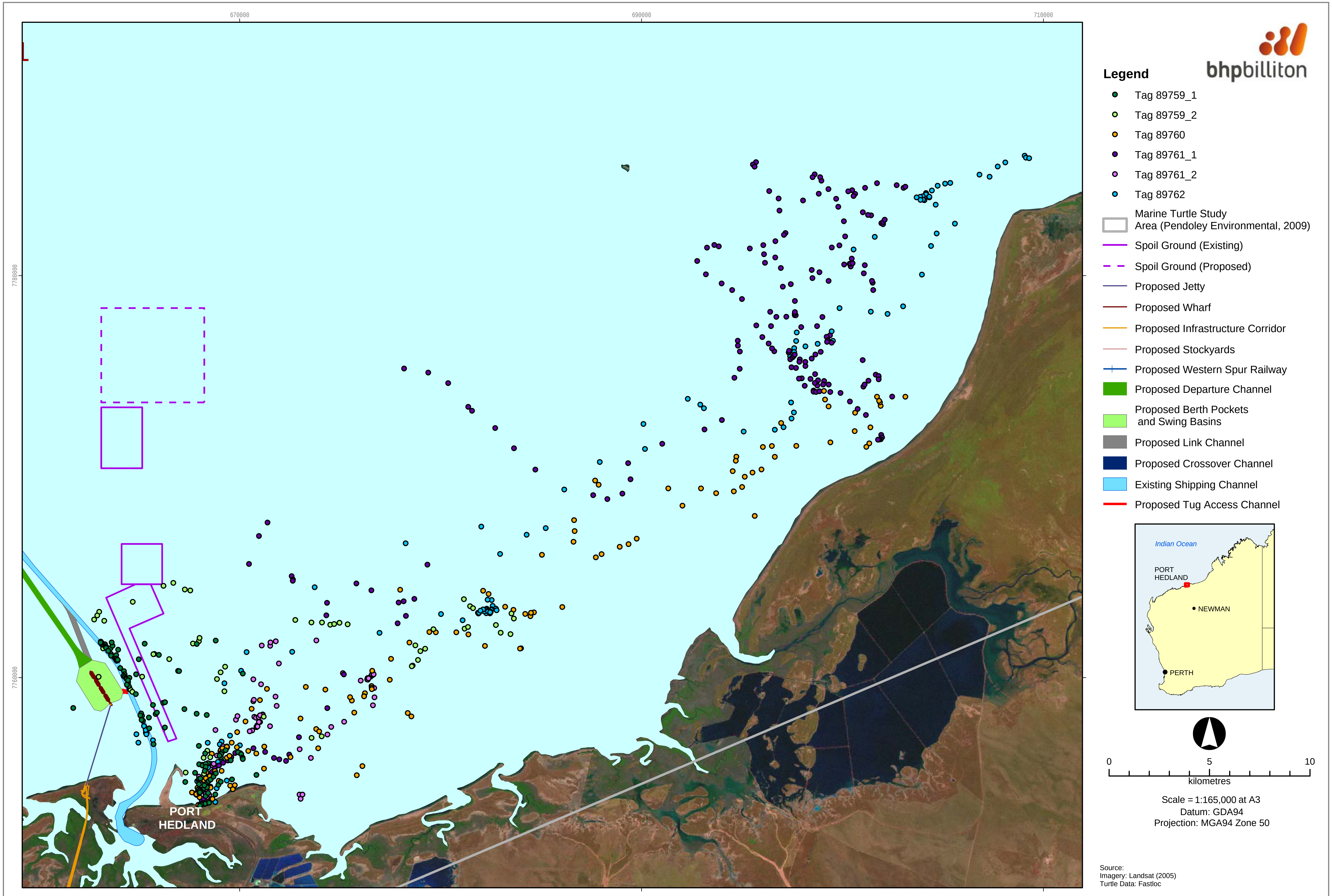

Figure 11 Internesting movements of four flatback turtles tracked from Cemetery Beach, Port Hedland

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5.5.2 Post-nesting Migration

The four turtles tracked from Cemetery Beach (identified by numbers 89759, 87960, 87961 and 87962) had all commenced post-nesting migration by the 6 January 2009. Following their final nesting, turtles quickly left the Port Hedland area and migrated either north-east or south-west parallel to the coast. Migration took 20 to 27 days, during which time all of the turtles travelled a minimum of 405 - 942 km. Migration speeds could only be calculated for two turtles and were 1.21 ± 0.85 and 1.07 ± 0.50 $km.h^{-1}$.

The four turtles all travelled to discrete foraging grounds with clearly definable boundaries, and remained in these foraging grounds for the remainder of the tracking period. Two turtles (89759 and 89762) migrated south-east to foraging grounds located amongst islands on the North West Shelf (**Figure 12**). Turtle 89762 travelled to a foraging ground 20 km north-west of Barrow Island where it was tracked for 186 days, while turtle 89759 continued further south to an area approximately 15 km north-west of Thevenard Island, where it was tracked for 139 days. Both of these foraging grounds were in water approximately 30 - 80 m in depth.

The other two turtles migrated to foraging areas north of the nesting beach. Turtle 89760 migrated to a foraging area 30 km north-west of Broome, adjacent to Parker Price Point (**Figure 12**), where it was tracked for 52 days. This turtle foraged in the shallowest area, were the maximum water depth recorded was 38 m. Turtle 89761 travelled furthest of the four turtles, migrating over 900 km to a foraging ground approximately 90 km north-west of Kuri Bay in the northern Kimberly (**Figure 12**). This turtle remained in its initial foraging ground for most of the remaining 133 days it was tracked, making two short trips up to 100 km to the north-east. The turtle returned to the previous foraging ground following each of these two trips (**Figure 12**).

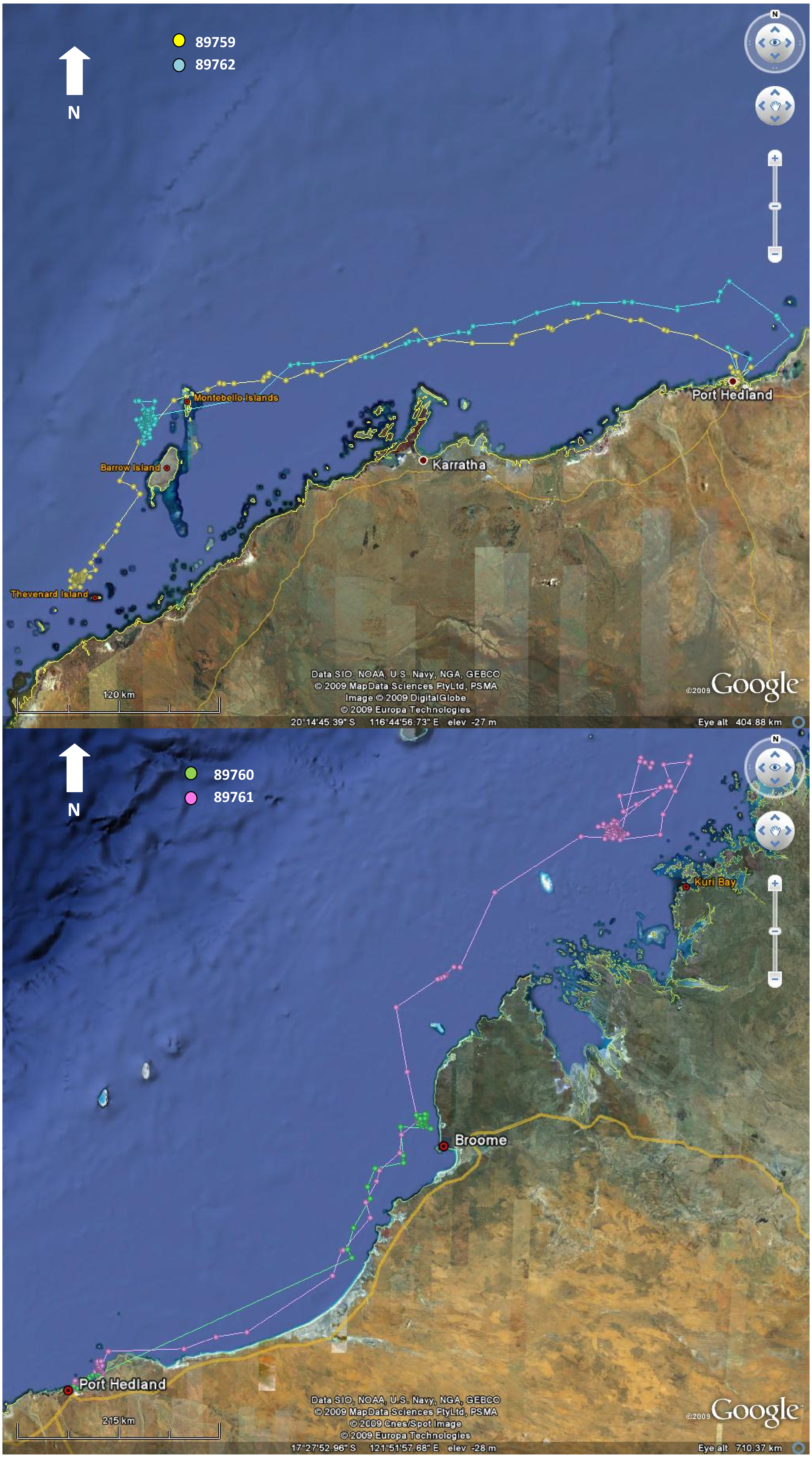

Figure 12: Migration routes of flatback turtles 89759, 89762, 89760 and 89761 following nesting (KiwiSat data, filtered with filter 2 was used to produce these tracks).

5.6 Opportunistic Observations and Collections

Juvenile green turtles were commonly seen in all shallow water habitats throughout the marine study area during the survey. While formal transect surveys were not part of this work scope, general observations suggest that juvenile and sub adult green turtles were most frequently observed in creek mouths, over shallow subtidal and intertidal habitat.

Collections of turtle material were made opportunistically during the survey. Material collected included scutes from green turtles, and eggshell and tissue samples from flatback turtles to be used for stable isotope analysis.

5.7 Summary of Field Survey Results

5.7.1 Objective: Identify Nesting Habitat and Quantify Nesting Usage

Generally, all available suitable nesting sand along the mainland coast with a narrow intertidal or no intertidal zone supported some level of flatback turtle nesting. No hawksbill and only three green turtle tracks were identified during the survey, indicating these species are unlikely to nest in high numbers within the Port Hedland region and therefore not of concern.

The aerial surveys showed that there was high nesting activity at Mundabullangana and beaches immediately to the north and south of Mundabullangana. There was no visible activity between Cape Thouin and Downes Island. East of Port Hedland, turtle nesting activity was evident on Cemetery Beach, Pretty Pool, Paradise Beach and two unnamed beaches further east (Beach 196/Beach 197). Nesting at all these beaches was at much lower densities than that recorded at Mundabullangana. There was very little evidence of nesting activity east of these beaches and extending up to the De Grey River.

A regionally significant flatback rookery occurs at Mundabullangana (>1700 females per annum; Pendoley *et al.* in press) located approximately 50 km west of the proposed development and was the highest density (143 tracks per km), nesting beach identified during the survey. Moderate density (1 track per 5 – 10 m) flatback turtle nesting was identified at Cemetery Beach and a low (1 track per 10m+) to moderate (1 track per 5 – 10 m) density was recorded at Paradise Beach. Cemetery Beach is located approximately 6 km and Paradise Beach approximately 15 km east of the proposed development. Lower flatback turtle nesting activity was present at Pretty Pool and Downes Island. Downes Island is located adjacent to the proposed development. North Turtle Island, approximately 50 km from the proposed development, also supports low density flatback nesting. None of these rookeries, however, are considered significant in a regional context when compared with major rookeries such as Mundabullangana and Barrow Island, which support over 1000 nesting females per annum (**Table 5**; Pendoley *et al.*, in press).

Table 5: Summary of turtle nesting densities at nesting beaches in the Port Hedland region.

Beach/Project Proximity	Nesting Density (no. tracks/km)	Regional Significance
Mundabullangana	143 (high)	Major rookery
Downes Island	1.4 (low)	
Cemetery Beach	31.6 (moderate)	
Paradise Beach	6.7 (low to moderate)	
Pretty Pool	1.8 (low)	
North Turtle Island	2.4 (low to moderate)	

5.7.2 Objective: Identify Internesting Habitat

The four flatback turtles tracked from Cemetery Beach all utilised shallow, near shore habitat for internesting, which is typical of most marine turtle species (Plotkin 2009); however, they showed differences in their movements. The principal internesting habitat utilised by these turtles was to the north and north-east of the nesting beach with only one turtle internesting to the west of Cemetery Beach, within the vicinity of the proposed Outer Harbour development. From these data sets it appears that the most important internesting habitat for flatback turtles nesting at Cemetery Beach is the nearshore zone extending 50 km north-east along the coast, away from the proposed Outer Harbour development, which mostly consists of bare sediment or bare sediment over hard substrate (SKM 2009). This warrants further investigation however, as the sample size of this study was very small (n = 4), and may simply reflect individual habitat selection rather than the behaviour of the population overall.

5.7.3 Objective: Identify Feeding Habitat

The aerial surveys identified concentrations of resident foraging turtles around the offshore islands, including North and Little Turtle Islands, and out from the De Grey River, located in the eastern half of the marine study area. The aggregations of turtles sighted during the aerial surveys were confirmed at North Turtle Island, where hundreds of juvenile green turtles were observed on the intertidal platform and this area is considered to be a significant foraging habitat for green turtles. Opportunistic observations during the surveys found that juvenile and sub-adult green turtles were most frequently observed in creek mouths and over any shallow subtidal and intertidal habitat, presumably foraging. These areas are known to support large areas of macroalgae (SKM 2009), upon which green turtles are known to feed (Bjorndal 1997; Pendoley Environmental 2009). It is also known from satellite tracking studies of green, flatback, loggerhead and hawksbill turtles that the De Grey River may be an important post-nesting foraging ground for these turtles (K. Pendoley, pers. comm.; http://www.seaturtle.org/tracking).

5.7.4 Objective: Identify Migratory Paths

Turtles migrated to foraging grounds long distances from the nesting beach, which is consistent with data from flipper tag return studies and recent satellite tracking programmes (www.seaturtle.org/tracking; Limpus 2009). While none of the tagged turtles remained close to the nesting beach to forage, this does not indicate that waters surrounding Port Hedland are not used by other foraging turtles. Other turtles from this population, or turtles migrating from other rookeries, may use these areas as foraging grounds. Other satellite tracking programmes to date have shown that the North Turtle/Little Turtle Islands (50 km north east of the proposed development) and De

Grey River area are foraging grounds for green, flatback, loggerhead and hawksbill turtles (www.seaturtle.org/tracking).

The four turtles tracked during this survey migrated to four different locations, presumably foraging grounds; one off the north-west coast of Barrow Island (Pilbara region), one off the north-west of Thevenard Island (Pilbara region), one just offshore from Parker Price Point near Broome (Kimberley region – north east) and one offshore from Kuri Bay (Kimberley region – north east).

These results illustrate the variability in marine turtle behaviour, highlighting the importance of large and long-term datasets for marine turtles. The turtles all migrated to foraging grounds in shallow, sub-tidal waters. The shallow water depths of 12 - 80 m in these foraging grounds are typical of observations of flatback turtles foraging in Queensland, where they occupy shallow (6 - 40 m), turbid waters in soft-bottomed sub tidal habitats (Limpus 2009). The greater water depths recorded in the present study may indicate use of a wider range of habitats by flatback turtles in Western Australia, or may simply reflect the paucity of data Australia wide on the foraging habitat of this species.

5.8 Ongoing/Additional Studies

The four satellite tagged flatback turtles from Cemetery Beach are programmed to transmit data for at least two years and it is anticipated they will continue to provide further information on their migratory routes, foraging, nesting and internesting habitats. Three of the four transmitters have currently ceased operating. The other transmitter ceased operating temporarily but has begun transmitting data again. It should be noted that PTTs frequently cease transmitting prematurely and there is no way to predict if and when this may occur, and they may also turn back on again. Cessation of transmitters may be due to loss of battery power, battery bleed, loss of the PTT and harness, loss of the aerial or fouling of the saltwater switches of the PTT unit. Any additional data gathered from the satellite transmitters will be added to this report as an addendum.

Stable isotope analysis is currently being undertaken for the study to help identify the food sources being used by marine turtles nesting in the marine study area and use this information in conjunction with the satellite telemetry data to identify potential foraging grounds. Samples of turtle material were collected during the summer survey and potential food sources are currently being collected by the SKM marine team. These samples will be analysed and the results detailed in a separate report.

6.0 RISK IMPACT ASSESSMENT

6.1 Risk Assessment Overview

This section examines the potential threats to marine turtles within the Port Hedland region that may arise from construction and operational activities of the proposed Outer Harbour Development. Marine turtles are long-lived animals and therefore, changes to reproductive success and/or mortality rates can exert substantial long term demographic effects.

Based on the findings of this survey, and previous studies in the region, the marine turtle life stages considered to be at risk from the proposed development are:

- **nesting and internesting female flatback turtles** during the summer breeding season;
- **juvenile and adult marine turtles** of all species that forage, rest or pass through the area; and
- **post-hatchling flatback turtles** that may utilise nursery habitat in the Port Hedland region.

Breeding male flatback turtles have not been considered in the risk assessment as it is unknown where male flatback turtles are found or where mating occurs. The lack of anecdotal report of turtle aggregations for the Port Hedland area suggests that mating may not occur nearby. Satellite tracking data indicate that the migratory routes of the turtles within the Port Hedland region are further offshore and therefore should not be impacted by the proposed development and are therefore not considered in the risk assessment.

6.2 Potential Impacts to Marine Turtles

The potential impacts of the proposed Outer Harbour Development on marine turtles that were identified from the risk assessment (summary in **Table 6;** detail in **Appendix B**) are discussed in the following sections. The assessment relates both to individual turtles and populations as defined by the Consequence Risk Table in **Appendix B**)

Table 6: Summary of environmental risks to marine turtles from the Port Hedland Outer Harbour Development.

Potential Impact	Inherent Risk	Management Proposed	Residual risk	Confidence Level
Injury or death as result of collisions, entrainment by dredges or burial by spoil disposal.	Medium	• Fauna observation procedure. • Vessel speeds. • Reporting all injuries and mortalities. • Inspection of hopper loads, where required. • Sweeping the area with tickler chains prior to dredging, where required.	Low	Low (dredging) – high (vessel collisions)
Reduced productivity due to reduced developmental and foraging habitat	Low	• Implementation of Dredge and Spoil Disposal Management Plan.	Low	Medium
Behavioural changes	Low - medium	• Minimise light spill and reduce	Low	Medium

Potential Impact	Inherent Risk	Management Proposed	Residual risk	Confidence Level
e.g.: adverse effects on navigation and responses to artificial light		lighting to as low as reasonably practicable to comply with safety standards and minimise impacts to turtles.		
Behavioural changes e.g.: responses to underwater noise	Medium	• Engineering controls on equipment to control noise emissions. • Fauna observation procedure. • Carry out "soft-starts" for pile driving. • Reporting all injuries and mortalities.	Low	Low
Death or sub-lethal effects as a result of hydrocarbon spills or waste disposal	Low	• Standard management procedures and contingency plans. • Operating within PHPA limits and will comply with PHPA procedures.	Low	High

6.2.1 Light Spill

Artificial lighting has the potential to reduce the reproductive success of marine turtles by deterring females from nesting beaches, and disorienting or misorienting hatchlings on the beach and at sea. Potential sources of light from the proposed Outer Harbour Development include the land based facilities, jetty, wharf, ship-loader and conveyor lights as well as moored and operating dredging and export vessels (dredging is assumed to be 24 hour operations). A light assessment study has been completed for the proposed Outer Harbour Development, including an assessment of the visibility of light at the turtle beaches (Bassett 2009).

6.2.1.1 Nesting females

Artificial night lighting on or near nesting beaches may disrupt the nesting behaviour of marine turtles (Salmon 2005, Salmon *et al*. 1995). Although lighting may not be the primary cause, nesting densities are typically lower at beaches exposed to artificial light (Salmon 2005). Higher nesting density has also been found in the shadows of buildings and trees, compared with illuminated areas. A study by Witherington (1992*a*) found that nesting turtles did not show the same avoidance to nesting on beaches illuminated with low pressure sodium (LPS) vapour lights. Witherington and Martin (1996) suggested that light-mediated variations in adult female turtle nesting behaviours, such as the location of beach emergence, nest construction, and whether (and at what stage) nesting is abandoned, may affect success of egg deposition, hatchling production and seaward return of adults.

Low levels of flatback turtle nesting (1.4 tracks/km) were identified at Downes Island, which is located adjacent to the proposed facilities to the west. Light from the proposed Outer Harbour Development may potentially affect the nesting females at Downes Island. However, the risk to nesting females is still considered to be low, given the level of lighting from existing urban and industrial development in Port Hedland, and the low numbers of nesting turtles at Downes Island. The next closest nesting beach is Cemetery Beach (6 km to the east), which supports a moderate flatback rookery (31.6 tracks/night) based on regional turtle nesting activity. Experienced nesters are likely to continue to use the nesting beaches; it may be the first-time nesters (new recruits) that may be deterred from nesting.

The light assessment determined that Cemetery Beach will experience light from the proposed jetty, albeit less than moonlight. During the construction period, lighting on ships and dredge vessels will also be visible from the beach. However, existing port development and cumulative modelling results shows that the order of magnitude in the illuminance value is the same; therefore it is unlikely that the proposed Outer Harbour Development will provide any significant or detectable increase in effect on the nesting females.

6.2.1.2 Hatchlings

On the beach

Upon emerging from the nest, turtle hatchlings crawl directly towards the sea, a behaviour known as sea finding. The sea finding process is directed by several cues; light brightness, shape and form of the beach environment, and to a lesser extent beach slope (Lohmann *et al.* 1996, Tuxbury and Salmon 2005). Hatchlings crawl away from the dimmer landward horizon, toward the brighter seaward horizon (Mrosovsky and Carr 1967, Tuxbury and Salmon 2005). They also crawl away from the higher, dark silhouette of the dune towards the lower seaward horizon (Limpus 1971, Salmon *et al*. 1992, Van Rhijn and Van Gorkom 1983, Witherington 1992*a*). Beach slope is considered a secondary cue relative to vision (Lohmann *et al.* 1996, Salmon *et al.* 1992). A summary of the responses of marine turtle hatchlings to visual cues are shown in **Table 7**.

Hatchlings have a strong tendency to orient towards the brightest direction, with brightness being a function of light intensity, wavelength and hatchling spectral sensitivity (Witherington 1992*b*). A light will not appear bright to a turtle if its wavelength is outside the spectrum of light that is visible to the animal. Both green and hawksbill hatchlings are notably more responsive to light of shorter wavelengths than to lights of longer wavelengths (i.e. orange to red light), even at heightened intensities of the longer wavelength light (Granda and O'Shea 1972, Mrosovsky and Shettleworth 1968, Witherington 1992*a*, Witherington and Bjorndal 1991*b*). Red light must be almost 600 times more intense than blue light before green turtle hatchlings show an equal preference for the two colours (Mrosovsky 1972). Yellow light has been found to elicit an aversion response in loggerhead turtles, and not to attract green turtles (Witherington 1992*a*, Witherington and Bjorndal 1991*b*).

Table 7: Visual cues used by hatchlings during sea finding following emergence from the nest.

Cue	Behavioural observations
Light wavelength	Short wavelength light is highly attractive to hatchlings. Long wavelength light is *relatively* less attractive to hatchlings.
Light intensity	High intensity light is more attractive than low intensity light. High intensity *long* wavelength light may be more attractive than low intensity *short* wavelength light.
Beach silhouettes (Shape and form)	Hatchlings move away from tall, dark, vegetated horizons and towards low, light, flat horizons.
Light directivity	Hatchlings integrate light over a broad area (~180°). They often ignore bright point sources of light. Broad sky glow is more attractive than a single bright point source of light.
Trapping effect of light	Hatchlings that enter a bright pool of light may be trapped within the spill of light and be unable to crawl away from the light spill area, both onshore and in the ocean.
Moon light	Bright moonlight may override the effects of artificial light.
Clouds	Artificial light reflected off clouds creates a broad area of sky glow that may be attractive to hatchlings.

Light intensity can also strongly influence the degree of disorientation in hatchlings. In a series of experiments, flatback turtle hatchlings exposed to 500 W high pressure sodium vapour oriented in a more seaward direction than 1000 W and 1300 W of the same luminary type and all intensities of fluorescent and metal halide light (Pendoley 2005).

Under tests in controlled conditions in Western Australia, both green and hawksbill turtle hatchlings more frequently orientated towards short wavelengths than long wavelengths (Pendoley 2005). Flatback turtles did not show the same ability to discriminate between wavelengths in the blue to green range, however they more often moved towards green light when the alternative light source was in the yellow-red range.

Based on the different responses of turtles to lights of different wavelengths, a number of different light types have been trialled with the aim of reducing hatchling attractions to lights. Lights emitting large proportions of short wavelength light (metal halide, halogen, fluorescent, mercury vapour etc.) are the most disruptive to sea finding behaviour, while low pressure sodium vapour lights is only weakly attractive to green and loggerhead hatchlings, and are therefore the least disruptive (Witherington and Bjorndal 1991*a*, Witherington and Bjorndal 1991*b*, Witherington and Martin 1996). Filtered high pressure sodium (HPS) vapour is an acceptable alternative after low pressure sodium (LPS) light.

Studies have shown that green and loggerhead turtle hatchlings respond to shape cues during sea finding (Limpus 1971, Salmon *et al.* 1992). Hatchlings crawl away from a higher vegetated dune silhouette and toward the lower and flatter horizon over the ocean (Mrosovsky and Shettleworth 1968, Salmon *et al.* 1992, Van Rhijn and Van Gorkom 1983). This cue may have greater importance during a full moon, when the higher levels of ambient light may mean that the ocean is not the brightest horizon (Lohmann *et al*. 1996, Tuxbury and Salmon 2005).

Green, loggerhead and flatback turtle hatchlings are most influenced by artificial light glow when it is situated low in the horizon relative to the hatchling (Limpus 1971, Salmon *et al.* 1992). Maintaining a dark, high dune or vegetation silhouette behind nesting beaches is therefore an effective management strategy for inland light sources (Tuxbury and Salmon 2005).

Artificial lighting may adversely affect hatchling sea finding behaviour in two ways; disorientation, where hatchlings crawl on circuitous paths; or misorientation, where they move landward, possibly attracted to artificial lights (Salmon 2005, Witherington and Martin 1996). The consequence of this disruption to sea finding is often mortality, resulting from increased exposure to predation, dehydration and exhaustion (Salmon 2005, Witherington and Martin 1996).

Anecdotal reports suggest that some flatback hatchlings on Cemetery Beach are currently being misoriented by light, however, the source of light is unknown and it is difficult to isolate the different light sources in the area. The light assessment determined that the western end of Cemetery Beach will experience light from the proposed jetty falling on the beach, albeit less than moonlight (Bassett 2009). During the construction period, lighting on ships and dredge vessels will be visible from the beach. The light sources will be visible as a series of point sources along the jetty. Given; that hatchlings tend to ignore bright point sources of light, that Cemetery Beach is over 6 km away from the proposed development and the level of existing lighting, the impact of light from the proposed facilities is considered a low risk to hatchlings emerging from the nest.

In the ocean

Once into the water, hatchlings orientate by wave fronts and to not appear to rely on visual cues (Lohmann *et al.* 1990). Even if hatchlings are disorientated by light on their crawl to the water, they are able to navigate successfully upon reaching the water, provided that there are nearshore waves.

Once flatback hatchlings enter the water it is assumed that they scatter in a fan-like pattern. It is considered possible that a small proportion of hatchlings may be exposed to the lights from the proposed wharf, jetty and vessels from the Outer Harbour Development and become entrapped in the light spill, increasing predation risk, chance of boat strike and reducing hatchling survival rate. If this does occur, over the lifetime of the operation of these facilities, it may lead to a reduction in local population viability and therefore the risk to hatchlings from the permanent marine facilities is considered medium.

Lighting from construction and operations vessels is considered a low risk to flatback hatchlings as they are a moving target and unlikely to entrap hatchlings which are typically carried away from their natal beaches by tides and currents. It is only the small proportion of hatchlings that are carried within tens of metres of the light source that may be attracted and 'trapped' by light spill on the ocean.

6.2.1.3 Juvenile and adult turtles

The effect of artificial lighting of adult or juvenile turtles at seas is not known. Visual cues are among the array of cues mature turtles use for navigation (Avens and Lohmann 2003, Luschi *et al*. 1996), however it is not known whether these are affected by artificial lighting, and whether or not turtles are able to compensate through the use of other cues.

Juvenile and adult turtles are known to occur within the proposed development area, as small aggregations of turtles were recorded off Downes and Finucane Island during the summer field survey. Given that they were not observed during the winter aerial survey, these adult turtles are likely to be mainly breeding turtles. The summer and winter field surveys confirmed that juvenile green turtles are common in creek mouths and over any shallow subtidal and intertidal habitat within the Port Hedland area.

There is no information, published or otherwise, to suggest light might have an impact on adult or juvenile turtles in the water. Given the mobile nature of turtles and the lack of any information suggesting otherwise, the impact of light from the proposed Outer Harbour Development is considered to be a low risk to juvenile and adult turtles.

6.2.2 Dredging Entrainment and Disposal Burial

Dredging can affect marine turtles directly through injury or mortality through accidental intake. Turtles can also become physically entrained in a dredge (NRC 1990). In some areas, marine turtles have been reported to rest and hibernate in deep water shipping channels, which places them at higher risk from entrainment in dredges (Felger *et al*. 1976, USAEWES 1997). Dredging can also affect turtles indirectly through habitat modification (MMS 2007). Modification of the seabed, and increased water turbidity caused by dredging can also affect turtles' foraging, internesting or resting habitat, and hence reduce their fitness.

Incidental take via hopper dredges has been recognised as a cause of marine turtle injury and mortality during dredging activities for over 25 years in the US (Dickerson *et al.* 1991, Dickerson *et al*. 2004, Nelson *et al*. 1994, Slay 1995). The most extensive dataset on entrainment of turtles in hopper dredges is held by the US National Marine Fisheries Service (NMFS) on dredging in southeastern USA. In the decade (1980 –1990) 174 entrained marine turtles were documented during trailer suction hopper dredging operations conducted in southeast America. This equates to 1.2 turtles per 100 000 m^3 of dredge spoil (Reine and Clark 1998). Entrainment rates vary greatly between dredging projects, seasons, and actual species entrained. For example, a dredging operation in North Carolina recorded a turtle entrainment rate of 6.5 turtles per 100 000 m^3 of dredge spoil (Reine and Clark 1998). The mortality of entrained turtles may vary significantly between species; Reine and Clark (1998) reported that 90 % of entrained loggerhead turtles died, while 50 % of entrained green turtles died. Seasonal migration of turtles at the time of dredging can result in higher rates of turtle entrainment. As hatchlings remain within a few metres of the surface (Lohmann and Lohmann 1993, Salmon and Wyneken 1987) they are unlikely to be entrained in dredges, however they may be affected by light spill from the dredges and support vessels.

A recent study on the interactions between dredges and marine turtles in Queensland by the Port of Brisbane using a THSD has reported an average turtle capture per year of 2.3 turtles per year since 2001/02 (Morton 2007). This equated to an average turtle capture of 0.00099 turtles per dredging hour and all turtles dredged were killed (Morton 2007). Information compiled estimates that approximately 1-5 loggerhead and green turtles are killed by TSHD dredges in Queensland each year (Morton 2007).

The type of dredge, draghead type and timing of dredging influences the level of potential impact that dredging may have on the turtles. Turtles may also rest in dredge channels, placing them at increased risk of entrainment during subsequent maintenance dredging (USAEWES 1997).

The Outer Harbour Development proposes to undertake dredging using a combination of a trailer hopper suction dredge (THSD) and a Cutter Suction Dredge (CSD). While CSDs do not move as quickly as THSDs, suction forces at the rotating cutter head are similar. The dredging operations are proposed to occur over a 24 hour period using both types of dredge vessels for approximately four years. Dredging is likely to occur over at least four summer breeding seasons.

Satellite tracking of four female flatback turtles from Cemetery Beach indicated that internesting habitat is generally located to the east of Cemetery Beach away from the proposed development. One of the turtles did spend some time internesting within the one of the proposed spoil disposal areas. Given the small sample size of turtles tracked and high conservation value of breeding females, a precautionary approach is recommended. The remigration interval for flatback turtles is generally 1 - 3 years, meaning that the whole nesting population at Cemetery Beach may be exposed over the course of the dredging programme. The potential impact to internesting female flatback turtles from becoming entrained in the THSD draghead, during dredging, buried by spoil disposal or struck by vessels is considered a medium risk to the local population based on the risk assessment matrix (**Appendix B**).

Resident juvenile and adult green turtles are known to occur within the proposed development area. The field surveys confirmed that juvenile green turtles were common in creek mouths and over any shallow subtidal and intertidal habitat within the Port Hedland area. The most significant aggregations of resident foraging turtles are located further away (approximately 50km) from the proposed development, around the offshore islands and near the De Grey River. The potential impact to the resident population of juvenile and adult turtles is considered to be medium.

6.2.3 Noise and Vibration

Detailed analysis of potential marine noise and potential impacts on marine mammals has been conducted by Salgado Kent *et al.* (2009) for the proposed Outer Harbour Development. The noise sources related to the proposed development in order of predicted severity of underwater noise impacts are pile drivers, increased shipping and vessel traffic associated with the proposed offshore jetty/wharf and dredging, typically the Trailer Suction Hopper Dredges (TSHDs; Salgado Kent *et al.* 2009).

The equipment proposed for construction activities in the proposed Outer Harbour development has most of its energy below 1 KHz but the nature of the signals (impulsive *vs.* continuous) and the source levels vary. Source levels for pile driving will range from a sound exposure level (SEL) of 207-209 dB re 1 $\mu Pa_{2.s}$ @ 1 m, while from dredging with a TSHD source levels are expected to be below a MSP (mean square pressure) of 180 dB re 1 µPa @ 1 m (Salgado Kent *et al*. 2009). The highest noise levels are likely to be emitted by a TSHD compared with a CSD (Salgado Kent *et al.* 2009). Overall, approximately 1500 piles are expected to be driven over a total of approximately three years. Most pile driving work will take place between 0700 and 1900 hrs, 7 days per week, with potential need to drive a pile to finish beyond 1900 to 2200 hrs.

Very little is known about the hearing ability or behavioural responses of marine turtles to acoustic stimuli. The most recent measurements of turtle hearing underwater on green turtles has found much expanded ranges, with higher sensitivities, compared to previous studies such as Bartol and Ketten (2006). Hearing ranges of 50-1600 Hz, with maximum sensitivities over a broad low frequency range of 100-400 Hz, were recorded (Dow *et al.* in press). No research has been conducted on the hearing sensitivity of flatback turtles. The frequencies from dredging and pile driving overlap with the sensitivity range of turtles recorded in previous studies (e.g. Bartol and Ketten 2006; Dow *et al.* in press).

McCauley *et al.* (2000), using two stranded juvenile loggerhead turtles, found that marine turtles showed behavioural responses to an air gun at a received level around 166 dB re 1 µPa RMS (RMS is the square root of the MSP) and avoidance behaviour at around 175 dB re 1 µPa RMS. A similar study by O'Hara and Wilcox (1990) showed avoidance behaviour at a received level of around 156-161 dB re 1 µPa RMS. Turtles displayed agitated behaviour, abrupt body movements, startle responses, and even prolonged inactivity at the bottom of the tank in response to low frequency signals (Lenhardt *et al.* 1983, 1996). Temporary threshold shift (TTS) in hearing occurred in loggerhead turtles exposed to many pulses from a single airgun less than 65 m away (Moein *et al.* 1994). Using data available on TTS in response to impulse noise for tortoises (Bowles *et al.* 1997) an estimate of repeated pulses (3 s duration) above 185-199 dB re 1 µPa at the most sensitive hearing frequencies may result in TTS in leatherback turtles (Eckert *et al.* nd). Injury or TTS in marine turtles may be caused by multiple pile driving pulses, particularly if animals are within metres of the source.

For non-pulsed noise sources such as dredging and boat traffic, marine turtles may become disturbed and exhibit disturbance responses at around 120-180 dB re 1 µPa MSP (O'Hara and Wilcox 1990, Samuel *et al.* 2005). Turtles are unlikely to experience TTS or injury from shipping or dredging noise, however there is a possibility of TTS or an increase in boat strikes if they become habituated to the noise and remain within the vicinity for some period (Dickerson *et al.* 2004, Geraci and Aubin 1980).

The noise from pile driving during construction of the jetty is considered to pose a medium risk to marine turtles in the area, although it is considered that the regular pulses from piling activities may result in avoidance behaviour. It is acknowledged that little is known of the impact of noise on marine turtles and that this requires further investigation. Studies have shown that whales may be more sensitive to noise impacts during sensitive periods of their life history, e.g. migration, and show behavioural responses to lower noise levels (Salgado Kent *et al.* 2009). It is unknown whether marine turtles may show similar responses during sensitive periods, such as during breeding or migration.

6.2.4 Boat Strike

Turtles are at risk from boat strike when they rise to the surface to breathe or when they surface as a 'startle' response to a situation, such as dredging noise, or visual cues (MMS 2007). As vessel traffic increases within marine turtle habitat, the incidence of boat strike is expected to increase (MMS 2003, MMS 2007, NRC 1990). This effect may be amplified if anthropogenic noise causes turtles to spend more time at the surface of the water (Samuel *et al*. 2005). A summary of the stranding database for Queensland in 2000 found 56 % of the 139 turtles with identified anthropogenic causes of strandings and mortalities showed injuries consistent with boat strike (Haines and Limpus 2000), however, this is a high use vessel area compared with Port Hedland. The species documented included green, loggerhead, hawksbill and olive ridley turtles. Amongst marine turtles, green turtles may be at most risk from boat strike, as they forage in shallow, nearshore habitats, and are slow swimmers (Davenport and Davenport 2006).

The collision risk between vessels and marine turtles has been shown to be linked to vessel speed. In a study of collision, risk between a vessel and green turtles Hazel *et al.* (2007) found that turtles were much less likely to flee when approached by a vessel at 11 or 19 km^{-1} (6 or 10 knots) than if they were approached at 4 km^{-1} (2 knots). In addition, turtles fled at twice the distance when approached by the slow boat (2 knots) than when approached by boats at intermediate or fast speeds (6 - 10 knots). The combination of these two factors means that turtles are at far greater risk of being struck by boats travelling at 11 km^{-1} than by boats travelling at 4 km^{-1} (Hazel *et al*. 2007). While conducting the study the boat operators were able to avoid actual turtle collisions while travelling at higher speeds through emergency avoidance strategies; their small craft size (6 m aluminium boat), having two trained observers and only conducting the study when there was extremely good visibility. In addition, results of the study suggested that turtles detected approaching vessels visually, so the ability of turtles to avoid vessels at night may be significantly less (Hazel *et al*. 2007).

Boat strikes from construction and dredging vessels associated with the proposed Outer Harbour Development is considered more likely to occur to marine turtles during construction due to higher vessel traffic (and the use of smaller vessels that can travel at higher speeds) and less likely during operations with larger vessels moving slowly. The potential impact to marine turtles within the proposed development area is considered a low risk, given that most vessel movements will be in deep enough water that turtles can more easily escape, reducing the risk of encounters.

When the proposed Outer Harbour Development attains its nominal throughput capacity (in addition to the Inner Harbour), the average number of ore carrier arrival and departure movements per day is anticipated to be in the range of 3-4 total daily movements for 250,000 to 280,000 tonne loads per departure – dependant on tidal constraints. Breeding female flatback turtles, juvenile and adult turtles may occur within the proposed development area and therefore may be potentially impacted.

6.2.5 Loss or Reduction in Habitat

Existing seabed benthic communities at the wharf, berths, shipping channel and dredge spoil grounds will be lost directly through dredging or spoil disposal. Potential marine turtle habitat may also be lost indirectly through an increase in TSS in the water column that may diminish food supply in the vicinity by smothering food sources (Rice and Hall 2000). During construction and operations, levels of TSS in the water column may increase in the vicinity of the wharf, shipping channel and spoil ground as a result of dredging, spoil disposal and propeller wash from iron ore carriers.

6.2.5.1 Internesting habitat

Internesting habitat does exist within the proposed dredge footprint and dredge spoil disposal areas. Satellite tracking data from four flatback turtles nesting at Cemetery Beach showed that they generally internested to the east of the proposed development area; however, some of the time internesting females were tracked within the proposed development area. A precautionary approach is recommended due to the high conservation value of breeding females and that there will inevitably be some loss of internesting habitat; however, the potential impact to internesting females is considered a low risk as they are likely to move to other habitat available within the wider area.

6.2.5.2 Foraging habitat

The proposed dredge footprint and dredge spoil disposal areas generally lack any Benthic Primary Producers (SKM 2009). The three potential spoil ground locations have very little benthic cover; epifauna was observed at some locations and limited to small sponges and sea whips attached to rubble, feather stars clinging to sea whips and hydroids attached to small rocks (SKM 2009). These habitats are considered limited foraging habitat for turtles, although turtles were observed in these areas. These habitats are well represented elsewhere within the region as shown by large aggregations of juvenile and adult turtles foraging on offshore islands and intertidal platforms within the wider Port Hedland region. In addition, the Port Hedland area has naturally high levels of turbidity and periodic severe events associated with cyclones.

Sediment fate modelling undertaken for the dredging activities, indicates that the potential zone of impact will be restricted to the areas immediately adjacent to the dredge footprint and dredge disposal areas as well as areas further north-east. Overlaying the modelling data with the benthic habitat mapping indicates that impacts to benthic marine habitat are likely to be minimal in these areas. However, the sediment fate modelling data also indicate that another zone of potential impact from TSS generated turbidity is isolated patches along the inshore margin where the coastal morphology acts as a trapping zone for fine sediments. Juvenile and adult turtles, particularly green turtles, are common along the shallow intertidal platforms and creek mouths within this inshore margin and therefore foraging habitat in these areas may be potentially impacted. The potential impacts to foraging turtles are considered to be low, given the short to medium term effects of the increased TSS levels. Turtles are likely to simply move to similar habitats that are well represented in the region.

6.2.6 Hydrocarbon Spills

Biological, physical and chemical processes that act on oil following its release into the environment alter the composition and associated toxicity of the chemical mixture to the extent that it may bear little resemblance to the original spilled oil (NAS 2003). Turtles may be affected by hydrocarbon spills through direct surface contact, inhalation of evaporated hydrocarbons and direct or indirect ingestion. Turtles have been shown to be extremely sensitive to exposure to oil, in all their life stages. Respiration, diving patterns, and blood chemistry have all been found to be significantly affected by oil exposure (Lutz *et al*. 1986). Salt glands may also temporarily fail, and skin structure and sensory organs can be disrupted (Bossart 1986). Egg development may be altered or arrested by oiling, while hatchlings are extremely vulnerable to oiling, while crossing the beach, and in the water (Fritts and McGehee 1982). The long term effects of chronic exposure to oil are still unknown (MMS 2007).

A hydrocarbon spill has the potential to impact on all life stages of marine turtles. Hatchling, post hatchling and juvenile flatback turtles are likely to be particularly vulnerable to oil spills given their usage of nearshore habitats. Fouling of nesting beaches by oil close to the proposed development would affect not only the eggs and hatchlings but also the females hauling ashore to nest. Juvenile and adult green turtles are common in creek mouths and over any shallow subtidal and intertidal habitat within the proposed development area. A hydrocarbon spill is considered highly unlikely to occur given the strict industry standards and compliance. If a spill does occur, the most likely scenario would be a small oil spill due to the failure of equipment or pipelines likely to be contained on the vessel; larger spills associated with vessel collision or grounding are more unlikely.

6.2.7 Contaminant Discharges

Typical discharges from a project similar to the proposed Outer Harbour Development may include sewage, cooling water, deck drainage, etc. The effects of elevated water temperature, salinity, turbidity or nutrients on marine turtles of any age class are not known and nothing is available in the literature on these topics. There may be potential links between decreased water quality and the occurrence of fibropapillomatosis in marine turtles. This condition, commonly termed fibropapilloma, is characterised by tumours 0.1 cm to >30 cm in diameter that grow on the soft skin of the turtles. These growths may severely debilitate the animal and may cause death. They occur primarily in large juveniles and less frequently in adults (Foley *et al*. 2005). The etiology of fibropapilloma is unproven, however, bacterial infections, UV-B radiation, spirochid blood fluke eggs, leeches, chemical contaminants, or a combination of these stressors have been identified as possible agents for weakening the immune system of the turtle and contributing to the onset of the disease (George 1997). Concurrent stressors such as parasites and human activity (industrial activity, boating, dredging, etc) may make the turtles more susceptible to fibropapilloma (Herbst and Klein 1995).

While not yet proven in the literature, anecdotal reports suggest fibropapilloma in green turtles (and to a lesser extent in loggerhead turtles) is more prevalent in shallow, low energy waters with degraded habitats that are impacted by human discharges (agricultural, urban, industrial), while few or no lesions are found in animals in open ocean habitats (Foley *et al*. 2005, Herbst and Klein 1995, Limpus and Miller 1990). Current records suggest that Western Australian turtles are free from fibropapilloma.

Given the standard management procedures and contingency plans that must be adhered to in order to comply with industry standards, the risk from contaminants is considered low to the local marine turtle population.

6.3 Identified Risks from the Proposed Project

Most impacts on marine turtles from the proposed Outer Harbour development were considered to be low risk. The medium risk level impacts were considered to be:

- mortalities or injuries to internesting flatback turtles from **dredge entrainment, ship strike or disposal burial during dredging**;
- **noise impacts** to marine turtles from **pile driving during construction** of the permanent marine facilities; and
- **light impacts** to flatback hatchlings from the **operation** of the permanent marine facilities.

6.4 Existing Risks to Marine Turtles

Indirect stressors include non-industry related actions or natural stressors occurring at a distance from the action, either spatially or temporally. It is important to recognise the non-industry sources of stress that may be contributing to a cumulative impact on the marine turtle populations in the vicinity of the proposed development and take these factors into account when considering management and mitigation measures.

6.4.1 Human Disturbance

Increased human presence at a site can significantly increase stress levels to turtles. Human presence or movement that is visible from the beach may disrupt or deter nesting females. This may cause a turtle leaving the water, crawling up the beach, or digging a nest, to abandon the nesting attempt and return to the water. The animals may return to the same or a nearby beach either late the same night or the next night, females may select alternative nesting beaches.

Vehicle traffic on nesting beaches by day or night can cause death of turtle eggs through compression or erosion of the nest. Any tyre ruts remaining after vehicles exit the beach become significant obstacles to hatchling turtles and can trap the hatchlings resulting in mortality due to dehydration, predation, exhaustion and/or delay their entry to the sea and result in lower survival rates due to lower energy reserves. In addition, small recreational vessels also pose a risk to marine turtles in the water from boat strikes.

The beaches close to Port Hedland town (for example Cemetery Beach and Paradise Beach) have high levels of human activity. Vehicle tracks were observed on the majority of beaches visited within the marine study area during the field surveys. In particular, Paradise Beach, which supports moderate flatback nesting, had very high levels of vehicular traffic, including ATV and 4WD vehicles. A high level of nest predation by humans for the eggs was observed on Paradise Beach during the census surveys. On 10 December 2008, attempts had been made to dig up 100 % of the clearly visible nests on the beach for the eggs. In addition, an adult flatback turtle was also found butchered on Paradise Beach on 10 December 2008.

6.4.2 Predation

Eggs, hatchlings and adult turtles are all eaten by both natural and feral predators (Stancyk 1979). In Australia predators of each turtle life stage include:

- Eggs – varanid lizards, crabs, dingoes, foxes (Bustard 1972; King *et al.* 1989) and golden bandicoots (Morris 1987).
- Hatchlings – crabs, varanid lizards, sharks, seagull, feral cats, brahminy kites, nankeen kestrels, crows, seagulls, black-necked storks, beach stone-curlews, rufous night herons, pelicans (Bustard 1972; Hope and Smit 1997; King *et al.* 1989; Limpus 1973; Limpus *et al.* 1993; Limpus *et al.* 1983; Whiting and Guinea 1999), sea eagles, burrowing bettong, octopus, golden bandicoots, possums.
- Adults and juveniles – hammerhead sharks, white sharks, tiger sharks (Bustard 1972; Cropp 1979).

The predation rate of all life stages is poorly known. In Australia, a study of the predation rate on flatback eggs and hatchlings found Varanid lizards were a 'significant and serious predator' with 50 % - 60 % of nests laid by flatback turtles destroyed (Blamires and Guinea 2003). The level of predation varies both spatially across a beach and temporally throughout the nesting season (Blamires and Guinea 1997). Additionally it is possible that predators may undertake seasonal migrations from inland foraging sites to the nesting beaches (Carr 1973).

6.4.3 Cyclones and Storms

The Pilbara region of Western Australia is exposed annually to both the highest number of cyclones and to the highest severity of cyclones in the southern hemisphere. The abnormally high tides, waves and excessive rainfall typically associated with cyclones can kill or injure adult marine turtles and destroy nests via fresh or seawater inundation, erosion or accretion of sand over the nest or preventing hatchlings' escape from under storm debris or seaweed wrack. The proportion of nests lost to storms has not been quantified for any nesting population in Australia. However, studies in Florida on leatherback, loggerhead and green turtles (Pike and Stiner 2007) have shown that storm surges significantly decreased reproductive output by lowering the number of nests that hatched and the number of hatchlings that emerged from nests, but the severity of this effect varied by species due to the variations in the seasonal timing of nesting (Pike and Stiner 2007).

7.0 POTENTIAL MANAGEMENT STRATEGIES

The section is a discussion of management strategies that are in the literature or that have been applied in previous development projects, to minimize potential risks identified in **Section 6** associated with the construction and operation of the proposed project to an acceptable level. These recommendations are ordered in priority, firstly addressing project activities likely to have a higher risk level of impact on marine turtles. There were no predicted high risk impacts to marine turtles as a result of the proposed Outer Harbour Development. These potential strategies should be considered within the scope of the project scale, engineering constraints, security and safety requirements, and metocean limitations. A Marine Turtle Management Plan is currently being prepared for the construction activities of the proposed project.

7.1 Medium Risk Impacts

7.1.1 Noise

The hearing sensitivity of flatback turtles and the behaviour of flatback turtles to noise is not well understood, it is difficult to quantify the potential risk to turtles from pile driving. According to advice from SVT Engineers (G. Bennett, pers. comm.), the level of noise that causes physical injury and behavioural effects need to be identified for turtles and then it will be possible to define:

- A zone of physical injury; and
- A zone of avoidance.

Mitigation measures that are generally applied to other projects work on zone of influence design. Trained Fauna Observers (TFOs) on board vessels maintain a watch for marine fauna within a monitoring zone of a specified distance. If a turtle (or other marine fauna) moves into this monitoring zone a watch will be maintained and all vessels are notified of its presence. There are limited mitigation measures available for pile driving (Bennett, G. pers. comm.). Mitigation measures suggested by Salgado Kent *et al.* (2009) with regards to marine mammals and the impact of noise from the proposed development included:

- Timing construction works around sensitive periods wherever possible;
- Carrying out a "soft start" for pile driving to allow animals close to the source to move away and not be exposed to sound intensities sufficient to cause them serious injury;
- Using air/bubble curtains to trap sound from the hammer. However, bubble curtains need to be designed carefully and further studies need to be done to assess their effectiveness. There are potential designs that can be effective in reducing sound energy received by an animal in proximity. However, the use of air/bubble curtains can increase the time and cost of pile driving.

7.1.2 Dredge Entrainment and Disposal Burial

A Dredging and Spoil Disposal Management Plan has been prepared and will be implemented for the duration of the dredging programme. Based on the available information, the following aspects of marine turtle biology and engineering are considered important to managing marine turtle interactions with dredging:

- environmental windows;
- dredge draghead type;
- deflector for draghead;
- relocating turtles; and
- dispersal of turtles.

7.1.2.1 Environmental windows

Biological studies on the relative abundance of marine turtles in channels can assist in defining seasonal windows when marine turtles are least likely to be present (Nelson *et al.* 1994, Slay 1995). The establishment of environmental (or seasonal) windows restricts dredging to periods when turtles are least abundant or least likely to be affected by operations (Dickerson *et al.* 1991).

Dickerson *et al.* (2004) recommended monitoring sea water temperature as an indicator of marine turtle presence/absence, since abundance is reduced at temperatures below 16 °C. Application of this assessment method in the Pilbara region of WA is unlikely to be successful as the water temperatures range throughout the water column between 21 and 30 °C (ChevronTexaco 2005). Additionally, the water temperatures are clearly suitable for the resident foraging animals that are present within the region year-round. While temperature is an appropriate environmental indicator in more temperate locations, it is unlikely to be suitable within the sub-tropical waters of the Pilbara region of Western Australia.

In eastern Australia, regulators recognize the need to manage dredging around environmental windows; dredging is scheduled to occur at times to avoid peaks in turtle abundance. For example, dredging in Bundaberg is mostly timed to minimise conflict with mating and nesting marine turtles at Mon Repos Beach. Similarly, other ports are dredged in the winter months, which are considered a lower risk to turtles (GBRMPA 2007).

The potential presence of up to five species (primarily green, flatback, hawksbill and potentially olive ridley and loggerhead) and two different groups (resident foraging and migratory breeding turtles) of turtles in the waters off Port Hedland means that turtles are likely to be present in the area year-round and reduces the usefulness of environmental windows. Biologically, the breeding females have an extremely high conservation value and protection of the internesting females from dredging is clearly a priority.

7.1.2.2 Dredge draghead type

The USACE investigations into dredging and marine turtle interactions have found the incidental take of marine turtles has only been documented for operations using hopper dredges with trailing suction dragheads. As of 2004, no incidental take of turtles had been reported from clamshell, pipeline cutterhead, or any other dredge type. This difference is possibly related to the speed at which the dredges operate; clamshell and pipeline dredges are slow relative to suction hopper dredges. Operationally hopper dredging is favoured by engineers, as it is more time and cost efficient. Nonetheless, hopper dredging has been restricted by the USCAE in channels known to contain high numbers of turtles; no documented marine turtle takes have occurred since the implementation of this management action (Dickerson *et al.* 2004).

On-board management is also used effectively to minimise risks to turtles (pumps are turned off when the drag head is lifted from the bottom, and jet pumps are used to provide a mobile water curtain). These measures appear to be equally, if not more effective than turtle deflectors in reducing risks to turtles (GBRMPA 2007).

7.1.2.3 Deflectors for dragheads

Throughout the 1980s the USACE tested a series of 'cow catcher' type turtle deflectors on dredge dragheads (Dickerson *et al.* 2004), but none were completely successful. The USACE's marine turtle research programme systematic approach to investigating biological and engineering solutions to the problem of turtle entrainment resulted in the development and field-testing of three draghead configurations; California-style draghead unmodified, California-style draghead with chain deflector and California-style draghead with a rigid deflector.

As a result of the demonstrated success of the California-style draghead with a rigid deflector, the NMFS has recommended the use of this rigid deflector design in the vicinity of turtle habitats since 1993 (Dickerson *et al.* 2004). Although marine turtle entrainment rates have declined substantially since these deflectors were introduced, they are less effective than a standard dredge on a sea floor that is rocky or uneven (Dickerson *et al.* 2004, Nelson 1999). If the draghead does not maintain constant contact with the seabed it can trap turtles and expose them to the draghead intake, although this is acknowledged to be uncommon. Further modifications made by the USACE to the California-style draghead configuration in 1988 included the covering or screening of the water intake at the top of the draghead to prevent the entrainment of smaller turtles from the water column. However, the California draghead is only suitable in soft sediments and cannot always be deployed in capital dredging programmes where harder material is being removed.

Within Australia, turtle deflectors have only been used during dredging in the Great Barrier Reef Marine Park and in Brisbane Port, where they were made of a series of chains. Turtle deflectors have been fitted for use on the drag-heads of dredges except where their use is prevented by practicality or safety concerns. A recent shift from rigid to flexible deflectors has assisted in addressing concerns about their use (GBRMPA 2007).

7.1.2.4 Relocating turtles

Trawling has been tested as a method for removing turtles from channels prior to dredging (Bargo *et al.* 2005, Dickerson *et al.* 2004, Nelson 1999). Specially trained and licensed shrimp trawlers sweep the seabed ahead of dredges to capture and relocate turtles. Relocation operations have recorded mixed success. The first trial was carried out in Canaveral Harbour in 1981 after high numbers of turtles were found there. A total of 1250 turtles were captured by trawling over a four month period. Many of the relocated turtles subsequently returned to the channel and for this reason, in addition to the high cost (USD $300,000), this relocation method was considered impractical at the time.

Subsequent trawling programmes in channels with low to moderate numbers of turtles have been more successful. For example, a June 1991 trawling programme in Brunswick Harbour relocated 71 turtles 11 – 22 km away from the channel and only one was recaptured. Of the 27 turtles trawled from Savannah Harbour the same year, none returned following relocation.

There are numerous examples of similar relocation trawling results, which seem to indicate this method has merit. Nonetheless, relocation trawling is costly and poses logistical and safety difficulties regarding movement and manoeuvrability of vessels (Reine and Clarke 1998). Relocation of marine turtles has potential when marine turtle densities are relatively low, but is less successful when turtles are in high densities (Bargo *et al.* 2005, Dickerson *et al.* 1991, Nelson *et al.* 1994).

7.1.2.5 Dispersal of turtles

The USACE has studied and tested various methods for 'startling' turtles in an effort to disperse them from the path of dragheads. The methods tested include sonic pingers, air cannons, tickler chains, water injectors and bubblers (USAEWES 1997). None of the methods tested were shown to predictably and consistently disperse the turtles. Turtles became habituated to the acoustic equipment, using the sonic pinger as a resting site (Dickerson *et al.* 2004).

7.1.2.6 Management of turtles applied to other Pilbara dredging projects

Dredging programmes that have been undertaken in the Pilbara region of Western Australia and have need to address the potential risks to turtles include the Dampier Port dredging for Hamersley Iron (SKM 2006) and the Pluto LNG development for Woodside (SKM 2008). The mitigation measures employed for these dredging programmes are similar and have generally included:

- Trained Fauna Observers on board vessels to maintain a watch for marine fauna within a monitoring zone of a specified distance. If a turtle (or other marine fauna) moves into this monitoring zone a watch will be maintained and all vessels are notified of its presence.
- If the marine fauna does not move away, the dredge relocates into another area. Dredging or spoil disposal may only commence after the marine fauna has not been sighted after a certain time (has been designated as 10 - 20 min).
- Fitting of turtle excluder devices (e.g. chains) when keel clearance for the loaded dredge is >4 m. When keel clearance is <4 m the dredge will move slowly through the area to allow the noise to encourage marine fauna to leave the area.
- Turning dredge pumps off as soon as practicably possible after the draghead clears the bottom.
- All injuries/deaths to be reported to the Department of Environment and Conservation (DEC) and Department of the Environment, Water, Heritage and the Arts (DEWHA).

There are a number of potential issues with these current mitigation measures. These are now being recognised by the DEC, who are looking at new management conditions arising from recent assessment of other large-scale dredging projects in the Pilbara region. Maintaining TFOs on board may be a suitable management method for marine mammals, but it is now being recognised that it is not suitable for marine turtles. It is limited by TFOs not being aware of any turtles that are resting on the seabed; although turtles are not visible on the surface they may still be present underwater. Turtles can also spend up to approximately two hours underwater before needing to come to the surface to breath, indicating that 10 - 20 mins is not an adequate time limit for turtles. In addition, TFOs cannot observe turtles at night and the proposed development is a 24 hour dredging programme. The fitting of excluder devices and encouraging turtles out of the area prior to dredging and spoil disposal are considered useful management tools; however, their effectiveness needs to be demonstrated.

7.1.3 Light

In 1996, a number of 'Best Available Technology" methods for mitigating light pollution near marine turtle nesting beaches were suggested by Witherington and Martin (1996). More recently, Salmon

(2005) has reviewed subsequent research from the intervening 10 years since Witherington and Martin's 1996 report. His review of recent research results, and of three current light management plans in place for south Florida, along with the Witherington and Martin (1996) report, can now be considered appropriate 'Best Available Technology" as at 2005.

7.1.3.4 Requirements for Practical Light Management

In summary, the practices currently being used or recommended to mitigate the adverse effects that artificial light has on hatchling orientation include:

- Use a base case for design of zero lighting and add only essential lighting as required to the design;
- Switch off unnecessary lighting (when not in use);
- Avoid use of metal halide, halogen and fluorescent light in proximity to turtle beaches. Use high pressure sodium lights where possible;
- Replace short wavelength light with long wavelength light;
- Minimise the number of lights;
- Minimise the wattage of lights;
- Exclude short wavelength light with filters;
- Use reflective materials to delineate equipment or pathways;
- Shield lights behind structures;
- Shield light fixtures to prevent sky glow;
- Redirect lighting onto work areas;
- Lower the height of light poles;
- Recess lighting into structures;
- Use timers;
- Use motion-activated switches;
- Use embedded road lighting;
- Use personal light sources (hand or head torch) to navigate dark work areas;
- Use low reflective paint on equipment to reduce reflected sky glow; and
- Reduce/minimise the light spill onto the ocean from jetties and vessels.

7.2 Low Risk Impacts

7.2.1 Boat Strikes

The collision risk between vessels and marine turtles has been shown to be linked to vessel speed. In a study of collision risk between a vessel and green marine turtles Hazel *et al.* (2007) found that turtles were at far greater risk of being struck by boats travelling at 6 knots than by boats travelling at 4 km.h^{-1} (Hazel *et al*. 2007). In addition, results of the study suggested that turtles detected approaching vessels visually, so the ability of turtles to avoid vessels at night or in highly turbid water may be significantly less.

7.2.2 Water Quality and Turbidity

A Dredge and Spoil Disposal Management Plan has been prepared for the proposed Outer harbour Development and will be implemented to minimise the sediment plume and potential effects on marine habitats. Other dredging projects within the Pilbara region have required a water quality monitoring programme during the duration of the dredging programme.

7.2.3 Hydrocarbon Spills

Standard management procedures and contingency plans apply in order to comply with strict industry standards and relevant legislation concerning hydrocarbon spills. BHP Billiton Iron Ore are operating within Port Hedland Port Authority (PHPA) limits and, as such, will comply with PHPA management procedures. Sand and water samples can be collected to establish baseline levels of petroleum hydrocarbons in the Port Hedland region.

7.2.4 Contaminant Discharges

Standard management procedures and contingency plans apply in order to comply with industry standards and relevant Acts. BHP Billiton Iron Ore are operating within PHPA limits and, as such, will comply with PHPA management procedures. Standard measures include grabs and deflector plates to minimise and capture any bulk cargo spill, in addition, a deck containment system to stop spillages will be implemented. Ballast water will be managed in accordance with the Australian Quarantine and Inspection Service system and BHP Billiton Iron Ore’s Invasive Marine Species Management Plan.

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BHP BILLITON IRON ORE

SATELLITE TRACKING OF FLATBACK TURTLES FROM CEMETERY BEACH, PORT HEDLAND

2008/2009

Prepared by

Pendoley Environmental Pty Ltd

For

SKM

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1 INTRODUCTION

1.1 Movement Patterns in the Flatback Turtle

The flatback turtle is the only species of marine turtle that is endemic to the Australian continental shelf (Limpus 2009). Although it has been the subject of study in eastern Australia for a number of years, and more recently in Northern and Western Australia, knowledge of its internesting movements, migration and habitat use remains poor. Tagging studies have recorded internesting intervals in flatback turtles of 13 to 16 days (Limpus 2009). It is thought that female turtles remain nearshore in the internesting period, however this has not been confirmed in published studies and the extent of their movements during this time is poorly known (www.seaturtle.org/tracking; Plotkin 2003). The knowledge of migration behaviour in flatback turtles is also poor. Tag return studies have recorded individual turtles being caught in fisheries over 1000 km from the nesting beach at which they were tagged, indicating that many flatback turtles engage in long-distance breeding migrations (Limpus *et al.* 1983; Prince 1998). Information on flatback turtle feeding grounds has also been gained from tag returns from fisheries and indicates that flatback turtles forage in shallow, turbid, subtidal habitats.

In recent years the advances in satellite tracking technology has allowed marine turtle biologists to gain much more accurate and detailed information on the movements, behaviour and habitat use of marine turtles (Godley *et al.* 2008). Although widely used in other marine turtle species, to date there are no published studies using satellite tracking technology with flatback turtles. The aim of this project was to use satellite tracking technology to study the inter- and post- nesting movements of flatback turtles nesting on Cemetery Beach, near Port Hedland, Western Australia. This information will be used in assessing the possible impact on this population from industrial activity, and inform management of these impacts. A secondary objective of this study was to assess and compare the two data types provided by the Sirtrack Fastloc platform terminal transmitters used to collect the position data on the flatback turtles.

1.2 Acknowledgements

This program was designed by Dr Kellie Pendoley. The satellite transmitters were attached by Paul Tod (Crackpots Pty Ltd) and Nic Sillem (Pendoley Environmental) with the assistance of Kelly Howlett and volunteers from Care for Hedland Environmental Association. Cover image is courtesy of Calen Offield. Figures were produced using Google Earth Pro Ref ID# 1839881.

2 METHODOLOGY

2.1 Field Methods

Platform terminal transmitters (ptts) were deployed on four turtles from Cemetery Beach.

Satellite transmitters were attached on the 5th and 6th of December 2008, however did not commence transmitting until after midnight on both occasions, so the start dates have been reported as the 6th and 7th of December respectively.

State of the art Fastloc GPS ptts used for this study and were designed and built by Sirtrack Pty. Ltd, Hamilton, New Zealand. The Fastloc ptts not only transmitted real time location data via the ARGOS GPS system (ARGOS LC) but also transmitted GPS location data that is subsequently processed by Sirtrack technicians to extract the high quality GPS latitude and longitude positions for the turtles. Because the ARGOS LC data is generated using the Doppler shift to calculate locations in real time, the quality of this data is directly linked with the degree of displacement of the ptt between two geographical points at the time of the fix. Consequently the accuracy of the ARGOS LC data improves when the turtle is swimming constantly in one direction (e.g. migration), and is less reliable when a turtle is stationary (e.g. nesting, interesting or foraging). Although more accurate, Fastloc ptts are also more costly than a standard Kiwisat101 ptt which collects only ARGOS LC data only.

The ptts were mounted on a polycarbonate plate lined with a neoprene wetsuit material and the plate is positioned on the turtle using webbing through 6 slits made on the plate. The harnesses and webbing were designed and built by Paul Tod (Crackpots Pty Ltd). The design was taken from Sperling & Guinea (2004), but the harnesses were made larger to account for the larger size of flatbacks in Western Australia. The harnesses were made from nylon seat belt webbing with six straps centred about a magnesium ring. Velcro was attached to the straps to secure the harness in place and corrodible wire was used to hold the straps in place.

Cemetery Beach was patrolled during the night around high tide to find suitable turtles to attach the ptt units. For a turtle to be considered suitable it needed to: have all its flippers intact, have no damage or large barnacles on the carapace, and be an appropriate size for the harness. The nesting females were left undisturbed to nest and the ptt was attached only after they had successfully nested and were returning to the water.

The ptt was positioned near the front part of the turtle's shell behind the head. When the turtle surfaces to breathe, the ptt breaks the water, and a salt water switch turns the ptt on. The signals transmitted are uploaded to ARGOS polar orbiting satellites. The data is then downloaded from the satellite to the ARGOS collection centre in France. A computer mapping program maps the best available data and plots the location of the turtle.

2.2 Data Processing

The Fastloc transmitters produced two types of data; ARGOS LC data and Fastloc GPS (hereafter Fastloc) data. ARGOS LC tracking information was downloaded, sorted and filtered from the Argos databank using the Satellite Tracking and Analysis Tool (Coyne & Godley 2005). Argos assigns location classes (LC) to each location as an estimate of accuracy. These classes are LC3 (± 150 m), LC2 (± 350 m), LC 1 (± 1000 m) and LC0 (> 1000 m). Two sets of ARGOS LC data were generated using two different data filters. Filter 1 (LC3, LC2, LC1, angle filter 45 °, speed < 5 kmh^{-1}) was the filter retaining only the most accurate points. It was used to calculate swimming speeds and distance the turtle travelled. Filter 2 (LC3, LC2, LC1, LC0, LCA, angle filter 70 °, speed < 5 km^{-1}) retained a greater number of points and was used for other calculations, and in figures to improve the pictorial display of migration routes.

Fastloc data were downloaded from the Argos satellite system and sent to Kevin Lay at SirTrack for processing. The data were processed using a specially developed SirTrack software program. The program uses satellite data from the Argos output, combined with data on satellite movements from the NASA ephemeris website to calculate GPS locations. Data from the Fastloc system have a high level of accuracy, with fixes using 6 or more satellites having an error of less than 100 m (Bryant 2007). Data sources were selected for use in different calculations on an ad-hoc basis, with the goal of optimising detail of information, while maintaining the greatest level of data quality possible.

A number of definitions were generated during data processing:

- Nesting attempt – where a fix was located on the nesting beach.
- Successful nesting attempt – where a fix was located on a beach and the turtle was not recorded on the beach for the next seven days. If a turtle moved within 200 m of the nesting beach and the subsequent fix on the nesting beach would make the internesting interval >20 days then it was deemed that the turtle had nested at some point during this period. Where this was the case, the last record close to the beach before it moved away was used as the nesting date.
- Nesting interval – the time in whole days from one successful nesting attempt to the next nesting attempt (whether successful or not) (Whiting *et al.* 2007).
- Displacement during internesting – was calculated from the Fastloc data and measured as a straight line distance in Google Earth from the place of deployment to the furthest point on the track line.
- Migration starting point – the first day of obvious movement away from the nesting beach after the final nesting.
- Migration end point - when the turtle diverged from the direct path it had been maintaining since leaving the nesting beach and began to traverse within a defined area.

3 RESULTS

3.1 Transmitters

The four transmitters remained active for 106 to over 246 days (mean 197; **Table 1**). One transmitter (89761) was still active when ARGOS LC data were most-recently downloaded (11 August 2009). Processed Fastloc data was available for dates up to and including 31st May 2009. Because there is a time lag between receiving the databank disks from France, and then completing the post-processing in New Zealand, we have not included Fastloc data after 31st May 2009 in this report. Two transmitters were still producing usable Fastloc data at this stage (89759 and 89761; **Table 2**). Although ptt 89762 was also still active at this stage, data after 31 December 2009 could not be solved at post-processing, possibly due to a fault in the onboard computer.

In general, Fastloc data produced more high quality fixes than ARGOS LC data within a similar time period (**Tables 1 and 2**). During the internesting period a greater number of high quality GPS (Fastloc) fixes were obtained, compared with ARGOS LC data, giving information on fine-scale movements (**Figure 1a**). In contrast, during migration, the ARGOS LC data gave a greater number of fixes (**Figure 1b**).

Table 1: ARGOS LC transmission information of the four flatback turtles that were satellite tracked following nesting at Cemetery Beach, Port Hedland.

Turtle ID	Date Released	Last Transmission	Days at Large	# Fixes (LC1-3)	# Fixes (LCA, LC0-3)
89759	7/12/2008	05/08/2009	239	117	323
89760	7/12/2009	22/03/2009	106	40	128
89761*	6/12/2009	11/08/2009	246	150	328
89762	6/12/2009	16/07/2009	221	90	200
Mean (SD)			**197 (79)**	**99 (46)**	**245 (98)**

*Ptt 89761 was still active when data were downloaded on 11 August 2009.

Table 2: Processed fastloc transmission information of the four flatback turtles that were satellite tracked following nesting at Cemetery Beach, Port Hedland.

Turtle ID	Date Released	Last Transmission*	Days at Large*	# Fixes*
89759	7/12/2008	13/05/2009	157	910
89760	7/12/2009	20/03/2009	104	458
89761	6/12/2009	28/05/2009	173	1113
89762	6/12/2009	30/12/2008	25	340
Mean (SD)			**145 (36)**	**705 (366)**

*Data presented exclude all data collected after the cutoff date of 31 May 2009. Ptts 89759 and 89761 were still active at this time. Ptt 89762 was also still active at this time, however data collected after the 31 December could not be solved, possible due to a fault in the on-board computer.

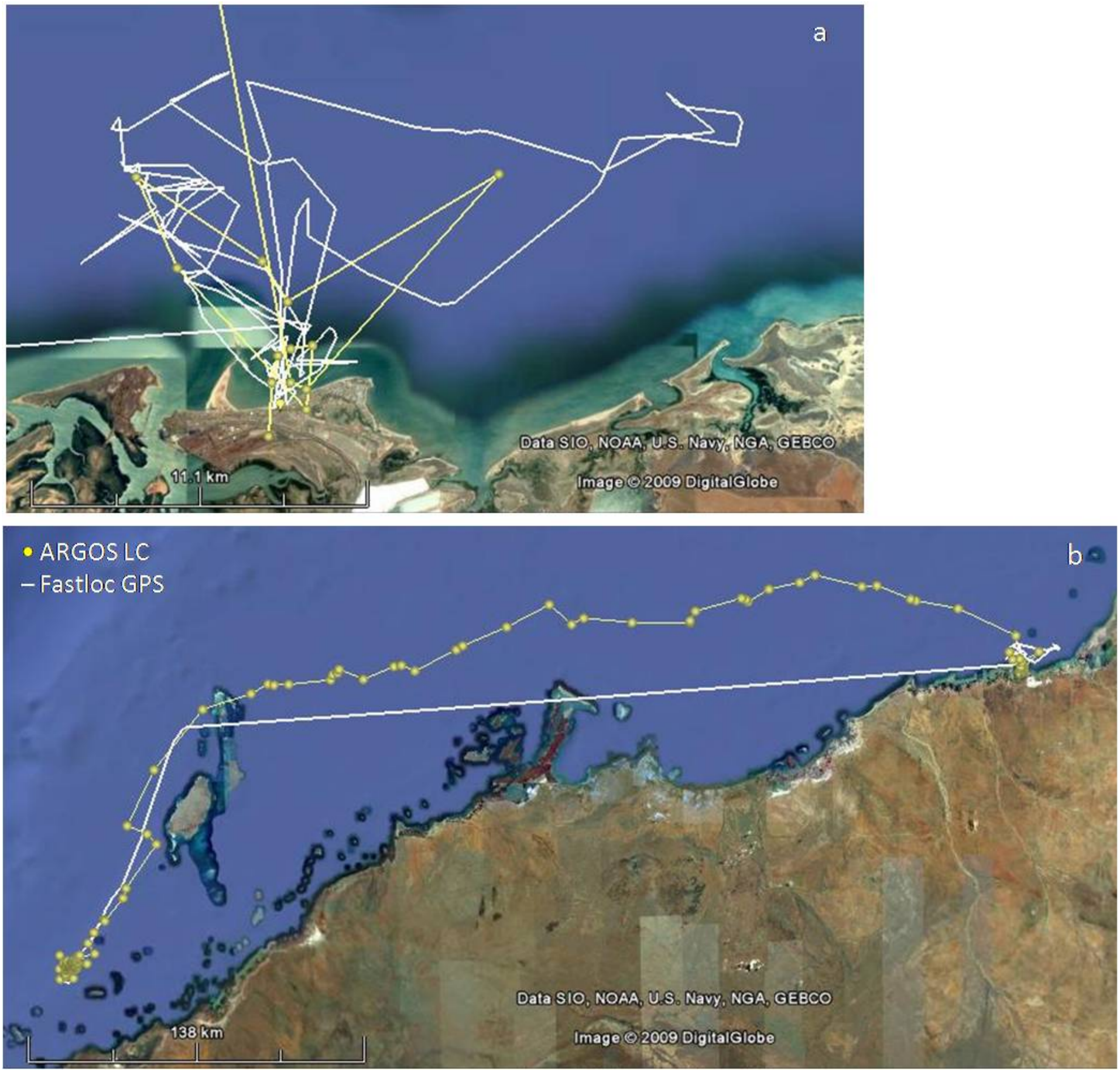

Figure 1: Comparison of ARGOS LC and Fastloc GPS satellite track paths of turtle 89759 during the internesting period (a) and migration (b).

3.2 Internesting

All turtles returned to re-nest at Cemetery beach at least once, with two turtles returning twice (**Figure 2**). Internesting intervals ranged from 11 to 18 days, with a mean of approximately 14 days (**Table 3**). During the internesting period turtles remained in shallow coastal waters less than 3 m in depth, although some moved extended distances (> 40 km) from the nesting beach (**Figure 2**). During the two shortest internesting periods of 11 days (turtle 89759 internesting period 1 and turtle 89761 internesting period 2) turtles remained closer to the nesting beach than they did during longer inter-nesting periods. Three turtles spent the internesting period in water to the north-east of the nesting beach, between Cemetery Beach and the western coastline of the De Grey River Delta, while the fourth turtle (89759) utilised habitat both north-east and north-west of Cemetery Beach, remaining closer to the beach overall (**Figure 2**).

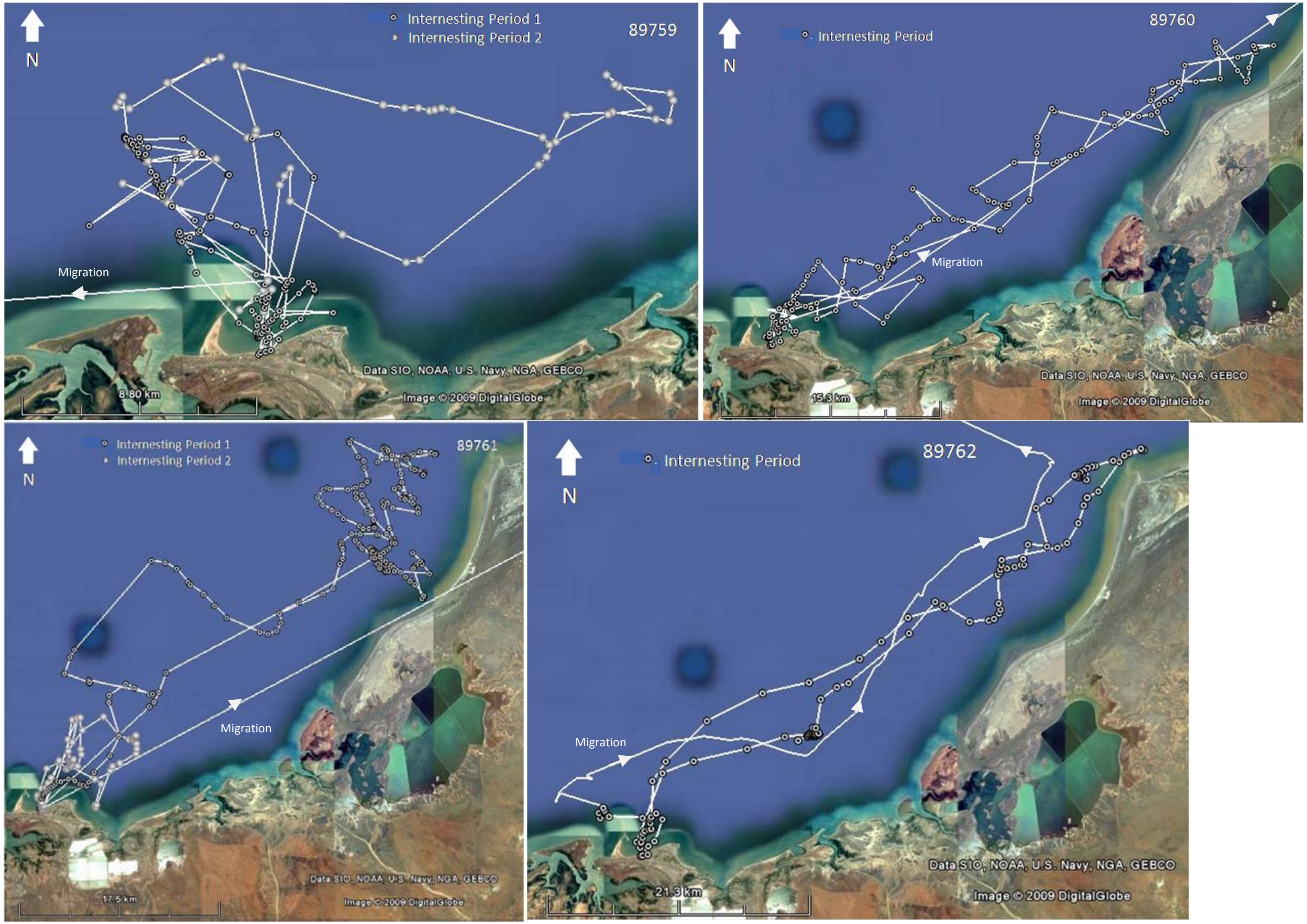

Figure 2: Internesting movements of four flatback turtles tracked from Cemetery Beach, Port Hedland (using Fastloc data). Note varying scales.

Table 3: Internesting intervals of flatback turtles from Cemetery Beach, including the maximum distance turtles moved away from the nesting beach during this period. All were calculated from a combination of Fastloc and ARGOS LC Filter 2 data. Dashes indicate insufficient points to be calculated.

Turtle ID	Date of Nesting	Date Returned	Re-nesting Interval (days)	Max. km from beach	Max. km Offshore	Max Water Depth (m)
89759	8/12/2008	19/12/2008	11	9.6	9.6	-
		04/01/2009	15	18.1	6.5	1.67
89760	7/12/2008	25/12/2008	18	40.5	10.3	3
89761	6/12/2008	19/12/2008	13	46.6	19.5	3
		30/12/2008	11	8.9	7.2	1
89762	6/12/2008	19/12/2008	13	52.0	10.1	-
Mean (SD)			**13.8 (3.0)**	**37.0 (19.3)**	**11.8 (5.3)**	**2.33 (1.2)**

3.3 Migration and Foraging Grounds

The four turtles had all commenced post-nesting migration by the 6th of January. Following their final nesting, turtles quickly left the Port Hedland area and migrated either north -east or south-west parallel to the coast. Migration took 20 to 27 days, during which time all of the turtles travelled a minimum of 405 to 942 km (**Table 4**). Due to an insufficient number of high quality data fixes (ARGOS LC 3, 2, or 1; Table 1) and/or unclear migration start and end dates, migration speeds could not be calculated for turtles 89760 and 89762. Migration swimming speeds for turtles 8959 and 89761 were 1.21 ± 0.85 and 1.07 ± 0.50 kmh^{-1}, respectively (**Table 4**).

The four turtles all travelled to discrete foraging grounds with clearly definable boundaries and remained in these foraging grounds for the remainder of the tracking period. Two turtles (89759 and 89762) migrated south-east to foraging grounds amongst islands on the North West Shelf (**Figure 3**). Turtle 89762 travelled to a foraging ground 20 km north-west of Barrow Island where it was tracked for 186 days, while turtle 89759 continued further south to an area approximately 15 km north-west of Thevenard Island, where it was tracked for 139 days. Both of these foraging grounds were in water approximately 30 to 80 m in depth.

The other two turtles migrated to foraging areas north of the nesting beach. Turtle 89760 migrated to a foraging area 30 km north-west of Broome (**Figure 4**), where it was tracked for 52 days. This turtle foraged in the shallowest area, were the maximum water depth recorded was 38 m. Turtle 89761 travelled furthest of the four turtles, migrating over 900 km to a foraging ground approximately 90 km north-west of Kuri Bay in the northern Kimberley region (**Figure 4**). This turtle remained in its initial foraging ground for most of the remaining 133 days it was tracked, making two short trips up to 100 km to the north-east. The turtle returned to the previous foraging ground following each of these two trips (**Figure 4**).

Table 4: Summary of migration and foraging ground characteristics of flatback turtles tracked following nesting at Cemetery Beach, Port Hedland. Min. Dist. Migration: minimum distance the turtle travelled during migration; Days in Foraging Ground: Number of days the turtle remained in foraging area before transmissions ceased; Max. Disp.: The maximum displacement from the nesting beach that the turtle was recorded; Max. And Min. Water depth: Maximum and minimum water depths corresponding to KiwiSat fixes within the foraging ground. Speeds and distances were calculated using ARGOS LC data Filter 1; all other numbers were calculated from ARGOS LC data Filter 2 and/or Fastloc data. Dashes indicate values that could not be calculated.

Turtle ID	Migration Duration (days)	Mean (SD) Migration Speed (kmh^{-1})	Min. Dist. Migration	Days in Foraging Ground	Max. Disp. (km)	Max. water depth (m)	Min. water depth (m)
89759	20	1.21 (0.85)	486	139	409	80.4	35.4
89760	-	-	463	52	468	38.0	12.3
89761	27	1.07 (0.50)	942	133	916	96.7	29.4
89762	21	-	405	186	350	63.1	28.2
Mean (SD)	**22.7 (3.79)**		**574 (248)**	**128 (56)**	**536 (258)**	**70 (25)**	**26 (10)**

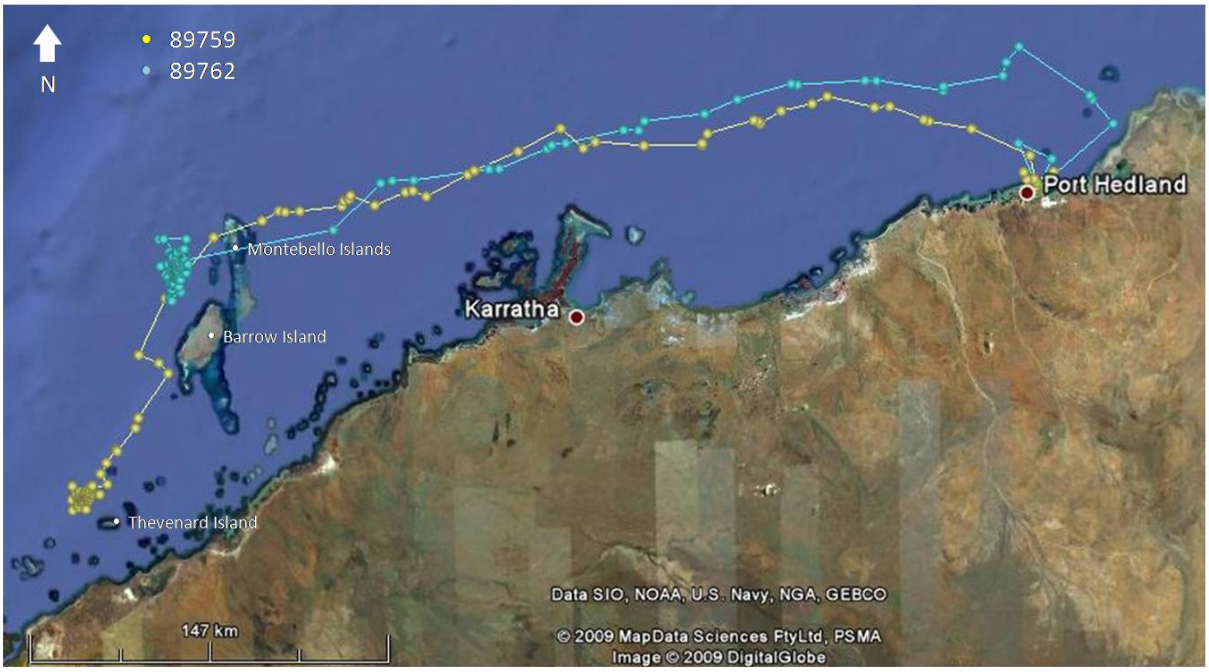

Figure 3: Migration routes of turtles 89759 (Cecilia) and 89762 (Camo) following nesting. ARGOS LC data (filter 2) was used to produce these tracks.

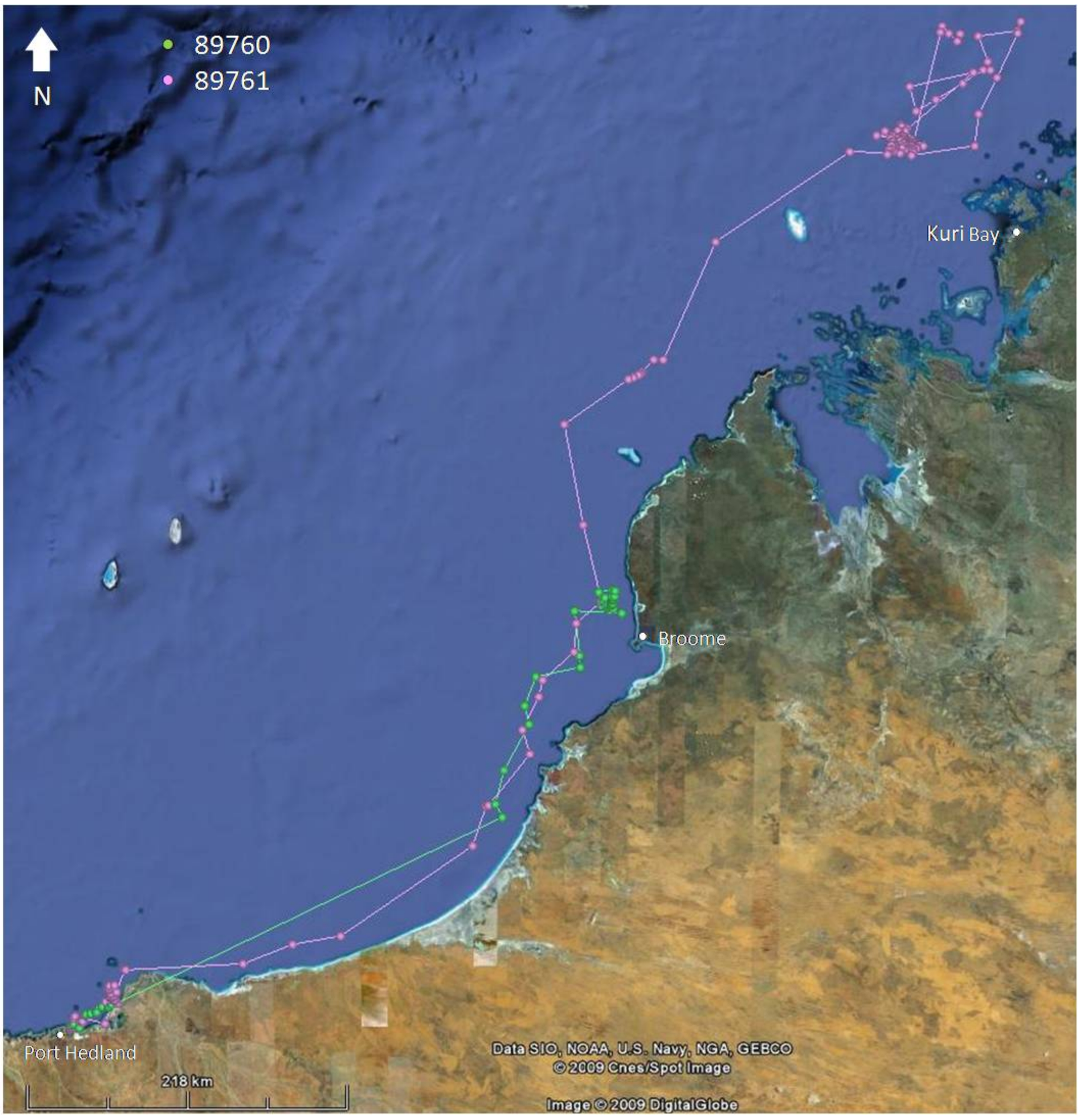

Figure 4: Migration routes of turtles 89760 (Mystery) and 89761 (Lucky) following nesting. ARGOS LC data (filter 2) was used to produce these tracks.

4 DISCUSSION

4.1 Transmitters

The two data types performed differently during different periods. The Fastloc GPS data produced more high quality fixes during the internesting period. This was expected as GPS data is able to give more accurate fixes than the ARGOS LC (Doppler shift) transmissions (Yasuda & Arai 2005). In contrast, the Fastloc transmitters under-performed compared with the ARGOS LC transmitters during the migration period. This may be due to behavioural differences in the turtle at these times, as turtles spend more time at the surface during internesting than they do during migration (Hamel *et al.* 2008). It may be that during the migration period the flatback turtles spent insufficient time at the surface for the Fastloc transmitter to upload sufficient data for a fix. The difference in effectiveness of the transmitters between these two time periods demonstrates the utility of maintaining both data types (ARGOS LC Doppler shift and Fastloc GPS) in the satellite tag.

4.2 Internesting

The internesting interval of 13.8 days recorded in this study is similar to the 9 to 17 day intervals reported for flatback turtles in Queensland (Limpus *et al.* 1984; Hope & Smitt 1998). The four turtles all utilised shallow, near shore habitat for internesting, which is typical of most marine turtle species (Plotkin 2009). However, they showed differences in their movements. Although no data are yet to be found in published literature, other satellite tracking programs have also found the internesting movements of flatback turtles to be variable. Some individuals remain relatively close to the nesting beach (within 10 km), while others have been observed to travel over 50 km from their nesting beach during the internesting period (www.seaturtle.org/tracking).

The principal internesting habitat utilised by these turtles was to the north and north-east of the nesting beach, with only one turtle internesting to the west of Cemetery Beach (**Figure 2**). From these data it appears that the most important internesting habitat for flatback turtles nesting at Cemetery Beach is the nearshore zone extending 50 km north-east along the coast. This warrants further investigation however, as the sample size of this study was very small (n = 4), and may simply reflect individual habitat selection rather than the behaviour of the population overall.

4.3 Migration and Foraging Grounds

The average migration speed of 1 to 1.2 $km.h^{-1}$ was similar to swimming speeds recorded during migration for loggerhead (1.3 $km.h^{-1}$; Nicholls *et al.* 2000) and olive ridley turtles (0.70 to 1.79 $km.h^{-1}$; Whiting *et al.* 2007). Turtles migrated to foraging grounds long distances from the nesting beach, which is consistent with data from tag return studies and recent satellite tracking programs (www.seaturtle.org/tracking). While none of the tagged turtles remained close to the nesting beach to forage, this does not indicate that waters surrounding Port Hedland are not used by foraging flatback turtles. Other turtles from this population, or turtles migrating from other rookeries, may use these areas as foraging grounds.

The turtles all migrated to geographically remote foraging grounds in shallow, subtidal waters. The shallow water depths of 12 to 80 m in these foraging grounds are typical of the depths utilised by flatback turtles foraging in Queensland, where they occupy shallow (6 to 40 m), turbid waters in soft-bottomed sub tidal habitats (Robins & Mayer 1998, cited by Limpus 2009). The greater water depths recorded in the present study may indicate use of a wider range of habitats by flatback turtles in Western Australia, or may simply reflect the paucity of data Australia wide on the foraging habitat of this species. The small sample size in this study, as well as the high level of variation within the sample demonstrates the need for further study of the foraging grounds of this species.

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APPENDIX B: Risk Assessment

Table A1: Risk Assessment Table

Hazard/ Stressor	Source of Hazard	Turtle Life Stage	Project Phase (Construction or Operations)	Potential Impacts	Likelihood	Consequence	Inherent Risk	Assumptions/Comments	Existing Environment	Additional avoidance, mitigation and management measures	Likelihood	Consequence	Residual Risk	Assumptions/ Comments	Confidence Level
Physical interaction	Dredging and dredge spoil disposal.	Internesting flatback turtles	Construction	Injury or death of turtles as a result of entrainment in the dredge, burial by spoil disposal or collision with vessel.	4	2	Medium	Assumes that dredging operations are 24 hr using THSD and CSD for 56 months. Majority of dredging will be done using a combination of CSD to crush the material and THSD to recover and dispose of the dredge material. Less than 10% of all dredge material will be original sea-bed removed by the CSD. Cutter suction dredges have a low incidence of turtle entrapment.	Satellite tracking results show that breeding females from Cemetery Beach do utilise dredging and dredge disposal areas as internesting habitat.	Implementation of DSDMP which includes: *Low operating risk to turtles* • Induction of vessel crew. • The Vessel Master will be advised of environmental matters from on-site environmental staff. • Trained vessel crew on project vessels will monitor and report turtle sightings during daylight hours during the construction phase. • Reporting of all incidents of injury or mortality to BHPBIO who will report to DEC and DEWHA as required. *Medium operating risk to turtles* All of the above, and • Visual inspection of hopper loads for evidence of turtles. *High operating risk to turtles* All of the above, and • Sweep the intended dredge area with tickler chains using a separate vessel prior to dredging or following 48 hour stoppage.	2	2	Low	Different management measures have been applied based on differing dredge operating conditions. Undertake further investigations into the movements of turtles within the dredge and disposal areas.	Low – undertake further studies into movement and behaviour of turtles within the dredging and disposal areas.
		Juveniles and adults – all species	Construction		4	1	Low		Resident foraging turtles concentrated around offshore islands, but also utilise creek mouths and intertidal platforms, including the dredge and disposal areas.		2	1	Low		
	Construction and operational vessels.	All stages except eggs – all species	Construction	Injury or death of turtles as a result of collision with vessel.	4	1	Low	Turtles detect danger visually. Assumes there will be higher vessel traffic and smaller vessels during construction which pose a greater risk to turtles.	Field survey results show that turtles utilise the proposed development area for internesting and foraging habitat.	Vessel crew will undertake site induction by appropriately trained project personnel. Vessel speeds will be under the control of the Vessel Master.	3	1	Low	Risk of boat strikes increase with increased vessel speed, increased vessel number and decreased keel clearance.	High

Hazard/ Stressor	Source of Hazard	Turtle Life Stage	Project Phase (Construction or Operations)	Potential Impacts	Likelihood	Consequence	Inherent Risk	Assumptions/Comments	Existing Environment	Additional avoidance, mitigation and management measures	Likelihood	Consequence	Residual Risk	Assumptions/ Comments	Confidence Level
			Operations		3	1	Low	Assumes frequency of small vessel movements will be less during operations. Assumes 2-3 movements of iron ore carriers daily.		The Vessel Master will be advised of environmental matters from on-site environmental staff. Trained crew members on project vessels will monitor and record turtle sightings during daylight hours during the construction phase. Reporting of all incidents of injury or mortality to BHPBIO who will report to DEC and DEWHA as required.	3	1	Low		
Sea bed disturbance	Dredging and dredge spoil disposal. Construction and operations of marine facilities.	Internesting flatback turtles	Construction	Direct loss of internesting habitat, resulting in females moving elsewhere.	5	1	Low	Assumes loss of potential internesting habitat for flatback turtles, however, loss of habitat will be small in context of surrounding areas with similar habitat.	Satellite tracking results show that breeding females from Cemetery Beach do utilise dredging and dredge disposal areas as internesting habitat.	Implementation of DSDMP.	5	1	Low	Existing environment is highly turbid and the increase in TSS from project unlikely to impact turtles. Lack of BPPH in the dredging and disposal areas. The loss of habitat around the dredge and disposal areas is not significant due the general absence of suitable foraging habitat for turtles in this area. However, juvenile and adult turtles are commonly found along the intertidal platforms and creek mouths. Plume modelling suggests that the inshore margins may be impacted from TSS generated turbidity. Effects are likely to be short or medium term.	Medium – sediment fate modelling has been undertaken, but lack of habitat mapping along inshore margins which has been identified as a zone of potential impact and turtles are known to occur in these areas.
		Juveniles and adults – all species	Construction	Reduction in foraging habitat directly through dredging and spoil disposal, and indirectly through an increase in TSS in water column and smothering of food sources.	5	1	Low	Subtidal habitat mapping indicates that invertebrates cover 5.6 %, hard corals 5.0 %, macroalgae 4.4 %, sponges 2.2 % and soft corals 0.9 % of survey area (SKM 2009). Lack of BPPH in the dredging and disposal areas. Loss of potential foraging habitat for marine turtles is likely to be minimal in these areas in context of surrounding areas with similar habitat. Sediment fate modelling (APASA 2009) indicates that the zone of potential impact from TSS generated turbidity was generally around the dredging and disposal areas and to the north-east of these areas, as well as isolated patches along the	Resident foraging turtles known to occur within dredge and disposal areas but are more concentrated around offshore islands, creek mouths and intertidal platforms. Naturally high levels of turbidity in the region and periodic severe events associated with cyclones.		5	1	Low		

Hazard/ Stressor	Source of Hazard	Turtle Life Stage	Project Phase (Construction or Operations)	Potential Impacts	Likelihood	Consequence	Inherent Risk	Assumptions/Comments	Existing Environment	Additional avoidance, mitigation and management measures	Likelihood	Consequence	Residual Risk	Assumptions/ Comments	Confidence Level
								inshore margin where the coastal morphology acts as a trapping zone for fine sediments. The zone of potential impact generally doesn't overlap with the mapped areas of biota. However, the areas along the inshore margin have not been mapped.							
			Operations		3	1	Low	Potential for an increase in TSS in the water column from iron ore carriers propeller wash.			3	1	Low		
Artificial lighting	Permanent terrestrial facilities.	Nesting flatback turtles	Construction and operations	Light may deter nesting females on nesting beaches.	3	1	Low	Results of light assessment indicate that the western end of Cemetery Beach will experience the most impact from light sources associated with project (Bassett 2009). Results of light assessment indicate the loading wharf/jetty will be directly visible at some locations along Cemetery Beach and lighting on ships will be visible from Cemetery Beach (Bassett 2009). It is assumed that experienced nesters will continue to use the beach, but new recruits (first-time nesters) may be deterred. It is assumed that light will misorient a small proportion of flatback hatchlings. Hatchlings tend to scatter once in the open ocean and are carried by tides and currents. Very little is known about the effect of light on juvenile and	Existing lighting including street lighting, sports lighting and feature lighting is visible to turtle nesting beaches such as Cemetery Beach. Low density nesting occurs on Downes Island, adjacent to project area. Moderate density nesting occurs on Cemetery Beach which is 5 km from the project. Resident foraging turtles known to occur within dredge and disposal areas but are more concentrated around offshore islands, creek mouths and intertidal platforms.	Minimise light spill and to reduce lighting levels and light spill to as low as reasonably practicable and to comply with safety standards and minimise impacts to turtles.	2	1	Low	Existing port development and cumulative modelling results shows that the order of magnitude in the illuminance value are the same (Bassett 2009), therefore, impacts of light on marine turtles are likely to be insignificant. Broad sky glow is more attractive to hatchlings and they tend to ignore bright point sources of light such as lights from vessels and along the jetty. Hatchlings tend to scatter once in the open ocean and are carried by tides and currents, and there is little control over their directions.	Medium – light impacts on nesting females and hatchlings on the beach has been studied. However, very little is known on the effects of light on hatchlings, juveniles and adults at sea.
		Flatback turtle hatchlings	Construction and operations	Light spill or glow may have adverse effects on the navigation of hatchlings reducing hatchling survival rate.	4	1	Low				3	1	Low		
	Permanent marine infrastructure.	Flatback turtle hatchlings	Construction	Light spill or glow may have adverse effects on the navigation of hatchlings reducing hatchling survival rate.	3	1	Low				3	1	Low		
			Operations		3	2	Medium				3	1	Low		
		Juveniles and adults – all species	Construction and operations	Light spill or glow may attract juveniles and adults to the area increasing risk of vessel collisions or localised predation.	3	1	Low				2	1	Low		
	Construction and operational vessels.	Flatback turtle hatchlings	Construction	Light spill or glow may have adverse effects on the navigation of hatchlings reducing hatchling survival rate.	3	1	Low				2	1	Low		
			Operations		2	2	Low				2	1	Low		
		Juveniles and adults – all	Construction	Light spill or glow may attract juveniles and	3	1	Low				2	1	Low		

Hazard/ Stressor	Source of Hazard	Turtle Life Stage	Project Phase (Construction or Operations)	Potential Impacts	Likelihood	Consequence	Inherent Risk	Assumptions/Comments	Existing Environment	Additional avoidance, mitigation and management measures	Likelihood	Consequence	Residual Risk	Assumptions/ Comments	Confidence Level
		species	Operations	adults to the area increasing risk of vessel collisions or localised predation.	2	1	Low	adult turtles at sea.			2	1	Low		
Marine noise and vibration	Construction and operations of marine facilities. Dredging and dredge disposal.	All stages except eggs – all species	Construction	Physiological (hearing) damage or behavioural changes from construction activities (pile driving).	4	2	Medium	Predicted 3 years of pile driving using 4 hammers concurrently. An analysis on proposed marine noise and potential impacts has been conducted on marine mammals (Salgado Kent *et al.* 2009). However, very little is known about the behavioural responses of marine turtles to noise or frequency sensitivity ranges in marine turtles.	Satellite tracking results show that breeding females from Cemetery Beach do utilise dredging and dredge disposal areas as internesting habitat. Resident foraging turtles known to occur within dredge and disposal areas but are more concentrated around offshore islands, creek mouths and intertidal platforms.	Engineering controls on construction equipment to control noise emissions to be installed as per manufacturer's specifications and to meet regulatory requirements. Induction of vessel crew. Carry out 'soft-starts' for pile driving. Marine turtle observation and recording process. Reporting of all incidents of injury or mortality to BHPBIO who will report to DEC and DEWHA as required.	3	1	Low	The regular pulses from pile driving are likely to result in marine turtles avoiding the area. However, it is unknown whether turtles during critical life stages (e.g. breeding) are more sensitive to noise impacts. However, turtles may become habituated to non-lethal noise from a persistent source (e.g. vessel noise).	Low – frequency sensitivity ranges are unknown for flatback turtles. Very little is also known about responses of marine turtles to noise – need to undertake further studies.
			Operations	Behavioural changes from vessel noise.	3	1	Low	Fewer vessels during operations compared with construction.			3	1	Low		
Leaks and spills	Vessel collisions or grounding. Storage and transport of chemicals, fuels or other hazardous materials. Failure of equipment or pipelines.	All stages – all species	Construction and operations	Toxicity from diesel/oil spills may result in mortality or sub-lethal effects on marine turtles.	1	3	Low	Likelihood of spill is very unlikely. In the highly unlikely event that a major spill does occur, BHP Billiton Iron Ore's Oil Response Procedure and the PHPA will manage the impacts.	Marine turtles known to occur within and offshore of Port Hedland.	No additional mitigation required.	1	3	Low	Likelihood of spill is very unlikely.	High – based on impacts being confined to local area and management strategies being routine, standard and proven practices.
Liquid and solid waste disposal	Domestic waste and treated sewage.	All stages – all species	Construction and operations	Ingestion of solid wastes or toxicity from liquid discharges may result in mortality or sub-lethal effects on marine turtles.	2	2	Low	Assumes management and disposal of wastes from construction and operation will be in accordance with BHP Billiton Iron Ore's controls as detailed in the EMP.	Marine turtles known to occur within and offshore of Port Hedland.	No additional mitigation required.	2	2	Low	Waste will not be disposed of to the sea.	High – based on impacts being confined to local area and management strategies being routine, standard and proven practices.

Table A2: Risk Definition – Consequence

Relevant Consequence Criteria	Negligible 1	Minor 2	Moderate 3	Significant 4	Serious 5
Marine Environment					
Listed Marine Fauna*	▪ Local and temporary behavioural impact ▪ Local and temporary decrease in abundance.	▪ Widespread, short-term or local, long-term behavioural impact ▪ Local, long-term or widespread, short-term decrease in abundance ▪ No reduction in local population viability	▪ Widespread and long-term behavioural impact ▪ Local, long-term or widespread, short-term decrease in abundance ▪ Reduced local population viability ▪ No reduction in population viability within Port Hedland region or in surrounding waters	▪ Local, long-term or widespread, short-term impact to population ▪ Reduced population viability within Port Hedland harbour region or in surrounding waters	▪ Widespread, long-term impact to population ▪ Extinction within Port Hedland region or reduced viability in the immediate region

*relevant to marine turtles

Table A3: Risk Definition – Likelihood

Likelihood Category		Description
Almost Certain	5	Very likely to occur on an annual basis or during construction
Likely	4	Likely to occur more than once during the life of the proposed development
Possible/Occasionally	3	May occur during the life of the proposed development
Unlikely	2	Not likely to occur within the life of the proposed development
Rare/Improbable	1	Highly unlikely, but theoretically possible

Table A4: Environmental Risk Assessment Matrix

		Consequence category				
		Negligible	Minor	Moderate	Significant	Serious
Likelihood	Almost Certain	Low	Medium	High	High	High
	Likely	Low	Medium	High	High	High
	Possible/Occasionally	Low	Medium	Medium	High	High
	Unlikely	Low	Low	Medium	Medium	Medium
	Rare/Improbable	Low	Low	Low	Medium	Medium